Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa

by

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ABSTRACT

Effective water, sanitation and hygiene (WASH) services are vital for public health, education and sustainable development. Despite global commitments like the Sustainable Development Goals (SDGs), significant challenges persist in low- and middle-income countries. This study assessed WASH conditions and Menstrual Hygiene Management (MHM) practices across 40 high schools representing all five socio-economic quintiles (Quintile 1–5) in Durban, South Africa, with a focus on evaluating services; identifying microbial risks; and developing a risk reduction framework. A mixed-methods approach was employed, incorporating quantitative surveys to assess student knowledge and infrastructure quality, alongside microbiological analyses of drinking water for diarrhoeagenic *E. coli*. Qualitative insights were gathered through focus groups with school administrators and educators. Findings revealed substantial inequities across school quintiles: lower-quintile schools (1–3) experienced inadequate sanitation, intermittent water supply and poor maintenance, while higher-quintile schools (4–5) demonstrated better facility functionality and hygiene resources. The absence of gender-sensitive sanitation facilities adversely affected female students' dignity during menstruation. Water quality analyses indicated 99.98% compliance with SANS 241:2015 guidelines, although one isolated non-hazardous *E. coli* instance was detected. Qualitative analyses highlighted systemic issues, including maintenance gaps and insufficient policy support for MHM. The study developed a novel WASH Risk Reduction Framework to guide policymakers and administrators in identifying risks and implementing targeted interventions. By emphasising stakeholder engagement and sustainability, this framework aims to enhance WASH environments in schools. This research supports SDG 6 (Clean Water and Sanitation) and contributes to SDGs 3 (Good Health), 4 (Quality Education) and 5 (Gender Equality).

Keywords: WASH services, public health, South Africa, menstrual hygiene management, *Escherichia coli*, risk assessment, infrastructure, gender equity, school quintile, SDGs.

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LIST OF ACRONYMS

Acronym	Description
3M™	3M Company (manufacturer of Petrifilm™)
ABCD	Asset-Based Community Development
ANOVA	Analysis of Variance
CFU	Colony-Forming Units
CLTS	Community-Led Total Sanitation
COVID-19	Coronavirus Disease 2019
CPE	Carbapenemase-Producing Enterobacteriaceae
DEC	Diarrhoeagenic *Escherichia coli*
DNA	Deoxyribonucleic Acid
DOE	Department of Education
DWS	Department of Water and Sanitation
EAEC	Enteroaggregative *Escherichia coli*
EHEC	Enterohemorrhagic *Escherichia coli*
EIEC	Enteroinvasive *Escherichia coli*
EMIS	Education Management Information System
EPEC	Enteropathogenic *Escherichia coli*
ESAR	Eastern and South African Regions
ESRS	European Sustainability Reporting Standards
ETEC	Enterotoxigenic *Escherichia coli*
F	Forward Primer (PCR)
FIT	Fit for School
GEMR	Global Education Monitoring Report
GIZ	German Agency for International Cooperation
GLAAS	Global Analysis and Assessment of Sanitation and Drinking Water
GWP	Global Water Partnership
IBM SPSS	International Business Machines Statistical Package for the Social Sciences
JMP	Joint Monitoring Programme
KAP	Knowledge, Attitudes, and Practices

Acronym	Description
MDGs	Millennium Development Goals
MHM	Menstrual Hygiene Management
NEIMS	National Education Infrastructure Management System
NGO	Non-Governmental Organization
PHAST	Participatory Hygiene and Sanitation Transformation
PCR	Polymerase Chain Reaction
PPPs	Public-private partnerships
QC	Quality Control
QMRA	Quantitative Microbial Risk Assessment
qPCR	Quantitative PCR
SABS	South African Bureau of Standards
SANS 241:2015	South African National Standards for Drinking Water
SDGs	Sustainable Development Goals
TSB	Tryptic Soy Broth
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VIF	Variance Inflation Factor
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization
WRC	Water Research Commission
WSSCC	Water Supply and Sanitation Collaborative Council

CHAPTER 1: INTRODUCTION

1.1 Introduction

Access to safe and adequate water, sanitation and hygiene (WASH) is a fundamental human right and a key determinant of public health and education, according to the World Health Organization [WHO] and United Nations Children's Fund [UNICEF] (WHO & UNICEF, 2017; UNICEF & WHO, 2020). Schools play a crucial role in hygiene promotion, yet many educational institutions globally, especially in low- and middle-income countries, still lack proper WASH facilities (Ngwenya et al., 2018; Poague et al., 2022a; Dibaba et al., 2024; Andleeb et al., 2025; Byansi et al., 2025). Poor sanitation and hygiene impact on student health, school attendance, and gender equity, reinforcing educational disparities (Ahmed et al., 2021; Adane et al., 2025). To address these disparities, public schools in South Africa are categorised into five quintiles based on the socio-economic status of the surrounding communities. Quintile 1 schools serve the poorest communities, while Quintile 5 schools are situated in the wealthiest areas (Van Dyk & White, 2019; Maistry & Africa, 2020).

Despite efforts such as the United Nations' (UN) Sustainable Development Goal (SDG) 6, which aims to ensure the availability and sustainable management of water and sanitation for all (UN, 2015), and national initiatives like the school quintile system, the availability of safe WASH services in schools remains inconsistent (Pereira et al., 2024; Wilbur et al., 2024; Radebe et al., 2025). This study investigates WASH conditions in selected high schools across different school quintiles (1–5) in Durban, South Africa, aiming to assess WASH challenges and propose a risk reduction framework.

1.2 Background to the Study

WASH was introduced as a critical global health initiative in 2001 at the International Conference on Freshwater in Bonn, Germany, led by the Water Supply and Sanitation Collaborative Council (WSSCC) (WRC, Report No. 2381/P/15). WASH encompasses the supply of potable water, safe sanitation and hygiene promotion

(WHO & UNICEF, 2017). Historically, WASH has been considered a fundamental human right and a key driver of public health (Okesanya et al., 2024; Zegeye, 2024).

The SDGs emphasize the necessity of universal access to WASH, particularly in schools, to enhance student well-being, academic performance and gender equity (UN, 2015). SDG 6 focuses on clean water and sanitation, while SDG 3 (Good Health), SDG 4 (Quality Education) and SDG 5 (Gender Equality) further highlight the need for sustainable WASH interventions (WHO, 2018). The SDGs target improving waterborne disease prevention, upgrading school infrastructure and addressing gender disparities by ensuring safe and private sanitation facilities for girls (Shrestha et al., 2023; Byansi et al., 2025).

Despite these efforts, South Africa continues to face significant WASH challenges in schools. A 2018 Water Research Commission (WRC) report found that 29% of schools lacked improved sanitation facilities (WRC, Report No. TT 757/18). Furthermore, poor infrastructure and fragmented governance have hindered WASH improvements in educational settings. Many South African schools still rely on pit latrines, while others lack proper handwashing stations and menstrual hygiene management (MHM) facilities (Mchenga et al., 2020; Radebe et al., 2025). These challenges disproportionately affect female students, contributing to absenteeism and further widening gender inequalities in education (Ahmed et al., 2021).

The consequences of inadequate WASH extend beyond student health to school performance and public health outcomes (Rosenthal et al., 2020). Poor sanitation can result in bacterial, viral, and protozoan infections, with diarrhoeal diseases being the most common consequence (Stauber et al., 2013; Kuandyk & Omarova, 2024). Inadequate waste disposal, combined with poor hygiene practices, also increases the risk of contamination from faecal indicator bacteria such as *E. coli*, which is commonly used to assess microbial water quality (Goshu et al., 2021; Dimpor et al., 2024; Murei et al., 2023). Improved WASH infrastructure, hygiene education and behavioural interventions are crucial to breaking the cycle of WASH-related diseases and their impact on school attendance (Ahmed et al., 2021; Assefa et al., 2025).

In South Africa, national efforts to improve WASH conditions in schools have been hampered by fragmented governance and inconsistent data collection (WRC, Report No. TT 757/18). The administration of WASH is divided amongst multiple government departments, resulting in a lack of cohesive policy implementation. Additionally, the focus on urban infrastructure development often overlooks the challenges faced by under-resourced schools in rural and peri-urban areas (Gwimbi et al., 2019). Without an integrated WASH framework, schools struggle to maintain sanitation facilities, provide clean water and promote hygiene awareness amongst students and staff (Radebe et al., 2025). This study aims to examine the provision of WASH facilities in selected Durban high schools to ascertain current WASH conditions, microbial water quality risks and menstrual hygiene management. The findings of this research were used to develop a risk reduction framework that may enhance the provision of safe WASH to schools.

1.3 Research Problem

Globally, access to safe WASH remains a major public health and development challenge, particularly in developing countries where many communities still lack adequate services (Royo et al., 2022; Jitu & Masud, 2025). Many schools in low-economy counties in Southern Asia and sub-Saharan Africa lack funding, expertise and administrative support, and are far from reaching satisfactory standards of WASH, with some having almost no proper facilities (Shrestha et al., 2023; Barrington et al., 2025). Studies have also reported that a significant proportion of schools in low-income countries continue to lack adequate sanitation services, highlighting persistent global inequalities in WASH provision (Poague et al., 2025).

Progress in WASH provision is monitored globally through initiatives such as the WHO/UNICEF Joint Monitoring Programme (JMP), which tracks essential WASH services in schools using basic service indicators (UNICEF & WHO, 2024). However, while these indicators provide important insights into service coverage, they do not fully capture all aspects affecting the health, well-being and learning environment of students and school personnel. The JMP therefore relies on data collected from national assessments and stakeholder consultations to monitor progress and inform global WASH interventions (Girmay et al., 2023; Abdulhadi et al., 2024). These monitoring efforts contribute to international initiatives aimed at improving WASH conditions in schools and advancing progress toward the SDGs (Karim et al., 2024; Jahan et al., 2025).

Within the Eastern and Southern African Region (ESAR), WASH provision in schools remains limited, and opportunities for improvement are still constrained by infrastructure and resource challenges (Jitu & Masud, 2025). In South Africa, evidence has shown that sanitation infrastructure in many schools remains inadequate. For example, a report by Matthews (2018) indicated that toilets in several schools in KwaZulu-Natal, Limpopo and the Eastern Cape provinces were old and the buildings were dilapidated.

WASH in schools remains key to achieve SDGs 3, 4 and 6 by 2030. Nevertheless, a study by UNICEF & WHO (2024) revealed that the achievement of free access in many countries to fundamental WASH facilities in schools by 2030 represents a major challenge. This requires a renewed effort amongst all the stakeholders. In a study conducted in Ethiopia, it was indicated that some school children carry water to school and obtain water from different sources, including rivers and lakes, due to insufficient water availability at the schools (Tadesse et al., 2024).

Providing basic services alone does not adequately address the risk of WASH-related diseases amongst school students. Good hygiene practices within schools play a crucial role in limiting disease transmission, including the spread of illnesses such as COVID-19 (O'brien et al., 2025). Unfortunately, inadequate WASH facilities and limited access to hygiene resources continue to negatively affect students' attendance, academic concentration and performance, further deepening inequalities in education (Gul et al., 2025). This situation mostly impacts girls, who often face absences or reduced concentration due to inadequate menstrual hygiene provisions (Dibaba et al., 2024; Gul et al., 2025). Despite the known challenges, menstrual hygiene remains under-researched within school-based WASH interventions, highlighting a critical gap in existing studies (Bourne & Ahsan, 2025). Therefore, this study aims to explore these issues in depth and to propose practical strategies to manage and mitigate WASH-related health risks in schools.

Addressing WASH challenges in schools is essential for protecting student health, promoting dignity, and supporting student school attendance, which ultimately contributes to improved educational outcomes and advances progress toward the SDGs.

1.4 Rationale for the Study

Since the announcement of the SDGs in 2015, information on the progress of school WASH has been limited in South Africa. Research by Radebe et al. (2025) in uMfolozi Local Municipality, South Africa, found that WASH conditions were inadequate and there was no provision for menstrual waste disposal facilities. Studies have found that inadequate WASH supply in schools is a global challenge (Bolatova et al., 2021; Adane et al., 2025; Jahan et al., 2025). For example, research by Dibaba et al. (2024) and Magwe (2025) has indicated that inadequate WASH facilities in schools contribute to a higher prevalence of diarrhoeal diseases amongst students compared to those in schools with appropriate WASH infrastructure. Moreover, other studies have found that the WASH status in public schools is inadequate, which has a significant impact on the high occurrence of the most common diseases in students. The study also recommends that educational institutions should strive to improve the state of the school environment by providing safe WASH. The lack of facilities for disposal, including WASH structure, prevents female students from coping with menstruation in school (Olatunji & Taiwo, 2021; Pereira, et al., 2024; Poague et al., 2025; Jahan et al., 2025; Magwe, 2025).

Despite the significance of menstrual health education in promoting overall well-being, adolescents in low-income countries like Nepal continue to face severe misunderstandings, cultural restrictions, and misbeliefs regarding menstruation (Sharma et al., 2024). Many young girls engage in poor menstrual hygiene practices due to inadequate knowledge, exacerbated by cultural taboos that discourage open discussions about menstruation (Magwe, 2025). These practices often include the improper disposal of menstrual materials and a lack of adequate sanitation facilities, which can lead to serious health issues such as reproductive infections (Shresthaet al., 2025). Access to menstrual hygiene-enabling tools within school WASH facilities, including clean water, private sanitation spaces, and appropriate disposal mechanisms, is essential for addressing unsafe menstrual hygiene practices, mitigating infection risks, and fostering dignity and well-being among adolescent girls.

A report published by the WHO (2022) indicates that water quality monitoring in schools is infrequent and often inadequate. The report highlights that many rural schools, particularly in sub-Saharan Africa, experience poor water quality, with significant risks of faecal contamination. Furthermore, it notes that many countries lack sufficient requirements for regular surveillance to assess water quality and service delivery, which is critical for ensuring safe drinking water in educational settings (WHO, 2024; Poague et al., 2025). However, the microbial quality of water is a public concern because this is the main source of diarrhoeal diseases (Tandoh et al., 2025; Ahiabor & Donkor, 2025). Clean water, sanitary services and sanitary environments are vital in schools for the development of students by increasing school attendance, contributing to a child's dignity and promoting acceptable WASH practices among school students (Byansi et al., 2025; Magwe, 2025; Poague et al., 2025).

In South Africa, the national school funding model uses a poverty-based quintile system to classify public schools from Quintile 1 (poorest) to Quintile 5 (wealthiest). The system is designed to prioritise financial support to the poorest schools, with Quintile 1–3 schools designated as no-fee schools and expected to receive more government funding than Quintiles 4 and 5 (Van Dyk & White, 2019; Maistry & Africa, 2020). This funding is intended for general operational purposes, including teaching materials, infrastructure, and learner support, but is not ring-fenced for WASH (Köhler, 2020; Mokgwathi et al., 2023). While the policy intent is to achieve equity, several studies have shown that schools in lower quintiles often struggle with poor infrastructure, capacity limitations and competing budgetary demands (Köhler, 2020; Lombo & Subban, 2024). In practice, this has contributed to persistent disparities in WASH provision across quintiles. As such, many lower-quintile schools continue to experience inadequate sanitation; an unreliable water supply; and lack of menstrual hygiene facilities (Tlhabudugwane et al., 2024; Radebe et al., 2025). These systemic and structural challenges underscore the need for context-specific research into the adequacy and equity of WASH delivery in schools, particularly in historically disadvantaged urban areas such as Durban in South Africa.

Enhancing WASH practices in schools can improve students' living requirements and behaviours throughout their educational lifetime (Shrestha et al., 2023). Research showed that WASH awareness and experience was insufficient for high-school students. Research by Andleeb et al. (2025) also found that students' hygiene behaviour and WASH knowledge were not satisfactory. Therefore, the intervention of multiple stakeholders is needed to promote acceptable WASH practices amongst school students (Poague et al., 2025).

Everyone has a part to play in ensuring that in schools every child in school receives WASH benefits. In 2010, the Worldwide Call to Action on WASH in Schools asked for the participation of different stakeholders in combined efforts to support WASH in schools (UNICEF, 2012). The Call to Action by UNICEF (2012) and Cavill et al. (2020), outlines six points of action to unite stakeholders with the goal of universal access to WASH in schools. This study therefore intends to respond to the Call to Action where academic expertise is called upon to research and generate evidence that will strengthen the delivery of safe WASH in schools. The findings of this study were used to establish a risk-reduction framework for addressing the identified challenges of WASH amongst the selected Durban high schools. This will contribute to the improvement of SDGs 3,4,5 and 6, thereby preventing or controlling the incidence of WASH-related diseases, whilst improving school performance and attendance.

1.5 Aim and Objectives

The aim of this study is to examine the current WASH practices (including menstrual hygiene practices) and associated challenges in selected high schools in Durban, KwaZulu-Natal, South Africa, with the aim of informing strategies to improve WASH conditions in schools.

The objectives crafted to achieve this aim were to:

1. determine the students' knowledge, attitudes and practices about WASH, as well as the incidence and prevalence of WASH-related diseases;
2. examine the state of WASH at each of the selected school, including menstrual hygiene management;
3. determine the microbiological quality of drinking water supplied to learners through the municipal water supply system, focusing on the detection of Escherichia coli and associated virulence genes of diarrhoeagenic E. coli (DEC);
4. assess the microbiological risks associated with drinking water supplied to learners through the municipal water supply system using quantitative microbial risk assessment (QMRA).
5. compare and contrast WASH status and conditions at different school quintiles;
6. develop a risk reduction framework that facilitates the adequate provision of WASH in schools, considering differences in WASH conditions across quintiles and supporting efforts toward achieving SDG 6.

1.6 Research Questions

The study addresses the following questions:

i. What is the level of WASH knowledge, attitudes and practices (KAP) amongst students in the selected schools?

ii. What is the prevalence of WASH-related diseases amongst students in the selected schools?

iii. What is the current state of WASH and MHM at selected Durban high schools?

iv. What is the microbiological quality of drinking water supplied to learners through the municipal water supply system in terms of *E. coli* and the prevalence of virulence genes in diarrhoeagenic *E. coli* (DEC) strains?

v. What are the potential microbiological risks and occurrence of DEC strains in drinking water supplied to learners through the municipal water supply system in the selected schools?

vi. Is there a difference between WASH status and conditions from Quintiles 1 to Quintile 5?

vii. What type of intervention framework is required to enhance WASH risk reduction in schools?

1.7 Significance of the Study

Inadequate WASH continues to be an essential obstacle in various parts of the globe (Abuzerr, 2025; Koua et al., 2025; Sharma et al., 2025). Many public schools in low-revenue countries have insufficient WASH services (Pereira, et al., 2024; Byansi et al., 2025; Magwe, 2025). Understanding students' knowledge, attitudes and practices about WASH, as well as the incidence and prevalence of WASH-related diseases, will provide essential insights into the effectiveness of current interventions and highlight gaps that need to be addressed. This understanding can inform targeted educational programs and policy decisions aimed at improving WASH conditions. Examining the availability and conditions of WASH facilities at each selected school, including menstrual hygiene management, will reveal critical deficiencies and barriers to effective WASH provision. Such insights are vital for developing tailored interventions that not only reduce the occurrence of WASH-related diseases but also enhance school enrolment, retention and overall educational effectiveness (Bick et al., 2024).

This research represents an innovative effort to create a framework prototype designed to enhance the provision of adequate and safe WASH in schools. The findings will contribute to designing a comprehensive framework based on SDG 6, which could be employed in schools to meet multiple SDGs (3, 4, 5 and 6). By providing knowledge and guidelines, this study aims to assist policymakers by making it significant for planners, public health officials, educators and the Water sector. Furthermore, this research responds to the Call to Action that urges academic expertise to generate evidence that will strengthen the provision of safe WASH in schools (Cavill et al., 2020). The findings will enhance the body of knowledge in Environmental Health and will be useful at local, national and international levels. Ultimately, this study contributes to the provision of WASH in schools by generating actionable insights that can guide the successful implementation of WASH initiatives.

1.8 Assumptions

Studies have shown that WASH in schools is insufficient in many of the low-revenue countries (McMichael, 2019; Donde et al., 2020; Poague et al., 2022b; Pereira et al., 2024; Royo et al., 2022). The first assumption of this study was that WASH would present several challenges in selected high schools, regardless of the economic status of the school.

1.9 Limitations

This study concentrated on conducting a survey and gathering information that was used to identify challenges linked to WASH provision and menstruation practices in selected Durban schools. The research was limited to public/government high schools only. The research was also restricted to schools consisting of both male and female students. Private and single-sex high schools were not included in the study. Water quality analysis studies were limited to microbiological analysis only.

1.10 Delimitations

The scope of this study was limited to examining WASH and MHM challenges in 40 selected high schools across poor and wealthy neighbourhoods of Durban, South Africa. The study was therefore geographically delimited to selected high schools within the Durban metropolitan area. The target demographic for this analysis was school-going students and school personnel. Both male and female students were recruited to participate in this study. The study included only learners and school personnel from the selected schools. The research was conducted within the school environment over a 12-month period. Quantitative data were collected quarterly, once in each season, to capture potential seasonal variations in WASH conditions and water quality. Water quality analysis was limited to microbiological assessment. Qualitative data were also collected on a quarterly basis, though not always from the same respondents, with insights being additive across the study period. The characteristics of participants were guided by the inclusion and exclusion criteria described in Table 3.1 of the methodology section.

1.11 Structure of the Thesis

This thesis is partitioned into six chapters. The chapters cover the introduction, literature review, research methodology, qualitative and quantitative data analysis results, presentation of findings on research objectives, and findings summary, conclusions and recommendations.

Chapter 1: Introduction

This initial chapter introduces the research project background, research problem, rationale for the research, aim and research objectives. It also describes the basic assumptions, the importance of the study, limitation and delimitation of the research.

Chapter 2: Literature review

The second chapter contains a comprehensive review of the study-related literature, focusing on key areas based on the research objectives, as well as the executive summary of the literature reviewed.

Chapter 3: Research Design and Methodology

The Research Design and Methodology chapter provides an in-depth discussion of the study design and methodology, describing aspects such as the target population, sample size, data collection methods, data analysis techniques and operational definitions of variables.

Chapter 4: Data Analysis

The fourth chapter presents an analysis of both qualitative and quantitative data. It includes the analysis of WASH infrastructure, MHM, KAP amongst students, microbial water quality, QMRA, and the prevalence of WASH-related diseases.

Chapter 5: Study Discussion and the Developed WASH Risk Reduction Framework

This chapter provides a comprehensive discussion of the findings, critically interpreting the results in the context of existing literature, national policies and the SDGs. It also presents the WASH Risk Reduction Framework developed from the study findings to guide the improvement of WASH provision in schools.

Chapter 6: Summary, Conclusions and Recommendations

The final chapter presents a concise summary of the key findings, draws overall conclusions, and provides practical recommendations for policy, practice and future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter comprehensively reviews the literature relevant to this study, examining the evolution of WASH practices and their impact on public health and education. The review focuses on the historical development of WASH systems, the current state of WASH in schools, the implications of inadequate facilities, and potential strategies for improvement. Research gaps as informed by literature are identified and described.

2.2 Overview of WASH and its Global Significance

The WASH pillars are widely acknowledged as essential to public health, environmental sustainability and socio-economic development. Access to WASH services is central to disease prevention and health promotion (Johannessen et al., 2014; Okesanya et al., 2024; Abuzerr, 2025). As Jordanova et al. (2015) and Poague et al. (2022a) pointed out, the availability of clean water and sanitation infrastructure supports healthier communities and fosters economic productivity. Furthermore, the inclusion of WASH in the global development discourse reflects its growing importance in efforts to build resilient and equitable societies (Pereira & Marques, 2021; Poague et al., 2024; Jitu & Masud, 2025; Kucici & Shettima, 2025).

Bute et al. (2023) argued that access to safe drinking water, appropriate sanitation facilities and consistent hygiene practices plays a vital role in reducing communicable diseases and improving well-being. Over time, progress in WASH has been driven by a combination of scientific discovery, engineering innovation and political will. For instance, Anthonj et al. (2021) noted that technological developments have enabled cost-effective water purification and sanitation solutions. Similarly, policy reforms and increased global awareness, as discussed by De Wit et al. (2024) and Okesanya et al. (2024), have contributed to the expansion of WASH services in many regions. Achuo and Asongu (2024) emphasised that these advancements are particularly significant in addressing the health burdens of low-income populations.

However, despite global progress, significant disparities in WASH access remain. Millions of people in low- and middle-income countries still lack access to improved water sources or adequate sanitation systems (Das et al., 2025; Naz et al., 2025). Khan (2025) observed that WASH inequality is most evident in rural areas, informal settlements and regions affected by poverty and conflict. According to Piper et al. (2017) and Anthonj et al. (2024), these service gaps are associated with increased vulnerability to waterborne diseases, including diarrhoea and cholera. Mustapha et al. (2024) and Underhill et al. (2025) highlight that without targeted interventions, these conditions will continue to undermine human development and resilience.

Poor WASH access also exacerbates existing social inequalities. Donkor (2022) explained that women and girls are often disproportionately affected by inadequate sanitation as they bear the burden of water collection and are more vulnerable to health and safety risks. Shrestha et al. (2023) and Okesanya et al. (2024) further noted that menstrual hygiene challenges in resource-limited settings can lead to school absenteeism, reduced participation in public life, and long-term educational disadvantages. Tackling these issues requires not only infrastructure development but also inclusive policies that respond to gender, cultural and contextual needs. As suggested by Dhoba (2022), effective WASH interventions must be multi-sectoral, combining investment, governance and community engagement. Dickin and Gabrielsson (2023) and John and Ajibade (2024) emphasised that sustainable progress depends on partnerships between governments, non-governmental organisations and affected communities. This is further supported by Kucici and Shettima (2025), who argued that community-driven models tend to result in better service uptake and long-term success.

In school environments, WASH facilities are especially critical. Jasper et al. (2012) found that improved school sanitation reduces absenteeism, limits the spread of infectious diseases, and supports overall student health. According to Karon et al. (2017), access to handwashing facilities contributes to behaviour change and fosters lifelong hygiene practices. Sharma et al. (2024) observed that when WASH facilities are lacking, learning environments become unsafe and exclusionary. This is particularly problematic for girls, who may miss school due to menstruation if schools do not provide private, functional toilets and access to hygiene materials. As Davis et al. (2018) and Shah et al. (2022) highlighted, these conditions directly affect girls' dignity, school attendance and academic outcomes.

There is increasing recognition that inadequate WASH infrastructure in educational settings reinforces broader socio-economic disparities (Habtu et al., 2025; Kucici & Shettima, 2025; Magwe, 2025). Nunbogu and Elliott (2022) pointed out that learners from marginalised backgrounds are more likely to attend schools without reliable water supply, clean toilets or hygiene education programmes. These inequalities contribute to a cycle of disadvantage that can extend into adulthood.

Understanding the historical development of WASH systems offers important insight into current gaps and provides direction for future strategies. Cairncross et al. (2010) suggested that analysing past sanitation approaches helps to contextualise present-day interventions. Hutton and Chase (2017) and Haque and Freeman (2021) similarly argued that current effective policies must be informed by lessons from past successes and failures. Burton et al. (2021) and D'mello-Guyett et al. (2024) added that linking historical trends to current evidence allows for more sustainable and locally relevant WASH solutions. This study therefore integrates historical and contemporary insights to inform risk reduction strategies aimed at improving WASH conditions in schools.

2.3 Evolution of WASH Practices

The historical development of WASH practices reflects major transitions in human society, science and infrastructure. Angelakis and Zheng (2015) and Johannessen et al. (2014) have noted that WASH systems evolved in response to changing population dynamics, urbanisation and public health threats. These transformations can be broadly categorised into three phases: ancient civilisations, the industrial era and the modern period. According to De Feo et al. (2014), understanding this evolution is essential for contextualising current WASH challenges and for identifying strategies that can improve WASH service delivery, especially in vulnerable settings such as schools. Freeman et al. (2013) emphasised that drawing on historical lessons allows for more responsive and sustainable interventions in contemporary public health planning.

2.3.1 Ancient Water and Sanitation Systems

Structured efforts to manage water and sanitation were already evident in some of the world's earliest civilisations. The Indus Valley Civilization, which flourished between 2600 and 1900 BCE, incorporated advanced WASH elements such as covered drainage systems, household latrines and shared public baths into its urban planning. These systems were designed to remove wastewater and supply clean water to densely populated settlements (Garrison, 1929; De Feo et al., 2014). Angelakis et al. (2023) explained that such infrastructure reflected a foundational understanding of the importance of separating waste from living spaces, laying the groundwork for later public health approaches.

The Minoan civilisation in Crete implemented aqueducts and rainwater harvesting systems, supported by terracotta pipelines and cisterns, to ensure consistent water supply during dry periods (Antoniou et al., 2014). These water conservation and delivery techniques indicated a strategic response to environmental limitations and revealed the early integration of hygiene practices in urban life. Similarly, according to Yannopoulos et al. (2017), these systems were not only technologically impressive but also culturally embedded, as cleanliness and water access were linked to community organisation and religious practices.

In ancient Egypt, water purification was achieved using alum, a coagulant that helped to clarify turbid water drawn from the Nile. Samia and Azharia (1999) and Fouad et al. (2021) noted that this method represented an early form of water treatment, predating modern chemical disinfection processes. Meanwhile, the Roman Empire developed highly sophisticated WASH infrastructure, including aqueducts that delivered fresh water from distant sources and sewerage systems such as the Cloaca Maxima that channelled wastewater out of the city (Pietz & Zeisler-Vralsted, 2021). Public toilets and bathhouses were made widely accessible, reinforcing hygiene as a civic responsibility and promoting communal health (Antoniou et al., 2016; Zimmermann, 2023).

Despite these significant advancements, access to WASH infrastructure was not evenly distributed. In rural settlements, communities often relied on rivers, ponds or shallow wells, which were susceptible to contamination from faecal matter and other pollutants. According to Whittington et al. (1993), many of these populations practised open defecation and lacked systems for proper wastewater disposal, leading to increased exposure to pathogens. Weaver et al. (2016) and Shrestha et al. (2023) highlighted that diseases such as diarrhoea, dysentery and typhoid were common in areas without basic sanitation.

A limitation of ancient WASH systems was the lack of scientific understanding about micro-organisms and disease transmission. Although aqueducts, sewers and public bathhouses improved environmental cleanliness, communities lacked knowledge about microbial contamination. Moe and Rheingans (2006) argued that the absence of Germ Theory meant that sanitation was implemented for practical or aesthetic reasons rather than for disease prevention. Consequently, outbreaks of waterborne diseases persisted even in well-developed urban centres.

These disparities between urban and rural populations laid the foundation for structural inequalities in WASH access that persist today. Sinharoy et al. (2019) and Nguyen et al. (2025) stressed that while early innovations introduced fundamental WASH concepts, their limited reach excluded marginalised populations. Magwe (2025) further suggested that examining these early exclusions helps inform current strategies for more inclusive and equitable service delivery, particularly in school and community settings.

2.3.2 The Industrial Revolution and Public Health Reforms

The Industrial Revolution (18th–19th centuries) brought a dramatic shift in population patterns, with people migrating from rural areas to rapidly growing urban centres. This accelerated urbanisation-overwhelmed existing water and sanitation infrastructure, resulting in overcrowded housing, unregulated waste disposal and widespread contamination of water sources. According to Konteh (2009), these deteriorating conditions increased the incidence of diseases such as cholera, typhoid and dysentery in industrial cities. Gallardo-Albarrán (2024) added that these public health crises highlighted the urgent need for systematic reform and intervention.

Public health reformers, scientists and engineers responded to these challenges by advocating for centralised sanitation infrastructure and environmental health regulations. In England, the passing of the Public Health Act of 1848 was a pivotal moment as it empowered municipalities to develop drainage systems; ensure water supply; and manage waste (Strand, 2018). Vanderslott et al. (2019) observed that this Act marked the beginning of state-led responsibility for WASH services, establishing a model later adopted by many other industrialising countries.

During this period, Florence Nightingale’s influence was particularly significant in promoting hygiene in institutional settings. Her experiences during the Crimean War demonstrated the impact of sanitary practices on mortality rates in hospitals. McDonald (2020) noted that Nightingale's work not only improved conditions in military hospitals but also shifted public understanding of sanitation as a determinant of health, especially in vulnerable populations.

Municipal investment in sewer networks and piped water systems followed, with large cities like London and Paris implementing separate systems for drinking water and waste to prevent cross-contamination. Prasad (2013) and Adugna (2023) described how urban design was modified to prioritise WASH infrastructure, including underground sewers and elevated water reservoirs. These interventions were complemented by growing public awareness campaigns that promoted cleanliness and discouraged unsanitary behaviours.

Scientific developments in bacteriology played a decisive role in improving WASH systems during this era. The emergence of Germ Theory, supported by the work of Pasteur and Koch, linked microbes to disease transmission and validated the need for water treatment (Milgroom, 2023). Tomes (1990) argued that filtration and chlorination were adopted based on this understanding, leading to substantial reductions in waterborne disease. As Montgomery and Elimelech (2007) explained, these practices soon became essential components of public health policy in industrial societies.

Governments began integrating hygiene education into public health campaigns, while urban planning regulations mandated the inclusion of sanitation facilities in housing developments. According to Bailey et al. (2021), these policy shifts helped institutionalise WASH as a public good. Freeman et al. (2013) and Johannessen et al. (2014) postulated that these reforms were instrumental in reducing child mortality and improving the quality of life in urban centres.

However, the global distribution of these advancements remained uneven. Many countries in the Global South, particularly in Africa, Asia and Latin America, were excluded from these reforms due to colonial policies that prioritised extractive infrastructure over local development. Rautanen et al. (2010) argued that this historical under-investment has contributed to the persistent lack of WASH services in many developing regions. Gallardo-Albarrán (2024) similarly noted that colonial legacies continue to shape the structural limitations of WASH access in formerly colonised territories.

Anthonj et al. (2021) concluded that while the Industrial Revolution advanced sanitation infrastructure and public health in industrialised countries, it also introduced patterns of inequality that continue to affect global WASH systems. Addressing these inherited disparities requires a deeper understanding of how infrastructure development has historically favoured certain populations while excluding others.

2.3.3 The Modern Era: Global WASH Initiatives

In the twentieth century, WASH practices transitioned from national reforms to globally co-ordinated initiatives. This shift was largely influenced by increasing awareness of the health implications of poor sanitation and the need for cross-border solutions to water-related challenges. Rapid urbanisation, population growth and the global spread of infectious diseases further highlighted the importance of international co-operation in addressing water and sanitation challenges. As a result, global institutions began to play a more prominent role in guiding policy development and establishing standards for water safety and sanitation management (Rajapakse et al., 2023). According to Rautanen et al. (2010), the formation of the WHO in 1948 marked a pivotal moment in the global institutionalisation of WASH. The WHO's mandate included setting international guidelines for water quality, disease prevention and sanitation standards, thus embedding WASH within the broader framework of public health.

Giné-Garriga et al. (2016) noted that post-World War II development agendas increasingly prioritised access to safe water and sanitation as central to poverty reduction and health improvement. WHO guidelines and technical support programmes enabled many governments in the Global South to begin formulating national WASH strategies, although implementation varied significantly due to political, financial and infrastructural constraints (UNICEF & WHO, 2024).

One of the most defining developments came in 2000 with the adoption of the Millennium Development Goals (MDGs). These goals aimed, amongst other priorities, to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. Satterthwaite (2016) explained that while the water target was largely met, sanitation progress lagged, particularly in sub-Saharan Africa and parts of Asia. Weststrate et al. (2018) observed that the uneven achievement of WASH-related MDGs highlighted deep-rooted structural inequalities in service provision and funding allocation.

Following the MDG review, the global community adopted the SDGs in 2015, with Goal 6 specifically focused on ensuring the availability and sustainable management of water and sanitation for all by 2030. Biswas et al. (2024) argued that SDG 6 reflects a more comprehensive and ambitious agenda by including targets related to hygiene, equity, water quality and integrated water resources management. Rajapakse et al. (2023) added that the SDGs recognised WASH as not only a health issue but also a matter of education, gender equality and climate resilience.

According to Chirgwin et al. (2021), the modern era has also seen the rise of technological innovations aimed at making WASH services more affordable, sustainable and scalable. Advances include solar-powered water purification systems, decentralised sanitation units and mobile applications for monitoring service delivery. Kumar et al. (2023) highlighted the increasing role of artificial intelligence and data analytics in managing water distribution networks and predicting contamination events. These tools are particularly beneficial in rural and peri-urban settings, where conventional infrastructure may be lacking or unreliable.

Miller et al. (2025) noted that the integration of biodegradable toilets and locally adapted filtration technologies has expanded WASH coverage in resource-constrained settings. Similarly, Das et al. (2025) reported successful pilot projects that used low-cost water testing kits and community training to improve hygiene behaviours in informal settlements.

Despite these technological and institutional gains, significant disparities in WASH access continue to persist globally. Acheampong et al. (2024) argued that financial limitations, weak governance and limited community engagement are major barriers to the realisation of universal WASH access. In many low-income countries, basic sanitation remains unavailable to large segments of the population, and hygiene practices such as regular handwashing are constrained by water scarcity and the lack of soap (Biswas et al., 2024). Magwe (2025) emphasised that without inclusive policies and sustained investment, the SDG 6 targets are unlikely to be fully achieved.

The modern global WASH agenda has undoubtedly expanded the scope of what is possible, but its success depends on local adaptation, equity-driven strategies and strong multisectoral collaboration, Schools remain a critical focus area where the impacts of both historical neglect and recent progress are highly visible (Rhodes-Dicker et al., 2021; De Wit et al., 2024).

2.3.4 Implications for WASH provisioning in Schools

The historical evolution of WASH systems has significantly influenced present-day approaches to sanitation and hygiene in educational institutions. As noted by Sravanthi et al. (2023), improved WASH infrastructure has been instrumental in reducing the global burden of communicable diseases. However, while these benefits have reached many urban areas, schools in under-resourced settings still face substantial deficits in access to clean water, functional toilets and hygiene facilities.

Libanda et al. (2024) argued that schools act as microcosms of society, and as such, reflect broader patterns of infrastructural inequality. In contexts where WASH services are poorly maintained or altogether absent, students are exposed to increased health risks, including diarrhoeal diseases, skin infections and parasitic illnesses. This situation is compounded by inadequate maintenance systems; a lack of soap or water for handwashing; and overcrowded or non-functional toilet facilities. These challenges are especially prevalent in rural and informal urban schools (Sharma et al., 2025).

In many schools across low-income countries, sanitation facilities are often not designed with gender, age or disability in mind. Mushota et al. (2021) found that girls are affected by inadequate menstrual hygiene facilities, leading to discomfort, embarrassment and absenteeism during menstruation. This is further supported by Sharma and Adhikari (2022), who observed that many learners avoid using school toilets altogether due to a lack of privacy or cleanliness. Such conditions undermine learners' dignity and compromise their right to a safe and supportive learning environment.

The consequences of poor WASH conditions in schools extend beyond health impacts. Poague et al. (2022b) illustrate a direct relationship between access to sanitation and educational outcomes. When students fall ill frequently due to unhygienic conditions or are unable to attend school during menstruation, their academic performance suffers. Ahmed et al. (2021) emphasised that this is particularly evident in marginalised communities, where learners already face systemic barriers to educational achievement.

Disparities in school WASH infrastructure are also shaped by socio-economic inequalities. Pu et al. (2022) noted that schools in wealthier areas are more likely to have functional WASH facilities, while those serving low-income populations often depend on inconsistent government support or community-led maintenance. Barrington et al. (2025) observed that the lack of targeted investment and monitoring results in prolonged WASH system failures in disadvantaged schools. As Chatterley et al. (2018) suggested, addressing these challenges requires more than infrastructure alone. Interventions must include hygiene education, clear maintenance protocols, and regular monitoring to ensure sustainability. Chirgwin et al. (2021) added that community engagement is equally important, particularly in settings where school facilities are used by surrounding households.

Pu et al. (2022) posit that WASH interventions in schools must be informed by local context and designed through a participatory process that includes learners, teachers and caregivers. Magwe (2025) asserts that solutions that are not locally accepted or understood tend to fail despite the availability of resources. Equally important is the integration of school WASH into national education and health policy frameworks to ensure long-term commitment and accountability (Kucici & Shettima, 2025). Ensuring equitable access to WASH in schools is central to achieving SDG 6 and to fostering inclusive, quality education. Donkor (2022) argued that without addressing the gaps in school WASH infrastructure, efforts to promote health and education equity will remain incomplete. As Poague et al. (2025) concluded, the historical exclusion of certain groups from WASH services must inform current strategies, ensuring that every learner, regardless of background, has access to safe and dignified sanitation and hygiene.

2.4 The State of WASH in Developing Countries

Access to safe drinking water, adequate sanitation and hygiene services remains a critical challenge across many developing countries. As observed by Kucici and Shettima (2025), millions of people in these regions are still underserved, facing daily struggles related to unsafe water sources; inadequate toilet facilities; and the absence of handwashing stations. Al-Hamawi et al. (2025) and Victor et al. (2025) further highlighted that these deficiencies are not only a public health concern but also a barrier to sustainable development. The persistence of WASH inequalities between urban and rural areas, as well as amongst socio-economic groups, has far-reaching implications (Das et al., 2025; Magwe, 2025; Poague et al., 2025).

These gaps in service delivery are the result of complex and interconnected challenges. Gebremichael et al. (2021) attributed the ongoing inadequacies to historical neglect, limited infrastructure investment, governance weaknesses and environmental pressures. Bishoge (2021) and Achuo and Asongu (2024) noted that even where policies exist, financial constraints and fragmented implementation hinder progress. Addressing these issues demands a context-sensitive, multi-sectoral approach that reflects the unique constraints and opportunities within developing regions (Howard et al., 2021; De Wit et al., 2024).

Evidence from different regions illustrates how these challenges manifest in practice. A review study conducted across several countries in sub-Saharan Africa found that inadequate sanitation infrastructure and poor hygiene practices remain widespread, contributing to the transmission of diseases such as cholera, typhoid, dysentery and diarrhoeal illnesses. These conditions are often aggravated by poverty, limited funding for WASH infrastructure and weak governance structures, which collectively hinder the effective implementation of sanitation and hygiene interventions. Consequently, many communities in sub-Saharan Africa continue to experience a high burden of diseases associated with unsafe WASH practices (Okesanya et al., 2024).

Similar challenges have been documented in South Asia. In Nepal, despite considerable improvements in WASH coverage over the past two decades, inequalities persist between urban and rural populations as well as between socio-economic groups. National assessments show that many households still rely on basic water services located far from their homes, while only a small proportion of the population has access to safely managed drinking water services. Furthermore, contamination of water sources with microbial pollutants, including *E. coli*, remains a persistent concern in several communities due to inadequate water treatment systems and poor sanitation infrastructure (Shrestha et al., 2023).

In rural settings globally, unsafe sanitation environments continue to contribute significantly to disease burdens and mortality. Studies assessing deaths attributable to unsafe sanitation have highlighted that rural populations in developing countries are particularly vulnerable due to inadequate sanitation infrastructure, limited access to safe water and insufficient public health interventions (Wolf et al., 2023; Okesanya et al., 2024; Wang et al., 2025; Shoab et al., 2026; Riviwanto et al., 2026). These conditions are strongly associated with diarrhoeal diseases and other environmentally related health risks, especially among vulnerable groups such as children and the elderly (Wang et al., 2025). These examples illustrate that the persistence of WASH challenges in developing countries is closely linked to deeper systemic and infrastructural constraints that limit the effective provision and sustainability of WASH services (De Wit et al., 2024; Barrington et al., 2025; Yimenu et al., 2026).

2.4.1 Systemic and Infrastructure Barriers to WASH Provision

Efforts to improve WASH in developing countries continue to face significant systemic and infrastructure barriers that limit progress towards universal access. Developing countries generally refer to nations with lower- or middle-income levels, limited industrialisation and constrained public infrastructure compared with developed countries (Biswas et al., 2024; Okesanya et al., 2024). Developed countries, such as Germany, Canada and Australia, typically have well-established water supply systems, advanced sanitation infrastructure and stronger institutional capacity to maintain WASH services (Wolf et al., 2023; Barros, 2024). In contrast, many developing countries, including South Africa, India, Kenya and Nigeria, particularly in regions such as sub-Saharan Africa and South Asia, continue to face challenges in expanding and maintaining reliable WASH services due to infrastructure deficits, financial limitations and governance constraints (Okesanya et al., 2024; Tshona et al., 2025). These challenges are shaped by historical inequalities, weak governance structures, urbanisation pressures, outdated infrastructure and persistent financial constraints. Understanding these interlinked barriers is essential for identifying sustainable solutions (Evaristo et al., 2023; John & Ajibade, 2024).

Colonial legacies in WASH infrastructure are particularly evident in regions such as India, South Africa, Kenya and Nigeria. Abrams et al. (2021) and De Wit et al. (2024) explain that colonial administrations often prioritized urban centres for service delivery in these countries, neglecting rural and indigenous communities. In India for instance, British colonial policies led to significant investments in urban areas like Mumbai and Delhi while rural regions were left underserved. Similarly, in South Africa, the apartheid system enforced racial segregation, resulting in robust infrastructure for urban areas and inadequate services for marginalised communities.

Empirical evidence from case studies further illustrates how these systemic barriers manifest in practice. For example, a case study conducted in rural communities of the Amathole District Municipality in South Africa revealed that inadequate water provision is strongly linked to ageing infrastructure, ineffective governance structures and limited financial resources, which together constrain municipalities' ability to deliver reliable water services to rural populations (Tshona et al., 2025). Similarly, research examining WASH vulnerability in rural villages and small towns in South Africa found that climate-related pressures, limited municipal capacity and persistent socio-economic inequalities continue to undermine equitable access to water and sanitation services in marginalised communities (Abrams et al., 2021).

Beyond South Africa, similar governance and infrastructure constraints have been observed in several developing regions. For instance, analyses of water governance systems across countries in Asia, Africa and Latin America highlight how fragmented institutional arrangements, weak policy coordination and insufficient financing mechanisms continue to impede progress towards achieving universal access to safe water and sanitation (Evaristo et al., 2023). Comparable findings have also been reported in studies examining WASH service delivery in rapidly urbanising regions of Asia and Africa, where climate variability, population growth and limited municipal capacity place additional pressure on water and sanitation infrastructure, thereby constraining equitable service provision (de Wit et al., 2024).

This unequal distribution of resources created systemic disparities that continue to influence access today. Angelakis et al. (2023) and Bazaanah and Mothapo (2023) observed that many developing countries inherited WASH systems that were not designed for equitable coverage. In Kenya, colonial policies favoured the highlands, leaving rural populations without adequate access to clean water. In Nigeria, the focus on urban development during colonial rule has contributed to ongoing challenges in rural sanitation and water supply. Rapid urbanisation has compounded these historical inequities. As cities expand, informal settlements grow without formal planning, leaving residents without access to clean water or sanitation (Kim et al., 2022; Dickin & Gabrielsson, 2023). Aydamo et al. (2023) reported that many urban slums operate without sewerage systems or a reliable water supply, creating environments where preventable diseases flourish. Tumwebaze et al. (2023) argued that the pace of urban growth often outstrips government capacity to respond with adequate infrastructure. These broader inequities are also reflected in school contexts, where schools located in poor communities, particularly lower quintile schools, often lack safe water and sanitation facilities. In contrast, better-resourced high quintile schools, situated in wealthier communities, benefit from more reliable provision (Van Dyk & White, 2019; Maistry & Africa, 2020). This linkage between community-level WASH disparities and the school environment underscores how historical and spatial inequalities directly shape the conditions under which learners access education. Such disparities not only affect the health and safety of students but also their overall educational outcomes, perpetuating a cycle of inequality (Mokgwathi et al.,2023).

Poor governance remains a significant obstacle. Giné-Garriga et al. (2021) noted that many governments lack the institutional capacity to enforce WASH regulations, ensure quality control or invest in long-term system maintenance. Shrestha et al. (2023) and Mensah et al. (2022) added that in some contexts, political instability and corruption further erode accountability. As a result, facilities deteriorate, services remain unreliable and communities lose trust in public provision. Addressing these challenges requires not only increased funding but also stronger policy enforcement and decentralised governance (Dhoba, 2022; Evaristo et al., 2023; Kalbar & Lokhande, 2023; John & Ajibade, 2024).

Additionally, infrastructure deficiencies represent a pressing barrier to WASH advancement. Many communities either lack piped water systems altogether or rely on ageing infrastructure that cannot meet current demand. Poorly maintained systems frequently break down, leading to unreliable services and an increased risk of contamination (Kulkarni, 2020; George-Williams et al., 2024). The absence of sustained investment in infrastructure expansion and upkeep has left many areas without the minimum services required for daily living. Another significant challenge is financial constraints. Poague et al. (2025) reported that many developing countries face significant budget limitations for WASH infrastructure, with donor funding often fragmented and short-term in nature. This financial instability hampers both the scale and sustainability of improvements. Some progress has been made through innovative financing approaches, including micro-financing, community-based funding models, and public-private partnerships. However, John and Ajibade (2024) cautioned that the success of these approaches depends on strong institutional support and a careful alignment with local needs and governance realities.

2.4.2 Socio-economic Disparities and WASH Accessibility

Socio-economic inequality plays a central role in determining who has access to reliable WASH services. According to Bick et al. (2024), schools with higher incomes are more likely to benefit from piped water, in-house sanitation and private hygiene facilities. In contrast, low-income communities, especially in peri-urban and rural areas, rely on shared or unimproved sources that pose health risks (Biswas et al., 2024; Kumar et al., 2024).

A study conducted in Akinyele Local Government Area in Ibadan, Nigeria found pronounced inequalities between public and private schools. The study revealed that none of the surveyed public schools provided adequate sanitation and hygiene services, whereas private schools were more likely to provide basic sanitation and hygiene facilities. As a result, students attending public schools were significantly more likely to engage in unsafe sanitation practices such as open defecation compared with students in private schools, highlighting how socio-economic differences between schools directly influence WASH accessibility and hygiene behaviour (Wada et al., 2022). Similarly, research examining school sanitation conditions in rural communities in Zimbabwe reported that inadequate WASH infrastructure disproportionately affects learners in resource-constrained schools. The study documented that many schools lacked functional toilets, reliable water supply and adequate menstrual hygiene facilities, conditions which particularly disadvantaged female learners and contributed to increased absenteeism during menstruation (Chidakwa, 2024).

Building on this, Abrams et al. (2021) highlight how government investments prioritise urban centres, leaving rural communities dependent on unsafe water sources. Wada et al. (2022) extend this argument by showing that such structural disparities are reflected in inadequate WASH facilities in peri-urban and low-income school settings. This is particularly relevant to the present study, which evaluates schools across quintiles located in both well-resourced and under-resourced areas of Durban. Such evidence illustrates how socio-economic and spatial inequalities directly influence school WASH provision and access.

In school environments, the lack of sanitation facilities exacerbates the challenges faced by adolescent girls. Shah et al. (2022) and Sharma et al. (2024) documented how inadequate menstrual hygiene facilities lead to absenteeism and school dropout. Beyond absenteeism, inadequate MHM also undermines girls' participation and concentration in class, limiting their educational attainment (Chidakwa, 2024). MacArthur et al. (2023) emphasised the need for targeted interventions that consider both gender and income disparities, while Robinson et al. (2024) address the unique needs of marginalised learners. Kumar et al. (2023) argued that bridging the WASH gap requires both infrastructure and community-based education. Such evidence underscores the importance of evaluating WASH provision across school quintiles, as inequities in access are not only infrastructural but also deeply embedded in broader patterns of social and educational inequality.

2.4.3 Health Implications of Poor WASH Conditions

The health consequences of poor WASH conditions are well documented. Diarrhoeal diseases, cholera and typhoid continue to account for a significant share of preventable illness and death, particularly amongst children (Andrés et al., 2021; Shayo et al., 2023; Wolf et al., 2023). Naz et al. (2025) reported that these diseases are closely linked to unsafe drinking water, poor hand hygiene and inadequate sanitation. Evidence from developing regions further demonstrates the magnitude of these risks. For example, studies in South Asia have shown that urban poor communities in cities such as Patna in India experience frequent disruptions in water supply, inadequate sanitation facilities and heightened exposure to waterborne diseases due to flooding and poorly maintained WASH infrastructure (Sharma et al., 2025).

Hand hygiene is especially critical in controlling the spread of respiratory and intestinal infections. However, in many schools and public institutions, the absence of handwashing stations or soap makes basic hygiene practices difficult to maintain. Fagunwa et al. (2023) and Seth and Pingali (2025) explained that open defecation, still practised in some regions, increases the risk of faecal contamination, particularly when surface water is used for drinking or cooking. In such contexts, contaminated water sources may facilitate the transmission of pathogens which are responsible for a range of gastrointestinal illnesses. The continued circulation of these pathogens reflects systemic gaps in sanitation infrastructure and hygiene behaviour, particularly in communities where safe water and sanitation services remain limited (Andrés et al., 2021). Similar challenges have also been documented in parts of Southern Africa, including South Africa, where inequalities in access to safe water, sanitation infrastructure and hygiene facilities persist in some communities and institutions, contributing to ongoing public health risks (Tseole et al., 2022; Rhadebe et al., 2025).

Beyond acute infections, poor WASH conditions can also contribute to long-term health impacts, particularly among children. Repeated exposure to contaminated water and unhygienic environments has been associated with chronic intestinal infections, undernutrition and impaired physical development. Studies have shown that frequent diarrhoeal episodes during early childhood can contribute to stunting and reduced cognitive development, which may have lifelong consequences for health and productivity (Shayo et al., 2023; Wolf et al., 2023). These broader health effects highlight that inadequate WASH services are not only a short-term public health concern but also a significant barrier to human development and well-being.

The implications for education are severe. McMichael (2019) observed that students who fall ill due to unsafe water and poor sanitation miss more school days, which contributes to lower academic performance and early dropout. In addition to illness-related absenteeism, inadequate sanitation and hygiene facilities can also affect students' concentration, comfort and overall learning experience within the school environment (Sharma et al., 2024). Poorly maintained toilets, lack of clean water and inadequate handwashing facilities may discourage students from using sanitation facilities during school hours, thereby increasing exposure to unhygienic conditions. These challenges are particularly pronounced for adolescent girls, who may experience additional difficulties managing menstrual hygiene in schools that lack adequate WASH infrastructure (Chidakwa, 2024)..

Breaking this cycle requires integrated WASH interventions that go beyond infrastructure and include hygiene promotion and behavioural change strategies. Effective interventions often combine improvements in water supply, sanitation infrastructure and hygiene education with community engagement and policy support. Such integrated approaches are essential for reducing the burden of WASH-related diseases and for creating healthier learning environments that support both student well-being and educational attainment.

2.4.4 Efforts to Improve WASH in Developing Countries

Despite the significant challenges posed by infrastructure deficiencies and financial constraints, various efforts have been made to improve WASH conditions in resource-limited settings. Community-Led Total Sanitation (CLTS) has emerged as a one successful model for promoting behaviour change and reducing open defecation (Mumin et al., 2024). For example, CLTS programmes have been implemented in communities in the Northern Region of Ghana to promote improved sanitation behaviours and eliminate open defecation through community mobilisation and behaviour change strategies (Muktar et al., 2024). These initiatives demonstrate how community participation and local leadership can improve sanitation practices and strengthen the sustainability of sanitation interventions. Zuin et al. (2019) explain that CLTS empowers communities to identify local solutions, with support from government and non-governmental organisations.

Kouassi et al. (2023) found that such programmes often lead to improved sanitation outcomes when properly supported. In Burkina Faso, for example, the implementation of CLTS in the Sissili province resulted in a substantial increase in sanitation coverage, with latrine coverage rising from 29.51% before the intervention to 90.44% after implementation, demonstrating the impact of community-led sanitation initiatives in improving rural sanitation conditions. CLTS programmes have also been implemented in Ethiopia as part of national sanitation strategies aimed at increasing household latrine utilisation and reducing open defecation in rural communities. Studies conducted in the East Wollega Zone in Western Ethiopia reported that community mobilisation through CLTS programmes contributed to increased latrine utilisation and improved sanitation behaviour among households (Shama et al., 2023).

Hygiene education has also played a vital role. Mulopo and Chimbari (2021) noted that integrating WASH education into school curricula has helped to instil lifelong hygiene habits in children, with benefits extending to their families and communities. Technological advancements are further driving progress in WASH initiatives. Shrestha et al. (2023) reported that innovative solutions such as water filtration systems, solar-powered pumps and decentralized wastewater treatment units have been successfully deployed in remote areas. These technologies are not only cost-effective but also scalable, making them well-suited for low-income contexts where traditional infrastructure may be lacking. The adaptability of such technologies allows communities to implement solutions tailored to their specific needs, thereby improving access to clean water and sanitation.

Efforts to improve WASH conditions have benefited from co-ordinated support amongst various stakeholders. Organizations such as the WHO, the United Nations Development Programme (UNDP) and Water.org, a non-profit organization focused on providing access to safe water and sanitation, play crucial roles by offering technical assistance, policy advocacy and funding (WHO, 2023a). The SDG 6 has further strengthened international commitment to achieving universal access to WASH by 2030, providing a framework for accountability and collaboration (UN, 2024).

While notable progress has been made in improving WASH conditions, long-term success hinges on inclusive planning, adequate funding and systems that are resilient to climate change and demographic shifts (WHO, 2023a). Continued collaboration between governments, civil society and local communities remains essential to effectively reducing WASH disparities and enhancing the quality of life across developing countries (Grant et al., 2023; Okesanya et al., 2024). This multifaceted approach not only addresses immediate needs but also lays the groundwork for sustainable development in the WASH context. These interventions are often implemented through community-based sanitation models that promote behavioural change and encourage community participation in addressing sanitation challenges.

2.4.5 Community-Based Sanitation Models and Approaches for WASH Improvement

Various models and participatory approaches have been implemented to improve sanitation and hygiene practices in developing countries. These approaches recognise that sustainable WASH improvements require not only infrastructure development but also behavioural change, community participation and local ownership of sanitation interventions (Tsekleves et al., 2022; Kumar et al., 2023; John & Ajibade et al., 2024). One widely recognised model is CLTS, which focuses on mobilising communities to collectively eliminate open defecation practices through awareness, social mobilisation and collective action. CLTS programmes encourage communities to recognise the health risks associated with open defecation and to take responsibility for improving sanitation conditions within their environments (Mumin et al., 2024).

Other community-based development approaches have been applied to strengthen sanitation interventions. One such approach is Asset-Based Community

Development (ABCD), which focuses on identifying and mobilising existing community assets, local knowledge and leadership to address development challenges (Skhosana, 2025). In the context of WASH programmes, the ABCD approach encourages communities to utilise their own resources, local knowledge and social structures to address sanitation and hygiene challenges. For example, a community-based sanitation education programme implemented in Mandalamekar Village in Bandung Regency, Indonesia applied a Local Asset-Oriented approach adapted from the ABCD framework. The programme engaged village officials, community health volunteers and local women's groups in identifying community assets that could support improved hygiene and sanitation practices. Participatory activities such as community discussions, sanitation education sessions and demonstrations of hygienic practices encouraged residents to adopt improved behaviours related to hand hygiene and the use of safe water. This approach strengthened community participation and increased knowledge of sanitation and hygiene practices, demonstrating how asset-based approaches can empower communities to improve water and sanitation conditions using locally available resources (Marsiati, 2025).

Another widely applied participatory model in WASH programmes is Participatory Hygiene and Sanitation Transformation (PHAST). PHAST is a community-based approach that promotes improved hygiene practices, sanitation behaviour change and community management of water and sanitation infrastructure through participatory learning processes. The approach actively involves community members in identifying hygiene and sanitation problems, analysing their causes and planning practical solutions to improve water and sanitation conditions (MacArthur et al., 2023). PHAST programmes have been implemented in several countries to strengthen community participation in WASH initiatives. For example, WASH projects implemented in Magway Region in Myanmar used the PHAST approach to engage communities in sanitation planning, hygiene promotion and water management activities, thereby strengthening community ownership and sustainability of WASH facilities (Win et al., 2024). Participatory approaches such as PHAST have been shown to improve hygiene awareness, increase the use of sanitation facilities and strengthen community engagement in maintaining water and sanitation services (MacArthur et al., 2023; Win et al., 2024). Collectively, these models highlight the importance of participatory and community-driven approaches in addressing sanitation challenges, particularly in regions where open defecation remains prevalent. By promoting behavioural change, community ownership and local leadership, these approaches contribute to more sustainable sanitation outcomes and improved public health in resource-constrained settings.

2.5 The Importance and Benefits of WASH Provision in Schools

Schools are amongst the most critical settings where the consequences of inadequate WASH access are most visible and most urgent to address. The provision of WASH services in schools plays a pivotal role in supporting a safe, healthy and inclusive learning environment. As Ngure et al. (2014) and Shanazarov (2025) suggested, schools are critical spaces where children not only receive education but also develop lifelong hygiene behaviours. Access to clean water, functional sanitation facilities and handwashing stations has a direct impact on learners' health, school attendance and academic performance. According to Azupogo et al. (2023), WASH in schools also contributes to broader goals of gender equity, dignity and child protection. When schools are equipped with adequate WASH infrastructure, the entire learning environment becomes more conducive to student well-being and achievement (Ayelazuno & Tetteh, 2025).

2.5.1 Health and Hygiene Promotion

Ensuring access to safe WASH facilities is essential for maintaining the health of learners. Schools that lack adequate WASH services expose children to preventable illnesses such as diarrhoea, typhoid and cholera, which are leading causes of school absenteeism (WHO, 2019). Prüss-Ustün et al. (2019) and Shrestha et al. (2023) noted that these conditions are exacerbated by poor hygiene environments, particularly in schools where handwashing stations are either non-functional or unavailable.

Pieters et al. (2025) identified handwashing with soap as one of the most effective interventions for reducing disease transmission in school settings. However, WHO & UNICEF (2021) highlighted that in many developing countries, basic hygiene facilities remain absent or poorly maintained. Wada and Oloruntoba (2021) observed that this lack of infrastructure contributes to high rates of school-related illnesses, particularly in rural and underserved communities. When implemented correctly, hygiene education programs can significantly enhance students' understanding and practices, resulting in reduced infection rates and healthier school environments (Kothari et al., 2022; Michael et al., 2023).

2.5.2 Impact on School Attendance and Academic Performance

The absence of reliable WASH infrastructure in schools is associated with high levels of absenteeism. Girmay et al. (2023) reported that younger children are particularly susceptible to waterborne and hygiene-related illnesses, which directly disrupt their education. In many cases, the lack of drinking water forces students to leave school grounds in search of water, further reducing instructional time (Anthonj et al., 2021; Choudhuri & Desai, 2021).

Toilets that are broken, unclean or inaccessible contribute to discomfort and reduced classroom engagement. This is particularly relevant for girls, who often miss school during menstruation when MHM facilities are lacking (Nabwera et al., 2021; Poague et al., 2024). Schools that have invested in WASH facilities consistently report improved learner retention and reduced absenteeism (Cronk et al., 2020; Sharma et al., 2024). Girmay et al. (2023) added that students perform better academically when their basic health and hygiene needs are met. Furthermore, Kumar et al. (2023) and Sifullah et al. (2024) emphasised that WASH access not only benefits learners but also enables teachers to deliver lessons more effectively in a disruption-free environment. Overall, these findings indicate that adequate WASH provision in schools is not only a public health requirement but also a critical factor influencing school attendance, learner participation and academic performance.

2.5.3 Gender Equity and Menstrual Hygiene Management

WASH provision in schools plays a transformative role in advancing gender equity. Girls face unique challenges during menstruation, especially in schools where sanitation facilities are either unavailable or not designed with gender sensitivity. De

Guzman et al. (2022) explained that in many cultures, menstruation remains a taboo subject, and the lack of appropriate infrastructure can lead to shame, absenteeism and school dropout.

The presence of gender-segregated toilets, clean water for washing and proper disposal facilities enables girls to manage their menstrual health with dignity and confidence (MacArthur et al., 2023; Thurairasu, 2023). According to Dickin and Gabrielsson (2023), this contributes significantly to increased school attendance and learner participation. Jahan et al. (2024) and Adane et al. (2025) found that menstrual hygiene interventions not only improve educational outcomes but also empower girls with knowledge and autonomy over their health.

Evidence from school-based studies provides real-life examples of how inadequate WASH facilities affect girls' experiences during menstruation. For example, a study conducted in public schools in Ethiopia reported that many girls miss classes during menstruation due to the absence of safe spaces for changing menstrual materials and limited access to water and sanitation facilities (Adane et al., 2025). Girls in the study described feelings of embarrassment, fear of stigma and difficulties concentrating in class when appropriate menstrual hygiene facilities were unavailable regularly (Assefa et al., 2025). Similarly, research conducted in other school contexts highlights that inadequate sanitation infrastructure and lack of privacy can discourage girls from attending school during menstruation. In some cases, poorly maintained toilets, absence of water for washing and lack of disposal facilities create significant barriers for girls attempting to manage menstruation safely and privately within the school environment regularly (Thurairasu, 2022).

Palgunadi et al. (2024) and Schmitt et al. (2021) highlighted that menstrual health education, when integrated into school curricula, helps break down stigma and creates a supportive learning environment. However, economic barriers also play an important role in shaping menstrual hygiene practices. Studies have shown that many girls from low-income households struggle to afford sanitary products, which further contributes to absenteeism and discomfort during menstruation regularly (Head et al., 2025). Additionally, providing free or subsidised menstrual products can reduce economic barriers that prevent girls from attending school regularly (Thomas & Melendez-Torres, 2024). These findings highlight that effective menstrual hygiene management and gender-sensitive WASH facilities are essential for promoting gender equity, improving school attendance among girls and creating a supportive learning environment in schools.

2.5.4 Safety, Dignity and Psychological Well-being

WASH infrastructure in schools contributes not only to physical health but also to learners' safety, dignity and emotional well-being. Sharma et al. (2024) noted that many students, especially girls, feel unsafe using shared or poorly maintained toilets, particularly in the absence of privacy or security. This lack of safety can cause anxiety, discomfort and disengagement from school activities.

Well-designed sanitation facilities that are clean, gender-segregated and regularly maintained foster a respectful and inclusive school climate (Poague et al., 2022b; WHO & UNICEF, 2023). Wada et al. (2022) reported that unhygienic conditions and social stigma related to menstruation can cause emotional distress, especially amongst adolescent girls. When these issues are not addressed, they may lead to chronic absenteeism and school dropouts. Creating safe WASH environments promotes learner confidence and engagement. According to Sharma and Adhikari (2022), students are more likely to participate fully in school life when they are not distracted by discomfort or fear. Integrating WASH into school health policies ensures that all students, regardless of gender or background, are afforded the conditions necessary for learning with dignity (Assefa et al., 2025). While safe and dignified WASH environments benefit all learners, these conditions are not equally accessible to every student. Learners with disabilities frequently encounter additional barriers when sanitation and hygiene facilities are not designed to accommodate their accessibility needs, highlighting the importance of inclusive WASH infrastructure in schools.

2.5.5 WASH Accessibility for Learners with Disabilities

Access to safe WASH facilities is essential for all learners; however, students with disabilities frequently face significant barriers when school infrastructure is not designed to accommodate their needs. Evidence indicates that persons with disabilities are disproportionately affected by inadequate access to WASH services, particularly in low- and middle-income countries where inclusive infrastructure and services remain limited (Wilbur et al., 2024; Azupogo et al., 2025). These inequalities are often reinforced by environmental and institutional barriers that restrict the ability of learners with disabilities to access water and sanitation facilities safely and independently in school settings (Dassah & Bisung, 2023).

In many schools, sanitation facilities lack accessible features such as ramps, handrails, widened entrances and adapted toilets, which restricts the ability of learners with mobility impairments to use these facilities independently. Physical barriers within the built environment, including steep pathways, narrow doorways and poorly designed sanitation facilities, have been identified as key obstacles preventing students with disabilities from accessing school WASH services (Dassah & Bisung 2023; Pereira et al., 2024; Azupogo et al., 2025).

When such facilities are inaccessible, learners may be forced to rely on assistance from peers or teachers, thereby compromising their privacy and dignity. Research examining WASH access among vulnerable populations further indicates that structural barriers and limited inclusive infrastructure can significantly reduce the ability of individuals with disabilities to access safe water and sanitation services (Wilbur et al., 2024; Pereira et al., 2024; Azupogo et al., 2025; Salleh et al., 2025). Limited access to inclusive WASH facilities can also discourage school attendance and participation among children with disabilities. Studies show that inequalities in access to WASH services contribute to broader disparities in education and wellbeing among persons with disabilities (Wilbur et al., 2024). In addition, assessments of WASH provision in schools have highlighted that although many schools provide basic drinking water services, sanitation and hygiene services often remain inadequate, particularly in relation to accessibility and usability for vulnerable groups (Pereira et al., 2024).

Promoting inclusive WASH infrastructure is therefore essential for ensuring equitable learning environments. Accessible sanitation facilities that incorporate appropriate design elements such as adequate space, supportive handrails, non-slip flooring and clear signage can significantly improve safety and independence for learners with disabilities (Dassah & Bisung, 2023; Wilbur et al., 2024; Salleh et al., 2025). Strengthening disability-inclusive WASH policies and infrastructure is therefore critical for reducing inequalities and ensuring that all learners are able to access WASH facilities safely, independently and with dignity. Ensuring equitable access to WASH services for all learners, including those with disabilities, reflects broader principles of social justice and inclusion. These considerations are closely aligned with the recognition of WASH as a fundamental human right.

2.5.6 WASH in School as a Human Right

The global recognition of WASH as a human right reinforces the obligation of nations and education systems to provide equitable access to clean water and sanitation in schools. Pereira et al. (2024) and Zegeye (2024) emphasised that access to WASH is not merely a development goal but a fundamental right tied to health, education and human dignity.

The SDGs, particularly Goal 6, call for universal and equitable access to safe WASH by 2030 (UN, 2015). As part of this commitment, the WHO and UNICEF have issued minimum standards for WASH in schools, encouraging governments to integrate hygiene infrastructure with education and health programming (WHO & UNICEF, 2023).

WASH progress has been made in several countries through multi-sectoral partnerships that involve governments, non-governmental organisations, private sector actors and communities (WHO & UNICEF, 2022; De Wit et al., 2024). Poague et al. (2022b) highlighted examples where public-private partnerships have enhanced WASH delivery in schools. National-level policies that allocate dedicated budgets, set enforceable standards and promote awareness campaigns have resulted in significant improvements in both health and academic outcomes (McGinnis et al., 2017; Sharma & Adhikari, 2022).

Nevertheless, gaps in WASH access persist, particularly in rural and low-income areas. Infrastructure shortages, limited funding and weak policy enforcement continue to hinder the realisation of WASH rights in schools. As such, sustained advocacy, inclusive planning and local accountability mechanisms remain critical to ensuring that every learner enjoys their right to a safe and hygienic school environment (Bazaanah & Mothapo, 2023; John & Ajibade, 2024).

The benefits of WASH provision in schools extend well beyond disease prevention, influencing attendance, learning, gender equality and dignity. However, achieving equitable access will require sustained investment, policy commitment and inclusive implementation (Biswas et al., 2024; De Wit et al., 2024; Robinson et al., 2024). These priorities directly support global efforts toward 2030 WASH targets in school environments (Okesanya et al., 2024; Magwe, 2025).

2.6 The 2030 Vision for WASH in Schools

The 2030 vision for WASH in schools aligns closely with SDG 6, which seeks to ensure universal access to safe water and adequate sanitation by 2030. This global mandate places schools at the centre of health and education equity (Addie, 2025), recognising their role in shaping lifelong behaviours and fostering inclusive learning environments (Ahmed et al., 2021; Poague et al., 2025; Sugita, 2022; Ngcongo & Tekere, 2023). Governments, international agencies and local communities are expected to collaborate to implement sustainable WASH solutions that address infrastructural and behavioural change (John & Ajibade, 2024; Rhodes-Dicker et al., 2025).

2.6.1 Infrastructure Development for Universal WASH Access

Infrastructure development remains a cornerstone of achieving universal WASH access in schools. All schools must have reliable access to clean water; functional and gender-segregated sanitation facilities; and adequate handwashing stations (Bolatova et al., 2021; Wada et al., 2022; Shrestha et al., 2023). Facilities must also cater to the needs of learners with disabilities, ensuring inclusive access (Francis et al., 2022). These requirements are reflected in global policy initiatives such as the WHO/UNICEF WASH in Schools programme and the SDGs, which promote universal access to safe water and sanitation in educational institutions (WHO & UNICEF, 2021).

Targeted investment is critical, particularly in resource-constrained areas where piped water systems and improved sanitation are often lacking (Gaiffe et al., 2023; Gallandat et al., 2024). For example, WASH initiatives implemented in basic schools in the Nabdam District in the Upper East Region of Ghana aim to improve access to potable water, sanitation facilities and hygiene promotion through national education policies and the WASH in Schools programme. However, empirical evidence shows that many schools still experience inadequate toilet facilities, limited handwashing infrastructure and insufficient funding for maintenance, which affects the sustainability of these interventions (Mensah et al., 2022).

In such contexts, rainwater harvesting, solar-powered purification and low-cost ecological sanitation models offer feasible alternatives (Hafeez et al., 2020; Kumar et al., 2023; Ejairu et al., 2024). For instance, solar-powered water purification technologies have been proposed as sustainable solutions for remote and off-grid communities where conventional water infrastructure and electricity supply are limited, enabling communities to access safe drinking water using renewable energy sources (Anjimoon et al., 2024).

To ensure long-term durability and effectiveness, WASH infrastructure must be supported by regular maintenance schedules and dedicated budgets. Nelson et al. (2021) and Herath et al. (2022) emphasised that the lack of ongoing maintenance often leads to the rapid deterioration of facilities. John and Ajibade (2024) advocated for mandatory inspections and consistent financial support to prevent infrastructure collapse and safeguard intended benefits.

2.6.2 Hygiene Education as a Key Component of WASH Sustainability

Behavioural change, driven by hygiene education, is essential for the sustainability of WASH interventions. Ginja et al. (2019) and Sugita (2022) highlighted that students equipped with hygiene knowledge are more likely to practise safe behaviours and influence their households and communities. Schools must therefore integrate structured hygiene education into the curriculum (Iqbal et al., 2023; Kuandyk et al., 2024).

Effective approaches to enhancing WASH education include peer education models, hygiene clubs and teacher-led campaigns. Interactive, participatory methods have shown success in reinforcing key practices such as handwashing and safe water use (Winter et al., 2021). Moreover, embedding hygiene messages in health and science subjects ensures that WASH is consistently reinforced throughout learners' educational journey.

Cultural relevance is also vital. Tailoring hygiene messages to reflect community beliefs and involving local leaders in advocacy enhances acceptance (Ejairu et al., 2024; Kuandyk & Omarova, 2024). As community hubs, schools can drive broader WASH awareness and transformation.

2.6.3 Policy Implementation and Multi-Sectoral Collaboration

Effective policy implementation is crucial for achieving the 2030 WASH targets. Governments must institutionalise WASH within education policy and infrastructure planning frameworks (Ahmed et al., 2021; Poague et al., 2022a). Alignment with international guidelines from WHO and UNICEF ensures consistency and quality services (WHO & UNICEF, 2021).

In practice, policy implementation often occurs through collaborative programmes involving government institutions, development partners and community stakeholders. For example, school WASH initiatives implemented through partnerships between ministries of education, district authorities and international organisations have supported the provision of sanitation facilities, safe water points and hygiene education programmes in schools. These initiatives aim to improve learner health outcomes while also strengthening the overall school environment. Evidence from school WASH programmes shows that multi-stakeholder collaboration plays an essential role in translating policy commitments into operational infrastructure and hygiene interventions (Mensah et al., 2022; Achuo and Asongu, 2025).

John and Ajibade (2024) noted that collaboration across government departments, NGOs, private sector actors and community groups is necessary to implement these policies. However, inadequate enforcement has been a persistent challenge. Weets and Katz (2024) and Achuo and Asongu (2024) stressed that many schools operate without meeting basic standards due to weak regulatory oversight. Strengthening monitoring mechanisms and building capacity for enforcement at national and local levels can address this gap (Kucici & Shettima, 2025). Empirical studies further show that even when WASH infrastructure projects are implemented, sustainability depends on effective coordination between school authorities, local government institutions and community structures responsible for facility maintenance. In some districts, weak institutional coordination, limited financial resources and inadequate monitoring mechanisms have reduced the long-term effectiveness of WASH programmes, resulting in poorly maintained sanitation facilities and inconsistent water supply in schools (Mensah et al., 2022; Kucici & Shettima, 2025). Such efforts ensure that WASH implementation is consistent, equitable and accountable.

2.6.4 Monitoring and Evaluation for Effective WASH Implementation

A robust monitoring and evaluation framework enables governments and partners to track progress, measure effectiveness and adjust strategies as needed. De Wit et al. (2024) and Win et al. (2024) emphasised the importance of standardised tools to assess compliance and prioritise interventions. Integrating WASH indicators into Education Management Information Systems (EMIS) provides real-time data on school-level conditions, thereby enabling targeted resource allocation (Okesanya et al., 2024; Rahman et al., 2024). Win et al. (2024) further noted that linking WASH monitoring to broader education indicators enhances strategic planning.

Monitoring of WASH services is commonly conducted through structured surveys, facility inspections and water quality testing carried out in school environments. For instance, a large multi-country assessment of WASH conditions in rural schools across countries such as Ethiopia, Ghana, Kenya, Tanzania and Uganda collected survey data and water samples from more than 2,600 schools in order to assess the availability of water supply, sanitation facilities and hygiene services (Cronk et al., 2020).

In addition, monitoring activities enable authorities to evaluate whether drinking water supplied in schools complies with prescribed standards. These monitoring activities occur at multiple administrative levels. At national level, education ministries integrate WASH indicators into national monitoring systems such as Education Management Information Systems to track school infrastructure and service provision. At district level, government agencies responsible for water and sanitation services, such as the Department of Public Health Engineering in Bangladesh, coordinate monitoring and implementation of WASH programmes in schools and communities (Cronk et al., 2020; Rahman et al., 2024). At the local level, school-based monitoring initiatives, such as student-led audits and participatory assessments, promote accountability and ownership (Poague et al., 2025). Parental involvement in school WASH monitoring strengthens community engagement and ensures long-term sustainability (Cronk et al., 2020; Habtegiorgis et al., 2021; Tsekleves et al., 2022).

Effective monitoring systems also depend on the availability of adequate resources and clearly defined operational processes. These include trained personnel responsible for conducting inspections, data collection tools, laboratory or field equipment for water quality testing and institutional coordination between education and water authorities (Olatunji & Taiwo, 2021; Ahmed et al., 2023). Monitoring processes generally involve systematic data collection, verification of infrastructure functionality and reporting through institutional databases to inform decision-making. Evidence from school WASH monitoring programmes has shown that such systems can improve identification of infrastructure gaps and guide targeted interventions aimed at improving water supply, sanitation facilities and hygiene services in schools (Cronk et al., 2020; Girmay et al., 2023; Radebe et al., 2025). However, several challenges continue to affect the effectiveness of monitoring systems, including limited financial resources, shortages of trained personnel and weak institutional coordination in some contexts, which may reduce the reliability and frequency of monitoring activities (Ahmed et al., 2023; Girmay et al., 2023; Rahman et al., 2024).

2.6.5 Addressing Climate Resilience in WASH Programs

Given the growing impacts of climate change on water availability and sanitation systems, WASH programs must integrate resilience strategies to effectively address these challenges. Climate change intensifies extreme weather events, including prolonged droughts and flooding, which weaken infrastructure, particularly in vulnerable regions (Howard et al., 2022; Ali et al. (2024). In refugee settings and other fragile environments, the situation is further complicated by climate-related environmental changes, such as increasing aridity, irregular rainfall and recurrent extreme heat. These factors not only diminish water sources but also heighten risks to sanitation services, making it imperative to adopt adaptive strategies (Yasmin et al., 2022).

To enhance the effectiveness of WASH programs in the context of climate change, innovative solutions are critical. Designing flood-resistant sanitation facilities ensures that sanitation services remain functional during extreme weather events, which are becoming more frequent due to climate change. Implementing rainwater harvesting systems in schools increases water availability, allowing communities to collect and store rainwater for sanitation and hygiene practices, particularly during dry spells exacerbated by changing climate patterns (Fabian et al., 2023; Wang et al., 2022). Additionally, groundwater recharge technologies, such as artificial aquifer recharge, further support sustainable water management by replenishing groundwater supplies, thus ensuring a reliable water source for communities facing the challenges posed by climate variability (WHO & UNICEF, 2023).

2.7 The Impact of Inadequate WASH in Schools

The absence of adequate WASH services in schools significantly undermines student health, academic performance and emotional well-being. According to Poague et al. (2025), schools that lack basic WASH infrastructure expose learners to heightened risks of illness, absenteeism and educational inequality. While these effects are most pronounced in under-resourced settings, they have far-reaching consequences across various learning environments (Kucici & Shettima, 2025).

2.7.1 Health Implications of Inadequate WASH Facilities

Exposure to unsafe drinking water and unsanitary conditions increases the likelihood of contracting diarrhoea, cholera, typhoid and intestinal parasites amongst school-aged children. Poor hygiene, particularly the absence of handwashing facilities, accelerates the transmission of respiratory infections and skin conditions such as scabies (UNICEF & WHO, 2024). UNICEF and the WHO (2022) attribute a significant share of global child morbidity and mortality to preventable, hygiene-related diseases.

Globally, inadequate WASH services remain a major contributor to disease burden. Approximately 2.2 billion people lack access to safely managed drinking water services, while unsafe sanitation and hygiene contribute to more than 1.4 million deaths annually associated with preventable diseases (Okesanya et al., 2024). In low- and middle-income countries, diarrhoeal diseases linked to poor WASH account for a substantial proportion of childhood illness and mortality, particularly in sub-Saharan Africa and South Asia. For example, studies have shown that poor WASH practices contribute to approximately 60% of diarrhoeal deaths globally, with many cases occurring amongst children under the age of five in resource-constrained settings (Wolf et al. 2023).

Context-specific research further illustrates the health risks associated with inadequate WASH facilities in schools. A study conducted in four schools in the Dhanusha and Chitwan districts of Nepal found that students in schools with unimproved WASH facilities frequently reported illness associated with unsafe drinking water, poor hygiene practices and the absence of soap at handwashing stations (Sharma et al., 2024). Learners indicated that untreated water from hand pumps was often consumed directly and that handwashing practices were inconsistent, increasing exposure to waterborne diseases and other infections.

Amongst adolescent girls, the lack of MHM resources is especially harmful. As highlighted by Schmitt et al. (2021), girls in schools without access to clean water, sanitary products and private toilets are more susceptible to reproductive tract infections and psychological distress. Furthermore, social stigma surrounding menstruation often discourages girls from attending school during their menstrual periods (Jahan et al., 2024).

2.7.2 Disruptions to Learning and Academic Performance

Inadequate WASH facilities directly interfere with the learning process. Research by Sharma et al. (2024) has shown that illness caused by poor sanitation contributes to frequent absenteeism and the loss of learning hours. For example, a study by Kagurusi et al. (2025) in Pader District, Uganda, indicated that approximately 14.1% of learners missed school due to diarrhoea. However, there was no mechanism in place to compensate for the lost time due to these health-related absences. Similar findings have been reported in other regions where inadequate WASH conditions contribute to school absenteeism. In Addis Ababa, Ethiopia, school-based research demonstrated that learners frequently experience water- and hygiene-related illnesses, including diarrhoeal and respiratory infections, which are associated with school absence and reduced participation in classroom activities (Bick et al., 2024). Comparable evidence has also been reported in India, where inadequate school WASH infrastructure has been linked to increased absenteeism among learners due to hygiene-related illnesses (Sharma et al., 2024). These findings collectively demonstrate that WASH-related illnesses continue to disrupt school attendance across several regions, particularly in parts of East Africa and South Asia where WASH infrastructure remains inadequate. This highlights a gap in addressing the impacts of diarrhoea on educational outcomes in the study area. In contexts where MHM is not adequately supported, many girls are forced to miss school, leading to persistent learning gaps and, over time, lower academic achievement (Poague et al., 2022a). Unpleasant physical environments, such as toilets with foul odours, poor ventilation or inadequate cleaning, contribute to discomfort and anxiety, which impair focus and motivation (Wada et al., 2022; Okesanya et al., 2024). Taken together, the evidence suggests that inadequate WASH provision in schools does not only affect learner health but also undermines consistent school attendance, concentration in class and overall academic performance. Addressing WASH deficiencies is therefore essential for protecting both the health and educational outcomes of learners, particularly in resource-constrained school environments.

2.7.3 Social Inequality and Gender Disparities

WASH inequalities in schools reflect and reinforce broader social inequities. According to Kucici and Shettima (2025), students from rural and low-income communities are disproportionately affected by inadequate facilities. Girls and children with disabilities often bear the greatest burden as they face both practical and social barriers to using existing infrastructure (Jahan et al., 2024).

A study conducted in sub-Saharan Africa found that one in four girls misses school during menstruation due to the lack of proper facilities (UNICEF & WHO, 2024). Children with mobility impairments often find it difficult to access toilets, sinks, or hygiene materials, further limiting their participation in daily school life (Poague et al., 2025). Promoting inclusive WASH design, such as wheelchair-accessible toilets and adaptive hygiene equipment, is thus essential for advancing equity in education (Wilbur et al. 2024).

2.7.4 Psychological and Emotional Impacts of Poor WASH Conditions

Beyond the physical consequences, inadequate WASH services affect learners' mental and emotional well-being. Girls experiencing menstruation-related challenges in school often report feelings of shame, anxiety and social isolation (Thomas & Melendez-Torres, 2024). This distress reduces classroom participation and confidence, thereby undermining academic and personal development (MacArthur et al., 2023). As noted by Habtegiorgis et al. (2021), noted that learners exposed to unsanitary and overcrowded school environments are more likely to experience chronic stress. In the absence of accessible WASH facilities, students with disabilities frequently feel excluded and dependent on peers or teachers for basic hygiene needs, an experience that erodes their dignity and self-esteem (Tsekleves et al., 2022). Creating psychologically safe and supportive WASH environments is therefore not only a matter of public health but also of promoting educational inclusion and dignity for all learners.

2.8 Barriers to Effective MHM in Schools

Building on the evidence presented in the previous section, it becomes apparent that MHM represents a critical component of the WASH agenda in schools. Inadequate facilities not only hinder girls' access to quality education but also perpetuate stigma and inequity in learning environments. A focused exploration of MHM provides insight into how schools can better support adolescent girls and promote gender-sensitive WASH systems (Habtegiorgis et al., 2021; Hussein et al., 2022; Betsu et al., 2024).

In many lower-income contexts, schools continue to lack gender-sensitive sanitation infrastructure. As noted by Sharma et al. (2024), the absence of separate toilets for girls and boys, combined with non-lockable doors and poor lighting, undermines privacy and discourages menstrual management during school hours. Girls in such environments frequently report leaving school early or missing classes entirely during menstruation (Olson et al., 2022; Sidle et al., 2025; Poague et al., 2025).

Access to clean and reliable water is another persistent challenge. Menstrual hygiene requires adequate water for washing hands; cleaning re-usable products; and maintaining personal cleanliness. In water-scarce schools, students may resort to unsafe hygiene practices, increasing the risk of infections such as urinary tract infections and reproductive health complications (Adane et al., 2025; Kucici & Shettima, 2025). Evidence from sub-Saharan Africa shows that menstrual-related absenteeism is more prevalent in schools without a consistent water supply (Njee et al., 2024; Msovela et al., 2025).

Additionally, the absence of appropriate disposal facilities for used menstrual products further undermines girls' ability to manage menstruation with dignity (Poague et al., 2025). Many schools do not provide sanitary bins, incinerators, or safe waste disposal options, resulting in girls discarding used menstrual products in latrines or open spaces, which contributes to unsanitary conditions, blocked toilets and increased feelings of embarrassment (Wada et al., 2022; Assefa et al., 2025). The lack of discreet disposal mechanisms not only affects health and hygiene but also affects school attendance and participation (Dutta et al., 2024; Joshi & Mendhe, 2025).

Beyond infrastructure, cultural stigma and misinformation surrounding menstruation remain formidable barriers. In communities where menstruation is considered taboo, girls often receive little to no information before menarche and feel unprepared to manage their periods at school (Schmitt et al., 2021; Royo et al., 2022; Kirira et al., 2023; Sharma et al., 2024; Thomas & Melendez-Torres, 2024). The absence of menstrual health education in curricula perpetuates silence, shame and low self-confidence, particularly for younger learners (Schmitt et al., 2021; MacArthur et al., 2023; Betsu et al., 2024).

2.8.1 Educational and Psychological Implications of Poor MHM in Schools

Inadequate MHM services in schools are strongly correlated with absenteeism and diminished academic engagement. Studies have shown that adolescent girls without access to menstrual products or safe facilities are significantly more likely to miss school days during their period (Miiro et al., 2018; Shah et al., 2022; Method et al., 2024). A study in Kenya reported that nearly half of school-aged girls missed at least one day of school each month due to menstruation, with sanitation concerns being the most cited reason (Sidle et al., 2025).

Psychologically, girls who are unable to manage menstruation hygienically often report feelings of anxiety, fear of stigma and reduced self-esteem (Åkerman et al., 2024). The fear of accidental leaks, teasing or odour discourages participation in classroom activities and sports, leading to social withdrawal and lowered confidence

(Dutta et al., 2024; Adane et al., 2025). In contrast, Mo and Morris, (2024) state that students who feel supported by staff and peers in managing their periods are more likely to attend school consistently and engage positively with their education.

Over time, poor MHM provision deepens gender disparities in educational outcomes. Schmitt et al., (2021) state that girls who regularly miss school during menstruation face greater risk of falling behind academically and may ultimately drop out (Shah et al., 2022). This learning gap limits their prospects, including access to tertiary education, employment and financial independence. Thus, menstrual hygiene must be recognised as both a public health and human rights issue that intersects with gender equality in education (Adane et al., 2025).

2.8.2 Addressing the Gaps: Strategies for Improving MHM in Schools

Improving MHM in schools requires a holistic, gender-responsive approach. Firstly, infrastructure must be upgraded to include private, well-maintained toilets with functional locks, sufficient lighting and access to water (Blake et al., 2025). These facilities should be equipped with sanitary product disposal options such as pedal bins or incinerators to maintain hygiene and dignity (Schmitt et al., 2021; Bhakta et al., 2024).

Secondly, integrating menstrual health education into the school curriculum is vital. MHM education should be inclusive, targeting both male and female learners to reduce stigma and foster peer support (Roux et al., 2023; Jones & Baldwin, 2025). School clubs and peer-led initiatives can complement formal lessons by creating safe spaces for discussions around menstruation (Yillah et al., 2025). Evidence from intervention studies across low- and middle-income countries demonstrates that combining menstrual health education with the provision of menstrual supplies and improved WASH facilities can significantly improve school attendance, knowledge and hygiene practices amongst schoolgirls. For example, intervention trials involving more than 17,000 schoolgirls across countries including Ethiopia, Kenya, Ghana and Bangladesh showed improvements in menstrual knowledge, attitudes and hygiene practices, while also reducing school absenteeism during menstruation (Betsu et al., 2023).

Thirdly, schools must form partnerships with government bodies, NGOs and private entities to ensure sustainable access to menstrual products (Shomuyiwa et al., 2024). In many low-income settings, affordability remains a key barrier. Free or subsidised product distribution has been shown to significantly reduce absenteeism and enhance girls' participation in school (Shah et al., 2022; Agyei-Sarpong, 2025). For instance, research conducted in Lapai Local Government Area in Nigeria reported that period poverty significantly affects school attendance and well-being among adolescent girls, highlighting the need for subsidised menstrual products, curriculum-based menstrual education and improved healthcare support as key policy interventions (Alkali, 2024).

Engaging parents, teachers and local leaders in awareness campaigns helps to normalise menstruation and challenge harmful cultural narratives (Schmitt et al., 2021; Olson et al., 2022). As noted by Chidakwa (2024), community-driven efforts are essential to fostering supportive environments that prioritise girls' health and education. Moreover, training school staff, particularly female teachers, to provide guidance and emotional support around MHM creates a more inclusive environment. Many girls lack trusted adults to turn to for menstrual-related concerns (Betsu et al., 2023). Empowering teachers with relevant knowledge and resources ensures that no learner is left unsupported (Mahfuz et al., 2021).

Lastly, the continuous monitoring and evaluation of MHM initiatives are crucial. Regular audits of school facilities, tracking of absenteeism rates, and assessments of knowledge retention can help refine programmes and sustain progress over time (Joshi et al., 2024). Observations from flood-affected regions in Bangladesh further demonstrate that the absence of adequate sanitation facilities and menstrual supplies in schools and temporary shelters forces women and girls to use unsafe alternatives such as cloth or paper, increasing health risks and highlighting the importance of integrating menstrual hygiene support into disaster preparedness and public health responses (Al-Mamun et al., 2025).

2.9 Obstacles and Hurdles in Achieving Optimal WASH Conditions in Schools

Despite global efforts and increased awareness of the importance of WASH in schools, many schools, particularly those in low-resource settings, continue to face persistent challenges in achieving optimal conditions (Sangalang et al., 2020; Kucici & Shettima, 2025). As highlighted by Okesanya et al. (2024) and Magwe (2025), WASH infrastructure plays a critical role in promoting health, equity and academic performance. However, these benefits are often undermined by structural, financial and socio-cultural barriers that limit the effectiveness and sustainability of school-based WASH programs.

2.9.1 Financial and Resource Constraints

One of the most significant barriers to effective WASH implementation in schools is limited financial investment (John & Ajibade, 2024). According to Jama et al. (2024), budgetary constraints prevent many schools, especially those in quintile 1 and 2 categories, from constructing or maintaining essential WASH infrastructure. In such settings, basic amenities such as functioning toilets, clean water supply and soap are often unavailable or poorly maintained (Rose et al., 2023).

Moreover, WASH funding is frequently embedded within general education budgets, with no dedicated allocations or specific guidelines (Byansi et al., 2025). This lack of targeted financial planning contributes to disparities between urban and rural schools (Victor et al., 2025). Schools without piped water often face additional costs to purchase water, further straining already limited operational funds (Poague et al., 2025).

The absence of sustainable financing models also complicates the long-term maintenance of existing WASH infrastructure. Poorly maintained WASH facilities deteriorate quickly, requiring costly repairs or complete overhauls, which many schools cannot afford (John & Ajibade, 2024; Byansi et al., 2025). These financial hurdles reinforce WASH inequality across socio-economic contexts (Hussain et al., 2024; Sharma, et al., 2025).

2.9.2 Infrastructure Limitations and Poor Maintenance

Infrastructure deficiencies remain a widespread and persistent challenge in the provision of adequate WASH services in schools. Poague et al., (2025) state that many schools, particularly those in under-resourced settings, continue to operate without basic WASH infrastructure, including gender-segregated toilets, functional handwashing stations and appropriate waste disposal systems. The absence of these essential facilities not only compromises hygiene practices but also exposes learners to communicable diseases, including diarrhoeal infections and respiratory illnesses, which affect younger children (Olatunji & Taiwo, 2021; Mensah et al., 2022; Girmay et al., 2023). The lack of appropriate WASH infrastructure also undermines students' dignity and safety, with female learners particularly disadvantaged due to the absence of menstrual hygiene-friendly spaces, which can contribute to absenteeism and disengagement from education.

Even in schools where WASH infrastructure is present, poor maintenance remains a significant barrier to effective service delivery. Many schools lack dedicated staff responsible for facility upkeep and often operate without clear maintenance schedules or budgets. As a result, broken taps, blocked or overflowing toilets, and empty soap dispensers are common occurrences that render facilities unusable and discourage proper hygiene practices amongst students (Herath et al., 2022). Sharma et al. (2024) further noted that poorly maintained WASH facilities diminish student confidence in using school sanitation services, contributing to increased absenteeism and the spread of hygiene-related illnesses. Geographical challenges further compound these issues, particularly in remote rural areas where water scarcity, limited transport infrastructure and poor supply chains hinder both the daily functioning of schools and the consistent delivery of hygiene supplies such as soap, sanitary materials, and cleaning equipment (Poague et al., 2025). In extreme cases, schools without a reliable water source require students to fetch water from distant streams or unprotected sources, reducing instructional time and increasing children's exposure to unsafe water and related health risks (Ahmed et al., 2023). The evidence therefore indicates that infrastructure limitations and poor maintenance practices remain critical barriers to effective WASH provision in schools. Ensuring sustainable WASH services requires not only improved infrastructure but also long-term maintenance planning, adequate financial resources and institutional accountability.

2.9.3 Governance and Policy Gaps

The absence of coherent policy implementation and weak governance structures continues to obstruct school WASH efforts. While many governments have adopted national WASH guidelines, enforcement remains inconsistent (Giné-Garriga et al., 2021; Haque & Freeman, 2021; John & Ajibade, 2024). According to John and Ajibade (2024), poor interdepartmental co-ordination, particularly between health and education ministries, results in fragmented programs lacking continuity. Furthermore, schools are rarely included in monitoring frameworks, and data on sanitation coverage or hygiene practices is either outdated or unavailable. Without reliable data, policymakers struggle to design effective interventions or justify resource allocations (Jafari et al., 2024; Biswas et al., 2024).

In addition to governance challenges, differences in WASH provision are frequently observed between schools operating in different socio-economic environments. In many low-resource settings, schools face persistent constraints such as unreliable water supply, inadequate sanitation infrastructure and limited handwashing facilities. These conditions increase the risk of waterborne and hygiene-related diseases among school children and can negatively affect their learning environment (John & Ajibade, 2024; Okesanya et al., 2024; Tadesse et al., 2024). For example, a study conducted in primary schools in the uMfolozi Local Municipality in KwaZulu-Natal reported that although most schools had some form of water infrastructure, the reliability of water supply remained a major challenge, and sanitation facilities were often inadequate. The study further found that pit latrines were commonly used due to limited water availability for flush toilets, while handwashing facilities were often insufficient or poorly maintained (Radebe et al., 2025). These examples demonstrate that variations in infrastructure availability and resource allocation can lead to significant differences in WASH conditions across schools.

According to Wilbur et al., (2024) the lack of technical support and oversight also contributes to disparities as many schools in Yemen operate independent of district-level authorities, making it difficult to standardise WASH delivery. In such cases, the responsibility falls on individual school administrators, many of whom lack the training or resources to address sanitation and hygiene issues systematically (Handayani & Supriatna, 2024; Okesanya et al., 2024; Wilbur et al., 2024).

2.9.4 Socio-Cultural Barriers and Community Engagement Challenges

Cultural perceptions and social norms significantly influence WASH behaviour. In many households, girls are expected to collect water or manage hygiene-related tasks, which reduces the time available for education and reinforces inequality (Bick et al., 2024; John & Ajibade, 2024). Schools that do not offer gender-sensitive infrastructure, such as private toilets and menstrual product disposal bins, amplify these disparities (Otieno et al., 2024).

Community buy-in is critical to sustaining WASH interventions, yet many programs fail due to limited parent and stakeholder involvement. Schools often operate in silos, and without community engagement, it becomes difficult to mobilise resources or promote long-term behaviour change (Anthonjet al., 2021; Haque & Freeman, 2021; Barrett et al., 2024). Conversely, initiatives that involve school governing bodies, local leaders and learners in sanitation decisions have shown improved outcomes in hygiene maintenance and programme sustainability (Gouge et al., 2023).

2.9.5 Climate Change and Environmental Challenges

Climate variability increasingly threatens the sustainability of school WASH systems. Rising temperatures, extended droughts and erratic rainfall patterns disrupt water availability and compromise existing infrastructure (Mishra, 2023; Borah, 2025). In flood-prone regions, latrines and septic systems may overflow, thus contaminating drinking water and exposing learners to severe health risks (Matte et al., 2024).

Environmental degradation also affects the ability of schools to manage solid and liquid waste safely. Some schools still rely on pit latrines or unlined waste channels that are vulnerable to environmental stress (Sharma et al., 2024; Byansi et al., 2025; Radebe et al., 2025). According to Khan et al. (2024), transitioning to resilient systems such as composting toilets, rainwater harvesting and solar-powered purification is essential for safeguarding school sanitation in the face of climate change. However, these technologies require significant capital and technical expertise. Without government support and local capacity-building, many schools are unable to implement adaptive infrastructure that addresses both current needs and future risks (Bolatova et al., 2021; Chirgwin et al., 2021; Ahmed et al., 2023; Shrestha et al., 2023; Magwe, 2025). While progress has been made in recognising these systemic barriers, the sustainability and maintenance of WASH infrastructure remain ongoing concerns that require targeted attention and practical strategies within the school environment (Sharma et al., 2025).

2.10 Ensuring the Operational Sustainability of WASH Facilities in Schools

Sustaining WASH facilities in schools extends beyond initial infrastructure development. While construction efforts have expanded access in many regions, the long-term functionality of WASH systems often remains uncertain, especially in under-resourced settings (Byansi et al., 2025; Poague et al., 2025). Persistent challenges such as inconsistent funding; a lack of trained personnel; poor waste management systems; and limited community ownership continue to undermine school-based hygiene efforts (Kusumaningtiar et al., 2024; Pereira et al., 2024; Sharmaet al., 2024). To safeguard the gains made through WASH investments, a comprehensive and operationally focused strategy is required, one that supports financial planning, human resource capacity, inclusive engagement and robust monitoring systems (Magwe, 2025).

Evidence from real-world school contexts demonstrates how these operational challenges affect the sustainability of WASH facilities. For example, a study conducted in Kampala schools found that although improved sanitation technologies were present, many schools still operated at limited sanitation service levels due to inadequate operation and maintenance practices, lack of dedicated sanitation budgets and poor facility management (Byansi et al, 2025). Similarly, research in Bekasi City, Indonesia, reported that many schools had insufficient handwashing facilities and lacked soap, which undermined the effectiveness and sustainability of hygiene interventions despite the presence of basic infrastructure (Kusumaningtiar et al., 2024). In another example from Tanzania, significant disparities were observed between rural and urban schools, with urban schools demonstrating substantially higher levels of adequate WASH infrastructure than rural schools, highlighting how socio-economic and geographic factors influence the sustainability of school WASH systems (Magwe, 2025). These real-life examples illustrate that sustainable WASH services require not only infrastructure provision but also consistent maintenance systems, institutional accountability and adequate financial and technical support.

2.10.1 Funding Constraints

A major barrier to sustaining school WASH services is the lack of dedicated funding streams for routine maintenance. While initial infrastructure projects may receive donor or government support, ongoing servicing and replenishment costs are often overlooked (Okesanya et al., 2024; Sharma et al., 2024; Nkonde et al., 2025). In many cases, schools must rely on general operating budgets, already stretched to cover basic educational needs, which rarely account for sanitation supplies, plumbing repairs or facility upkeep (Poague et al., 2025). Lower-quintile and rural schools are affected, receiving significantly insufficient funding and external support compared to urban schools (Blose, 2024; Mdhluli, 2025). Without ring-fenced allocations, WASH facilities rapidly deteriorate, with broken toilets, leaking taps and empty soap dispensers becoming the norm (Naz, et al., 2024; Sharma et al., 2025).

Establishing dedicated WASH maintenance budgets at school and district levels would ensure a reliable mechanism for ongoing support (Byansi et al., 2025; Poague et al., 2025). Public-private partnerships can also supplement these efforts by mobilising resources from local businesses, NGOs or corporate social responsibility programmes. A sustainable financing model that blends public funding with community support is essential for protecting infrastructure investments (Crawfurd et al., 2023; Naz et al., 2024).

2.10.2 Poor Infrastructure Management and the Lack of Trained Maintenance Staff

A further critical limitation to the sustainability of school WASH services is the lack of skilled personnel to oversee maintenance effectively. Many schools do not employ dedicated sanitation workers or maintenance staff, which results in delayed repairs and further damage to infrastructure (Dalisay et al., 2024; Byansi et al., 2025). In the absence of structured policies or preventive servicing plans, maintenance tends to be reactive, addressing breakdowns only after they become severe. This reactive approach not only increases long-term costs but also allows minor issues to escalate, eventually rendering WASH facilities unusable and unsafe (Jahan et al., 2024; Barrington et al., 2025).

Teachers and learners are sometimes expected to maintain facilities themselves, yet they typically lack the necessary training or tools. However, (Pereira et al., 2024) state that while student-led hygiene clubs have proven valuable for promoting sanitation culture, they cannot substitute professional facility oversight. To address this gap, schools should institutionalise regular inspections and maintenance schedules. Governments can support this process by offering technical training for school staff in basic plumbing, sanitation oversight and WASH monitoring practices. These capacity-building initiatives are especially critical in rural schools where professional services may be unavailable (Jahan et al., 2024; John & Ajibade, 2024; Barrington et al., 2025; Radebe et al., 2025).

2.10.3 Inadequate Waste Management and Sanitation Services

Sustainable sanitation must also include effective waste management systems. In many schools, learners frequently discard general waste such as leftover food, paper and packaging directly into toilets, handwashing sinks and drainage systems instead of using designated waste bins (Shanmugasundaram & Luthra, 2024; Ikogho & Onoharigho, 2025). In addition to general waste, sanitary waste, including used menstrual materials, is often flushed down toilets, pushed into drainage outlets or left exposed on toilet floors due to the absence of dedicated disposal facilities (Haque & Freeman, 2021; Barrett et al., 2024). These practices result in blocked toilets, damaged infrastructure and unsanitary conditions that render the facilities unusable for other learners, particularly for those who already face barriers to accessing safe and private sanitation (Schmitt et al., 2024).

Addressing these challenges requires the implementation of both practical infrastructure solutions and targeted behaviour change initiatives. Schools should prioritise the installation of covered waste bins near toilets and handwashing areas, as well as the provision of appropriate disposal units for sanitary waste to discourage the misuse of sanitation facilities (Pereira et al., 2024; Wilbur et al., 2024). Regular waste removal through partnerships with local municipalities or service providers is equally essential to prevent waste accumulation, facility blockages and environmental contamination (Shrestha et al., 2023; Ikogho & Onoharigho, 2025).

Furthermore, the integration of hygiene education and waste management awareness into the school curriculum can help foster a culture of responsibility, ensuring that learners understand the importance of proper waste disposal and the collective responsibility of keeping shared facilities clean and functional (Chirgwin et al., 2021; John & Ajibade, 2024). Without these combined efforts, adequate infrastructure, consistent service delivery and sustained behaviour change, schools face the ongoing challenge of seeing even improved WASH systems deteriorate over time (Dalisay et al., 2024; Byansi et al., 2025). This deterioration ultimately leaves learners without access to the safe, clean sanitation essential for their health, dignity and educational success (Okesanya et al., 2024). These findings highlight that inadequate waste management and sanitation services remain critical barriers to maintaining safe and functional WASH facilities in schools. Ensuring sustainable sanitation requires not only appropriate infrastructure but also consistent waste management systems and sustained hygiene education to support responsible waste disposal practices among learners.

2.10.4 Lack of Community Engagement and Stakeholder Support

The effective maintenance of school WASH facilities relies not only on adequate funding and infrastructure but also on the meaningful involvement of communities and key stakeholders. When local communities are not actively engaged, WASH programmes frequently suffer from neglect, vandalism and poor maintenance as the sense of ownership and shared responsibility is weak or entirely absent (Chirgwin et al., 2021; Nelson et al., 2021; Win et al., 2024). In many settings, school sanitation continues to be perceived as the exclusive responsibility of the government, which leads to minimal participation from parents, caregivers and other community members in the upkeep or protection of WASH facilities (Byansi et al., 2025; Poague et al., 2025). This disconnect not only limits the sustainability of improvements but also undermines the potential of WASH interventions to contribute to wider social development and wellbeing.

Conversely, where communities are meaningfully involved, school WASH initiatives tend to show greater sustainability, stronger accountability and improved hygiene outcomes. Evidence suggests that schools supported by active parent-teacher associations, local health workers, faith-based organisations and sanitation committees are better able to maintain their facilities and encourage positive hygiene behaviours amongst learners (John & Ajibade, 2024; Barrington et al., 2025). Mobilising local resources, such as volunteer labour and material donations, can significantly reinforce daily maintenance routines; reduce the burden on school staff; and embed WASH values within broader community development goals (Ayembilla et al., 2024; Bick et al., 2024). Building genuine partnerships between schools and surrounding communities not only strengthens local ownership but also ensures that the gains made through WASH interventions are preserved, valued and passed on to future generations (John & Ajibade, 2024).

2.10.5 Weak Monitoring and Evaluation Systems

The absence of structured monitoring and evaluation frameworks limits WASH sustainability in many schools. Without reliable data, it is difficult to assess infrastructure condition, identify recurring issues or make informed decisions on repairs and upgrades (De Wit et al., 2024; Al-Hamawi et al., 2025). Most schools do not maintain sanitation records, and few conduct regular audits or feedback assessments with learners. This lack of tracking contributes to delayed intervention and underreporting of facility issues (John & Ajibade, 2024).

Establishing real-time, school-based WASH monitoring systems, possibly linked to district or provincial education dashboards, can close this gap. Such systems would enable schools to document facility conditions, track repairs and report challenges in a timely and transparent manner, thereby strengthening accountability at multiple levels (Nelson et al., 2021; Kucici & Shettima, 2025). Routine hygiene audits, combined with student participation in cleanliness assessments, have proven effective in some school settings (Singhet al., 2022). A robust monitoring and evaluation system ensures accountability, informs funding priorities, and supports data-driven improvements in school sanitation policies (Johnson et al., 2025).

A robust monitoring and evaluation system does not merely serve administrative purposes but plays a transformative role in sustaining improvements, informing funding priorities and shaping evidence-based sanitation policies (Biswas et al., 2024). Such systems help decision-makers allocate resources effectively and measure the impact of WASH interventions over time (Nelson et al., 2021; Kucici & Shettima, 2025). Strengthening the operational sustainability of WASH facilities is only one part of the solution. Equally important are forward-looking strategies that continuously improve infrastructure, deepen hygiene awareness and embed accountability within community-school partnerships. Together, these efforts form the foundation for safe, inclusive and resilient school WASH environments where all learners can thrive (De Wit et al., 2024; Poague et al., 2025).

2.11 Enhancing WASH in School Environments

The enhancement of WASH services in schools is critical for creating safe, inclusive and effective learning environments. Poor WASH conditions remain a leading contributor to absenteeism, especially amongst adolescent girls, and continue to affect academic outcomes, health and student participation (Hussein et al., 2022; Shah et al., 2022; Akanzum & Pienaah, 2023). The consequences extend beyond the classroom as inadequate WASH undermines children's rights to dignity, safety and equal educational opportunity, further entrenching existing social inequalities (Pereira et al., 2024). Efforts to improve WASH must therefore address not only infrastructure but also behaviour, policy enforcement and stakeholder collaboration (Bick et al., 2024; Jahan et al., 2025).

2.11.1 Infrastructure Improvement and Universal Access to WASH Facilities

Access to basic WASH facilities remains inconsistent across many schools, particularly in lower-quintile and rural areas where infrastructure is either absent, outdated or unsafe. Many learners are still forced to use old or poorly maintained toilets or rely on unsafe water sources, posing significant health risks (Biswas et al., 2024; Kumar et al., 2024; Andleeb et al., 2025). Achieving universal access requires urgent efforts to build new WASH infrastructure where none exists and to rehabilitate or upgrade facilities that have deteriorated (Radebe et al., 2025). These improvements are essential to ensure that all learners have access to safe, functional and dignified sanitation and hygiene services, regardless of their socio-economic background or geographic location (De Wit et al., 2024).

For example, research conducted in Kakamega County in Kenya found that schools with reliable water supply systems, such as boreholes and protected wells, recorded higher levels of handwashing among learners, although the study also highlighted that infrastructure must be adequately maintained to sustain hygiene practices (Zadock et al., 2024). Similarly, a qualitative study conducted in the Central Gonja District in Ghana and Mtubatuba Municipality in South Africa documented persistent challenges in accessing safe drinking water and sanitation services in rural communities, where many households and schools continue to rely on communal taps, boreholes or untreated surface water sources, increasing exposure to waterborne diseases such as diarrhoea and cholera (Bazaanah et al., 2024).

At a broader global level, studies examining WASH access inequalities in low- and middle-income countries show that rapid urbanisation and the growth of informal settlements often result in inadequate sanitation infrastructure and limited access to safe water services, particularly for vulnerable populations such as women and children. These conditions contribute to health risks, increased socio-economic burdens and unequal access to basic services (Abdulhadi et al., 2024).

Schools must also be equipped with reliable handwashing stations, clean water and soap to support hygiene practices and create healthier school environments (Zadock et al., 2024). Radebe et al. (2025) advise that facility design must take accessibility into account to ensure that inclusion of learners with disabilities and those with special needs. Infrastructure improvements should not only meet technical standards but also contribute to the creation of child-friendly, inclusive learning spaces. Strengthening school WASH infrastructure is foundational to supporting the broader educational, social and wellbeing goals of learners (Poague et al., 2025).

2.11.2 Integrating Hygiene Education into School Curricula

Behavioural change is central to the long-term success of WASH programs. Embedding hygiene education into school curricula helps normalise handwashing, safe water handling and general sanitation practices from an early age (Ginja et al., 2019; Chirgwin et al., 2021; Nelson et al., 2021; Win et al., 2024). Beyond classroom instruction, experiential learning methods, such as hygiene clubs, peer-led initiatives and hands-on WASH campaigns, encourage student participation and reinforce positive habits (Anthonjet al., 2021; Pieters et al., 2025). Teachers also play a critical role and must be trained to deliver engaging WASH education. Collaborative efforts with health professionals and sanitation officers can further strengthen learning outcomes and bridge knowledge gaps (Tsekleves et al., 2022; Poague et al., 2025).

2.11.3 Stakeholder Engagement

Improving WASH services requires active collaboration that extends beyond the boundaries of individual schools. A wide range of stakeholders, including parents, local businesses, municipalities, non-governmental organisations (NGOs) and faith-based organisations, play complementary roles in resource mobilisation, infrastructure support and WASH advocacy (Chirgwin et al., 2021; Mensah et al., 2022; Chouhan et al., 2022; Byansi et al., 2025). Their involvement not only contributes to physical improvements but also helps foster a culture of hygiene and shared responsibility within the school community. Without such partnerships, efforts to improve WASH facilities may remain fragmented, underfunded and unsustainable (Mensah et al., 2022; Byansi et al., 2025).

Public-private partnerships and corporate social responsibility initiatives have played a vital role in supporting school sanitation and hygiene efforts in various regions. Pereira et al. (2024) and John and Ajibade (2024) emphasise that involving stakeholders from the earliest stages of WASH planning ensures that solutions are locally appropriate, context-sensitive and more likely to be maintained over time (Chouhan et al., 2022). Such collaborative approaches also bring in technical expertise, financial resources, and innovative solutions that schools alone may not be able to access. Community-driven efforts further strengthen transparency, accountability and long-term ownership, thus helping to ensure that WASH improvements are not only achieved but sustained into the future (Nelson et al., 2021; Kucici & Shettima, 2025).

2.11.4 Policy Enforcement and Institutional Support for School WASH Programs

Effective school WASH programs must be anchored in strong and enforceable policy frameworks that ensure that every learner has access to safe WASH services. While national guidelines exist in many countries, implementation and enforcement remain uneven, with rural and lower-quintile schools particularly affected by policy neglect (Nelson et al., 2021; Kucici & Shettima, 2025). Governments must strengthen accountability mechanisms by conducting regular inspections, setting clear benchmarks and enforcing minimum standards for sanitation facilities, hygiene education and water provision in schools (Wang et al., 2022; Naz et al., 2024). Without consistent oversight, well-intentioned WASH policies often fail to translate into practical improvements at the school level, leaving infrastructure gaps and health risks unaddressed.

In addition to enforcement, governments must ensure that school WASH programs receive adequate and ring-fenced financial support aligned with both national priorities and international commitments such as SDG 6. The use of monitoring tools and reporting frameworks, developed and promoted by global agencies such as the WHO and UNICEF plays a crucial role in tracking progress, identifying gaps, and informing evidence-based decisions (WHO & UNICEF, 2023). Institutional support should also include the establishment of cross-sector coordination between health, education and infrastructure departments to drive coherent and sustained WASH improvements (Pereira et al., 2024; Wilbur et al., 2024; Kucici & Shettima, 2025). Furthermore, drawing lessons from global best-practices and successful models elsewhere can help countries address persistent challenges and design interventions that are both locally appropriate and scalable (Haque & Freeman, 2021; Bick et al., 2024). With strong policy enforcement and institutional backing, schools can move closer to achieving equitable, safe and sustainable WASH services for all learners (Sharma et al., 2025).

2.12 Progress and Best-Practices in Implementing WASH Programs in Schools

The implementation of WASH programs in schools has gained global momentum, with increasing recognition of its role in promoting student health, enhancing academic performance and advancing equity in education (Shah et al., 2022; Wilbur et al., 2024). Despite regional disparities, concerted efforts by governments, development partners and local stakeholders have yielded promising outcomes in many parts of the world (Chirgwin et al., 2021; WHO, 2023a; John & Ajibade, 2024). While high-income countries have generally achieved near-universal school WASH coverage, many low- and middle-income countries continue to face significant obstacles. Nevertheless, emerging evidence highlights successful strategies that can serve as models for effective and sustainable WASH implementation (Nelson et al., 2021; Wilbur et al., 2024).

2.12.1 Global Progress in School WASH Implementation

Over the past two decades, international frameworks such as the WHO/UNICEF JMP have played a pivotal role in tracking school WASH progress and promoting accountability under SDG 6 (WHO & UNICEF, 2023; Pereira et al., 2024). The global push for improved WASH has prompted many countries to revise national policies, strengthen monitoring systems and expand budget allocations dedicated to school-based WASH services (Ahmed et al., 2021; Poague et al., 2022a; Girmay et al., 2023; Okesanya et al., 2024; Barrington et al., 2025). These policy shifts reflect a growing recognition of the integral role that WASH plays in advancing human health, educational outcomes and gender equity. By linking WASH to broader human development goals, governments are increasingly embedding hygiene interventions into their national education and health agendas.

In regions such as South Asia, national programs have successfully integrated WASH into both education and public health strategies, resulting in notable improvements in school sanitation coverage (Khan et al., 2023; Sardar et al., 2024). Large-scale interventions in countries like India and Bangladesh have not only increased infrastructure but also enhanced MHM and hygiene education for school-aged children. Sub-Saharan Africa has also witnessed the rollout of multi-sectoral WASH interventions aimed at expanding access, although progress has been slower due to funding and logistical challenges (Anthonj et al., 2021; Winter et al., 2021; Mensah et al., 2022; Wada et al., 2022). Similarly, in Latin America, countries such as Brazil and Mexico have institutionalised school-based hygiene programs through intersectoral collaboration, embedding WASH into national development frameworks and long-term policy planning (Mcmichael, 2019; Sangalang et al., 2020; Poague et al., 2024).

Despite these advancements, access to WASH in schools remains uneven, particularly in rural, remote and marginalised communities. According to WHO and UNICEF (2023), more than 30% of schools in sub-Saharan Africa still lack access to safe drinking water, while nearly 50% do not have even basic sanitation facilities. These disparities disproportionately affect girls, children with disabilities and those living in poverty, exacerbating existing inequalities in education, health and social outcomes. To close these gaps, stronger international co-operation, increased national investment and context-specific interventions are essential to ensure that no child is left behind in accessing safe, inclusive WASH services in schools (Poague et al., 2025).

2.12.2 Best-Practices for Effective WASH Implementation

Evidence from successful WASH programmes highlights the importance of combining national-level policy commitment with community engagement to ensure long-term sustainability. Countries that have embedded WASH within their national education and public health strategies, such as Bangladesh, Kenya and India, have demonstrated greater consistency in improving school sanitation (McMichael, 2019; Dakhode et al., 2022; Ahmed et al., 2023; Sharma et al., 2025). Barrington et al. (2025) state that policies in these settings often include minimum sanitation standards, clear lines of accountability and budgetary provisions that guide implementation and monitoring at local levels. Equally vital is the role of community involvement, where schools that actively engage parents, school management committees and local organisations in planning and maintaining WASH infrastructure report better outcomes in facility upkeep and learner participation (Orgill-Meyer et al., 2019; Johnson et al., 2025). The combination of top-down policy direction and bottom-up community ownership strengthens resilience and ensures that WASH services remain functional and valued by the school community (Manjong-Kofete et al., 2021; Sugita, 2022; Poague et al., 2024).

Several countries provide practical examples of how governance, financing and operational arrangements influence WASH outcomes in schools. In Bangladesh, the national School Sanitation and Hygiene Education (SSHE) programme integrated WASH within the national education system through collaboration between the Ministry of Education, UNICEF and local governments (WHO & UNICEF, 2022). The programme combined infrastructure development, hygiene education and community monitoring mechanisms, resulting in improved access to sanitation facilities and increased hygiene awareness among school learners (Ahmed et al., 2023). Similarly, Bick et al. (2025) reported that in Kenya, school-based WASH interventions implemented through partnerships between government agencies and development partners prioritised the provision of water supply systems, gender-segregated toilets and handwashing facilities, supported by school management committees responsible for maintenance and monitoring. These initiatives reported improvements in sanitation access and reductions in hygiene-related illness among learners (Bick et al., 2025).

In addition to governance and participation, effective WASH implementation requires a deliberate focus on hygiene education and behaviour change. Interactive, school-based hygiene education approaches, such as peer-led WASH clubs, daily handwashing routines and hygiene ambassadors, help instil long-term positive sanitation behaviours in learners (Handayani & Supriatna, 2024). For example, in Ethiopia the Fit for School (FIT) programme introduced structured group handwashing and toothbrushing activities integrated into the daily school routine (Bick et al., 2024). The programme was implemented through collaboration between government education authorities, international development partners and school administrators, demonstrating a coordinated governance and operational model. Evaluations of the programme reported measurable improvements in student hygiene behaviour and reductions in absenteeism linked to hygiene-related illnesses (Bick et al., 2024). Forro and Besa (2025) state that embedding hygiene education into daily school life ensures that WASH is not merely a one-time intervention but becomes part of the cultural fabric of the learning environment, fostering healthier habits that extend beyond the school gates.

Moreover, sustainable infrastructure design and financing are crucial to maintaining and expanding WASH services in schools. Best-practices in infrastructure focus on the provision of gender-sensitive, inclusive and environmentally sustainable sanitation facilities, such as segregated toilets, accessible handwashing stations and eco-friendly technologies like composting toilets and rainwater harvesting systems (Biswas et al., 2024; John & Ajibade, 2024). However, without sustainable financing, even the most innovative infrastructure cannot be maintained (Ssekyanzi et al., 2024). In several Sub-Saharan African contexts, public-private partnerships have been used to mobilise financial and technical resources to improve school

WASH services (Machete & Marques, 2021; Chandratreya, 2023; Madzivanyika et al., 2026). For instance, collaborative initiatives in Zimbabwe and South Africa have supported the construction of sanitation infrastructure, provision of hygiene materials and implementation of school-based hygiene education programmes through joint funding from government agencies, private sector partners and development organisations (Machete & Marques, 2021; Tseole et al., 2022; Chandratreya, 2023). These initiatives illustrate how diversified funding mechanisms and shared management responsibilities can strengthen the sustainability of WASH interventions in schools. Mobilising diverse funding streams and technical expertise ensures that WASH interventions are not only implemented successfully but also preserved for future generations of learners (Mundonde & Makoni, 2023).

2.13 Monitoring WASH in Schools: Global Perspectives

Monitoring WASH services in schools plays a central role in tracking progress, identifying service gaps and ensuring compliance with global public health and educational standards (Chirgwin et al., 2021; Dickin & Gabrielsson, 2023; Wilbur et al., 2024). Without effective monitoring systems, efforts to improve WASH infrastructure risk being inconsistent and unsustainable. International bodies such as UNICEF, WHO and UNESCO have developed frameworks that support countries in assessing school WASH conditions, with the goal of promoting equity, safeguarding learner health and enhancing education outcomes (Ahmed et al., 2021; Karim et al., 2024). Amongst the most prominent global monitoring tools are the SDGs, the JMP, the Global Education Monitoring Report (GEMR), and the Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) (WHO & UNICEF, 2023). The JMP provides internationally standardised indicators on WASH, including for schools, enabling countries to monitor progress and strengthen national reporting systems. The GLAAS initiative complements this by assessing the enabling environment for WASH, focusing on policy frameworks, financing and institutional capacity that underpin sustainable service delivery. The GEMR, while broader in scope, integrates WASH within its education monitoring agenda, linking school health, equity and learning outcomes to globally accepted standards.

Together, these initiatives establish a framework of internationally recognised indicators and tools that help countries strengthen their national WASH monitoring systems within the education sector. By ensuring comparability, transparency and accountability, they provide the basis for evidence-based planning and for aligning school WASH improvements with global development goals.

2.13.1 Global Frameworks and Initiatives for WASH Monitoring in Schools

Multiple global initiatives have recognised that effective monitoring of WASH in schools is essential for promoting inclusive and equitable access to education. These frameworks not only provide benchmarks for tracking service access but also guide national policy reforms and funding allocation by highlighting service disparities (WHO & UNICEF, 2023). The SDGs, JMP, GEMR and GLAAS offer globally accepted indicators that enable countries to strengthen their national WASH monitoring systems within the education sector (Girmay et al., 2023). Through these efforts, countries are better positioned to identify inequalities, address service gaps and sustain improvements in WASH service delivery (Bick et al., 2024).

2.13.2 The Sustainable Development Goals and WASH in Schools

Adopted in 2015, the UN SDGs set the global agenda for eradicating poverty and ensuring inclusive development by 2030. Specifically, SDG 6 of the SDGs explicitly focuses on ensuring access to clean water and sanitation for all. Specifically, Target 6.2 addresses the need for adequate and equitable sanitation and hygiene, with a particular focus on women, girls and vulnerable populations (Arora & Mishra, 2022; Rajapakse et al., 2023; Kumaravel et al., 2025). Within this framework, Indicator 6.2.1a measures the proportion of the population with safely managed sanitation, while Indicator 6.2.1b tracks the availability of handwashing facilities with soap and water (Rajapakse et al., 2023). These indicators serve as benchmarks for evaluating school WASH infrastructure. Despite global progress, nearly one-third of schools worldwide lack safe drinking water, and more than 600 million learners attend schools without adequate toilets (WHO & UNICEF, 2023). This persistent gap underscores the urgency of intensified efforts to meet the SDG 6 targets.

2.13.3 UNICEF/WHO Joint Monitoring Programme for WASH in Schools

The JMP, a collaboration between UNICEF and the WHO, is widely recognised as the leading global initiative for tracking WASH service levels in schools and communities (WHO & UNICEF, 2021; Rajapakse et al., 2023). The programme introduces a tiered classification system that categorises school WASH services into three levels, namely basic, limited and no service (Girmay et al., 2023). Schools are classified as having basic WASH services when they meet the minimum standards, including access to an improved water source, usable toilets and functioning handwashing facilities with soap available at the point of use (Olatunji & Taiwo, 2021; Ahmed et al., 2023; Girmay et al., 2023; Radebe et al., 2025). In contrast, limited services refer to schools where WASH infrastructure exists but is insufficient, shared or non-functional, while the no-service category represents complete absence of safe water, sanitation or hygiene facilities (WHO, 2022).

This classification system offers governments, donors and education authorities a valuable framework for identifying priority areas and allocating resources more effectively. By providing measurable benchmarks, the JMP allows countries to assess progress and address inequalities in WASH service delivery within educational settings. Furthermore, the programme encourages evidence-based policy reform through its emphasis on systematic data collection, transparency and international comparability (Girmay et al., 2023). Countries that integrate JMP indicators into their national monitoring systems tend to demonstrate greater consistency, improved decision-making and stronger alignment with global development goals, including the SDGs (Okesanya et al., 2024; Pereira et al., 2024). Overall, the UNICEF/WHO Joint Monitoring Programme provides an internationally recognised framework for assessing WASH service levels in schools, enabling countries to monitor progress, identify service gaps and strengthen accountability in achieving universal access to safe WASH (WHO & UNICEF, 2022).

2.13.4 The Global Analysis and Assessment of Sanitation and Drinking Water

The Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS), co-ordinated by the WHO and UN-Water, complements the JMP by focusing on the governance, financing and institutional capacity needed to sustain WASH services (Jiménez et al., 2018; WHO, 2023b). While the JMP primarily measures the presence of WASH services, GLAAS assesses whether countries have the enabling environment, including policies, funding mechanisms and institutional frameworks, to maintain and expand these services over time (Cronk et al., 2024; Mouadden et al., 2025).

Global GLAAS assessments reveal important patterns and variations in how countries support WASH services (Zyoud & Zyoud, 2023; WHO, 2023b; Cronk et al., 2024). High-income countries generally demonstrate stronger institutional coordination, stable financing and established monitoring systems, enabling consistent provision of WASH services in schools. In contrast, many low- and middle-income countries continue to face institutional fragmentation, limited technical capacity and insufficient public investment in WASH infrastructure. These disparities influence the ability of governments to maintain sanitation facilities, particularly in rural and disadvantaged communities (WHO, 2023b; Cronk et al., 2024).

GLAAS findings further show that although many countries have developed national WASH policies, significant differences remain in the level of financial commitment and implementation capacity. For example, several countries in Sub-Saharan Africa report strong policy frameworks but limited budget allocations for WASH maintenance and monitoring, while some Asian countries demonstrate stronger integration of WASH within national education and public health programmes. These variations highlight differences in governance structures, funding mechanisms and operational capacity that ultimately influence the sustainability of WASH services in schools (Okesanya et al., 2024; Mouadden et al., 2025).

In the South African context, similar governance and financing challenges have been reported. Radebe et al. (2025) found that many primary schools in KwaZulu-Natal experience persistent resource constraints, inadequate infrastructure maintenance and limited institutional support, which affect the sustainability of WASH services in schools. These findings reflect broader global patterns identified in GLAAS assessments, where disparities in governance coordination and financial investment contribute to unequal access to sanitation and water services across countries and regions. By advocating for stronger institutional capacity, increased investment and intersectoral collaboration, GLAAS plays a vital role in shaping sustainable WASH strategies for schools worldwide.

2.13.5 Quantitative Microbiological Risk Assessment for Drinking Water Safety

QMRA is a scientific framework used to estimate the probability of infection or illness resulting from exposure to pathogenic microorganisms present in environmental media such as drinking water (Hamilton et al., 2024; Islam et al., 2025; Clements et al., 2025). The approach integrates microbiological data with exposure and dose–response models to quantify potential health risks associated with microbial contamination in water systems. QMRA generally follows four key stages, namely hazard identification, exposure assessment, dose–response assessment and risk characterisation, which together enable researchers to estimate the likelihood of infection following exposure to contaminated water (Hamilton et al., 2024; Clements et al., 2025). This framework has been widely applied in water safety assessments, particularly in evaluating microbial risks in drinking water sources, wastewater reuse systems and environmental waters where human exposure to pathogens may occur (Panagiotou et al., 2023; Islam et al., 2025).

In microbial water quality studies, indicator organisms such as *E. coli* are commonly used to assess faecal contamination and the potential presence of pathogenic microorganisms. Although many *E. coli* strains are harmless commensal bacteria, certain strains possess virulence genes associated with DEC, including pathotypes such as EPEC, ETEC and EAEC, which are capable of causing gastrointestinal illness in humans (Delair et al., 2024). The presence of these pathogenic strains in water environments therefore indicates potential health risks associated with faecal contamination and exposure to unsafe water sources (Delair et al., 2024; Islam et al., 2025).

QMRA models enable researchers to integrate microbiological monitoring data with exposure scenarios to estimate infection risks associated with contaminated water. For example, risk assessments have been applied to evaluate human exposure to pathogens in reclaimed wastewater systems and other environmental water sources, demonstrating how microbial concentrations and exposure patterns influence infection probabilities (Panagiotou et al., 2023; Quon & Jiang, 2024). These studies highlight the importance of understanding pathogen occurrence in water systems and incorporating such information into risk-based water safety management approaches. Similarly, research examining microbial contamination and risk modelling has emphasised that QMRA can support evidence-based decision-making for improving water treatment practices and protecting public health (Hamilton et al., 2024; Islam et al., 2025).

Within school environments, QMRA can provide a valuable approach for evaluating potential health risks associated with contaminated drinking water supplied to learners. QMRA has been widely applied in water quality research to estimate infection risks arising from exposure to microbial pathogens in drinking water and other environmental waters (Hamilton et al., 2024; Islam et al., 2025; Clements et al., 2025). By integrating microbiological monitoring data with exposure assumptions and dose–response models, QMRA enables researchers to estimate the probability of infection associated with microbial contamination in water systems (Panagiotou et al., 2023; Quon & Jiang, 2024). In school drinking water contexts, the detection of *E. coli* and DEC virulence genes provides important indicators of potential faecal contamination and associated health risks for learners (Hamilton et al., 2024; Amatobi et al., 2024). Risk-based assessments that combine microbiological findings with exposure scenarios therefore contribute to improved understanding of drinking water safety in schools and support the development of effective WASH interventions aimed at protecting learner health learners (Panagiotou et al., 2023; Hamilton et al., 2024; Amatobi et al., 2024).

While global frameworks provide important guidance for monitoring WASH services in schools, their effectiveness ultimately depends on how these principles are translated into national policies and regulatory systems. Understanding how countries operationalise WASH monitoring within their own legislative and institutional frameworks is therefore essential. The following section examines the national policies and regulations that guide WASH monitoring in educational settings, with particular reference to the South African context.

2.14 National Policies and Regulations Guiding WASH Monitoring in Education

National-level monitoring and regulatory frameworks play a critical role in ensuring that schools WASH services meet established public health, safety and environmental standards. In South Africa, key policies such as the National Environmental Health Norms and Standards for Premises (Department of Health, 2015); the application of the SANS 241 for drinking water quality (SABS, 2015); and the use of the National Education Infrastructure Management System (NEIMS) database collectively guide the planning, implementation and monitoring of WASH in schools. These frameworks provide the basis for evaluating compliance, identifying infrastructure gaps and supporting decision-making on school sanitation and water provision. These policy frameworks and monitoring systems are intended to apply uniformly across all schools, regardless of location, socio-economic status or quintile classification, thereby setting consistent national standards for WASH provision and accountability (Mncube, 2023).

South Africa’s national monitoring efforts are also influenced by global WASH monitoring initiatives. The country has incorporated indicators aligned with the UNICEF/WHO JMP, which provides internationally comparable benchmarks for assessing WASH service levels in schools. As highlighted in the UNICEF South

Africa WASH Thematic Report, national initiatives such as the National School Sanitation Programme have been implemented to address disparities in sanitation access, particularly in historically under-resourced schools. Despite these efforts, significant gaps remain, with approximately 20% of schools still lacking basic WASH services, indicating persistent inequalities in infrastructure provision. These findings highlight the continued need for strengthened national monitoring systems, improved infrastructure investment and effective policy implementation to ensure equitable access to safe WASH services in schools (UNICEF South Africa, 2019).

2.14.1 National Environmental Health Norms and Standards for Premises

Issued in 2015, the National Environmental Health Norms and Standards for Premises, which cover schools amongst other facilities, provide a regulatory baseline for the provision of WASH infrastructure within educational institutions. These standards mandate that schools must ensure the availability of safe drinking water, gender-segregated and accessible sanitation facilities, and functional handwashing stations equipped with soap (SA Department of Health, 2015). The guidelines aim to create a healthy and conducive learning environment by setting minimum requirements for the physical conditions of school premises. By establishing uniform expectations across all educational settings, the standards contribute to safeguarding the health, safety, and dignity of learners and staff, according to Radebe et al. (2025).

In addition to specifying basic WASH requirements, the guidelines call for schools to provide toilets with adequate lighting, proper ventilation and handwashing facilities that support good hygiene practices (Tlhabudugwane et al., 2024). These provisions must be inclusive, ensuring accessibility for all learners, including those with disabilities, and must also address sanitary waste disposal systems, particularly for menstrual hygiene management. While the enforcement of these standards lies primarily with local and provincial health authorities, many schools, particularly in rural and lower-quintile settings, face challenges in meeting these requirements due to financial constraints and ageing infrastructure (Bazaanah &

Mothapo, 2023). Strengthening institutional support, resource allocation, and compliance monitoring is therefore essential to ensure that all schools can meet the national environmental health benchmarks set out in the guidelines.

2.14.2 The Role of SANS 241 in Ensuring Drinking Water Quality

The SANS 241 provides the official safety parameters for drinking water, setting maximum allowable limits for chemical, physical and microbiological contaminants (Malebatja & Mokgatle, 2022; Maselela et al., 2024; Masindi & Manjoro, 2024). These standards are critical in ensuring that the water supplied to schools is safe for human consumption and does not expose learners to waterborne diseases. Schools are required to guarantee that the drinking water provided is free from harmful pathogens, including *E. coli* and total coliform bacteria, which are indicators of faecal contamination and poor water quality (Hossain et al., 2022; Najeeb et al., 2024; Kawall et al., 2025). Regular monitoring in accordance with SANS 241 helps to protect children's health and supports the broader public health agenda by reducing the risk of diarrhoeal illnesses and other water-related diseases.

Although the Department of Water and Sanitation mandates routine water quality testing in line with SANS 241, many schools, particularly those in rural or under-resourced areas, lack the technical capacity and financial resources to comply consistently. Schools that rely on boreholes, rainwater harvesting or untreated surface water are particularly vulnerable to microbiological contamination, posing serious risks to learner health and wellbeing (Radebe et al., 2025). Without adequate funding, infrastructure and technical support, compliance with national water standards remains challenging for many educational institutions. Strengthening local water testing capacity, expanding access to affordable water treatment technologies, and fostering greater collaboration between water, health and education departments are essential strategies to support schools in meeting SANS 241 requirements and ensuring that all learners have access to safe, clean drinking water (Adom & Simatele, 2022; Olley et al., 2024).

2.14.3 WASH Monitoring Mechanisms and Implementation Challenges

WASH monitoring in South African schools is primarily carried out through the National Education Infrastructure Management System (NEIMS), a centralised database developed by the Department of Basic Education to track and report on school infrastructure conditions (Shibamba & Lethoko, 2024; Tlhabudugwane et al., 2024). NEIMS provides comprehensive data on the availability and condition of water supply systems, sanitation facilities and handwashing stations in schools across the country. This system plays a crucial role in identifying schools that require urgent interventions, supporting the prioritisation of infrastructure upgrades and guiding the equitable allocation of resources for WASH improvements (Abrams et al., 2021; Tseole et al., 2022). By maintaining a national database, NEIMS also enhances transparency and enables policymakers to monitor progress towards national and international development targets, including SDG 6.

Despite the existence of such monitoring mechanisms, several persistent implementation challenges continue to undermine the realisation of universal WASH access in schools. One of the major barriers is the lack of dedicated funding streams for the routine maintenance and upgrading of school infrastructure, which frequently results in the rapid deterioration of sanitation facilities and unreliable water supply, particularly in lower-quintile and rural schools (Tseole et al., 2022; Thusi & Matyana, 2024). Additionally, data collected through NEIMS is not always up-to-date or translated into timely action, leaving identified infrastructure backlogs unresolved for extended periods (Shibamba & Lethoko, 2024). Strengthening monitoring capacity; ensuring dedicated budgets for WASH maintenance; and improving the responsiveness of intervention strategies are essential to address these challenges and create safe, hygienic school environments for all learners.

2.15 Local Implementation and WASH Monitoring in Schools

Ensuring effective WASH monitoring at the local level is essential for translating national policies into meaningful, sustainable outcomes within individual schools. While national frameworks such as NEIMS and environmental health standards provide strategic guidance, the practical enforcement and day-to-day management of WASH services depend heavily on the actions and commitment of local authorities, educators, school management teams and surrounding communities (MacArthur et al., 2023; Robinson et al., 2024; Wilbur et al., 2024). Local-level actors are often better positioned to identify context-specific challenges, respond to urgent needs and foster a culture of hygiene within the school environment. Without strong local involvement, even well-designed national policies risk remaining theoretical rather than delivering tangible improvements on the ground (Shibamba & Lethoko, 2024; Radebe et al., 2025).

Persistent inequalities in WASH infrastructure, particularly between urban and rural schools in South Africa, further highlight the need for decentralised implementation and monitoring efforts. Many rural schools face unique barriers, including poor infrastructure, limited water supply and delayed maintenance, which national systems alone cannot fully address (Bazaanah & Mothapo, 2023; Muchaku & Zhou, 2025). Strengthening local governance structures, increasing resource allocation at district levels and empowering schools to manage their own WASH systems are key strategies to close these gaps. Tlhabudugwane et al. (2024) state that greater collaboration between local governments, education officials, parents and civil society is also essential to ensure that improvements in WASH reach the most underserved learners and that monitoring mechanisms lead to prompt corrective actions.

2.15.1 The Role of Local Authorities in WASH Implementation and Compliance

Local government structures, including municipal health departments and district education offices, serve as key actors in implementing and monitoring WASH policies in schools. Their responsibilities often include inspecting facilities, enforcing health and hygiene regulations and facilitating repairs or upgrades to sanitation infrastructure (Ngcongo & Tekere, 2023; Bazaanah et al., 2024). In South Africa, municipalities are also responsible for ensuring that water supplied to schools meets the standards outlined in SANS 241, which defines potable water quality (Bayne et al., 2024). However, in practice, the capacity of local authorities to manage WASH delivery effectively remains inconsistent, particularly in under-resourced and rural areas, where budgetary constraints, staff shortages and limited technical expertise often delay or weaken implementation efforts (Radebe et al., 2025).

Educators and school management teams are frontline custodians of WASH facilities. Teachers, principals and school governing bodies are tasked with maintaining sanitation facilities; reporting infrastructural faults; and embedding hygiene education into the school culture (Mokgwathi et al., 2023). In many schools, hygiene promotion is integrated into Life Orientation classroom discussions, encouraging students to take responsibility for their own health and cleanliness (Shuro & Waggie, 2024). However, Barrington et al., (2025) state that despite these efforts, schools often struggle to sustain WASH improvements without external technical support or adequate financial resources, highlighting the importance of multi-stakeholder collaboration between schools, communities and local government bodies.

2.16 Infrastructure Allocation amongst School Quintiles

Variations in the allocation and quality of WASH infrastructure across South Africa’s school quintiles continue to present a major challenge to achieving equitable education and universal access to essential hygiene services. The quintile system, which classifies schools from Quintile 1 (poorest) to Quintile 5 (wealthiest), was introduced to guide the distribution of financial resources based on socio-economic need, with the intention that lower-quintile schools would receive greater support to address historical disadvantages (Van Dyk & White, 2019; Maistry & Africa, 2020). In practice, however, this allocation has not sufficiently closed the infrastructure gap, leaving schools in poorer rural or peri-urban communities with deteriorating or inadequate WASH services, whilst wealthier urban schools remain better resourced. These ongoing inequities directly affect learners’ access to safe WASH services that are fundamental to health, dignity and educational success (Köhler, 2020; Mokgwathi et al., 2023; Lombo & Subban, 2024).

2.16.1 Disparities in WASH Infrastructure

Schools in Quintiles 1 and 2, which are predominantly located in rural or peri-urban areas, continue to face serious WASH deficiencies, including unsafe or poorly maintained sanitation facilities; intermittent water supply; and the absence of dedicated hygiene education (Mncube, 2023). In contrast, Quintile 4 and 5 schools, generally found in wealthier urban areas, benefit from well-maintained infrastructure supported by higher parent contributions, private donations; and supplementary funding sources (Molaudzi et al., 2022). These disparities not only compromise learner well-being but also perpetuate broader inequalities by limiting educational participation, particularly for girls who are disproportionately affected by inadequate menstrual hygiene facilities. The imbalance in WASH provision reflects systemic inequalities that require targeted interventions to ensure that no school community is left behind, according to Mokgwathi et al. (2023).

2.16.2 Impact of Funding on WASH Facilities

The allocation of financial resources plays a decisive role in determining the availability, functionality and sustainability of WASH services in schools. Quintile 1 to 3 schools frequently struggle with outdated or insufficient facilities, including deteriorating toilets, unreliable water points and a lack of essential hygiene supplies such as soap and sanitary materials (Tlhabudugwane et al., 2024). These challenges illustrate significant socio-economic disparities in WASH provision, where schools serving poorer communities are more likely to experience infrastructure shortages and maintenance backlogs compared with higher-quintile schools that often benefit from stronger financial support and parental contributions.

Although programmes like the Sanitary Dignity Programme were introduced to improve hygiene in lower-quintile schools, many of these initiatives face challenges related to inconsistent resource delivery, poor communication and limited community awareness (Melariri et al., 2024). Mncube, (2023) state that these shortcomings demonstrate the importance of not only increasing financial allocations but also strengthening local-level planning and monitoring to ensure that interventions reach the intended beneficiaries. These managerial and governance challenges often result in uneven implementation outcomes, where similar funding allocations produce different results depending on the effectiveness of institutional coordination, procurement processes and school-level management capacity.

Geographical disparities also influence WASH outcomes, as rural schools frequently face greater infrastructure deficits compared with urban schools due to limited municipal service coverage, weaker technical support and logistical challenges associated with infrastructure maintenance. In many rural areas, unreliable water supply systems and delayed maintenance of sanitation facilities contribute to persistent service interruptions, thereby affecting the consistent availability of safe WASH facilities in schools (Bazaanah et al., 2024; Abdulhadi et al., 2024).

A persistent lack of investment in school sanitation infrastructure has further entrenched unsafe conditions in many lower-quintile schools. Numerous rural schools continue to rely on outdated pit latrines, which have been associated with tragic student fatalities due to structural collapses, highlighting the urgent need for safer alternatives (Lombo & Subban, 2024). These technical disparities in infrastructure design and maintenance illustrate how funding limitations translate into unequal service outputs, where lower-quintile schools often receive basic or temporary sanitation solutions while better-resourced schools are able to install safer and more durable sanitation technologies.

Furthermore, inadequate handwashing facilities, lack of soap and insufficient MHM resources contribute to the heightened risk of disease transmission and absenteeism amongst learners. Such disparities ultimately translate into unequal health and educational outcomes, as learners in poorly resourced schools are more likely to experience hygiene-related illnesses, reduced attendance and diminished learning conditions. Achieving meaningful progress in WASH equity requires not only more consistent funding but also transparent resource allocation mechanisms that prioritise the most marginalised and vulnerable school populations (Steenkamp et al., 2022). Overall, the evidence indicates that funding disparities play a central role in shaping the quality and sustainability of WASH facilities in schools. Without equitable resource allocation, effective monitoring mechanisms and targeted investment in infrastructure maintenance, schools in lower quintiles are likely to continue experiencing persistent WASH deficiencies that negatively affect learner health, dignity and educational outcomes.

2.17 Chapter Summary

This chapter reviewed a broad body of literature relevant to WASH in school settings, with a particular emphasis on disparities across socio-economic contexts, especially in South African schools. The review of literature highlighted the global challenges surrounding school WASH access, particularly in low- and middle-income countries, and the implications for health, attendance and gender equity. International frameworks, namely the SDGs, the WHO/UNICEF JMP and the GEMR, were explored to provide context for global benchmarks in school WASH.

The chapter further examined the national and local WASH policies in South Africa, including the NEIMS, the National Norms and Standards for School Infrastructure, and the SANS 241 for water quality. While these frameworks offer important regulatory guidance, the literature reveals persistent implementation gaps, particularly in Quintile 1 and 2 schools, which often lack the infrastructure, maintenance and resources necessary to meet minimum WASH standards.

Additionally, the chapter emphasised the crucial role of community participation, public-private partnerships and hygiene education in sustaining WASH practices. It demonstrated that effective WASH delivery requires multi-stakeholder engagement, local monitoring systems and behaviour-change interventions that are inclusive and gender-sensitive. Gaps in MHM, poor monitoring systems and funding disparities were identified as key limitations in existing WASH interventions. Innovative approaches and best-practices, including digital monitoring tools, climate-resilient infrastructure and decentralised WASH governance, were proposed as potential solutions to address these inequities. However, challenges such as inconsistent funding and weak policy enforcement continue to hinder progress.

The chapter laid the foundation for the study by highlighting the urgent need for localized research to assess current WASH conditions in Durban high schools, examine microbiological risks and propose a risk-reduction framework for enhancing WASH provision. The findings discussed here justify the direction of the research undertaken in this study and set the stage for the methodological approach.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction and Study Design

This chapter outlines the methodological approach adopted to investigate the state of WASH conditions and MHM in selected high schools. Given the complex and multidimensional nature of WASH challenges, a mixed-methods research design was employed to integrate both qualitative and quantitative approaches. This allowed for a comprehensive understanding of infrastructural realities and the human experiences of those managing and using WASH services.

The qualitative component involved focus group discussions with school personnel, providing in-depth insights into the management of WASH systems, including operational challenges and context-specific strategies. This part of the study assessed the existing state of WASH services and MHM practices, as well as evaluating the KAP of students regarding these services. Conversely, the quantitative component focused on determining *E. coli* levels in drinking water, an important factor for ensuring water safety. Structured observations were conducted to evaluate the availability and condition of WASH infrastructure, while surveys assessed students' KAP. Additionally, the study examined the prevalence of WASH-related diseases and analysed the microbiological quality of drinking water.

To estimate the potential health risks associated with *E. coli* contamination in school water supplies, a QMRA was incorporated. This framework supported the evaluation of health risks associated with waterborne exposure, complementing the broader assessment of WASH conditions in schools.

The findings from both the qualitative and quantitative approaches were analysed together to provide a holistic understanding of the issues. A flowchart (Figure 3.1) illustrates the study design components, including the phases of data collection; data analysis; development of a risk reduction framework; and interpretation of conclusions. Based on the integrated results, challenges were identified, leading to the development of the risk reduction framework, which proposes actionable recommendations to address these issues.

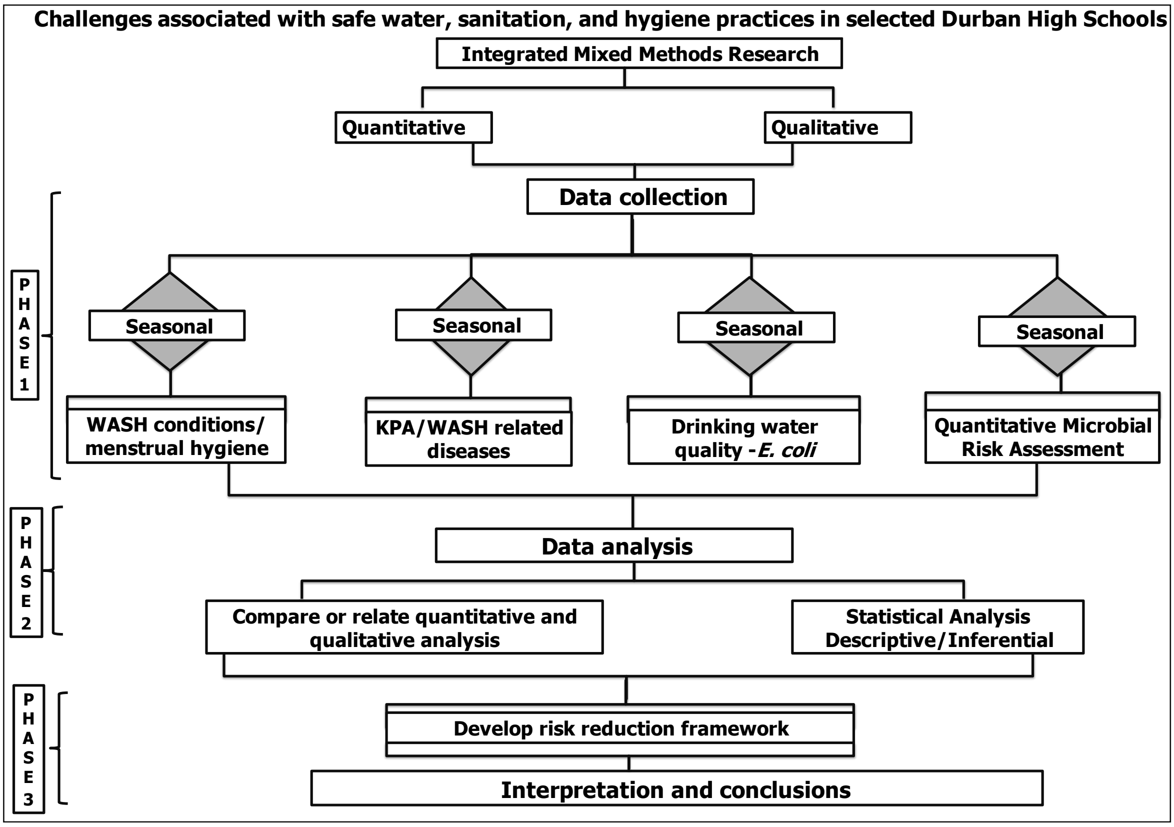

Figure 3.1: Flowchart illustrating the components of the study design

3.2 Description of Study Area

The study was conducted in Durban, located within the KwaZulu-Natal Province of South Africa. Durban is the third-largest city in the country, with an estimated population of approximately 4.1 million residents (Mclean et al., 2024; Cele et al., 2025; Olatoye et al., 2025). The city continues to experience rapid urban expansion and demographic growth, which place increasing demands on infrastructure, basic services and environmental resources. Urban planners, policymakers and community stakeholders are tasked with ensuring that development efforts align with environmental sustainability goals to secure a healthy and resilient urban environment for both present and future generations (Mclean et al., 2024; Cele et al., 2025). Figure 3.2 illustrates the map of the study area.

3.3 The Geographical Setting

In terms of geographic layout, the KwaZulu-Natal province comprises ten district municipalities and one metropolitan municipality, namely the eThekwini Metropolitan Municipality, within which Durban is situated (Figure 3.2). Durban spans approximately 2,300 square kilometres and features a diverse mix of urban, peri-urban and rural landscapes. Its strategic coastal location along the Indian Ocean has established it as a major port and a central hub for trade, commerce and industry, contributing significantly to the provincial and national economy. The city's geography influences its climatic conditions, biodiversity and socio-economic dynamics, making it a vital economic gateway and a critical site for balancing development with ecological sustainability (Gumede et al., 2023; Cele et al., 2025).

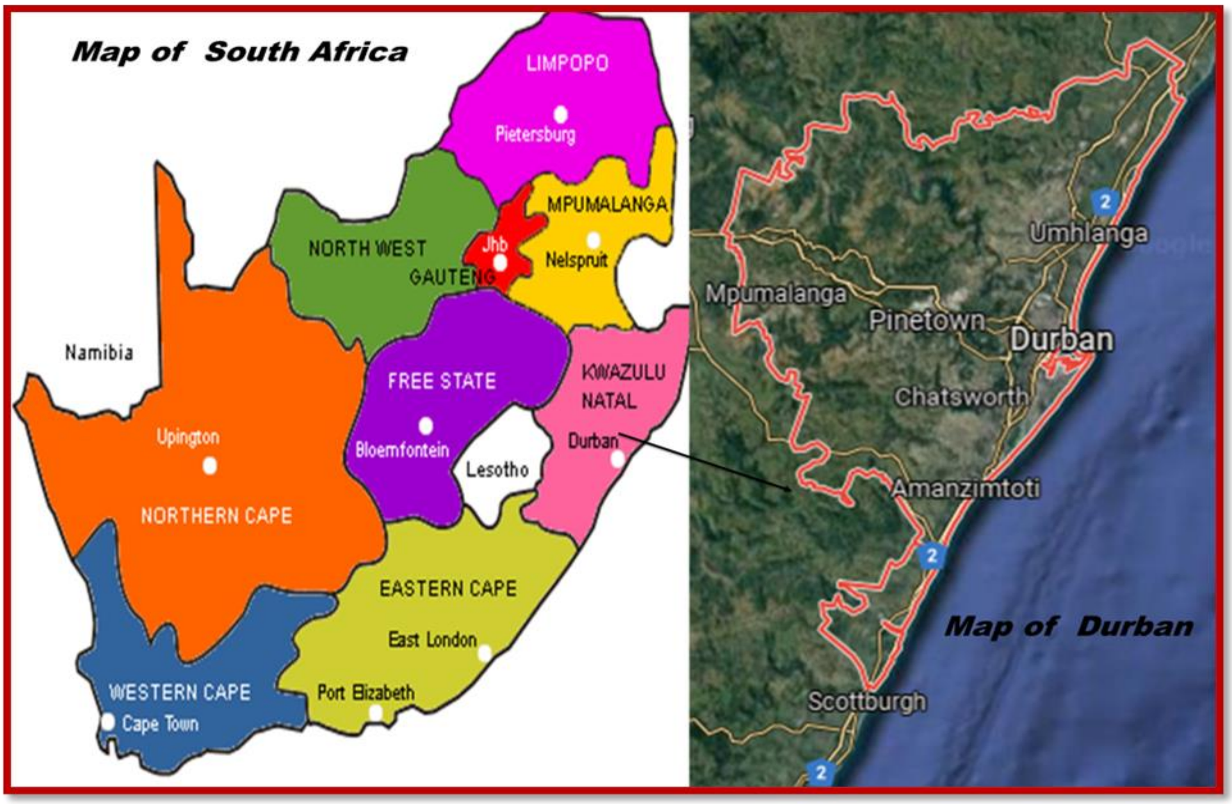

Figure 3.2: Map of the study area showing KwaZulu-Natal Province within South Africa and the location of Durban.

3.4 Educational Landscape

The KwaZulu-Natal Department of Education (KZNDoE) aligns its organisational structure with municipal boundaries, with the eThekwini Metropolitan area uniquely administered through two education districts, Pinetown and Umlazi, to improve logistical coordination and service delivery. Both districts encompass a heterogeneous mix of urban, peri-urban, rural and township settings, alongside pockets of informal settlement growth. These spatial and socio-economic contrasts shape school provisioning, enrolment patterns and the operational realities of infrastructure maintenance. They also directly influence how reliably water and sanitation services reach schools and how quickly faults are resolved (Gumede et al., 2023).

Within Pinetown and Umlazi districts, the schooling landscape comprises public ordinary primary schools (Grades R–7) and public ordinary secondary schools (Grades 8–12), as well as a smaller number of combined schools that serve learners from Grade R through to Grade 12 on a single site. Independent (private) schools operate across the same phases, ranging from low-fee to high-fee institutions with varied governance and resourcing models. The districts also include special schools and designated full-service/inclusive schools that accommodate learners with diverse educational needs, as well as a limited set of technical skills (Buthelezi et al., 2025). The present study specifically focused on public high schools (Grades 8–12) within these districts, comprising both boys and girls, to investigate the educational landscape and its implications for WASH service delivery.

Governance and funding arrangements further differentiate the system. Public schools are governed by School Governing Bodies and funded in line with the national quintile classification, with quintiles 1–3 being typically no-fee and quintiles 4–5 generally fee-paying (Van Dyk & White, 2019; Maistry & Africa, 2020). The present study focused on co-educational high schools across both districts to capture variations by quintile, governance type and locational context that are salient for WASH risk and service improvement.

3.5 Target Population

To select the study participants, a strict process was utilised to identify schools that met the requirements for inclusion as described in section 3.5.1. A comprehensive list of 219 high schools was extracted from the Department of Education Schools Master List Data, dated 3 March 2021 (https://www.education.gov.za/Programmes/EMIS/EMISDownloads.aspx).

The 219 high schools in the sampling frame were systematically stratified from Pinetown and Umlazi districts. The stratification of the sample served several purposes in this study. Firstly, it enhanced the efficiency of the survey design by ensuring that schools from different strata were adequately represented. This approach allowed for a more accurate estimation of population characteristics within each stratum. Secondly, stratification helped to improve the generalizability of the study findings. By including schools from various districts, geographic areas and school quintiles (1 to 5), the sample became more representative of the overall population. This ensured that the study results could be applied to a wider context.

3.5.1 Inclusion and Exclusion Criteria

The following criteria were established to determine the eligibility of schools for inclusion in the study. Eligible institutions were public ordinary high schools (Grades 8–12) listed on the EMIS master list for the study districts. Independent and specialized schools were excluded to maintain a coherent governance and funding context and to focus on the realities of public ordinary schooling.

Table 3.1: Inclusion and Exclusion Criteria

Inclusion	Exclusion
• Public schools, also known as Government Schools.	• Private schools
• Ordinary schools for normal students who do not require specialisation.	• Specialised schools
• Combination of boys' and girls' high schools.	• Single sex, boys or girls
• High schools from grade 8 to 12.	• Colleges that offer certain high school grades

• Schools that are in the Education Management Information Systems (EMIS) master list.	• Schools that are not registered in the EMIS database

3.6 Sampling Technique

The sample size was determined by considering the total number of strata and applying a two-stage sampling approach. A stratified random sampling method was employed to ensure representativeness across both school quintile classifications (1 to 5) and diverse geographical contexts, including urban (town), township, suburban and rural village settings.

In the first stage, schools were selected within each stratum using square root allocation, with the number of schools per stratum serving as the measure of size. In the second stage, learners were selected from the sampled schools using a systematic random sampling approach.

To ensure that each stratum was represented, proportional allocation was applied. The sample sizes for each stratum were determined using an inverse-variance weighted approach, as described by Kennedy-Shaffer and Hughes (2020), according to the following formula:

$$n_i = \left(\frac{N_i}{N}\right) \text{x}\, n \qquad \text{Equation (1)}$$

Where:

- n_i is the sample size for stratum i
- N_i is the population size for stratum i
- N is the total population size, and
- n is the total sample size.

According to this proportional allocation, a minimum of 28 schools could be selected. However, this number was increased to 40 schools to improve the reliability of estimates and ensure that larger strata were represented by at least two schools.

Table 3.2 presents an overview of the strata, including the number of schools per stratum, the sample size per stratum, and the list of selected high schools.

Table 3.2: List of Selected Durban High Schools for this study

No.	**Details of Stratification**					**Details of selected schools**		
	Strata	Number of schools in the strata	Number of students per strata	Proportional allocation	Number of schools to be selected	Name of selected school	Number of students	Area/ District
1.	P2TN	1	143	0,150685	1	Maphephetha Secondary School	607	Mgangeni, Maphephetha (P)
2.	P2TS	2	916	0,30137	1	Thabela High School	341	Kwasondela (P)
3.	P2TS	5	3770	0,753425	1	Umtapho High School	1502	Ntuzuma (P)
4.	P2RL	5	3687	0,753425	1	Dick Ndlovu Secondary School	840	Kwazelibomvu (P)
5.	P3TN	4	2321	0,60274	1	Dassehoek High School	982	Pinetown (P)
6.	P3SB	11	6631	1,657534	2	Maqhutshana Secondary School	439	Kwanyuswa (P)
						Thokozamnganga High School	327	Salem (P)
7.	P3TS	8	9055	1,205479	1	Mdepha High School	484	Kwaximba (P)
8.	P3RL	11	10523	1,657534	2	Hlahlindlela High School	992	Kwangcolosi (P)
						Ukusa Senoir Secondary School	724	Hammarsdale (P)
9.	P4TN	2	1995	0,30137	1	Trenance Park Secondary School	906	Trenance Park Verulam (P)
10.	P4SB	5	5248	0,753425	1	Newlands East Secondary School	1204	Newlands East (P)
11.	P4TS	19	14787	2,863014	2	Isibonelo High School	1120	Kwamashu (P)
						Siyathuthuka Secondary School	103	Inanda New Town A (P)
12.	P5TN	1	778	0,150685	1	Verulam Secondary School	1036	Waterloo (P)
13.	P5SB	12	10161	1,808219	2	Westham Secondary School	553	Westham (P)
						Hillcrest High School	1064	Alverstone (P)
14.	P5TS	17	11653	2,561644	2	Northmead Secondary School	934	Phoenix (P)
						Lenarea Secondary School	602	Phoenix (P)
15.	U1RL	1	392	0,150685	1	Isisusa Secondary School	392	Mahla Tribal Authority (U)
16.	U2SB	4	2296	0,60274	1	Margot Fonteyn Secondary School	1541	Klaarwater (U)
17.	U2TS	4	2296	0,60274	1	Siyabonga Secondary School	1773	Illovo North (U)
18.	U2RL	2	1854	0,30137	1	Isolenamba High School	1584	Golokodo-Ensimbini (U)
19.	U3SB	2	1346	0,30137	1	Lugobe High School	687	Umbumbulu (U)

No.	Details of Stratification					Details of selected schools		
	Strata	Number of schools in the strata	Number of students per strata	Proportional allocation	Number of schools to be selected	Name of selected school	Number of students	Area/ District
20.	U3TS	15	9081	2,260274	2	Makhumbuza High School	923	Umlazi (U)
						Nwabi High School	484	Ezingonyameni (U)
21.	U3RL	7	3764	1,054795	1	Adams College	1681	Adams Mission (U)
22.	U5TN	1	1327	0,150685	1	Amanzimtoti High School	836	Amanzimtoti (U)
23.	U4SB	2	1947	0,30137	1	Ganges Secondary School	1206	Merebank (U)
24.	U4TS	33	29922	4,972603	4	Aj Mwelase Senior Secondary School	596	Lamontville (U)
						Asoka Secondary School	756	Chatsworth(U)
						Bonela Secondary School	874	Bonela (U)
						Brindhavan Secondary School	601	Chatsworth (U)
25.	U4RL	1	1327	0,150685	1	Sidelile High school	1327	Umkomaas (U)
26.	U5TN	7	6272	1,054795	1	Centenary Secondary School	1064	Sydenham (U)
27.	U5SB	29	23544	4,369863	4	Marklands Secondary School	715	Shallcross (U)
						Phambili High School	935	Rossburgh (U)
						Rossburgh High School	910	Seaview (U)
						Brettonwood High School	913	Umbilo (U)
28.	U5TS	7	4900	1,054795	1	Sparks Estate Secondary School	957	Mayville (U)
Total		219	175015	13,33333	40		35515	

Pinetown District (P): P2 TN = Pinetown, Quintile 2 Town, P2SB = Pinetown, Quintile 2 Township, P2RL = Pinetown, Quintile 2 Rural, P3TN = Pinetown, Quintile 3 Town, P3SB = Pinetown Quintile 3 Suburb, P3TS = Pinetown, Quintile 3 Township, P3RL = Pinetown, Quintile 3 Rural, P4TN = Pinetown, Quintile 4 Town, P4SB = Pinetown, Quintile 4 Suburb, P4TS = Pinetown, Quintile 4 Township Pinetown, P5TN = Pinetown, Quintile 5 Town, P5SB = Pinetown Quintile 5 Suburb, P5TS = Pinetown, Quintile 5 Township.

Umlazi District (U): U1RL = Umlazi Quintile 1 Rural, U2SB = Umlazi Quintile 2 Suburb, U2TS = Umlazi Quintile 2 Township, U2RL = Umlazi Quintile 2 Rural, U3SB = Umlazi Quintile 3 Suburb, U3TS = Umlazi Quintile 3 Township, U3RL = Umlazi Quintile 3 Rural, U4TN = Umlazi Quintile 4 Town, U4SB Umlazi Quintile 4 Suburbs, U4TS = Umlazi Quintile 4 Township, U4RL = Umlazi Quintile 4 Rural, U5TN = Umlazi Quintile 5 Town, U5SB = Umlazi Quintile 5 Suburb, U5TS = Umlazi Quintile 5 Township.

Sourced from the Department of Education Schools Masterlist Data, dated 03 March 2021 (https://www.education.gov.za/Programmes/EMIS/EMISDownloads.aspx).

3.7 Sample Size Calculations

The sample size was calculated using the Cochran formula for proportions, which is appropriate for estimating the required number of participants with a specified level of precision and confidence. The formula used is:

$$n_0 = \frac{Z^2 \text{x } p \text{ x q}}{e^2} \qquad \text{Equation (2)}$$

where:

- Z is the Z-score corresponding to the desired confidence level (for 95%, Z=1.96),
- p is the estimated proportion of success (assumed to be 0.5 for maximum variability),
- q=1−p, and
- e is the margin of error (set at 0.05 for 5%).

Substituting the values:

$$n_0 = \frac{1.96^2 \text{x } 0.5 \text{ x } 0.5}{0.05^2}$$

$$n_0 = \frac{3.8416 \text{ x } 0.25}{0.0025}$$

$$n_0 = \frac{0.9604}{0.0025}$$

= 384.16

Given the population size of 175,015 students, the sample size was adjusted using the finite population correction (FPC):

$$n = \frac{n_0}{1+\frac{n_0-1}{N}} \quad \text{Equation (3)}$$

Where:

- n_0 is the initial sample size (from Cochran's formula),
- N is the total population size, and
- n is the adjusted sample size.

$$\approx \frac{384}{1+\frac{383}{175,015}}$$

$$\approx \mathbf{384}$$

Since the correction factor is negligible for such a large population, the estimated sample size remained approximately 384 students.

The initial sample size calculation was based on a simple random sampling framework and did not account for potential non-responses or design complexities. To strengthen the precision of estimates and improve the robustness of the data, over-sampling was applied. Specifically, the sample size was increased by 30%, resulting in a final target of approximately 500 learners. This adjustment enhanced the overall reliability and statistical power of the study, ensuring that the findings would remain valid despite possible participant attrition or uneven response rates across selected schools. The over-sampling approach also supported more stable sub-group analyses, contributing to the credibility and generalisability of the study outcomes.

Additionally, considering the specific context of the target population (Grades 8 to 12 learners), the study initially planned to sample 10 learners per grade within each school, totalling 50 learners per school. Given the number of schools and available resources, this would have resulted in a total sample of 2,000 learners. However, due to resource limitations and the need for manageable data collection, the decision was made to sample 30 learners per school, leading to an estimated total of 1,200 learners for the entire study. This approach aligns with recommended practices for sampling in survey research and reflects methods applied in previous studies using the Cochran formula (Singh & Masuku, 2014; Amin, 2024).

3.8 Selected Schools

To provide additional context to the study area, Figure 3.3 illustrates all the schools chosen for inclusion in this research. The selection process encompassed high schools from both Pinetown and Umlazi districts, reflecting a comprehensive representation of educational institutions within the boundaries of the Durban area.

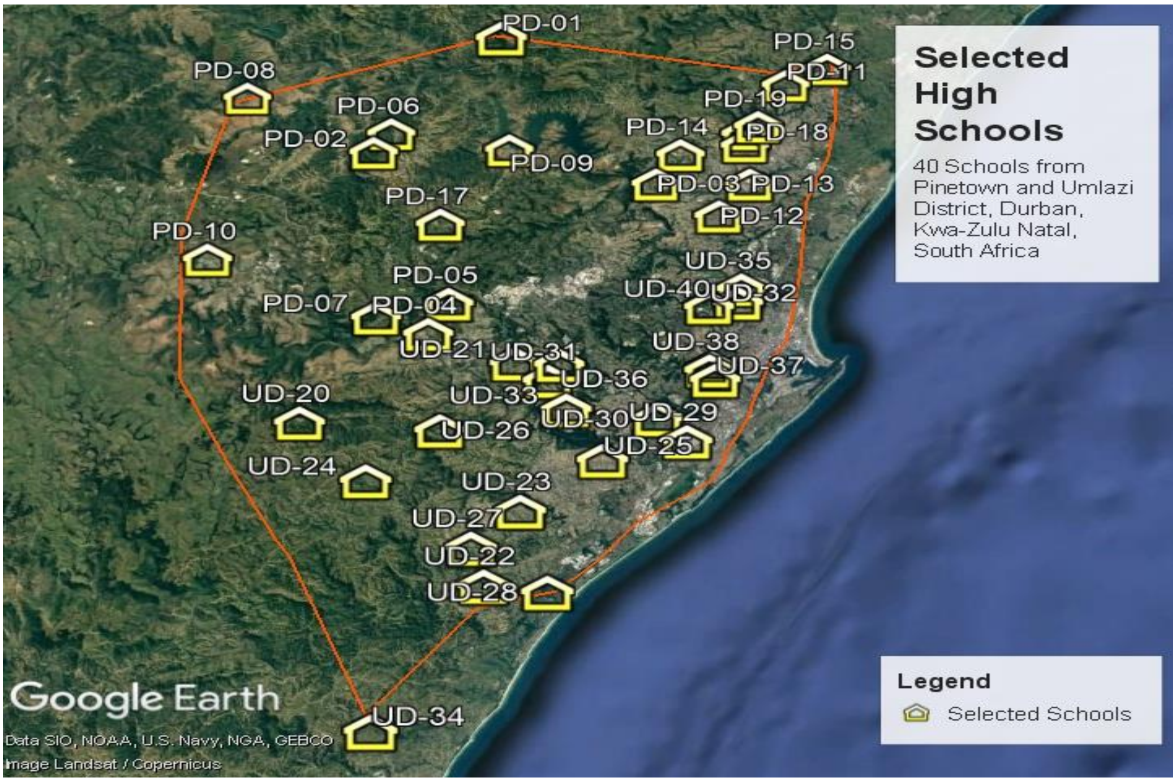

Figure 3.3: Map showing the selected schools included in the study within the Durban area

3.9 Data Collection Methods

This study employed a combination of qualitative and quantitative data collection methods to provide a comprehensive assessment of WASH conditions in selected schools. The data collection process was structured to address both infrastructural realities and behavioural practices influencing WASH within the school environment.

The qualitative data were collected through focus group discussions with school personnel, allowing for the exploration of operational challenges; management practices; and contextual insights regarding the functionality and sustainability of WASH services. These discussions were guided by a semi-structured question guide developed to ensure that key topics related to WASH management and service delivery were consistently explored across all focus group discussions.

The quantitative component involved multiple tools and sources, namely (i) an observational checklist to assess the availability and condition of WASH infrastructure; (ii) a structured Knowledge, Attitudes and Practices (KAP) questionnaire administered to learners; (iii) a health questionnaire to identify WASH-related diseases; and (iv) microbiological analyses of drinking water to assess contamination risks and estimate potential health impacts through QMRA.

Data collection was conducted over a period of 12 months to ensure seasonal representation and consistency. All tools were pre-tested for clarity and reliability, and the fieldwork was carried out by trained assistants under the supervision of the lead researcher. The sections that follow proffer a detailed description of the data collection procedures for each component of the study.

3.9.1 Qualitative Data Collection

Qualitative data were collected through focus group discussions to gain a deeper understanding of how WASH systems are managed and experienced within schools. This method was selected to encourage open dialogue amongst key school stakeholders and to capture collective experiences, perceptions and practices related to WASH service provision.

Participants included administrative personnel, educators and general support staff, including those involved in sanitation and maintenance. These groups were purposively selected based on their active involvement in managing or experiencing the schools' WASH systems. The group discussions were structured to promote active engagement, enabling participants to share insights, question assumptions and reflect on shared challenges and strategies.

A semi-structured interview guide (Appendix 3) was used to ensure consistency and comprehensiveness across all discussions. This guide covered thematic areas such as water access, sanitation maintenance, hygiene promotion, menstrual hygiene management and institutional support. While the guide provided structure, facilitators allowed flexibility for participants to raise issues they deemed important, thus ensuring that both anticipated and emergent themes could be explored.

Participation in the focus group discussions was voluntary, and informed consent was obtained from all participants prior to data collection. Discussions were conducted in English. However, where participants required clarification, explanations were provided in isiZulu to ensure understanding and inclusive participation. Instead of audio recording, the researcher documented the discussions through detailed written notes. This method of capturing data was chosen to foster a relaxed environment and minimise any discomfort that recording devices might introduce, particularly in a school-based setting.

By bringing together individuals with varied responsibilities, the focus group discussions facilitated a multi-dimensional understanding of WASH realities on the ground. The group format encouraged interaction, enabling participants to build on each other’s insights and reveal collective experiences, institutional barriers and adaptive strategies used in their efforts to maintain safe and functional WASH services. This process yielded rich, experience-based insights into the institutional realities of WASH provision and management in the school environment.

3.9.2 Quantitative Data Collection

Quantitative data were collected using multiple methods to assess both infrastructural and behavioural aspects of WASH conditions in the selected schools. These included structured observations, student questionnaires assessing KAP, disease symptom surveys and microbiological water quality testing.

3.9.2.1 Observations

Structured observations were employed to assess the availability, accessibility and condition of WASH infrastructure, including facilities for menstrual hygiene management. A contextual inquiry approach, similar to the one described by Berndt et al. (2014) and Jin et al. (2024), was used, wherein observation was conducted alongside informal questioning and engagement with staff members during site visits. This allowed for alignment with school-specific conditions and the collection of first-hand contextual data.

A semi-structured observational checklist (Appendix 1), adapted from WHO (2019) indicators, guided the documentation process. The checklist was designed to quantify observations by assigning numerical values to various aspects of water supply points, sanitation facilities and handwashing stations. Each item on the checklist was scored based on predetermined criteria, allowing for a systematic evaluation of the infrastructure's status. Observations relating to water availability were conducted once per month over a 12-month period to capture possible variations in water supply throughout the year.

Observations were conducted by trained fieldworkers under the supervision of the lead researcher, thus ensuring consistency and reliability in data collection. Notes were used to supplement checklist responses, providing context for the quantitative data collected. This quantitative approach enables statistical analysis and facilitates comparisons across different schools, enhancing the overall robustness of the findings.

3.9.2.2 Individual Interviews with Students

To assess students' KAP related to WASH, as well as the prevalence of WASH-related disease symptoms, a structured questionnaire survey was administered to students, using a semi-structured questionnaire adapted from UNICEF (2018) (Appendix 2). The questionnaire was administered through face-to-face interviews to ensure that all questions were clearly understood by participants and to minimise incomplete responses. Data collection was carried out quarterly to allow for seasonal variation, with new respondents selected for each round to broaden representation.

A systematic random sampling approach was used to recruit participants. Prior to participation, informed consent was obtained from the parents or legal guardians of minors, and student assent was also secured. Students completed the questionnaire with the assistance of the researcher in a face-to-face format conducted in a designated space within the school to ensure confidentiality and focus. Each student was guided through the questionnaire in a face-to-face interview format, conducted in a designated space within the school to ensure confidentiality and focus. Thirty students per school were interviewed, and responses were documented directly by the researcher to minimise missing data and enhance consistency.

3.9.2.3 Disease Symptom Survey

Integrated into the KAP questionnaire was a section on self-reported health symptoms commonly associated with inadequate WASH conditions. Students were asked whether they had experienced diarrhoea, skin rashes or other illness symptoms within the previous three months. This provided a basis for exploring associations between reported health outcomes and school WASH conditions.

3.9.2.4 Microbiological Analysis of Drinking Water

Water samples for analysis of the microbial quality of drinking water were collected from selected schools. The analysis focused only on the detection and enumeration of *E. coli* as an indicator of faecal contamination, in line with national and international water quality standards. A combination of field sampling, laboratory-based enumeration, biochemical confirmation and molecular screening for virulence genes was used. These methods were applied to evaluate potential microbial exposure risks amongst schoolchildren and to support broader assessments of environmental health conditions in school settings.

a) Sample Collection and Storage

Drinking water samples were collected from selected schools across the study area over a 12-month period to capture possible seasonal variations in microbial water quality. At each school, three sampling points were identified to reflect typical sources of water usage: the main tap used for drinking purposes, a tap near or inside the ablution facilities and any additional accessible tap within the school premises. This approach allowed for a comprehensive representation of water used for both consumption and hygiene within each school setting.

Although some schools reported during focus group discussions that nearby rivers were occasionally used as emergency water sources during prolonged municipal supply interruptions, this was not observed during the monitoring period. During sampling visits, schools relied on municipal water supplied through standpipe taps, and in some cases water tanks filled by the municipality were used as an alternative when the main supply was interrupted. Water samples for microbiological analysis were therefore collected from the primary water sources used by learners at the time of sampling, either from taps where water was available or from water tanks.

The water sampling procedure followed a systematic and standardised approach to ensure the accuracy and representativeness of the data The water sampling procedure followed a systematic and standardised approach to ensure the accuracy and representativeness of the data, as outlined in the National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners (Department of Health, 2015). Prior to the sample collection, preparatory steps were undertaken to minimise potential sources of contamination. These included flushing stagnant water from the tap by allowing it to run for three minutes. The tap nozzle was then disinfected by flaming with a burner until the water reached boiling point, effectively sterilising the outlet. To stabilise the water temperature and avoid heat-related artefacts, the tap was run again for two minutes before sampling.

A minimum of 500 mL of drinking water was collected from each sampling point using sterile plastic bottles. Care was taken to avoid contact with the inner surfaces of the cap and bottle. The bottle was held with one hand while the screw cap was removed with the other to prevent contamination. Immediately after collection, each bottle was sealed and labelled with a unique identification number, sampling location and date to ensure traceability and sample integrity.

In total, 1,440 water samples were collected over the duration of the study. To preserve microbial viability, all samples were placed in portable cooler boxes with ice packs and maintained at approximately 4 °C. These were then transported to the laboratory and analysed within one hour of sampling. The entire procedure adhered to the sampling protocols outlined in the National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners of the Department of Health (2015), ensuring compliance with national best-practices for environmental health monitoring.

Upon arrival at the laboratory, all drinking water samples underwent standardised preparation procedures to ensure integrity, traceability and compliance with quality control protocols. Prior to microbial analysis, the external surfaces of the bottles were cleaned using 70% ethanol to eliminate potential surface contaminants. Samples were temporarily stored in a 4 °C refrigerator if immediate processing was not possible.

b) Enumeration of E. coli Using the 3M™ Petrifilm™ Method

The enumeration of *E. coli* was performed to determine the microbial quality of drinking water samples. The 3M™ Petrifilm™ *E. coli*/Coliform Count Plate method was used (Palmares et al., 2024; Kurniati et al., 2025).

Each 3M™ Petrifilm™ plate was placed on a clean, level surface. The top film was carefully lifted to expose the inoculation area, and 1 mL of the water sample was aseptically dispensed onto the centre of the plate using a sterile micropipette. The top film was gently rolled back to cover the sample, avoiding air bubbles. A Petrifilm™ Flat Spreader was then placed at the centre of the plate to ensure even distribution, and the plate was allowed to solidify for one minute.

Plates were incubated at 42 ± 1 °C for 18–24 hours. After incubation, colonies were examined and interpreted using the manufacturer's guide. Colonies that appeared blue to red-blue in colour, with or without gas bubbles, were classified as *E. coli*. Results were recorded in colony-forming units per millilitre (CFU/mL). Colonies on the foam barrier were excluded, and none of the samples in this study exceeded the 150-colony threshold, hence serial dilutions were not required. During method validation, plates exceeding 150 colonies were analysed using an estimation technique based on counting a representative square and multiplying the average by 20, the total number of grid squares. This method ensured consistency with 3M™ Petrifilm™ interpretation guidelines.

c) Isolation of E. coli

Following the initial detection of presumptive *E. coli* using the 3M™ Petrifilm™ method, as described in the previous section, representative colonies exhibiting characteristic *E. coli* morphology were selected for isolation and further analysis. These colonies were aseptically streaked onto nutrient agar plates to obtain pure cultures and incubated at 37 °C for 24 hours to promote optimal bacterial growth. Well-isolated colonies were subsequently selected and preserved by suspending them in 20% glycerol and storing at −80 °C. This preservation step ensured the long-term viability of the isolates for downstream molecular applications, including species confirmation and pathotype characterisation.

d) Confirmation of E. coli via Real-Time PCR

Preserved *E. coli* isolates stored in 20% glycerol at −80 °C were first revived by streaking onto nutrient agar plates and being incubated at 37 °C for 24 hours to obtain fresh bacterial growth. Colonies displaying characteristic *E. coli* morphology were then selected and used for molecular confirmation.

Confirmation of *E. coli* identity was achieved through a real-time polymerase chain reaction (PCR), targeting the *uidA* gene. This gene encodes the β-D-glucuronidase enzyme, a well-established molecular marker specific to *E. coli*. Real-time PCR reactions were performed using the Applied Biosystems QuantStudio™ 5 Real-Time PCR System, which provided high sensitivity and specificity. This step was essential to confirm the presence of *E. coli* and to distinguish it from other morphologically similar coliform bacteria, thereby ensuring the accuracy of all subsequent analyses.

e) Genomic DNA Extraction

Genomic DNA was extracted from confirmed *E. coli* isolates using a heat-lysis protocol. This approach was selected for its simplicity, cost-efficiency and ability to yield DNA suitable for PCR-based applications. A fresh bacterial colony was obtained by sub-culturing each isolate onto nutrient agar and incubating it at 37 °C for 18–24 hours. A single colony was then transferred into a sterile microcentrifuge tube containing 100 µL of nuclease-free water. The suspension was vortexed briefly and subjected to boiling at 95 °C for 10 minutes to lyse the bacterial cells and release genomic DNA. The lysates were then immediately cooled on ice for 5 minutes to stabilise the nucleic acids. Following centrifugation at 12,000 × g for 5 minutes, the supernatant, containing crude genomic DNA, was transferred to a fresh tube and stored at −20 °C until use as a PCR template. Although a simple extraction method was used, DNA quality and integrity were evaluated using spectrophotometric analysis and agarose gel electrophoresis, in line with procedures applied by Abia et al. (2015). This method yielded DNA of sufficient quality for both conventional and real-time PCR analyses.

f) PCR Amplification of the uidA Gene

Conventional PCR amplification targeting the *uidA* gene was performed to confirm the presence of *E. coli* in each isolate. Reactions were prepared in a total volume of 20 µL, comprising 2 µL of genomic DNA, 10 µL of OneTaq® Master Mix (New England Biolabs, South Africa), 0.5 µL (0.6 µM) of each primer specific to the *uidA* gene and 7 µL of nuclease-free water. The thermal cycling protocol included an initial denaturation at 94 °C for 30 seconds, followed by 35 cycles of denaturation at 94 °C for 15 seconds, annealing at 59 °C for 30 seconds and extension at 68 °C for 45 seconds. A final extension was carried out at 68 °C for 5 minutes. This amplification strategy was designed to reliably detect the *uidA* gene in environmental *E. coli* isolates and to provide a foundation for further virulence gene screening.

g) Gel Electrophoresis and Visualisation of PCR Products

PCR products were analysed by agarose gel electrophoresis to verify the presence and size of amplified DNA fragments. A 1% agarose gel was prepared using 1× TAE buffer and stained with ethidium bromide. PCR products (5–10 µL) were mixed with loading dye and loaded into the wells alongside a 100 bp DNA ladder for molecular size reference. Electrophoresis was performed at 100 V for one hour to allow an adequate separation of DNA fragments. The gels were subsequently visualised using the Gel Doc™ XR+ imaging system (Bio-Rad, South Africa). The presence of a single DNA band of the expected size was considered confirmation of a successful amplification and a positive result for the target gene.

h) Detection of DEC Pathotypes

To determine the pathogenic potential of confirmed *E. coli* isolates, further PCR assays were conducted to screen for specific virulence genes associated with DEC pathotypes. The targeted genes included *eaeA*, *stx*, *aggR*, *ipaH*, *est*, *elt*, *daaE* and *fliCH7*, which are linked to the six major DEC groups: enteropathogenic (EPEC), enterohemorrhagic (EHEC), enterotoxigenic (ETEC), enteroaggregative (EAEC), enteroinvasive (EIEC) and diffusely adherent *E. coli* (DAEC).

Each PCR reaction followed the same conditions described above for *uidA* amplification, with thermal cycling parameters optimised for each target gene as required. Primer sequences and expected amplicon sizes are summarised in Table 3.2. Positive controls (reference DEC strains) and non-template controls were included in each run to ensure the validity of amplification and to detect any potential contamination.

For the interpretation of results, the amplification of any of the targeted virulence genes was assessed by visualising the presence or absence of distinct bands at the expected sizes using agarose gel electrophoresis. The presence of a band was interpreted as a positive result for the corresponding gene, while the absence of amplification was considered a negative result. This approach allowed for the molecular classification of *E. coli* isolates under the appropriate DEC pathotype when virulence markers were detected.

Table 3.3: Primer sequences and expected amplicon sizes for DEC virulence gene detection

Pathogen	Virulence Gene	Primer sequence (5'- 3')	Amplicon Size
EPEC/EHEC	*eaeA*	(F) ATGCTTAGTGCTGGTTTAGG (R) GCCTTCATCATTTCGCTTTC	~384
EAEC	*éagg*	(F) AGACTCTGGCGAAAGACTGTATC (R) ATGGCTGTCTAATAGATGAGAAC	~254
EIEC	*ípaH*	(F) GTTCCTTGACCGCCTTTCCGATACCGTC (R) GCCGGTCAGCCACCCTCTGAGAGTAC	~619
EHEC	*fliCH7*	(F) TACCATCGCAAAAGCAACTCC (R) GTCGGCAACGTTAGTGATACC	~625
EHEC	*sxt*	(F) GAGCGAAATAATTTATATGTG (R) TGATGATGGCAATTCAGTAT	~348
ETEC	*St*	(F) TTTCCCCTCTTTTAGTCAGTCAACTG (R) GGCAGGATTACAACAAAGTTCACA	~190
ETEC	*Lt*	(F) TGCTATGTGCATACGGAGC (R) CCATACTGATTGCCGCAAT	~450
DAEC	*daaE*	(F) GAACGTTGGTTAATGTGGGGTAA (R) TATTCACCGGTCGGTTATCAGT	~360

Adapted from Mbanga et al. (2020)

3.9.3 Quality Control and Method Validation

To ensure the accuracy, reliability and reproducibility of both laboratory and field-based procedures, a series of quality control (QC) measures and method validation protocols were implemented throughout the study. These controls spanned both microbiological and survey-based components, addressing data integrity, methodological robustness and procedural compliance with accepted standards.

3.9.3.1 Laboratory Quality Control Measures

During the microbiological analysis of drinking water samples, strict laboratory QC procedures were observed. All equipment and materials used in the analysis were subject to regular sterility checks, and media batches were validated before use to ensure microbial selectivity and performance. Sterile techniques were used during sample handling, and results from each analytical run were evaluated against control standards. This approach was essential for ensuring that contamination was prevented and that results accurately reflected the microbiological condition of the samples.

3.9.3.2 Method Suitability Assessment for 3M™ Petrifilm™

For the detection of *E. coli* using the 3M™ Petrifilm™ method, a method suitability assessment was conducted to validate the technique for use in water samples, with a particular focus on tap water. This validation involved the preparation of Tryptic Soy Broth (TSB); inoculation of confirmed *E. coli* isolates; and serial dilution procedures to assess the detection range and consistency of the Petrifilm method.

Preparation of the Tryptic Soy Broth (TSB) Medium: TSB was prepared by dissolving 3 g of powdered broth in 100 mL of distilled water, followed by mixing on a magnetic stirrer and sterilisation at 121°C for 15 minutes. After cooling, 10 mL portions were dispensed into glass tubes and refrigerated at 4°C until use.

Inoculation of *E. coli* Culture into TSB: A pure *E. coli* culture was introduced into the broth using a sterilised inoculating loop. Following a 24-hour incubation at 37°C, turbidity was assessed to confirm bacterial growth.

Serial Dilution Procedure: A ten-fold dilution series ranging from 10^{-1} to 10^{-6} was prepared by transferring 1 mL of culture into a series of tubes containing 9 mL of sterile distilled water. Each dilution was mixed thoroughly before being transferred to the next. These procedures helped confirm the sensitivity and dynamic range of the Petrifilm™ method for enumerating *E. coli* in water samples.

3.9.3.3 Quality Assurance for Real-Time PCR

To ensure the reliability and validity of real-time PCR results, rigorous quality assurance measures were implemented during all amplification runs. Each reaction included both positive and negative controls. Positive controls consisted of DNA from well-characterised DEC reference strains to confirm the successful amplification of the target genes. No-template controls, which substituted DNA with nuclease-free water, were included in each run to monitor for potential contamination.

All reactions were performed in duplicate to enhance reproducibility. A Melt curve analysis was conducted following amplification to assess the specificity of each

PCR product. Only those samples that exhibited gene-specific amplification curves and distinct melt peaks consistent with positive controls were considered valid for interpretation.

3.9.3.4 Quality Assurance in Survey Data Collection and Entry

For the quantitative data collected through student interviews, additional quality measures were implemented to reduce data entry errors and ensure completeness. All interviews were conducted face-to-face by the lead researcher and two trained assistants using a structured questionnaire. To minimise incomplete or inconsistent responses, the interviewer filled in the questionnaire on behalf of each student, explaining each item where necessary.

After data collection, all completed questionnaires were securely stored and later entered into Microsoft Excel by a trained Information Technology specialist. As part of the quality assurance process, the lead researcher conducted a verification check of 10% of the data entries by comparing them against the original hard-copy forms. Any discrepancies were corrected before the statistical analysis was performed. This process ensured that the survey data used in the study was both accurate and reflective of participants' responses.

3.10 Data Analysis Techniques

This section presents the analytical procedures used to interpret the data collected through the qualitative and quantitative methods. Given the study's mixed-methods design, each data stream was analysed independently before being triangulated to provide a comprehensive understanding of WASH conditions in schools.

3.10.1 Qualitative Data Analysis

Qualitative data derived from focus group discussions were analysed using thematic analysis. The researcher transcribed all handwritten notes from the group discussions and read through them repeatedly to become immersed in the content. Initial codes were developed by identifying recurring issues, ideas and expressions relevant to WASH management practices. These codes were then organised into categories and refined into broader themes.

The data coding and organisation process was facilitated using QSR NVivo 12 qualitative analysis software, which allowed for a systematic categorisation and traceability of codes across the dataset. Thematic patterns were interpreted in relation to the study objectives and contextual insights from the school environments. To strengthen the credibility of the findings, the initial codes and themes were reviewed by an independent qualitative researcher. The final themes captured operational challenges, resource limitations, institutional practices and innovative coping strategies in school-based WASH management.

3.10.2 Quantitative Data Analysis

Quantitative data were analysed using International Business Machines Statistical Package for the Social Sciences (IBM SPSS) Statistics version 27. The analysis was structured to examine multiple dimensions of WASH conditions, including infrastructure availability, student KAP practices, health outcomes and microbial water quality. The statistical methods applied were selected based on the type of data collected and the distribution characteristics of each dataset.

Descriptive statistics, including frequencies, percentages, means, medians, minimums, maximums, skewness and kurtosis, were used to summarise WASH infrastructure characteristics, learner-to-facility ratios and responses from the KAP survey. These measures provided a baseline overview of existing conditions across participating schools.

To explore variations in WASH conditions and infrastructure availability across districts (Umlazi and Pinetown) and school quintiles, inferential statistics were employed. The Chi-squared test, supplemented by Fisher’s Exact Test where appropriate, was used to assess statistically significant differences in WASH adequacy across school quintiles and geographic districts. The Mann-Whitney U test was utilised to investigate associations between the condition of handwashing facilities and learner-to-toilet ratios, particularly when data were non-normally distributed. Additionally, the Kruskal-Wallis test, followed by Dunn-Bonferroni post hoc tests, was applied to assess differences in WASH access, specifically the availability of drinking water points and handwashing stations across various quintile groups.

For the KAP survey, student responses were scored and categorised into levels of KAP based on the correctness of their responses. Descriptive analysis was used to report the distributions of each KAP component, while inferential statistics were applied to explore variations across demographic groups. Analysis of Variance (ANOVA) was conducted to test for significant differences in KAP across gender, age, educational level, and socio-economic status. Pearson's correlation analysis was employed to examine the relationships among knowledge, attitudes, and practices. Additionally, multiple regression analysis was performed to assess the extent to which knowledge and attitudes predicted hygiene practices.

Data on WASH-related health symptoms were also analysed using binary logistic regression to examine potential associations between demographic characteristics (for example, age, sex, grade level, quintile and district) and the likelihood of reported illness symptoms. This approach helped identify predictive factors linked to WASH-related health risks in the school setting.

The microbiological dataset was analysed using descriptive techniques only due to the nature of the data. This analytical approach ensured methodological rigour while remaining responsive to the structure and distribution of the data collected.

3.10.3 QMRA

A QMRA was conducted to estimate the potential health risks associated with exposure to *E. coli* through school drinking water. This framework followed a four-step approach recommended by WHO (2016) and supported by prior scientific literature (Teunis & Havelaar, 2000; Haas, 2014, 2020; Ahmed et al., 2020; Burch et al., 2022; Yeboah et al., 2022). The key steps included hazard identification; exposure assessment; dose–response assessment; and risk characterisation.

3.10.3.1 Hazard Identification

Hazard identification focused on assessing the potential for *E. coli* contamination in school drinking water to cause adverse health effects. Based on published studies, an estimated 8% of total *E. coli* present in water is considered pathogenic. This value (0.08) was used to estimate the dose of pathogenic *E. coli* from the total *E. coli* count, as recommended by Teunis and Havelaar (2000) and Haas (2014).

3.10.3.2 Exposure Assessment

The exposure assessment aimed to quantify the level of exposure to pathogenic *E. coli* through daily water consumption. The number of pathogens ingested per day was estimated by multiplying the concentration of pathogenic *E. coli* (adjusted using the 0.08 factor) by the volume of water consumed. Daily ingestion volumes and water source usage patterns were obtained from questionnaire data collected from learners at selected schools.

3.10.3.3 Dose-Response Assessment

To determine the likelihood of infection from the ingested dose, an exponential single-hit dose-response model was applied (Teunis & Havelaar, 2000; Pérez-Reche, 2025). This model assumes that each ingested pathogen has an independent chance of causing infection. The formula used was:

$$P_{inf\ (c.V;r)=1-e^{-rc.V}} \qquad \text{Equation (4)}$$

where:

- P_{inf} is the probability of infection,
- C *is* the concentration of pathogens *(E. coli),*
- V is the ingested volume (water consumed by each student), and
- r is the exponential model parameter.

A single-hit model for the maximum risk curve, which is represented by an exponential model with r = 1, was employed.

This model is recommended for low-dose waterborne pathogen assessments and reflects widely accepted microbial risk practices.

3.10.3.4 Risk Characterisation

Risk characterisation involved estimating the probability of annual infection by applying the daily risk model over multiple exposures. The following formula was used:

$$P_{inf\ annual} = 1 - [1 - P_{inf/day}]^n \qquad \text{Equation (5)}$$

Where *n* represents the number of exposure days per year.

This approach enabled an estimation of cumulative infection risk over time based on the repeated consumption of potentially contaminated water. All input values for risk characterisation were derived from either a laboratory analysis, existing literature or student survey data.

3.11 Development of the WASH Risk Reduction Framework

To respond proactively to the potential health risks identified through the QMRA and to address WASH challenges in the selected high schools, a structured WASH Risk Reduction Framework was developed. This framework aimed to support the systematic identification, prioritisation and mitigation of the risks associated with inadequate WASH services. The development process drew on principles from the UNICEF and Global Water Partnership (GWP) Climate-Resilient Water Safety Planning Toolkit UNICEF & GWP (2017), which emphasises risk-informed, participatory and adaptive approaches.

The framework was informed by both quantitative data (such as microbial quality, KAP survey findings and infrastructure assessments) and qualitative insights from school personnel. This mixed-methods foundation ensured that the risk reduction strategies were both evidence-based and contextually grounded in the lived realities of the school environments.

3.11.1 WASH Risk Reduction Framework Development Process

The framework development followed a methodical process comprising four key phases, namely risk assessment; risk identification and prioritisation; intervention planning; and monitoring and evaluation. Each phase was designed to build on the preceding one, culminating in a comprehensive strategy to reduce WASH-related health risks and improve the overall school environment.

3.11.1.1 Risk Assessment

The first phase involved a structured evaluation of WASH challenges across six core domains: the availability of infrastructure; quality of drinking water; sanitation conditions; MHM; operational management of WASH services; and student KAP. These assessments incorporated data from microbiological testing, structured surveys and observational checklists, thus allowing for a holistic understanding of risk factors across the schools.

3.11.1.2 Risk Identification and Prioritisation

Following the risk assessment, hazards were systematically classified using a scoring mechanism that evaluated their frequency and potential impact. The classification system categorised risks into three levels: High (Score 3), frequent and expected to persist; Medium (Score 2), occasional with moderate recurrence potential; and Low (Score 1), rare and unlikely to escalate (Figure 3.4).

This prioritisation process was supported by a model that considered the interaction of four factors, namely hazard, exposure, vulnerability and capacity. Risks characterised by high levels of hazard, exposure and vulnerability, and limited capacity to respond, were prioritised for immediate intervention. The classification approach helped ensure that school-level responses were data-driven and strategically focused.

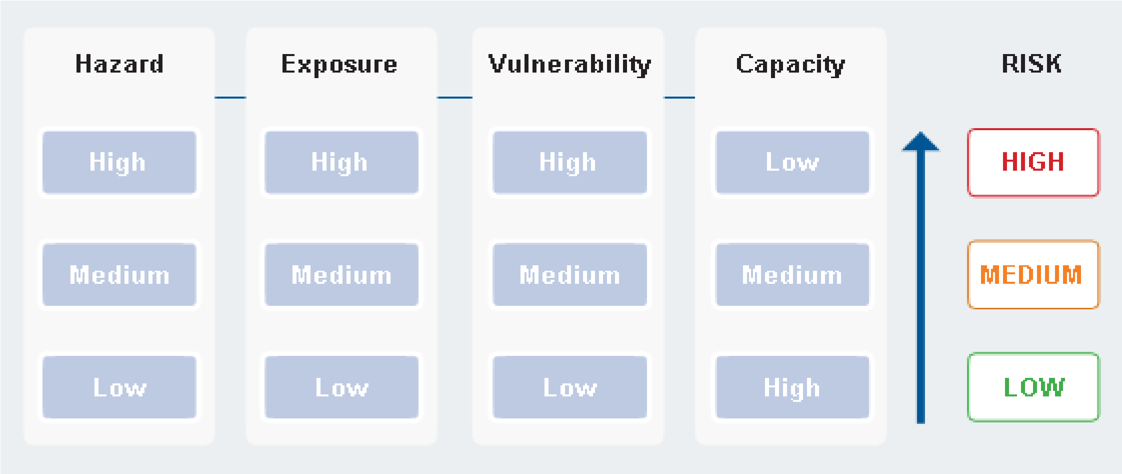

Figure 3.4: Risk classification matrix illustrating the interaction between hazard, exposure, vulnerability and capacity. Adapted from UNICEF & GWP (2017)

3.11.1.3 Intervention Planning

Following the risk identification and prioritisation phase, intervention strategies were systematically designed as the third step in the WASH Risk Reduction Framework development. These strategies were developed to address the specific risks classified across the key WASH domains, including infrastructure, water quality, sanitation conditions, menstrual hygiene management, operational management and hygiene behaviour.

The development of interventions was guided by international best-practices, relevant national policy documents (such as the National Environmental Health Norms and Standards and SANS 241), and practical considerations derived from the contextual realities of the participating schools. To ensure feasibility and relevance, proposed actions were aligned with existing institutional structures and resource limitations.

3.11.1.4 Monitoring and Evaluation Planning

The final phase of the framework development involved the design of a monitoring and evaluation (M&E) approach to accompany the proposed interventions. This step was undertaken to enable future assessments of both the implementation process and the effectiveness of interventions in addressing school WASH risks. An M&E structure was conceptualised to include both process indicators (for example, the implementation of interventions, reporting systems) and outcome indicators (for example, infrastructure functionality, presence of hygiene materials and routine monitoring practices).

3.12 Ethical Considerations

Application for ethical clearance was submitted to the University of South Africa's (UNISA) College of Agriculture and Environmental Sciences Institutional Research Ethics Committee (IREC). The research study commenced upon the granting of this ethical clearance (Appendix 7). Authorization to carry out the study was obtained from the KwaZulu-Natal Department of Education. Participation in the study was voluntary, with informed consent (Appendix 4) secured from all respondents to ensure their willing participation and their right to withdraw at any point if desired. For participants under the age of 18 years, permission was required from their parents or guardians.

The recruitment of participants occurred within the school environment and, where feasible, was conducted online. The confidentiality of participant information was rigorously respected and maintained throughout the study. Surveillance of WASH facilities and focus group discussions were undertaken within the school settings. All records were kept in a secure manner, safeguarded at all times. Data collected were initially recorded in Excel and subsequently transferred to SPSS for comprehensive analysis.

Furthermore, progress reports and applications for the renewal of ethical clearance were submitted to the Agriculture and Environmental Sciences Institutional Research Ethics Committee (IREC) on a yearly basis. This ensured that the study remained in compliance with ethical standards and adapted to any new ethical considerations arising during the course of the research.

3.13 Chapter Summary

This chapter has presented a comprehensive overview of the research methodology employed to WASH conditions in selected high schools in Durban, KwaZulu-Natal. A mixed-methods approach was adopted to capture both the technical and human dimensions of WASH, allowing for a nuanced understanding of infrastructural adequacy, hygiene behaviours and associated health risks. The qualitative strand focused on focus group discussions with school personnel to explore WASH management practices and contextual challenges, while the quantitative strand encompassed structured observations, student surveys, microbiological water quality testing and QMRA.

The study area was delineated geographically and educationally, with schools selected through a stratified random sampling approach across quintiles and regions to ensure representativeness. Sample size calculations were performed using Cochran's formula and adjusted to account for potential non-response, resulting in a final sample of approximately 1,200 learners.

Data collection methods were tailored to align with the objectives of the study. Tools included observation checklists, KAP questionnaires and laboratory-based microbial analyses using 3M™ Petrifilm™ and PCR techniques. The study adhered to rigorous quality assurance and ethical standards, including pretesting instruments, training fieldworkers, validating laboratory methods, and securing informed consent from participants.

Data analysis was conducted using both thematic and statistical techniques. NVivo software was used to identify emergent qualitative themes, while SPSS was employed to analyse quantitative data, including descriptive and inferential statistics and logistic regression. The QMRA followed the WHO's four-step model, namely hazard identification; exposure assessment; dose-response modelling; and risk characterisation, to estimate the potential for *E. coli* infection through drinking water.

Finally, the chapter detailed the structured development of a WASH Risk Reduction Framework. Grounded in the study's empirical findings and informed by the UNICEF/GWP Climate-Resilient Water Safety Planning approach, the framework followed four key phases: risk assessment, prioritisation, intervention planning, and monitoring and evaluation. This chapter sets the foundation for the subsequent presentation and discussion of findings by establishing the scientific, ethical and contextual rigour underpinning the study.

CHAPTER 4: DATA ANALYSIS

4.1 Introduction

This chapter presents the results of the study, outlining a detailed analysis of the data obtained against each of the study objectives. The chapter is structured to reflect the integration of various data sources, including focus group interviews, observational checklists, structured questionnaires, microbiological water testing and health-related surveys. Each section presents descriptive and inferential results without interpretation, offering a clear, objective account of the conditions found during the study. These findings lay the groundwork for the discussion and synthesis presented in Chapter 5, which interprets the results and proposes evidence-based recommendations for improving WASH service delivery in schools.

4.2 Qualitative Insights into WASH Practices and Management in High Schools

Information on WASH was obtained from focus group discussions with a total of 40 participants representing the schools included in the study, focussing on understanding the WASH conditions in the schools. While each school was represented, the number of participants from each school varied depending on the availability of personnel responsible for WASH management and related activities. Thematic analysis was used to identify key patterns and recurring themes, providing an in-depth exploration of participants' lived experiences tied to water availability, functionality, water quality and compliance; operations and maintenance of the water system; sanitation systems; menstrual hygiene management; and the impact of policy on access to drinking water. QSR NVivo 12 was used to identify key themes and sub-themes that reflect the participants' experiences and perspectives.

To complement the thematic analysis, a word cloud was generated to visually summarise the most frequently mentioned terms during the focus group discussions. As illustrated in Figure 4.1, terms such as water source, hygiene, school, available and drinking appear prominently, reflecting the dominant concerns and priorities expressed by school personnel. This visual representation provides a high-level overview of the recurring issues that shaped the discussions and supports the more detailed thematic findings.

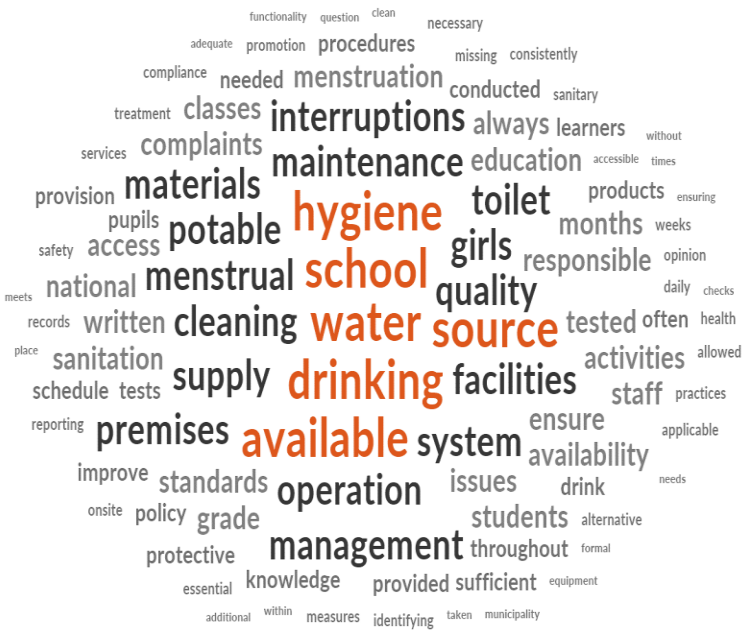

Figure 4.1: Word cloud illustrating frequently mentioned terms from focus group discussions

4.2.1 Water Provision and Management in Schools

Responses by staff participants regarding the availability, functionality, quality, operations and maintenance, and access policies of water within school settings are provided in this section. Diverse experiences and challenges that schools encounter in providing safe and reliable drinking water are highlighted.

4.2.1.1 Water Availability and Functionality

Table 4.1 presents the results on water availability and functionality. In most schools, water was not consistently available throughout the academic year. A total of 90.0% of schools reported that their supply was unreliable. In the Pinetown District, 89.5% of schools indicated this problem, while in the Umlazi District it was 90.5%. In 45.0% of schools, the supply lasted only a few hours when available. This short-duration supply was more common in Pinetown, where it was reported by 73.7% of schools, compared to 19.0% in Umlazi.

Only 10.0% of schools reported that they had access to potable water for most of the year, although occasional interruptions still occurred. This pattern was found in 10.5% of Pinetown schools and 9.5% of those in Umlazi. Most schools indicated that their water supply followed the same pattern as the surrounding community. This was reported by 94.7% of schools in Pinetown and 85.7% in Umlazi.

Amongst the schools that received water on the same schedule as the surrounding area, frequent interruptions were reported in 55.6%. These interruptions were more common in Pinetown (66.7%) than in Umlazi (44.4%). Looking at all schools, regardless of supply source, 52.5% experienced frequent disruptions in water access. Some of these interruptions lasted up to two weeks, causing serious interruptions to daily school activities.

When grouped by school quintile, the results showed clear differences in water access reliability. Lower-quintile schools (1–3) reported unreliable water access, while 84.6% of high-quintile schools (4–5) also experienced unreliable water access. Specifically, 92.9% of lower-quintile schools reported short-duration water supply, compared to only 19.2% of high-quintile schools. Only 15.4% of higher-quintile schools reported having water available throughout most of the year, with no lower-quintile schools falling into this category. Notably, both lower-quintile schools (92.9%) and high-quintile schools (88.5%) indicated that their water supply matched that of the surrounding community.

When regular supply was disrupted, schools relied on alternative sources. River water was used by 7.5% of schools, mainly in Pinetown (10.5%) and to a lesser extent in Umlazi (4.8%). All schools that used river water were in the lower quintiles. Boreholes were used by 5.0% of schools, all located in Umlazi and all in the higher quintiles. Rainwater harvesting tanks were mentioned by 2.5% of schools, which were only in Umlazi and in high-quintile contexts. Municipal standby tanks were used by 12.5% of schools overall. These were more common in Pinetown (26.3%) and were not reported at all in Umlazi. By quintile, 28.6% of lower-quintile schools used standby tanks, compared to only 3.8% of high-quintile schools.

The findings indicate that water availability throughout the school year was inconsistent for most of the surveyed schools. Ninety percent of respondents reported a lack of reliable water supply, with 45% noting that, when water was available, it typically lasted only a few hours before depleting again. Nevertheless, 10% of respondents indicated that potable water was generally available throughout the school year, although occasional interruptions occurred.

Most schools were found to be chiefly dependent on the municipal water system, which was frequently unreliable in terms of supply consistency, with regular interruptions affecting daily operations. Eighty-five percent of respondents reported that their schools' water supply mirrored that of the surrounding community and, amongst these, 53% noted frequent interruptions, with some disruptions lasting for up to two weeks. In response to water shortages, focus group discussions indicated that some schools resorted to alternative and often unreliable sources, including nearby rivers (7.5%) and rainwater harvesting tanks (2.5%).

Table 4.1: Water Availability and Functionality

Sub-theme	Participant Quotes	Key Issues Identified
Water availability consistency	*"No, the water is never available throughout the year." (Respondents 1, 20, 26). "The supply of water in the school has not been reliable" (Respondents 1–14,16, 18–24, 26, 27, 29–40).*	Majority of schools experience inconsistent water availability throughout the year.
Responsibility for potable water supply	*"The school receives the same water supply that the surrounding community is receiving" (Respondents 1–3, 5–25, 29–40).*	Water supplied by municipality, often unreliable.
Reliable supply in some schools	*"Potable water has generally been available throughout the school year, with only very rare interruptions" (Respondent 15, 17,25, 28). "When we do get water, it only lasts for a few hours and then it's gone again" (Respondents 1–14, 21–24).*	Some schools report reliable water supply, though this is an exception compared to the majority.
Water interruption frequency	*"The school has faced significant water supply interruptions." (Respondents 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 20, 21, 22, 23, 24, 26, 32, 33, 40).*	Frequent interruptions, up to two weeks, affecting sanitation.

Sub-theme	Participant Quotes	Key Issues Identified
Alternative water supply	*"At times, the school obtains water from a nearby river" (Respondents 1, 2, 21). "We use borehole water when there is no municipal supply" (Respondents 26, 34). "We have a rainwater tank that we use as an alternative" (Respondent 24).*	Schools resort to unsafe alternative water sources, increasing health risks due to waterborne diseases.
Municipal support during interruptions	*"The school utilises standby water tanks from the municipality during interruptions." (Respondents 2, 3, 4, 8 and 17).*	Temporary solutions such as water tanks are in place, but they are not always sufficient or sustainable.

4.2.1.2 Water Quality Assessment and Compliance

Table 4.2 presents the perceptions and experiences of school personnel concerning water quality and its compliance with SANS 241:2015 (SABS, 2015).

Table 4.2: Water Quality Assessment and Compliance

Sub-theme	Participant Quotes	Key Issues Identified
Absence of Water Quality Testing	*"This question is not applicable because the water quality has not been tested" (Respondents 1–28, 30–33, 35,36, 38–40).*	Lack of water safety data poses health risks due to uncertainty around water quality.
Compliance with Water Quality Standards	"*eThekwini Municipality used to test water quality for E. coli and reported compliance with national drinking water standards" (Respondents 29, 34, 37). This question is not applicable, as no water testing has been conducted within the past 12 months (Respondents 1–28, 29–33, 35,36, 38–40).*	Some schools conduct compliance testing; others lack assessments
Key Parameters considered in Water Testing	*"Recent water quality tests have specifically checked for the presence of E. coli" (Respondent 34). "Water used to be tested for E. coli; however, this has not been done for the past six months" (Respondents 29, 37).*	*E. coli* testing as key water safety indicator
Complaints and Reporting Mechanisms	*"There's no formal system, but any allocated personnel assist in managing water-related problems" (Respondents,1–14, 16, 20–26, 29–34, 36–40). "The maintenance team records complaints and follows up to resolve them" (Respondents, 15,17–19, 27,28, 35).*	Some schools report consistent supply, while others lack formal records

Sub-theme	Participant Quotes	Key Issues Identified
Measures in Response to Complaints	*"Complaints are logged, investigated, and actions are taken to implement suitable solutions" (Respondent 15,17–19, 27,28, 35).*	Schools document and respond to complaints

Focus group discussions revealed disparities in how schools monitored and assessed the quality of drinking water. Only 7.5% of schools reported that water quality had previously been tested by the municipality for *E. coli* and that results were shared, confirming compliance with national drinking water standards. All these schools were located in Umlazi District and fell within high-quintile categories (4–5). Within this group, 5.0% of schools indicated that testing had only occurred once during a six-month period. In contrast, 92.5% of schools had not conducted or received any form of water quality analysis in the past 12 months.

Participants who indicated that water quality analysis had not been conducted at their schools stated that they were unable to determine the safety of their drinking water. They explained that no microbiological monitoring had taken place, and no recent analytical results were available to confirm the status of the water supply. This absence of monitoring was reported by 89.5% of schools in Pinetown and 95.2% in Umlazi. When grouped by quintile, all lower-quintile schools (1–3) and 88.5% of high-quintile schools (4–5) had not carried out or received any form of water quality assessment within the past 12 months.

Reporting mechanisms for water-related complaints varied across schools. In 82.5% of schools, there was no formal system for reporting water issues. However, respondents indicated that any allocated personnel assisted in managing the problems as they arose. This was reported by most schools in both the Pinetown and Umlazi districts, including all lower-quintile schools (1–3) and most high-quintile schools (4–5). In contrast, 17.5% of schools stated that water-related complaints were recorded by the maintenance team and followed up accordingly. These schools were in both districts but were concentrated in high-quintile categories. All schools that described logging, investigating and responding to water-related complaints were from high-quintile schools in both Pinetown and Umlazi. No lower-quintile school reported having a structured procedure for complaint logging or follow-up.

4.2.1.3 Operation and Maintenance of Water System

The operation and maintenance of water systems in schools were managed through varied approaches, with patterns differing across both districts and quintiles (Table 4.3). Overall, 85% of respondents indicated that the responsibility for reporting water supply issues was shared amongst school principals, caretakers and maintenance teams. This was more commonly reported in the Umlazi district at 18% than in Pinetown at 12%, and it occurred slightly more in higher quintile schools (4–5) at 17% compared to 13% in lower quintile schools (1–3). The remaining 15% of respondents reported that there was no dedicated person responsible for reporting water supply issues, and that anyone appointed by the school at the time could take on this task.

Only 12.5% of schools reported having a formalised approach to documenting and addressing water-related complaints, ensuring that issues were logged and investigated promptly. This was more frequent in Pinetown at 8% than in Umlazi at 4%, and it was slightly more common in higher quintiles (7%) compared to lower quintiles (5%). Most schools, (87.5%), lacked such procedures, leaving water-related issues to be addressed informally or reactively. This lack of documentation may contribute to delays in problem resolution and reduced accountability.

Responsibility for maintaining water systems also varied considerably. In 20% of schools, all operational and maintenance tasks were undertaken by the school caretaker or maintenance team, while in the remaining 80%, minor issues were addressed internally, and major operational and maintenance work was outsourced to external service providers. This outsourcing pattern was more evident in Umlazi, where 45% of schools followed this approach compared to 35% in Pinetown. Higher quintile schools reported outsourcing more often (46%) than lower quintile schools (34%), reflecting possible differences in budget flexibility and access to service providers.

On-site water treatment methods were uncommon, with only 6% of schools reporting such practices, mainly in higher quintiles (4%) and almost exclusively in Pinetown (5%). Additionally, 12.5% of schools reported having a written operation and maintenance plan for the water supply system, whereas 87.5% had no such plan in place. Written plans were more common in higher quintiles (8%) than in lower quintiles (4%), and they were slightly more prevalent in Pinetown (7%) than in Umlazi (5%). The absence of these plans in most schools suggests a need for more structured management to ensure the sustainability of water systems.

Table 4.3: Operation and Maintenance of Water Systems

Sub-theme	Participant Quotes	Key Issues Identified
Responsibility for Reporting on Water supply Issues	*"The school principal, caretakers, and maintenance teams are responsible for identifying and reporting any issues related to the water system" (Respondents 1–8, 12, 13–19, 22–34, 36–40). "Anyone appointed by the school at that time could report issues related to water. There was no dedicated person responsible for this task" (Respondents 9, 10, 11, 20, 21, 35).*	Varies by school: principal, caretaker, or maintenance team
Complaints and Reporting Mechanisms	*"No formal complaints regarding the quality or availability of drinking water have been recorded." (Respondents 5, 7, 9,12,19,24,29, 21,32,34).*	Some schools report consistent supply, while others lack formal records
Measures in Response to Complaints	*"Complaints are logged, investigated, and actions are taken to implement suitable solutions." (Respondents 14, 17, 28,36, 39). "We don't have a proper system for reporting or handling complaints, problems are just dealt with as they come"(Respondents 1–13, 15,16,18–26,27,29 –35,37,38,40).*	Schools document and respond to complaints
Operation and Maintenance Responsibility	*"The caretaker is responsible for the operation and maintenance of the drinking-water facilities at the school." (Respondents 11,13, 14, 17, 24, 27,28,30). Minor issues are handled by the school caretaker or maintenance team, but major operational and maintenance work on the water supply is outsourced to a private plumber. (Respondents 1 –10,12, 15, 16, 18–23, 25,26,29, 31–40). The Department of Public Works handles the operation and maintenance of the water provision (Respondent 7).*	Responsibilities vary caretaker, external service, or government agency
Water Treatment Methods	*"Bleach is sometimes used to treat the water in the tanks." (Respondents 9,24,27). "No water treatment methods are conducted within the school" (Respondents 1–8, 10–23, 25, 26, 28–40).*	Minimal on-site treatment; reliance on assumption of water quality

Sub-theme	Participant Quotes	Key Issues Identified
Operation and Maintenance Plans	*"A written operation and maintenance plan is in place for the water supply system." (Respondent 15, 17,18, 27, 34). "No written operation and maintenance plan in place for the water supply system" (Respondents 1–14, 16, 19–26, 28–33, 35–40).*	Some schools have plans; others address maintenance only as issues arise

4.2.1.4 Access to Drinking Water: Sources and Policies

Participants shared insights into both the infrastructure available for drinking water provision and the policies that influenced students' access to safe and adequate drinking water. Table 4.4 presents a detailed summary of these sub-themes, illustrating respondents' perspectives on drinking water sources and policy-related challenges within their schools.

Table 4.4: Access to Drinking Water Sources and Policies

Sub-theme	Participant Quotes	Key Issues Identified
Drinking Water Sources	*"Drinking water is available from the school water taps and water tanks." (Respondents 2,3,5,17,24,27,36).*	Schools rely on taps and water tanks on premises; no centralised supply
	"Drinking water is provided through taps installed on the school premises." (Respondents 6, 7, 9–16, 18, 19–23, 25, 28–35, 37–40).	Reliance on school-specific infrastructure instead of centralised supply.
	"Drinking water is provided through water tanks filled by the municipality. Although taps are available, they have not supplied water for more than 12 months" (Respondents 1, 4, 8).	Long-term unavailability of piped tap water, resulting in reliance on municipal water deliveries via tanks.
Adequacy of Water Infrastructure	*"The school relies on one tap for all activities, including drinking by students and all other school activities" (Respondents 1,21).*	Limited infrastructure constrains adequate water access in some schools.
Dependence on Self-Supplied Sources	*"The school relies on a borehole constructed by the school with assistance from the community, as there is no water provision in the school or surrounding area by the local government" (Respondent 26).*	Reliance on self-supplied water sources without centralized municipal supply.
Policy on Accessibility of Drinking Water	*"The school does not have a written policy or rules to ensure that students have access to drinking water" (Respondent 1–14, 20–27, 29–33, 35 –40).*	Lack of formal policies in some schools leads to inconsistencies in access.
	"The school has a formal written policy that guarantees students have access to	Some schools have policies emphasising access to support hydration.

Sub-theme	Participant Quotes	Key Issues Identified
	drinking water" (Respondent 15–19, 28, 34).	
Policy Implementation Challenges	*"Yes, the Department of Education policy requires that schools have accessible drinking water, and here it is implemented." (Respondents 15, 17, 28). "The policy says we must have drinking water, but due to ongoing water interruptions and a lack of resources, implementing this requirement is a challenge." (Respondent 1–14, 16,18–27, 29–33, 35–40).*	Departmental policies exist but are inconsistently implemented across schools.
Health and Hygiene Implications	*"The school has faced significant water supply interruptions, making it difficult to maintain hygiene" (Respondents 1–14,16, 18–24, 26, 27, 29–40).*	Inadequate water access potentially impacts hygiene and health.

The results showed notable variation in both the sources of drinking water and the policies governing access across the surveyed schools, with differences evident across districts and quintiles (Table 4.4). Drinking water was most obtained from taps and water tanks located on school premises, with 55% of schools relying solely on taps and 17.5% using a combination of taps and water tanks. In 7.5% of schools, piped tap water had been unavailable for more than 12 months, resulting in complete reliance on water tanks filled by the municipality. Limited infrastructure was also observed in 5% of schools, where a single tap served all purposes, while one Quintile 4 school in the Umlazi District depended on a community-constructed borehole due to the absence of municipal water provision.

Policies on drinking water access also varied, with 67.5% of schools reporting no written policy to ensure regular access for students, and only 12.5% confirming the existence of a formal policy guaranteeing such access. Although the Department of Education mandates that schools have accessible drinking water, implementation was confirmed in only 7.5% of cases, mainly in Quintile 5 schools within the Pinetown and Umlazi Districts. In contrast, 72.5% of schools, spanning lower to higher quintiles, reported that ongoing water interruptions and limited resources hindered compliance. Water access interruptions were reported in 90% of schools, with respondents indicating that these disruptions adversely affected toilet cleanliness and handwashing, thereby compromising hygiene standards.

4.2.2 Sanitation Systems in Surveyed Schools

Based on participant responses, results related to the sanitation systems within surveyed schools, were analysed to reflect on the availability and types of toilets; the current state of sanitation facilities; and general hygiene and maintenance practices. Table 4.5 summarizes the data collected, highlighting key insights regarding sanitation systems in schools.

4.2.2.1 Availability and Types of Sanitation Systems in Surveyed Schools

Most surveyed schools, (78%), relied on a central municipal sewer system for the disposal of human excreta, with such facilities present in both Umlazi and Pinetown districts. Sewer connections were more common in higher-quintile schools, with all Quintile 5 schools and most Quintile 4 schools being connected to this service. As shown in Table 4.5, only one school, (3%), in Pinetown District reported using ablution facilities connected to a septic tank, in Quintile 3. Pit latrines, reported by 17,5% of schools, were concentrated in lower quintiles 1–2 in both districts, with facilities often described as being in a dilapidated state.

The inadequacy of sanitation facilities was highlighted by 65% of schools, where the number of learners had increased without a corresponding upgrade or addition of toilets. This challenge was reported in both Umlazi and Pinetown districts, but it was more frequently observed in Umlazi District, particularly in quintiles 2–4. In Pinetown District, the issue was most common in Quintile 3 and some Quintile 4 schools. Schools indicated that toilet overcrowding occurred especially during breaks, creating pressure on existing infrastructure. These findings show that facility adequacy issues are not limited to the lowest quintiles but extend to middle-quintile schools across both districts where enrolment growth has outpaced infrastructure development.

Table 4.5: Availability and Types of Sanitation Systems in Schools

Sub-theme	Participant Quotes	Key Issues Identified
Types of Sanitation Systems	*"The school uses a central municipal sewer system" (Respondents,3,7–20 22–23–40). "The school relies on*	Most schools rely on sewer systems, which do not require

Sub-theme	Participant Quotes	Key Issues Identified
	ablution facilities connected to a septic tank." (Respondent 5).	onsite maintenance schedules for sludge removal.
	"The school uses pit latrine toilet facilities, which are in a dilapidated state" (Respondents 1, 2, 4, 6,8, 20, 26).	Some schools lack access to flush toilets or sewer-connected facilities, relying instead on pit latrines
Inadequacy of sanitation facilities	*The number of learners has increased but the toilets has not been upgraded or added and become overcrowded during breaks (1–13,21–27, 29–34).*	Existing facilities are overwhelmed, particularly in larger schools, and more toilets are needed.

4.2.2.2 Condition of Sanitation Facilities

Table 4.6 presents the results on the condition of sanitation facilities across the surveyed schools. Pit latrines were reported to be associated with poor hygiene, unpleasant odours, contamination risks, and challenges in maintenance. These concerns were raised by 20.0% of schools overall, including 12.5% in Pinetown and 7.5% in Umlazi. The pattern was strongly linked to lower-quintile schools, with all schools in quintiles 1–3 reporting difficulties related to pit latrine use. Respondents described these facilities as unsafe and unhygienic, indicating an urgent need for improvement.

Approximately about 30% of schools stated that their sanitation facilities required upgrading, with recommendations for replacement with sewer-linked systems or improved flush toilets. This concern was reported by schools in both districts, with a higher proportion in Pinetown at 17.5% compared to Umlazi at 12.5%. Most of these responses came from lower-quintile schools, where 20% noted the need for infrastructure upgrades, although 10% of higher-quintile schools also raised the issue. Respondents described existing toilets as outdated and not fit for current needs.

Plumbing-related breakdowns were also reported as a recurring challenge. Overall, 27.5% of schools described frequent plumbing failures that disrupted sanitation access. These failures were identified in 15% of schools in Pinetown and 12,5% in Umlazi. The problem was observed across quintile groupings, with 15% of higher-quintile schools and 12,5% of lower-quintile schools reporting ageing plumbing that frequently broke down. Respondents noted that the unreliability of older systems compromised the regular functioning of sanitation facilities.

Shortages in the number of toilets to accommodate learners were reported by 77.5% of schools, corresponding to 31 respondents (1, 2, 4, 5, 6–10, 12, 13, 16, 18, 19, 20–26, 28–33, 37–40). Of these, 35.0% were from Pinetown District and 42.5% from Umlazi District. When analysed by quintile, 35.0% of the reports came from lower-quintile schools (1–3) and 42.5% from high-quintile schools (4–5). Respondents indicated that the available toilets were not sufficient to accommodate the student population, resulting in overcrowding and restricted access.

Table 4.6: Condition of Sanitation Facilities

Sub-theme	**Participant Quotes**	**Key Issues Identified**
Poor Condition of Facilities	*"The current pit latrines pose significant hygiene and sanitation challenges, including unpleasant odours, potential contamination risks, and difficulties in maintenance and waste management." (Respondents 1, 2, 4, 6,8, 20, 23, 26).*	Pit latrines in certain schools are in poor condition, posing sanitation risks and underscoring the need for modernisation.
	"The toilet facilities need upgrading from their current dilapidated state to a more modern system, such as a proper sewer connection" (Respondents 1, 2, 4, 6,8,13,16 21,22, 23,30, 40).	Many existing facilities are outdated and require upgrades to modern sewer systems to improve hygiene and usability.
Need for Water Connection	*"The school requires toilets to be connected to water tanks to ensure a reliable water supply for flushing." (Respondent 3)*	Reliable water connections are necessary to support sanitation systems and prevent contamination risks.
Infrastructure and Plumbing Issues	*"Plumbing upgrades are necessary due to the old system that frequently breaks down" (Respondents 3, 5, 9, 12,13,16,25,26 31,32,40).*	Frequent breakdowns indicate a need for plumbing upgrades to maintain consistent functionality.
Inadequate Number of Facilities	*"Additional toilets are recommended to better accommodate student needs." (Respondents 1, 2, 4, 5, 6–10,12,13, 16, 18,19,20 –26, 28 –33, 37–40).*	Insufficient toilets in some schools suggest a need for expansion to meet the needs of the school population.

4.2.2.3 General Hygiene and Maintenance

Challenges in maintaining hygiene standards were reported in several schools, with problems linked to both infrastructure limitations and behaviour-related issues. Student behaviours, such as vandalism and a lack of responsibility for cleanliness, were highlighted by 70.0% of respondents. These reports came from both districts, with 42.5% from Umlazi and 27.5% from Pinetown. When analysed by quintile, the majority were lower-quintile schools, accounting for 45.0% of the responses, while 25.0% came from high-quintile schools. Respondents emphasised that poor learner behaviour contributed directly to the deterioration of sanitation facilities.

The absence of formal school policies on hygiene was also evident. A total of 72.5% of schools reported lacking clear guidelines for cleaning and maintenance. This was slightly more common in Umlazi at 38.0% compared to 34.5% in Pinetown. Lower-quintile schools accounted for 42.5% of these responses, while 30.0% came from high-quintile schools. Respondents indicated that without written policies, there were no formal standards or accountability for maintaining hygiene.

Staff involvement in maintenance varied across schools. In 62.5% of schools, janitorial staff were not consistently assigned to clean toilets. This was reported more frequently in Umlazi (35.0%), compared to Pinetown 27.5%. By quintile, 40.0% of lower-quintile schools and 22.5% of high-quintile schools raised this concern. Respondents explained that inconsistent janitorial support led to irregular hygiene standards.

Routine cleaning practices were also not systematically implemented. In 77.5% of schools, respondents indicated that records of cleaning schedules were not kept. This pattern was reported in both districts, with 40.0% in Umlazi and 37.5% in Pinetown. By quintile, 45.0% of lower-quintile schools and 32.5% of high-quintile schools lacked formal cleaning schedules. Respondents stated that the absence of record-keeping limited the ability to monitor or enforce consistent hygiene practices.

The availability of cleaning materials varied significantly. Whilst 27.5% of schools (13–19, 24–29, 35, 38–40) reported an adequate provision of items such as mops, brooms, soap, gloves and detergents, 47.5% (1–12, 20–23, 30–34, 36) reported only partial availability. This was more evident in lower-quintile schools, where 35.0% indicated shortages, compared to 12.5% of high-quintile schools. Umlazi schools reported slightly higher availability at 20.0%, compared to 17.5% in Pinetown. Respondents explained that shortages led to difficulties in maintaining hygiene consistently.

Formal training for cleaning staff was unevenly distributed across the schools. Overall, 42.5% of schools reported that their staff had attended structured training in cleaning procedures, while the majority, accounting for 57.5%, indicated that no such training had taken place. When viewed by district, schools in Umlazi showed a slightly higher level of training participation at 47.6%, compared with 36.8% in Pinetown. However, the most notable differences appeared across the quintiles. None of the schools in the lower-quintile (1-3) reported training opportunities for their staff, underscoring a complete absence of capacity development in the lower-quintile schools, as shown in Table 4.7. By contrast, in Quintile 4 schools, 35.7% of staff had undergone training, while in Quintile 5, every school reported that their cleaning staff had been formally trained.

Finally, the need for hygiene education for learners was reported by 60.0% of schools. Reports were similar across districts, with 30.0% in Umlazi and 30.0% in Pinetown. Lower-quintile schools accounted for 35.0% of the responses, compared to 25.0% of high-quintile schools. Respondents stated that hygiene education could reduce vandalism and the misuse of facilities whilst encouraging responsibility for shared spaces.

Table 4.7: General Hygiene and Maintenance

Sub-theme	**Participant Quotes**	**Key Issues Identified**
Student Behaviour and Vandalism	*"To improve toilet facilities, it is necessary to address the students' attitudes and practices, as they are responsible for vandalism and poor maintenance." (Respondents 1–10, 12, 13, 20–24, 26,27, 29–34, 37–40).*	Poor student habits and vandalism contribute significantly to the deterioration of toilet facilities.

Sub-theme	Participant Quotes	Key Issues Identified
Role of School Policies in Hygiene	*"The school lacks clear policies that set guidelines for keeping facilities clean and maintained." (Respondents 1–14, 16, 18, 20–24, 26, 27,29–34, 36–40).*	Absence of formal hygiene policies limits accountability and clear standards for maintaining cleanliness in facilities.
Staff Involvement in Maintenance	*"Janitorial staff are not consistently assigned to clean the toilets, leading to inconsistent hygiene standards." (Respondents 1–11, 16,19, 20–26, 29–34).*	Inconsistent janitorial support affects the cleanliness and usability of toilet facilities.
Importance of Hygiene Education	*"Students should be educated on hygiene practices to encourage respect for shared spaces like bathrooms" (Respondent 10–14, 18–27, 29–34).*	Educating students on hygiene could reduce issues with misuse and neglect of facilities.
Maintenance of sanitation facilities	*"Records for the cleaning schedule of toilet facilities are not kept, making it difficult to monitor and maintain consistent cleanliness" (Respondents 1–16, 18–27, 29–40).*	Lack of cleaning schedules results in inconsistent maintenance, leading to unhygienic conditions.
Availability of cleaning materials	*"Basic cleaning materials including mops, brooms, soap, gloves, and detergents are available at the school" (Respondents,13–19, 24–29, 35, 38–40). "The school has a few items like brooms and mops but supplies such as soap and detergents run out quickly and are not replaced regularly" (Respondents 1–12, 20–23, 30–34, 36).*	While some schools have cleaning supplies, others lack essential materials to maintain hygiene.
Staff training on cleaning procedures	*"The cleaning staff have attended formal training on cleaning procedures, enhancing the effectiveness and safety of cleaning practices." (Respondents 13–19, 27–29, 34–40). "The cleaning staff have not attended any formal training on cleaning procedures (Respondents 1–12, 20–26, 30–33).*	Proper training for cleaning staff is critical, but not all schools offer it, impacting hygiene practices.

4.2.3 Menstrual Hygiene Management Practices

The findings reveal substantial variability in the provision of sanitary pads across schools and districts. Overall, 65% of schools indicated that girls continued to receive sanitary pads upon request as part of the school's MHM program, while 35% reported that the Department of Education had ceased supply, despite previous participation in the program.

In terms of district distribution, 56% of schools were in Pinetown and 44% in Umlazi. Notably, schools in lower quintiles (1–3), particularly within the Pinetown District, were more likely to continue receiving sanitary pads, with approximately 73%

confirming an ongoing supply, as shown in Table 4.8. Many highlighted this support as critical for promoting equitable access to menstrual hygiene products. Conversely, schools in higher quintiles (4–5), especially in Umlazi, faced greater disruptions, with only about 40% still receiving pads. Several schools in this group reported the complete discontinuation of pad distribution, forcing reliance on parents or external donations, and creating inconsistencies in access for learners.

The implementation of hygiene promotion initiatives varied significantly, with an overall coverage of 67.5%. Most hygiene education was delivered through Life Orientation classes (65.0%), with only 5.0% of support sourced from municipal or government partners. Alarmingly, 32.5% of schools had no hygiene promotion initiatives, with absence rates of 36.8% in Pinetown and 28.6% in Umlazi. A notable socio-economic divide emerged, as lower-quintile schools exhibited only 28.6% of coverage compared to 88.5% in higher-quintile schools. Amongst lower-quintile schools, 71.4% reported no hygiene promotion, whereas only 11.5% of higher-quintile schools lacked such initiatives. Partner sessions were exclusively found in higher-quintile settings, and where promotion existed, programs primarily focused on menstrual cycle knowledge and product use, while topics like stigma reduction and attendance support were addressed less consistently. This highlights an uneven resource allocation and variability in curriculum implementation.

Water and soap availability at girls' toilets was inconsistent across the sample, with all schools reporting interruptions in water supply that hindered handwashing during menstruation. In 30.0% of schools, water and soap were usually present, but intermittent tap failures limited effective handwashing. A further 32.5% maintained water at toilets but lacked reliable soap provision and re-stocking, experiencing periodic supply interruptions. The remaining 37.5% had no point-of-use water at toilet facilities, forcing learners to rely on yard taps or tanks, with no soap provided. Respondents in this group similarly reported interruptions that restricted access to water. These infrastructure limitations created barriers to effective MHM across both districts and all quintile levels.

Responses regarding support for attendance during menstruation clustered around three key areas, revealing notable differences by district and quintile group. Firstly, regular pad provision was mentioned by 37.5% of schools overall, with 12.5% in Pinetown and 25.0% in Umlazi. Notably, about 57.7% of higher-quintile schools identified this need, while no schools in the lower quintiles did. Secondly, the need for increasing the number of toilets was highlighted by 45.0% of schools, including 20.0% in Pinetown and 25.0% in Umlazi. This concern was particularly pronounced in lower-quintile schools, where 78.6% recognized the necessity for additional toilets, compared to just 26.9% in higher quintiles. Finally, 12.5% of schools indicated that no further measures were necessary, comprising 5.0% in Pinetown and 7.5% in Umlazi. Only schools from higher quintiles stated that no additional measures were needed, while 19.2% of these schools felt that current arrangements were adequate. These responses were not mutually exclusive, reflecting a complex landscape of needs and perceptions across different districts and socio-economic groups.

Sanitary waste management revealed significant gaps. Only 17.5% of schools had appropriate systems in place, which included sanitary bins and disposal through a contracted hazardous waste service under a waste management plan. The remaining 82.5% disposed of sanitary waste with general refuse and lacked a formal plan. While compliant systems were present in both districts, they were primarily concentrated in higher quintiles: 15.8% of schools in Pinetown had structured systems, compared to 19.0% in Umlazi. Across all forty schools, this corresponds to 7.5% and 10.0%, respectively. Notably, no schools in the lower quintiles reported compliant sanitary waste management, whereas 26.9% of higher-quintile schools did. This pattern highlights disparities linked to resources rather than a uniform practice across quintiles.

Table 4.8: MHM Resources

Sub-theme	Participant Quotes	Key Issues Identified
Availability of MHM Resources	*"Sanitary pads are provided to girls upon request, ensuring access to necessary*	Some schools provide sanitary pads upon request; however, inconsistent supply,

Sub-theme	Participant Quotes	Key Issues Identified
	products as part of the school's MHM program" (Respondents 1–12, 15,17,20–28, 30, 34). *"The school no longer receives sanitary pads from the Department of Education, which were previously provided to girls upon request as part of the MHM program" (Respondents 13,14,16,18,19, 29, 31–33, 35–40).*	particularly when support from the Department of Education ceased, hinders effective MHM in many schools.
Hygiene Promotion educational Activities	*"Hygiene promotion activities are supported by the municipality and government departments, enhancing students' understanding and practice of proper hygiene" (Respondent 11, 17).* *"Hygiene promotion is included in life orientation classes, with various activities conducted to educate students on the importance of maintaining good hygiene" (Respondents 3, 7, 9,10, 12, 14–19, 25 –39).* *"We don't cover hygiene promotion; our MHM lessons focus on the cycle and product use, with little on stigma, pain management, attendance support, or parent engagement" (Respondents 1,2 4, 5, 6, 8, 13, 20 –24,40).*	"Hygiene promotion activities were actively supported and integrated into Life Orientation classes, educating students on hygienic practices and fostering a culture of cleanliness in schools. However, hygiene-promotion coverage was uneven."
Actions to Promote Class Attendance during Menstruation	*"Providing sanitary pads at the school would help prevent disruptions caused by the unavailability of menstrual hygiene products, supporting girls' attendance and participation in school activities" (Respondents 13,14,16,18,19, 29, 31–33, 35–40).* *"Increasing the number of toilets could improve conditions for girls attending school during menstruation." (Respondent 1–8, 20–2, 30–33)* *"No additional measures are currently needed, as there have been no reported issues affecting attendance due to menstrual hygiene concerns; existing provisions appear sufficient." (Respondents 15, 17, 28,29, 34).*	Respondents suggest regular provision of sanitary materials and increased sanitation facilities to support female students' consistent attendance, with some schools already reporting sufficient provisions.
MHM-Enabling Infrastructure (Handwashing: Water & Soap)	*"We usually have water and soap at the girls' toilets, but on some days the taps don't work because of water interruptions, so learners leave without washing" (Respondents11,15–19, 27–28,36–39).* *"There is water at the girls' toilets, but soap is often not provided or replaced, and at times there are water interruptions" (Respondents 3, 5, 12–14, 22–25, 29, 34, 35, 40).* *"Water is not provided at the toilets; instead, a tap or tank is available within the school yard,*	Handwashing provision was uneven, with intermittent water supply and irregular soap replacement at points of use, reducing effective hygiene during menstruation."

Sub-theme	Participant Quotes	Key Issues Identified
	but soap for handwashing is never provided and there are water interruptions" (Respondents 1,2,4, 6–10, 20, 21,26, 30 –33).	
Management of Sanitary Waste	*"Sanitary bins are provided, and disposal is managed through the hazardous waste company appointed at that time, in line with the school's waste management plan" (Respondents 15, 17, 19, 27–29, 35).* *"Sanitary bins are not provided, and disposal is done through general waste, with no waste management plan in place" (Respondents 1–14, 16, 18, 20–26,30–34, 36–40).*	There was a variation in sanitary waste management across schools. While some had sanitary bins with disposal managed through a hazardous waste company under a waste management plan, others lacked bins and a plan, leading to disposal through general waste.

4.3 Quantitative Assessment

The quantitative analysis used data from observational checklists to assess the availability and quality of WASH facilities, focusing on key indicators aligned with JMP service ladders established by UNICEF and WHO, (2020). These indicators classify the infrastructure into basic, limited or no service levels, providing a structured overview of accessibility and adequacy in each school.

The SA 2015 National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners served as the foundational guidelines for assessing both the adequacy and condition of WASH facilities (Department of Health, 2015). To determine sufficiency, the analysis calculated the number of learners per water point and per toilet across different school quintiles, using the learner-to-facility ratios outlined in these standards to evaluate resource distribution and highlight any gaps in accessibility.

In addition, the adequacy and condition of toilet facilities were assessed against the SA 2015 National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners, along with the JMP service ladders, to evaluate their alignment with established health and hygiene norms. This dual application of the standards allowed for a comprehensive evaluation, highlighting compliance levels and identifying specific areas requiring improvement. Through this analysis, the report provides valuable insights into the adequacy and quality of WASH infrastructure within the surveyed schools.

To evaluate the adequacy of WASH infrastructure, statistical analyses examined variations across school quintiles and districts. Descriptive statistics were used to summarize the distribution and disparities in WASH facilities, while Fisher's Exact Test was applied to assess significant differences in facility adequacy. A p-value threshold of $p = 0.05$ was used to determine statistical significance, ensuring a robust evaluation of potential disparities based on socio-economic and geographic factors.

4.3.1 Water Provision by District and School Quintile

Noticeable variations in water provision levels were detected across schools from different socio-economic quintiles. Basic water services were more common in quintiles 2 to 5, while schools in the lowest quintile (1-3) were predominantly classified as having limited services. A strong socio-economic gradient was evident. Amongst schools with basic services, 41.7% were in Quintile 5; 29.2% in Quintile 4; 20.3% in Quintile 3; 8.3% in Quintile 2; and 0.0% in Quintile 1. Conversely, amongst schools with limited services, 43.8% were in Quintile 3; 31.3% in Quintile 2; 6.3% in Quintile 1; and 6.3% in Quintile 5. Fisher's Exact Test confirmed a significant association between service level and school quintile with a p-value of 0.003. quintile 3 schools exemplified the challenge of non-functional infrastructure, with 43.8% reporting limited services despite having improved water sources. Despite the presence of basic services in some schools, frequent water interruptions were documented across all quintiles, with more pronounced disruptions occurring in lower quintiles. Daily interruptions were notably prevalent.

In contrast, water service levels showed no significant difference between Pinetown with 57.9% basic and Umlazi with 57.1% basic districts, and the remainder classified as limited with a Fisher's Exact p-value of 1.000. Collectively, these results indicate that water provisioning is influenced more by socio-economic status than geographic location.

4.3.1.1 Water Distribution across School Quintiles and Districts

The distribution of water sources across school quintiles revealed noticeable disparities that reflect socio-economic differences. Schools in higher quintiles predominantly accessed piped water, a source widely regarded as more reliable and improved. In Quintile 1, only 2.5% of schools reported using piped water, while Quintile 2 schools showed slightly increased access, with 12.5% relying on piped supply and 5% depending on water tanks as shown in Table 4.9. The reliance on alternative water sources, such as rainwater or boreholes, was also more evident in these lower quintiles. In contrast, all schools in quintiles 4 and 5 had access to piped water, reflecting better infrastructure and resource allocation.

At the district level, both Pinetown and Umlazi schools predominantly accessed piped water. In Pinetown, 40% of schools reported using piped water, with an additional 7.5% relying on water tanks. In Umlazi, piped water access was slightly higher at 45%, and 7.5% of schools reported using rainwater or borehole sources as shown in Table 4.9. Statistical testing using Fisher's Exact Test revealed a borderline significant association between school quintile and water source ($p = 0.055$), suggesting some degree of socio-economic disparity in the types of water sources accessed. However, no significant association was observed between districts ($p = 0.103$), indicating that geographical location alone did not meaningfully influence water source distribution.

4.3.1.2 Water Availability across School Quintiles and Districts

The availability of water showed further disparities across school quintiles, particularly when assessing the frequency of interruptions experienced by schools. In Quintile 1, none of the schools reported having always available water, with 100% experiencing frequent interruptions. Similarly, in Quintile 2, no schools had continuous access to water, while 12.5% reported frequent interruptions and only 5% reported occasional interruptions. Quintile 3 showed a slight improvement, with 2.5% of schools having always available water and 12.5% reporting frequent disruptions. Schools in Quintile 4 demonstrated even better conditions, with 7.5% enjoying uninterrupted access and no schools experiencing frequent interruptions.

Quintile 5 schools, representing the wealthiest category, reported the most reliable water access, with 22.5% of schools having uninterrupted availability and none facing frequent disruptions as shown in Table 4.9.

Water availability by district showed that in Pinetown, 15% of schools reported as always having water available, while 22.5% experienced occasional interruptions and 10% faced frequent disruptions. In Umlazi, water availability was distributed more evenly, with 17.5% of schools always having water; 17.5% experiencing occasional interruptions; and 17.5% facing frequent interruptions as shown in Table 4.9. Statistical analyses revealed a highly significant association between school quintile and water availability ($p < 0.0001$), indicating that socio-economic factors were a key determinant of water supply reliability. No significant association was found between district and water availability $p = 0.618$, suggesting that geographical factors were less influential.

Table 4.9: Water Availability, Sources and Provision

Category (%)	Comparison of Categories							Fisher's Exact P = 0.05	
	School Quintile					District			
	1	2	3	4	5	Pinetown	Umlazi	Quintile	District
Water Availability (12 monthly observations)									
Always Available	0.0	0.0	8.3	33.3	81.8	15.0	17.5	0.000	0.618
Occasional Interruptions	0.0	28.6	50.0	66.7	18.2	22.5	17.5		
Frequent Interruptions	100.0	71.4	41.7	0.0	0.0	10.0	17.5		
Water Sources									
Pipe Water	2.5	12.5	20.0	22.5	27.5	40.0	45.0	0.055	0.103
Tank Water	0.0	5.0	2.5	0.0	0.0	7.5	0.0		
Tank Water/ Borehole Water	0.0	0.0	7.5	0.0	0.0	0.0	7.5		
Water Provision									
Basic Services	0.0	8.3	20.3	29.2	41.7	57.9	57.1	0.003	1.000
Limited Services	6.3	31.3	43.8	12.5	6.3	42.1	42.9		

4.3.2 Sanitation Provision across School Quintiles and Districts

The adequacy of sanitation services within school quintiles across the Pinetown and Umlazi districts was assessed using the National Environmental Health Norms and

Standards for Premises, which specify that the number of toilet facilities should be based on the total number of learners, with a recommended ratio of at least one toilet for every 25 children. In addition, the JMP service ladders were applied to classify sanitation services as either basic or limited, providing a structured approach to assessing the levels of provision across different socio-economic contexts. Fisher's Exact Test was applied to examine statistical associations and highlight significant trends in the data.

The analysis of sanitation provision by school quintile revealed distinct disparities aligned with socio-economic status. Limited sanitation services were predominantly reported in lower quintile schools, particularly in quintiles 1 to 3. Amongst these, 53.8% of schools in Quintile 2 reported limited sanitation access, reflecting significant gaps in compliance with the recommended facility-to-learner ratios shown in Table 4.10. In contrast, schools in Quintiles 4 and 5 demonstrated comparatively better access to sanitation services. Specifically, 40.7% of schools in Quintile 5 and 33.3% in quintile 4 met the basic service criteria. These findings highlight an upward trend in sanitation provision with increasing school quintile, suggesting that schools in higher socio-economic categories are generally better equipped with essential sanitation infrastructure.

When sanitation provision was examined by district, the results showed a relatively consistent pattern across both Pinetown and Umlazi. In Pinetown, 68.4% of schools met the basic sanitation standard while in Umlazi, 66.7% of schools achieved the same level, as shown in Table 4.10. The remaining schools in both districts, 31.6% in Pinetown and 33.3% in Umlazi, were classified under the limited sanitation category. These results suggest that sanitation provision is not substantially influenced by geographical district but is instead more closely associated with socio-economic factors.

Statistical testing using Fisher's Exact Test confirmed a statistically significant association between school quintile and sanitation provision with a p-value of less than 0.0001. This demonstrates that schools' socio-economic positioning plays a key role in determining sanitation service levels. However, the same analysis by district revealed no statistically significant difference in sanitation provision between Pinetown and Umlazi, with a p-value of 0.398.

4.3.2.1 Comparative Analysis of Schools Toilet Conditions by Quintile and District

In addition to assessing sanitation provision, the condition of toilet facilities was evaluated, revealing further disparities across school quintiles. Schools in lower quintiles, particularly quintiles 1 and 2, faced the most pronounced challenges with 20% of schools reporting poor sanitation conditions, including unclean, dilapidated or broken toilet facilities as shown in Table 4.10. In Quintile 3, 15% of schools reported similar issues, while this figure dropped to 10% in Quintile 4 and 5% in Quintile 5. These results illustrate that while sanitation conditions tend to improve with higher socio-economic status, significant maintenance challenges persist in some schools across all quintiles.

The analysis of toilet facility conditions by district revealed some variation. In Pinetown, 52.6% of schools reported having clean and well-maintained toilet facilities while 47.4% indicated maintenance challenges. In Umlazi, 57.1% of schools had clean and functional toilets while 42.9% reported deficiencies, as shown in Table 4.10. Although slightly better performance was noted in Umlazi, the findings highlight that substantial portions of schools in both districts continue to struggle with maintaining acceptable sanitation conditions.

Statistical analyses confirmed a significant association between school quintile and toilet conditions, with a p-value of 0.034 indicating that socio-economic status is linked to the condition of sanitation facilities. However, no significant difference was observed between Pinetown and Umlazi, with a p-value of 1.000 suggesting similar sanitation conditions across districts.

Table 4.10: Sanitation Provision and Condition

Category (%)	Comparison of Categories							Fisher's Exact P = 0.05	
	School Quintile					District			
	1	2	3	4	5	Pinetown	Umlazi	Quintile	District
Sanitation Provision									
Basic Services	0.0	0.0	25.9	33.3	40.7	68.4	66.7	0.000	0.398
Limited Services	7.7	53.8	38.5	0.0	0.0	31.6	33.3		
Sanitation Condition									
Unclean and Poorly Maintained	20.0	20.0	15.0	10.0	5.0	47.4	42.9	0.034	1.000
Clean and Well Maintained	80.0	80.0	85.0	90.0	95.0	52.6	57.1		

4.3.3 Handwashing Facilities Provision across School Quintiles and Districts

The adequacy of handwashing facilities was assessed in relation to the National Environmental Health Norms and Standards for Premises, which recommends at least one handwashing basin for every 25 children. In addition, the classification of services was guided by the JMP service ladders, which distinguish between basic, limited and no service levels.

The provision of handwashing facilities varied substantially across school quintiles. Schools in Quintile 1 were the most disadvantaged, with all schools classified under the no service category, indicating a complete absence of handwashing facilities. In Quintile 2, limited services were observed in some schools, although the majority (57.1%), still reported no handwashing facilities. Handwashing facilities first appeared in Quintile 3, where 58.3% of schools met this level, and access improved steadily through to Quintile 5, where 72.7% of schools achieved basic service provision. Facilities categorised as limited services were most common in quintiles 3 and 4, comprising 25.0% and 66.7% of schools respectively. Notably, no schools in Quintile 5 reported a complete absence of handwashing facilities. These patterns illustrate a clear trend of improved handwashing provision with increasing socio-economic status, as summarised in Table 4.11.

The comparison across districts showed that in Pinetown, limited services were the most frequently reported classification, accounting for 63.2% of schools, while basic services were reported in 21.1%. A further 15.8% of schools in Pinetown reported no facilities. In Umlazi, basic and limited services were equally distributed, each observed in 38.1% of schools, while 23.8% of schools reported no service. These findings suggest that while both districts had schools across all JMP service levels, Pinetown had a higher concentration of schools with limited services. Full numerical details are provided in Table 4.11.

Fisher's Exact Test revealed a statistically significant association between school quintile and the provision of handwashing facilities, with a p-value of 0.009. In contrast, no statistically significant association was found between provision and district, with a p-value of 0.346 as shown in Table 4.11.

4.3.3.1 Condition and Functionality of Handwashing Facilities by School Quintile and District

The condition and functionality of handwashing facilities also differed notably across school quintiles. Schools in Quintile 1 faced the most severe service challenges, with all schools reporting no functional handwashing facilities due to the complete absence of water or drainage systems. In Quintile 2, water-related problems were the dominant reason for non-functionality, affecting 57.1% of schools, while only 14.3% of schools had functional facilities. In Quintile 3, multiple issues were reported: 41.7% of schools were affected by water shortages, while broken or missing taps and clogged sinks each contributed to 25.0% of non-functionality cases. Functional facilities in Quintile 3 remained very limited, reported in only 8.3% of schools.

Improvements were evident in Quintile 4, where 44.4% of schools reported functional handwashing facilities. However, water-related issues persisted, affecting an equal percentage of schools. Quintile 5 demonstrated the highest level of functionality, with 45.5% of schools reporting operational facilities, although water-related disruptions were still present in the same proportion of schools. These findings reveal a clear pattern of progressively better handwashing facility functionality in higher quintile schools, while lower quintile schools faced more frequent and varied service challenges, as detailed in Table 4.11.

Comparative analyses across districts showed that in Pinetown, water-related issues such as no water or drainage affected 26.3% of schools, while functional facilities were reported at an equal 26.3%. Broken or missing taps contributed to an additional 15.8% of non-functionality cases. In Umlazi, water shortages were also the primary reason for non-functional handwashing, affecting 33.3% of schools. Functional handwashing facilities were present in 28.6% of schools, slightly higher than in Pinetown, while clogged sinks and drainage problems accounted for 19.0% of cases. The full details are presented in Table 4.11.

Fisher's Exact Test confirmed a statistically significant association between school quintile and the condition and functionality of handwashing facilities, with a p-value of 0.013. However, no statistically significant association was found between district and facility condition, with a p-value of 0.504, indicating similar challenges in both Pinetown and Umlazi.

Table 4.11: Handwashing Facilities Provision and Condition

Category (%)	**Comparison of Categories**							**Fisher's Exact P = 0.05**	
	School Quintile					**District**			
	1	**2**	**3**	**4**	**5**	**Pinetown**	**Umlazi**	**Quintile**	**District**
Handwashing Provision									
Basic Services	0.0	0.0	58.3	22.2	27.3	21.1	38.1	0.055	0.103
Limited Services	0.0	42.9	25.0	66.7	72.7	63.2	38.1		
No Services	100.0	57.1	16.7	11.1	0.0	15.8	23.8		
Reasons handwash facilities not functional									
No Water	0.0	0.0	25.0	44.4	45.4	26.3	33.3	0.013	0.504
No Water and Drainage	100.0	57.1	16.7	0.0	0.0	15.8	9.5		
Clogged Sinks and Drainage	0.0	14.3	25.0	0.0	9.1	5.3	19.0		
Broken Faucets and Basin	0.0	14.3	25.0	11.2	0.0	26.3	9.5		
Not Applicable, Functional	0.0	14.3	8.3	44.4	45.5	26.3	28.7		

4.3.4 Distribution Trends of WASH Facilities across School Quintiles

The distribution of WASH resources amongst school quintiles reveals significant disparities in accessibility and adequacy, as illustrated in Figures 4.2, 4.3 and 4.4. Figure 4.2 highlights a concerning trend in Quintiles 1 and 2, where the median ratio of learners to drinking water points is substantially higher compared to other quintiles, indicating a relative scarcity of drinking water resources. The presence of notable outliers and a wide interquartile range further underscores the uneven distribution of this essential resource.

Figure 4.3 illustrates the availability of toilet facilities, showing a generally better provision per learner across all quintiles. However, persistent constraints in Quintiles 1 and 2 are evident as these quintiles exhibit the highest median ratios, indicating a relative deficiency. The distribution is marked by outliers and asymmetrical box plots, indicating non-normality and uneven distribution within the quintiles.

Figure 4.4 depicts the provision of handwashing facilities, revealing stark contrasts amongst the quintiles. Quintile 5 shows a favourable ratio, while Quintiles 1 and 2 have lower median ratios but significant variance and outliers, particularly in higher quintiles. This non-normal distribution, with higher ratios of learners to handwashing facilities than the 1:25 standard, highlights broader issues of resource allocation that necessitate targeted interventions.

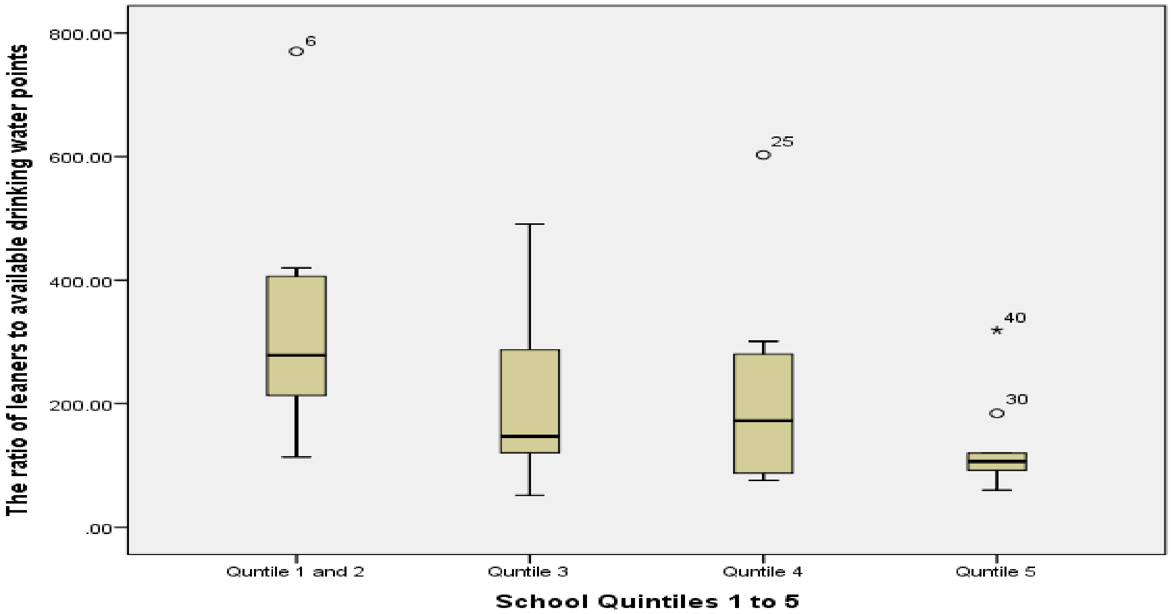

Figure 4.2: Distribution ratio of learners to available drinking waterpoints facilities at different quintiles schools

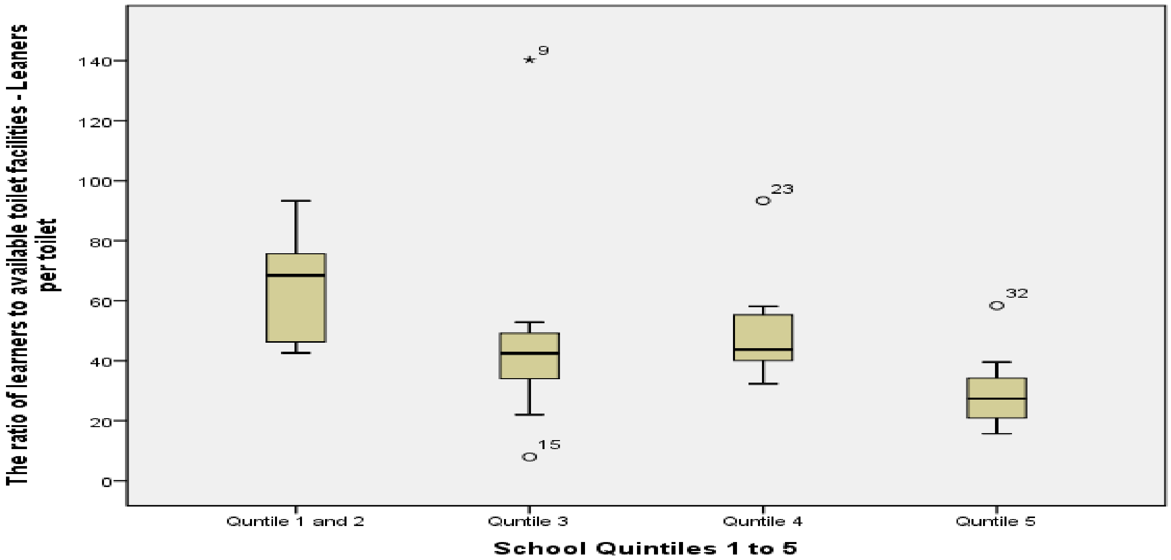

Figure 4.3: Distribution ratio of learners to available sanitation facilities at different quintiles schools

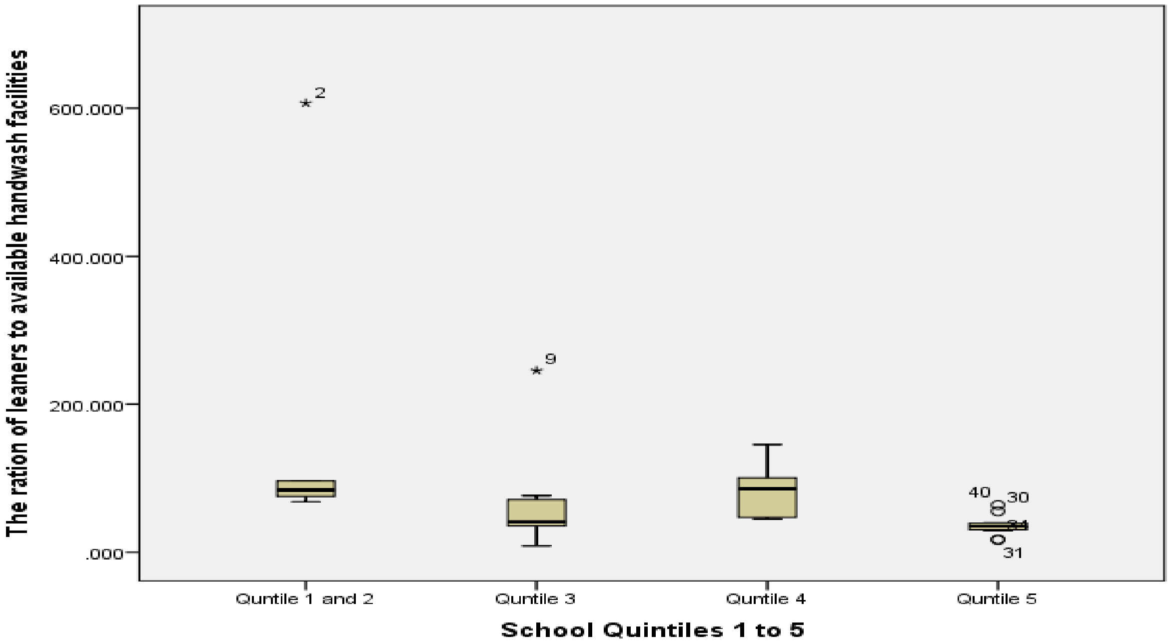

Figure 4.4: Distribution ratio of learners to available handwashing facilities at different quintiles schools

4.3.5 WASH Infrastructure Adequacy across School Quintiles

The adequacy of WASH infrastructure in schools was assessed by examining toilet facilities, drinking water points and handwashing facilities per learner across different socio-economic quintiles. These aspects were evaluated against national standards, including the National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners (Department of Health, 2015).

4.3.5.1 Drinking Water Points Per Learner

The availability of drinking water points was assessed by analysing the number of learners sharing a single water point. In Quintiles 1 and 2, the median ratio was 278.39 learners per water point, reflecting limited access. Quintile 3 showed a slight improvement, with a median of 146.90 learners per water point, while Quintile 4 had a median ratio of 172.67. Quintile 5, with a median ratio of 106.40 learners per water point, demonstrated the best access amongst the quintiles, yet it still indicated a need for increased provision to adequately meet demand as shown in Table 4.12.

4.3.5.2 Toilet Facilities Per Learner

The adequacy of toilet facilities varied significantly across school quintiles when assessed against the National Environmental Health Norms and Standards for Premises and Acceptable Monitoring Standards for Environmental Health Practitioners, which recommend a ratio of one toilet per 25 learners. The findings revealed that none of the quintiles met this standard.

In Quintiles 1 and 2, the median toilet ratio per learner was 68.43, indicating severe inadequacies as each toilet served nearly three times the recommended number of learners. Quintile 3 showed a slight improvement, with a median of 42.50 learners per toilet, although this ratio still far exceeded the standard. Quintile 4 had a median ratio of 43.70 learners per toilet, indicating similar challenges to Quintile 3. Quintile 5 demonstrated the closest adherence to the standard, with a median ratio of 27.36 learners per toilet. However, this still fell short of the recommended ratio. These results emphasize substantial deficiencies in toilet facilities across all socio-economic categories, particularly in lower quintiles (refer to Table 4.12).

4.3.5.3 Handwashing Facilities Per Learner

Handwashing facilities, critical for maintaining hygiene and preventing disease transmission, were also evaluated against the recommended ratio of one facility per 25 learners. The results revealed a widespread shortfall across all quintiles.

In quintiles 1 and 2, the median ratio was 83.94 learners per handwashing facility, highlighting significant inadequacy in hygiene infrastructure. Quintile 3 demonstrated a modest improvement, although the median ratio remained above the standard. Quintile 4 exhibited similar challenges, while Quintile 5, with a median ratio of 35.12 learners per handwashing facility, represented the best-case scenario but still did not meet the recommended ratio. These findings underscore the pervasive gaps in hygiene infrastructure, even in higher socio-economic quintiles, as shown in Table 10.12.

Table 4.12: WASH Infrastructure Adequacy Across School Quintiles

School Quintiles (1 to 5)	Descriptive statistics	Variables		
		Toilet-to-Learner Ratio	Water Point-to-Learner Ratio	Handwashing-to-Learner Ratio
		Statistics results		
Quintile 1 and 2	Mean	64.58	334.9107	169.13568
	Median	68.43	278.3929	83.93651
	Minimum	43	113.67	68.200
	Maximum	93	770.50	607.000
	Skewness	.114	1.529	2.439
	Kurtosis	-1.065	2.971	5.959
Quintile 3	Mean	46.62	208.5558	72.64798
	Median	42.50	146.9000	40.87500
	Minimum	8	51.50	8.583
	Maximum	140	491.00	245.500
	Skewness	2.450	1.195	2.224
	Kurtosis	7.751	.217	5.351
Quintile 4	Mean	50.61	223.4241	82.49670
	Median	43.70	172.6667	85.85714
	Minimum	32	75.50	45.300
	Maximum	93	603.00	145.667
	Skewness	1.742	1.562	.554
	Kurtosis	3.668	2.911	-.311
Quintile 5	Mean	29.40	125.7169	36.19501
	Median	27.36	106.4000	35.11538
	Minimum	16	59.71	16.625
	Maximum	58	319.00	63.800
	Skewness	1.376	2.330	.598
	Kurtosis	2.423	5.964	.541

The Kruskal-Wallis Test identified statistically significant differences in the ratios of learners to water points, toilets and handwashing facilities across school quintiles, with significant disparities in the learner-to-water points ratio ($p = 0.027$); learner-to-toilet ratio ($p = 0.01$); and learner-to-handwashing ratio ($p = 0.001$). Dunn-Bonferroni Post Hoc Tests revealed significant differences between specific quintiles, particularly between School Quintile 1 and the combined Quintiles 1 and 2 for water points ($p = 0.02$), toilets ($p < 0.001$), and handwashing facilities $p = 0.04$. A marginally significant difference in handwashing facility ratios was observed between School Quintile 1 and School Quintile 4 ($p = 0.06$), as shown in Table 4.13.

A significant association was found between the ratio of toilets per learner and the provision of handwashing facilities ($p = 0.05$), suggesting a correlation between the availability of toilets and better hygiene infrastructure. The Chi-Squared Test highlighted significant differences in water availability across quintiles ($p < 0.001$), indicating varying levels of water access, although sanitation provision showed no significant differences ($p = 0.44$), suggesting uniformity in improved sanitation facilities across all quintiles. Improved sanitation facilities as defined by the JMP standards include flush/pour flush toilets connected to a sewer system, septic tanks or pit latrine.

Significant disparities were also noted in the availability of hygiene facilities across quintiles ($p < 0.001$). Higher quintile schools 4 and 5 were better equipped with handwashing facilities containing both water and soap, whereas most schools in quintiles 2 to 5 had facilities with water but no soap, and some schools in quintiles 1 to 3 had no handwashing facilities at all. These findings highlight the inequity in hygiene infrastructure, emphasizing the need to ensure the provision of both water and soap for handwashing in all schools to promote better hygiene practices and overall student health, as shown in Table 4.13.

Table 4.13: Statistical Analysis of WASH Infrastructure Ratios

	Nonparametric Tests Kruskal-Wallis Test		
	Facilities-to-learner ratios		
	Water Points	**Toilet**	**Handwashing**
School Quintiles	0.027	0.01	0.001
Dunn-Bonferroni post hoc tests			
School Quintile 1 ** School Quintile 1&2	0.02	0.000	0.04
School Quintile 1 ** School Quintile 4	0.06		
Mann-Whitney Test			
Association between the ratio of toilet per leaner and Handwashing provision		0.05	
Chi-squared test with Fisher's Exact Test			
	Water	**Sanitation**	**Hygiene**
School Quintiles 1 to 5	0.000	0.44	0.000

4.4 Analysis of Hygiene Knowledge, Attitudes and Practices amongst Students

A 100% response rate was obtained from the administered questionnaires. The analysis examined the socio-demographic characteristics of the learners, offering insights into their gender, age, educational level and socio-economic backgrounds. This detailed demographic data was crucial for understanding the context in which the surveyed attitudes and practices were situated, providing a baseline for further statistical evaluations.

Furthermore, the analysis of variance (ANOVA) test was used to examine differences in KAP across various demographic categories, such as gender, age, educational level and socio-economic status. This analysis helped identify significant disparities amongst different student groups, which were essential for directing educational interventions.

Additionally, regression analysis was employed to explore how knowledge and attitudes predicted hygiene practices amongst students. Significant predictors were identified and their impacts were quantified, explaining a portion of the variance in hygiene practices. This analysis was crucial for understanding which factors most strongly influenced student behaviours and outcomes.

Moreover, correlation analysis was conducted to link the data on KAP. This analysis provided insights into how these elements interacted and influenced one another, which was instrumental in identifying leverage points for improving hygiene education and infrastructure in schools.

4.4.1 Response Rate Analysis

The study examines the KAP of learners towards hygiene successfully and retrieved 1200 of the 1200 administered questionnaires, resulting in a response rate of 100%. A response rate of at least 50% is considered adequate for analysis and reporting, while 60% is regarded as good and 70% or higher is considered excellent (Bennett et al., 2011). Thus, the response rate in this study significantly surpasses these benchmarks, providing a strong foundation for credible analysis and ensuring that the findings accurately reflect the views of the respondents.

4.4.2 Socio-Demographic Characteristics

Table 4.14 provides detailed information about the learners' gender, age group, school quintile, grade and districts. The data was presented in frequency tables to improve readability. The data shows a young sample of students, predominantly female (n=747, 62.3%), spread across various grades (8-12) and socio-economic quintiles (1-5), with grade 8 (n=364, 30.3%) and quintile 3 (n=390, 32.5%) being the most representative, respectively. The sample is almost equally split between the Pinetown (n=570, 47.5%) and Umlazi districts (n=630, 52.5%). The mean age (M= 15.45±1.927) indicates that most students are in the early high school years.

Table 4.14: Demographic Characteristics of Students

Variables	Frequency=1200	Percent=100
Gender		

Variables	Frequency=1200	Percent=100
Female	747	62,3
Male	453	37,8
Prefer not to say	1	0.9
Age Category (years)		
12-15	654	54,5
16-19	507	42,3
20-24	39	3,3
Mean age (SD)= 15.45(1.927)		
Student grade		
8	364	30,3
9	224	18,7
10	191	15,9
11	247	20,6
12	174	14,5
School Quintile		
Quintile 1	30	2,5
Quintile 2	210	17,5
Quintile 3	390	32,5
Quintile 4	270	22,5
Quintile 5	300	25,0
Districts		
Pinetown	570	47,5
Umlazi	630	52,5

4.4.3 Reliability of the Instrument

The reliability of the summative questions was assessed using Cronbach's alpha test, as proposed by George and Mallery (2019). The Cronbach’s alpha is a measure of internal consistency or how closely related a set of items are as a group. This test yields a scale that encompasses an unweighted total of the items. The typical interpretation of Cronbach's alpha (α) is as follows: a value greater than 0.8 suggests high (excellent) dependability, while values falling between 0.5 and 0.8 indicate moderate (acceptable) reliability. Conversely, results yielding α values below 0.5 indicate low reliability (Ekolu and Quainoo, 2019). Table 4.15 presents the results of the Cronbach's alpha test. As presented in Table 4.16, the knowledge scale consisted of 10 items and demonstrated moderate reliability ($\alpha = .543$). Similarly, the attitude scale, with nine items, ($\alpha = .536$) and practice scale measured with 10 items ($\alpha = .533$) exhibited moderately acceptable reliability, respectively.

Table 4.15: Cronbach's Alpha Values

Construct	Scales	Number of items	Cronbach's alpha score
Knowledge	C1-C10	10	0.543
Attitude	D1-D9	9	0.536
Practices	P1-P10	10	0.533

4.4.4 Students' Knowledge of hygiene WASH

Students' knowledge regarding WASH, a critical area in public health education, was explored to understand essential hygiene practices that are pivotal for maintaining health and preventing diseases. By analysing responses from a structured questionnaire, it was possible to pinpoint both areas of competency and significant gaps in their knowledge. The findings from this investigation are intended to inform targeted educational interventions, providing a foundation for refining teaching strategies and curriculum development. This approach not only addresses immediate educational needs but also contributes to the broader goal of enhancing public health through improved hygiene education.

The survey revealed school-relevant sanitation and hygiene knowledge gaps, as presented in Table 4.16. More than half of the students lacked awareness of the health risks associated with the improper disposal of human faeces: 53.3%, n = 640 (C3). Knowledge of personal hygiene materials was stronger: 69.1%, n = 829 correctly identified appropriate materials for bathing (C4), and 56.3%, n = 676 identified appropriate materials for anal cleansing (C5). However, 62.9%, n = 755 did not recognize the overall importance of maintaining cleanliness (C6).

Regarding handwashing, 53.3% or n = 640 knew the critical times to wash their hands (C7), yet 74.3% or n = 891 lacked knowledge of the importance of using soap and water (C8). Knowledge related to gastrointestinal protection was mixed: 54.8%, n = 658 were unaware of how to protect themselves (C9), whereas 55.8%, n = 670 knew how to protect others (C10). These findings indicate specific gaps in sanitation risk awareness, hygiene promotion and handwashing messaging within the school context.

Table 4.16: Students' Knowledge About WASH

Characteristics/Variables	Code	Wrong answer/ I don't know the answer (score 0) N (%)	Correct answer (score 1) N (%)
Importance of boiling water	C1	671 (55.9)	529 (44.1)
Duration to boil water	C2	697 (58.1)	503(41.9)
Proper disposal of faeces	C3	640 (53,3)	560 (46,7)
Material for bathing	C4	371 (30.9)	829 (69.1)
Material for anal cleansing	C5	524 (43,7)	676 (56,3)
Importance of cleanliness	C6	755 (62,9)	445 (37,1)
Critical handwashing times	C7	560 (46,7)	640 (53,3)
Importance of handwashing with soap	C8	891(74,3)	309 (25,8)
Self-protection against Gastrointestinal issues	C9	658 (54,8)	542 (45,2)
Protect others against Gastrointestinal issues	C10	530 (44,2)	670 (55,8)

4.4.4.1 Distribution of Student Knowledge of WASH

The distribution of students' knowledge of WASH is given in Table 4.17. The distribution of knowledge is nearly evenly split, but a slightly higher percentage of participants possess high knowledge at 51.7%, compared to 48.3% with poor knowledge. Students were categorised based on their scores, with those scoring 50% or higher classified as having high knowledge and those below 50% as having poor knowledge. This indicates a relatively balanced level of understanding amongst the students, with just over half demonstrating a higher level of knowledge.

The findings suggest that while there is a positive trend in knowledge levels, with the majority of students classified as having high knowledge, a significant portion of the population (nearly half) still exhibits poor knowledge, suggesting a need for further education or awareness efforts in the area being assessed.

Table 4.17: Distribution of knowledge

Variable	Scoring category	Frequency	Percent	Description
Poor knowledge	< 50% correct responses	580	48,3	Limited understanding of WASH concepts; unable to identify key practices and principles.
High knowledge	≥ 50% correct responses	620	51,7	Basic to strong understanding of WASH concepts; can accurately identify safe practices and principles.

Total		1200	100,0	

4.4.5 Students' Attitudes towards WASH

The assessment of students' attitudes and awareness highlighted a recognition of the critical importance of access to clean water, functional sanitation facilities, and adequate handwashing resources in schools. Most students at 84.3% (n = 1012), acknowledged the essential need for these facilities (A1). Furthermore, 90.8% (n = 1089) of participants recognised the necessity for school water to be safe for drinking (A2). These high levels of awareness reflect a solid understanding amongst students of the fundamental requirements for maintaining a healthy school environment.

When asked about the adequacy of the drinking water supply in their schools, 55.9% (n=671) of the students felt that their schools provided enough drinking water, whereas 44.1% (n=529) believed the supply was insufficient (A3). This indicates a significant concern about water availability amongst nearly half of the respondents.

Concerning sanitation practices, 90.6% (n=1087) of the students understood the importance of maintaining hygiene after using the toilet (A4). However, privacy concerns were evident as 70.3% (n=843) reported that their school's toilets did not provide enough privacy (A5). Furthermore, a significant number of students at 76.3% (n=916), expressed dissatisfaction with the functioning of the toilets, suggesting that maintenance issues are prevalent (A6).

Regarding hand-washing facilities, 83.0% (n=996) of the respondents agreed that such facilities should be available in schools (A7). Despite this strong agreement, 75.5% (n=906) of students reported that their schools did not have sufficient resources, such as clean water and soap, for hand washing (A8). This highlights a substantial gap between the recognition of what is necessary and the reality of what is provided. Additionally, when asked about their personal hand-washing practices at school, 54.2% (n=650) of the students indicated that they frequently used the school's facilities, while 45.8% (n=550) did not (A9).

These findings reveal a concerning discrepancy between student knowledge of what constitutes adequate WASH facilities and their actual experiences. The data illustrate significant gaps in the provision of essential services such as drinking water, privacy in toilets, and adequate hand-washing facilities in schools as shown in Table 4.18.

Table 4.18: Students' attitudes on WASH

Characteristics/Variables	Code	Wrong answer/ I don't know the answer (score 0) N (%)	Correct answer (score 1) N (%)
Access to clean WASH facilities is critical	A1	188 (15,7)	1012 (84,3)
Water should be safe to drink	A2	111 (9,3)	1089 (90,8)
School provides enough drinking water	A3	529 (44,1)	671 (55,9)
Importance of cleaning after toilet use	A4	113 (9,4)	1087 (90,6)
School's toilet provides enough privacy	A5	843 (70,3)	357 (29,8)
Toilets are always in good functioning order	A6	916 (76,3)	284 (23,7)
Handwashing facilities should be available	A7	204 (17,0)	996 (83,0)
Sufficient clean water and soap for hand washing	A8	906 (75,5)	294 (24,5)
Frequent hand washing at school	A9	550 (45,8)	650 (54,2)

4.4.6 Students Practices of WASH

The findings revealed that students' practices related to WASH within school environments vary in their adherence to ideal standards. Table 4.19 summarises all practice items on water consumption, toilet use, hygiene and menstruation-related challenges. Responses were coded as 0 = incorrect/unknown and 1 = correct.

In terms of water consumption, the data indicate that just over half (n = 655, 54.6%) of the students reported drinking water in a way that is considered appropriate at school (P1). Water consumption was evenly split, with half of the students (n = 600, 50%) meeting adequate daily water consumption and the other half not (n = 600, 50%) (P2).

Regarding how often the students utilize the toilet while at school (P3), the finding suggests that a majority (n=693, 57.8%) reported infrequent or inadequate toilet use, while only 42.3% (n=507) used the toilets regularly during school hours. A significant majority of the students (n=787, 65.6%) did not attend or were unaware of hygiene education programs (P4), while only 34.4% (n=413) reported students in them.

Furthermore, most students (n=948, 79.0%) reported not engaging in the inappropriate practice of urinating behind the toilets (P5), indicating better sanitation behaviour. Additionally, most participants (n=789, 65.8%) report cleaning up after themselves (P6), demonstrating responsible hygiene practices. A large proportion (n=899, 74.9%) of the students regularly wash their hands after using the toilet (P7), which is a positive sign for hygiene compliance.

A significant majority of the students (n=919, 76.6%) reported discomfort using school toilets during menstruation (P8), highlighting an important issue related to menstrual hygiene and privacy in schools. Nearly half of the students (n=585, 48.8%) reported missing school during menstruation, which reflects the challenges faced by girls during this period (P9). A little over half (n=672, 56.0%) reported challenges in maintaining personal hygiene during menstruation at school, while 44.0% (n=528) were able to manage it adequately (P10).

The data reflected a mix of positive and concerning trends in hygiene and sanitation practices at school. Some students demonstrated good hygiene habits, such as washing their hands after using the bathroom and cleaning up after toilet use. However, significant issues persisted, particularly regarding menstrual hygiene management, as 76.6% of female participants reported feeling uncomfortable using school toilets during their menstrual cycle. Additionally, 65.6% of participants did not attend hygiene education, and 57.8% reported inadequate toilet use.

Table 4.19: Students' Practices of WASH

Characteristics/Variables	**Code**	**Wrong answer/ I don't know the answer (score 0) N (%)**	**Correct answer (score 1) N (%)**
How do you usually drink water at school	P1	545 (45,4)	655 (54,6)
How much water consumption do you take per day while at school?	P2	600 (50,0)	600 (50,0)
How often do you utilise toilet while you are at school?	P3	693 (57,8)	507 (42,3)
Do you attend hygiene education that is offered in your school?	P4	787 (65,6)	413 (34,4)
Do you urinate behind the school toilets?	P5	252 (21,0)	948 (79,0)

Characteristics/Variables	Code	Wrong answer/ I don't know the answer (score 0) N (%)	Correct answer (score 1) N (%)
Do you clean up after yourself at the school toilets after using them?	P6	411 (34,3)	789 (65,8)
Do you wash your hands after going to the bathroom?	P7	301 (25,1)	899 (74,9)
Do you and your girls' friends feel comfortable using your school toilets during your menstrual cycles?	P8	919 (76,6)	281 (23,4)
Do you miss school during menstruation period?	P9	615 (51,2)	585 (48,8)
Do you maintain personal hygiene during menstruation while you are at school?	P10	672 (56,0)	528 (44,0)

4.4.6.1 Analysis of Handwashing Practices by School Quintile

Students' handwashing practices were also examined across school quintiles to determine whether hygiene behaviour varied according to socio-economic context. The results indicate that most students who reported washing their hands after using the toilet were concentrated in higher-quintile schools. Of the 899 students who indicated that they wash their hands all the time, the largest proportions were observed in Quintile 5 schools (33.3%), followed by Quintile 3 (26.3%) and Quintile 4 (23.4%). In contrast, only a small proportion of these responses originated from Quintile 1 schools (2.3%).

Responses indicating inconsistent handwashing were distributed across all quintiles but were most frequently reported in Quintile 4 schools (28.9%). In addition, a number of students reported that handwashing was not applicable because facilities were either unavailable or not in good condition. These responses were more noticeable in some middle- and lower-quintile schools, suggesting that the availability and condition of handwashing facilities may influence hygiene practices. Overall, the distribution of responses across quintiles highlights disparities in hygiene behaviour and access to functional facilities between schools serving different socio-economic communities (Table 4.20).

Table 4.20: Students' Handwashing Practices after Toilet Use by School Quintile

E8. Do you wash your hands after going to the bathroom?		School Quintile					
		1	2	3	4	5	Total
A. Yes, all the time	Count	21	133	236	210	299	899
	Expected Count	22.5	157.3	224.8	224.8	269.7	899.0
	% within E8. Do you wash your hands after going to the bathroom?	2.3%	14.8%	26.3%	23.4%	33.3%	100.0%
B. No, sometimes	Count	4	35	37	46	37	159
	Expected Count	4.0	27.8	39.8	39.8	47.7	159.0
	% within E8. Do you wash your hands after going to the bathroom?	2.5%	22.0%	23.3%	28.9%	23.3%	100.0%
C. No applicable, hand washing facilities are not provided	Count	4	24	9	35	16	88
	Expected Count	2.2	15.4	22.0	22.0	26.4	88.0
	% within E8. Do you wash your hands after going to the bathroom?	4.5%	27.3%	10.2%	39.8%	18.2%	100.0%
D. Not applicable hand washing facilities are not in good condition	Count	1	18	18	9	8	54
	Expected Count	1.3	9.5	13.5	13.5	16.2	54.0
	% within E8. Do you wash your hands after going to the bathroom?	1.9%	33.3%	33.3%	16.7%	14.8%	100.0%
Total	Count	30	210	300	300	360	1200
	Expected Count	30.0	210.0	300.0	300.0	360.0	1200.0
	% within E8. Do you wash your hands after going to the bathroom?	2.5%	17.5%	25.0%	25.0%	30.0%	100.0%

4.4.7 Correlation between KAP

Table 4.20 shows the Pearson correlation coefficients between three variables: KAP related to WASH. The correlation values ranged from -1, indicating a perfect negative correlation, to 1, indicating a perfect positive correlation. Correlation was interpreted using the following criteria 0 - 0.25 = weak correlation, 0.25 - 0.5 = fair correlation, 0.5 - 0.75 = good correlation, and greater than 0.75 = excellent correlation (Cohen, 1988).

The data in Table 4.23 revealed a small but significant positive correlation between knowledge and attitudes (r = 0.154, p < 0.0001). This indicates that as students' knowledge increases, their attitudes toward hygiene and sanitation tend to become more positive, although the relationship is not very strong. The attitudes assessed included students' beliefs about the importance of hygiene; their perceptions of sanitation facilities; and their willingness to engage in hygienic practices.

There is a moderate positive correlation between knowledge and practice (r = 0.273, p < 0.0001). This indicates that students with higher knowledge are more likely to engage in appropriate hygiene and sanitation practices. The strength of this relationship is stronger than that between knowledge and attitudes. Likewise, there is a moderate fair positive correlation between attitudes and practice (r = 0.302, p < 0.0001). This means that students with more positive attitudes toward hygiene are more likely to follow proper hygiene practices. The correlation is the strongest in this matrix, suggesting that attitudes may have a greater influence on practice than knowledge.

All the correlations are positive and statistically significant, indicating that better knowledge and more positive attitudes are associated with improved hygiene practices. The strongest relationship is between attitudes and practice, where r = 0.302, suggesting that attitudes play a key role in determining hygiene behaviour. Although knowledge also influences practice, with r = 0.273, its impact on attitudes is weaker, with r = 0.154.

Table 4.21: Correlations Between KAP of WASH.

Correlations				
		Knowledge	**Attitudes**	**Practice**
Knowledge	Pearson Correlation	1	0,154**	0,273**
	Sig. (2-tailed)		<0,001	<0,001
	N	1200	1200	1200
Attitudes	Pearson Correlation	0,154**	1	0,302**
	Sig. (2-tailed)	<0,001		<0,001
	N	1200	1200	1200

Practice	Pearson Correlation	0,273**	0,302**	1
	Sig. (2-tailed)	<0,001	<0,001	
	N	1200	1200	1200

**. Correlation is significant at the 0.01 level (2-tailed).

4.4.8 Association of Demographic Characteristics with KAP

The association between the respondents' socio-demographic characteristics and the mean KAP score is presented in Table 4.21. The table presents the means (M) and standard deviations (SD) of knowledge, attitudes and practices regarding WASH, segmented by demographics such as gender, age, grade, quintile and district. It also includes statistical tests (t-values and F-ratios) and their significance levels (p-values) for comparing these groups.

The independent samples t-test was applied to test the difference between the gender (Male and female) and the mean KAP scores. The results show that females (M = 0.4984, SD = 0.21473) have significantly higher knowledge scores than males (M = 0.4371, SD = 0.21065) with a t-value = 4.829, (p = 0.001). There is no significant difference in attitudes between genders (t-value = 0.809, p = 0.419). Females (M = 0.5914, SD = 0.19479) also demonstrate significantly better practices than males (M = 0.3945, SD = 0.16291) with a t-value = 18.032, p = 0.001.

The ANOVA value measured for age indicates no significant differences across age categories (F ratio = 2.047, p = 0.130). Significant differences exist amongst age groups (F ratio = 5.599, p = 0.004), suggesting that attitudes vary significantly with age. The mean value measured suggests that the students within 12-15 years of age had better attitudes (M=0.61±0.2) when compared to other age groups. No significant differences exist across age groups (F ratio = 1.954, p = 0.142).

The ANOVA value measured for the grade level indicates significant differences across grade levels (F ratio = 3.876, p = 0.004), showing that knowledge varies by school grade. Significant differences amongst grades (F ratio = 6.210, p = 0.001), suggesting that attitudes differ by grade level. There are marginally significant differences (F ratio = 2.277, p = 0.059), implying a trend that practices may vary by grade, although not conclusively. The mean value measured suggests that the students in grade 11 had higher knowledge (M=0.51±0.2), better attitudes (M=0.62±0.2) when compared to the groups while students in grade 9 practices WASH better than other grades (M=0.54±0.2).

The ANOVA measured for quintile and the KAP scores indicate that all three variables show significant differences across quintile groups (Knowledge: F ratio = 25.022, p = 0.001; Attitudes: F ratio = 15.040, p = 0.001; Practices: F ratio = 18.179, p = 0.001). This suggests that socio-economic status has a significant impact on knowledge, attitudes and practices. The mean value measured suggests that the students in Quintile 5 had higher knowledge (M=0.54±0.2), better attitudes (M=0.63±0.2) and practices (M=0.58±0.2).

In terms of district, the independent sample test suggests that Umlazi (M = 0.5054, SD = 0.21039) has significantly higher knowledge scores than Pinetown (M = 0.4419, SD = 0.21568) with a t-value = -5.157 and p = (0.001). No significant difference in attitudes between districts was observed (t-value = 0.850, p = 0.395). Umlazi (M = 0.5390, SD = 0.19647) has significantly better practices than Pinetown (M = 0.4928, SD = 0.21508) with a t-value = -3.895 and p = 0.001.

Table 4.22: Association of Demographic Characteristics with KAP

Demographics	Knowledge		Attitudes		Practices	
	M	***SD***	***M***	***SD***	***M***	***SD***
Gender						
Female	0,4984	,21473	0,5997	0,18495	0,5914	0,19479
Male	0,4371	,21065	0,5906	0,19526	0,3945	0,16291
t value	4,829		0,809		18,032	
Sig.	0,001		0,419		0,001	
Age (Years)						
12-15	0,4653	0,21104	0,6072	0,19555	0,5278	0,20955
16-19	0,4897	0,21917	0,5889	0,18044	0,5045	0,20167
20-24	0,4538	0,22577	0,5100	0,15655	0,5000	0,21885
F ratio	2,047		5,599		1,954	
Sig.	0,130		0,004		0,142	
Grade						
8	0,4484	0,20829	0,5986	0,19503	0,5126	0,21061
9	0,4585	0,21159	0,6181	0,20662	0,5388	0,21019
10	0,4942	0,21817	0,5893	0,17107	0,5298	0,20105
11	0,5105	0,22263	0,6203	0,17440	0,5202	0,19815
12	0,4822	0,21281	0,5370	0,17884	0,4799	0,20904

Demographics	Knowledge		Attitudes		Practices	
	M	*SD*	*M*	*SD*	*M*	*SD*
F ratio	3,876		6,210		2,277	
Sig.	0,004		0,001		0,059	
Quintile						
1	0,4433	0,16333	0,5519	0,19019	0,5000	0,20342
2	0,3567	0,19064	0,5111	0,15683	0,4290	0,19629
3	0,4882	0,20068	0,6094	0,18250	0,5249	0,20551
4	0,4811	0,21238	0,6111	0,18472	0,5048	0,19966
5	0,5393	0,22440	0,6300	0,20364	0,5813	0,19946
F ratio	25,022		15,040		18,179	
Sig.	0,001		0,001			0,001
District						
Pinetown	0,4419	0,21568	0,5914	0,19389	0,4928	0,21508
Umlazi	0,5054	0,21039	0,6007	0,18427	0,5390	0,19647
t value	-5,157		0,850		-3,895	
Sig.	0,001		0,395		0,001	

4.4.9 Multiple Regression Analysis of Predictors of Good Hygiene Practices

Multiple regression analysis was used to determine the predictors of good hygiene practices. The predictors measured were knowledge and attitudes. Normality was assessed using descriptive analysis, with skewness results falling within the acceptable range of +1 to -1, as recommended by Al-Qeisi (2009), indicating no need for data transformation. Residual analysis was also conducted using the normality P-P plot to evaluate the regression standardized residuals (Pallant, 2016). The P-P plot shown in Figure 4.5 demonstrated adequate normality, with standardized predicted values and residuals aligning along a straight line, suggesting no significant deviations from normality. Linearity and homoscedasticity assumptions were examined through the residual scatter plot, which displayed a linear pattern, thus confirming the linear relationship between practices of WASH and the independent variables (Saunders et al., 2017). This also verified the homoscedasticity assumption, indicating that the variances between the independent and dependent variables were consistent (Everitt & Skrondal, 2010).

Figure 4.5: Normal P-P Plot of Regression Standardised Residual

The final assumption of collinearity or multicollinearity, which requires no significant correlations between two or more independent variables, was evaluated. As noted by Saunders et al. (2017), high correlations, typically 0.90 or higher, indicate the presence of collinearity. After reviewing the correlations, no significant bivariate relationships were found. Additionally, Pallant (2016) and Saunders et al. (2017) suggested diagnosing collinearity by examining the tolerance coefficient and the variance inflation factor (VIF). A tolerance coefficient below 0.10 suggests collinearity, while a VIF above 10.0 indicates multicollinearity. Table 4.22 displays the collinearity statistics for the sample, showing that all tolerance coefficients were above the 0.10 threshold, and all VIF values were below 10.0. Thus, no multicollinearity was detected, and all independent variables were kept in the regression model. After confirming the assumptions, the influence of knowledge and attitudes towards good hygiene practices were tested using multiple regression analysis.

Table 4.23: Tolerance and VIF Distribution of Independent Variables

	Collinearity Statistics [a]	
	Tolerance	VIF
(Constant)		
Knowledge	,976	1,024
Attitudes	,976	1,024

	Collinearity Statistics [a]	
	Tolerance	VIF

a. Dependent Variable: Practice of hygiene

As shown in Table 4.23, the regression coefficient suggests that 0.379 indicates a moderate positive correlation (r=0.379; p<0.001) between the independent variables (Knowledge and Attitudes) and the dependent variable (Practices of Good Hygiene). This suggests that as knowledge and attitudes improve, practices of good hygiene also tend to improve. $R^2 = 0.143$ means that approximately 14.3% of the variability in the practices of good hygiene can be explained by the independent variables (Knowledge and Attitudes). This suggests that while there is a relationship, there are other factors not accounted for that also influence hygiene practices.

The beta coefficient for knowledge is given as ($\beta = 0.232$, p<.001), implying that for every one-unit increase in knowledge, practices of good hygiene increase by 0.232 units, holding attitudes constant. This is a positive effect, suggesting that higher knowledge is associated with better hygiene practices. Similarly, beta coefficient for attitude is given as ($\beta = 0.266$, p<.001), indicating that for every one-unit increase in attitudes, practices of good hygiene increase by 0.266 units, holding knowledge constant. This also reflects a positive relationship between attitudes and practices of good hygiene.

Table 4.24: Predictors of Good WASH Practices

IV	R	R^2	F	df1; df2	p-value	B (regression coefficient)	T	p-value	DV
Knowledge	0,379	0,143	100,253	2; 1197	<0,001	0,232	8,566	<0,001	Practices of good hygiene
Attitudes						0,266	9,825	<0,001	

In summary, the regression analysis demonstrates that both knowledge and attitudes significantly predict the practices of good hygiene. Knowledge has a moderate positive correlation with hygiene practices, and attitudes have a slightly stronger effect. Together, these variables explain a modest portion of the variance in hygiene practices, indicating the need for additional factors or variables to be considered for a more comprehensive understanding.

4.5 Microbiological Water Quality Assessment

Over the 12-month monitoring period, a total of 1,440 water samples were collected seasonally from taps at selected schools and analysed for the presence of *E. coli* as an indicator of faecal contamination. The analysis was conducted in adherence to the SANS 241:2015 water quality standards, which stipulate 0 CFU per 100 mL for *E. coli* in drinking water to ensure microbiological safety.

The results revealed that almost all the water samples (99.98%) complied with the permissible limits outlined in the SANS 241:2015 guidelines. This indicates that the water quality across most schools was consistently safe for human consumption. However, an isolated deviation was detected during the month of March at one school out of the 40 surveyed. In this instance, *E. coli* was quantified at 3 CFU/mL in one of the three replicates. This value corresponds to approximately 100 CFU per 100 mL, which exceeds the allowable limit. The detection was confirmed through enumeration on 3M™ Petrifilm™ plates and validated using biochemical identification tests.

This isolated occurrence represented a minor anomaly in an otherwise consistently safe water quality profile. While the breach of standards is noteworthy, its singular nature suggests a localized or transient contamination event that did not reflect systemic issues with the water supply across the surveyed schools. Such occurrences underscore the importance of routine water quality monitoring to identify and address temporary fluctuations in microbial contamination.

DNA was extracted from the three confirmed *E. coli* isolates to facilitate a molecular analysis of DEC strains. The quality and concentration of the extracted DNA were evaluated using a NanoDrop spectrophotometer. The extracted DNA showed concentrations ranging from 410.8 to 882.1 ng/µL, with A260/A280 ratios between 2.10 and 2.18, and A260/A230 ratios between 1.41 and 1.45, indicating high purity and suitability for molecular analysis. These values were within the acceptable range for molecular applications, including PCR amplification, indicating successful DNA extraction.

4.5.1 PCR Detection of DEC Strains

The extracted DNA was used for PCR analysis targeting DEC virulence genes.

Despite the detection of *E. coli* through cultural methods, none of the isolates tested positive for any of the DEC virulence genes. The absence of amplification for eaeA, aggR, ipaH, fliCH7, St and daaE confirms that the *E. coli* strains detected in the water samples did not possess pathogenic traits associated with diarrhoeagenic *E. coli*.

This result suggests that the detected *E. coli* was non-pathogenic and likely originated from non-hazardous faecal contamination sources. Such findings are critical in distinguishing between general faecal contamination and potential health risks posed by pathogenic *E. coli* strains.

4.5.2 Quantitative Microbiological Risk Assessment

QMRA was conducted to evaluate the potential health risks associated with *E. coli* contamination in drinking water consumed by students in selected high schools. The results are presented following the structured steps of hazard identification, exposure assessment, dose-response assessment and risk characterization, interpreted in the context of SANS 241:2015 water quality standards, requiring 0 CFU/100 ml for compliance.

4.5.2.1 Hazard Identification

The microbial hazard was identified through water quality analysis, which revealed the presence of *E. coli* in drinking water samples from one of the surveyed schools. Out of three replicates tested, one showed a positive concentration of 3 CFU/mL, while the other two replicates tested negative. Averaging across the replicates, the final concentration was determined to be:

Average Concentration $= \frac{3\ CFU/mL}{3}$ *= 1CFU/mL*

When expressed in terms of the standard unit of CFU/100 mL (as per SANS 241:2015), the concentration equates to:

E. coli Concentration (CFU/100 mL) =1CFU/mL×100=100CFU/100 mL

This test result exceeds the SANS 241:2015 water quality standard of 0 CFU/100 mL, confirming non-compliance and highlighting the presence of microbial contamination.

To assess the proportion of pathogenic strains, the assumption that 8% of *E. coli* are pathogenic was applied. This yielded a pathogenic *E. coli* concentration of:

Pathogenic Concentration = 100CFU/100 mL×0.08=8CFU/100 mL

4.5.2.2 Exposure Assessment

The exposure assessment quantified the dose of pathogenic *E. coli* ingested by students consuming the contaminated water. Each student was assumed to consume 1 Liter (1000 mL) of drinking water per day, based on standard water intake values. The daily dose of pathogenic *E. coli* for an individual student was calculated as:

Dose (CFU/day) =Pathogenic Concentration (CFU/mL) ×Volume Consumed (mL)

Substituting the values:

Dose (CFU/day) = 0.08 CFU/mL × 1000 mL = 80 CFU/day.

Thus, each student consuming water from the contaminated source ingests approximately 80 CFU/day of pathogenic *E. coli*. For the total student population of 687 students, the cumulative daily dose was calculated as:

Total Dose = 80 CFU/student × 687 students = 54,960 CFU/day.

This total dose represents the collective microbial exposure for the affected population.

4.5.2.3 Dose-Response Assessment

The dose-response assessment was conducted using the single-hit exponential model, which is used for evaluating the probability of infection due to pathogen ingestion. This model assumes that each ingested pathogen acts independently, with its own probability of causing infection. For this analysis, the maximum infectivity scenario (*r = 1*) was used, representing the upper bound of infection risk. The infectivity parameter (*r*) assumes that every ingested pathogen particle has a 100% probability of causing infection, as outlined in the WHO (2016) guidelines on QMRA.

The probability of infection (P_{inf}) was calculated using the formula presented in Equation 4 (Chapter 3):

$$P_{inf}\ (c.V;r) = 1 - e^{-rc.V}$$

Where *r = 1* (maximum infectivity), *C = 0.08 CFU/mL* (pathogenic concentration of *E. coli*), and *V=1000 mL/*day (daily water intake). Substituting these values yields:

$$P_{inf} = 1 - e^{-1 \cdot 0.08 \cdot 1000}$$

Simplifying the exponent:

$$P_{inf} = 1 - e^{-80}$$

The exponential term e^{-80}, calculated as approximately 1.804×10^{-35}, is an extremely small value effectively approaching zero. Consequently, the probability of infection simplifies to:

$$P_{inf} = 1 - 0 = 1.0.$$

This result indicates that under the assumption of maximum infectivity, the daily probability of infection for an individual consuming the contaminated water is 100%. This value represents the theoretical upper bound for infection risk, highlighting the critical severity of exposure in the absence of mitigation measures.

4.5.2.4 Risk Characterisation

To assess the annual risk of infection due to daily exposure, the cumulative risk formula was applied:

The risk characterization step extended the dose-response results to evaluate the cumulative risk of infection over an extended exposure period to assess the annual risk of infection due to daily exposure. The annual probability of infection $P_{inf\ annual}$ was calculated using the formula presented in Equation 5 (Chapter 3):

$P_{inf\ annual}{=}1{-}[1{-}P_{inf/day}\ ]^{n}$

Where $P_{inf\ annual} =$ 1.0 represents the daily infection probability, and *n* =365 corresponds to the number of exposure days in a year. Substituting these values into the equation yielded:

$P_{inf\ annual}{=}1{-}[1{-}1.0]^{365}$

Since (1−1.0) =0, the formula simplifies to:

$$P_{inf\ annual} = 1 - 0 = 1.0$$

Thus, the annual probability of infection remains 100%, consistent with the daily infection probability under the maximum infectivity scenario.

The risk characterisation phase concluded with the application of a single-hit dose-response model to estimate the probability of infection resulting from one-time exposure to contaminated drinking water. Under the maximum infectivity scenario, where the daily infection probability was assumed to be 1.0, the model yielded an annual infection probability of 100% (Pérez-Reche, 2025). While this outcome represents a theoretical upper-bound estimate rather than a reflection of actual cumulative exposure, it underscores the potential severity of health risks associated with the presence of pathogenic *E. coli* in school water supplies (Shi et al., 2024). To contextualise these modelled risk outcomes, the following section presents self-reported data on WASH-related disease symptoms amongst learners, providing insight into actual health conditions potentially linked to inadequate WASH services in the studied schools.

4.6 WASH-Related Diseases

The prevalence of WASH-related diseases amongst school students was estimated based on recent illnesses, symptoms and medical consultations to provide insights into the health impacts associated with inadequate WASH facilities. Additionally, it considers students' awareness of similar health conditions within their communities, highlighting the spread and recognition of these health issues. The information on WASH-related illnesses was based on students' self-reported responses collected through the health-related questionnaire, and verification through medical or clinic records was not undertaken as access to healthcare records was beyond the scope of this study.

The focus on WASH-related diseases is driven by the significant influence of these conditions on student health, attendance and educational outcomes. Analysing the interplay between socio-demographic factors and disease prevalence helps in identifying at-risk groups and in understanding how different elements such as age, gender, school grade, economic quintile and geographical location contribute to health disparities.

By highlighting patterns and trends in the occurrence of diseases and their symptoms, this section sets the groundwork for understanding the critical areas where interventions are needed. The findings presented aim to support efforts in improving WASH facilities and practices in schools, thereby enhancing student well-being and educational experiences. This exploration is pivotal for designing effective public health strategies that can lead to substantial improvements in school health policies and infrastructure.

4.6.1 Prevalence of Self-Reported Water-related Illnesses

Table 4.14 shows that a significant majority (63.6%) of respondents reported experiencing water-related illnesses within the past 12 months, while a smaller portion (36.4%) indicated no recent illness. This finding has important implications for health interventions, resource allocation and further research into the causes of these illnesses within the surveyed population.

Table 4.25: Response to statement on recent illness

		Frequency	Percent
Self-reported water-related illnesses	No	437	36,4
	Yes	763	63,6
	Total	1200	100,0

4.6.2 Common Symptoms Associated with WASH Deficiencies

The bar graph displays the prevalence of symptoms related to WASH diseases amongst a sample of (1,200) students. The symptoms and their corresponding percentages of prevalence are given in Figure 4.6. A high prevalence of headache (55.4%) and fever (46.5%) indicates that many participants experienced these symptoms, potentially associated with WASH-related causes such as diarrhoea, cholera and other waterborne infections. The survey specifically focused on WASH-related symptoms and does not explore other potential underlying illnesses that may also contribute to these symptoms. A moderate prevalence of symptoms such as fatigue (30.5%), sweats (31.8%) and abdominal cramps (21.8%) suggests that they are most probably related to hygiene or sanitation issues. A low prevalence of worms (11.2%) and bloody diarrhoea (8%) could indicate that fewer students are affected by severe gastrointestinal symptoms related to inadequate sanitation or water contamination.

The data presented highlights key areas for improving WASH conditions to reduce the prevalence of and contribution of WASH factors to these symptoms, particularly headaches, fever, and fatigue, which significantly affect a substantial portion of the population.

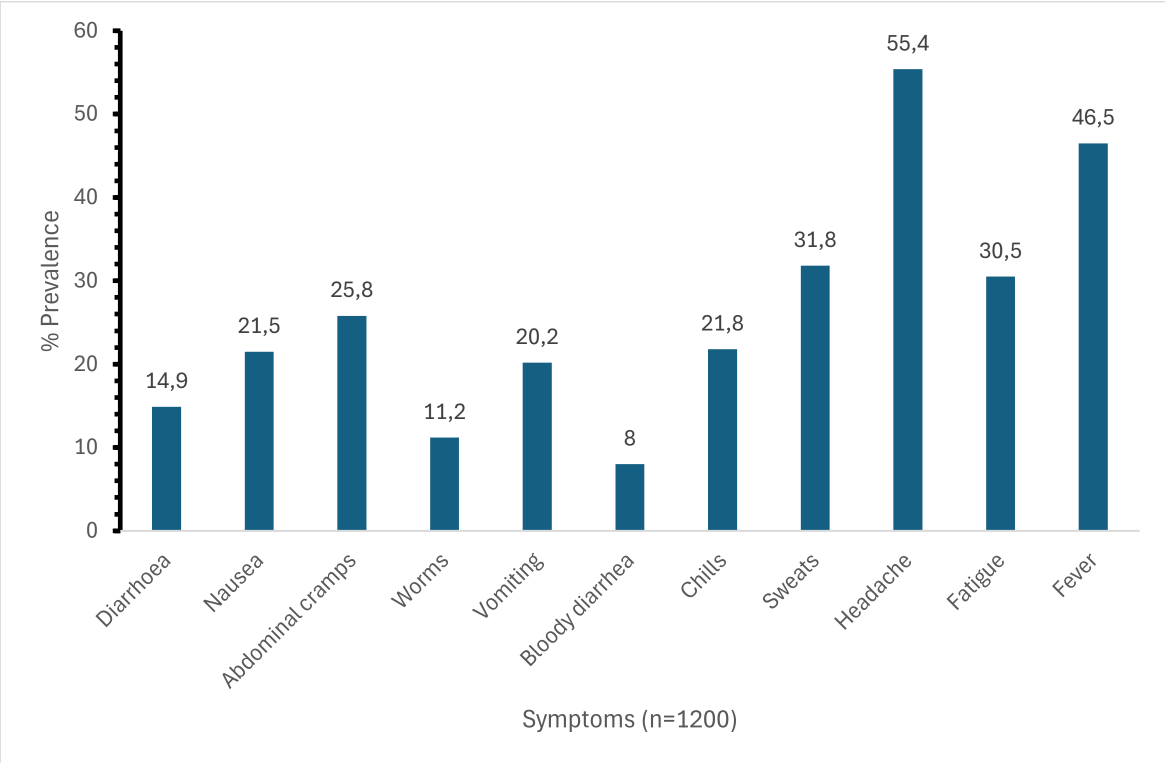

Figure 4.6: Self-reported symptoms associated with WASH related diseases

4.6.3 Learner Awareness of WASH-Related Illnesses

The response to the question on whether students had knowledge of anyone with similar symptoms show that majority (73.9%) (n=887) of participants (almost three-quarters) did not know anyone with similar symptoms in the past two weeks, suggesting that these symptoms might not be widespread or highly contagious in their immediate circles. However, almost a quarter of the students (26.1%) (n=313) did know someone with similar symptoms, indicating that the conditions related to these symptoms might be affecting specific groups or areas, warranting further investigation into the source and spread of these illnesses. This data provides insight into the potential spread of WASH-related diseases within the students' communities.

4.6.4 Healthcare-Seeking Behaviour amongst Learners

The response to the question on whether the students visited a doctor for identified health symptoms is given in Table 4.25. A significant majority (67.4%) did not seek medical attention despite experiencing symptoms. This may suggest that either the symptoms were perceived as mild or manageable without professional medical intervention, or there may be barriers to accessing healthcare, such as cost, the availability of services or a lack of perceived need. Conversely, 32.6% of respondents did see a doctor, indicating that a notable portion of the population felt that their symptoms were serious enough to warrant medical consultation. This could also reflect different levels of health awareness or access to healthcare services.

Table 4.26: Visiting a Doctor Following Symptoms Experienced

		Frequency	Percent
Did you see a doctor?	No	809	67,4
	Yes	391	32,6
	Total	1200	100,0

4.6.5 Clinically Confirmed WASH-Related Infections amongst Students

Figure 4.7 illustrates the percentage of disease conditions reported by students, which were subsequently confirmed by medical personnel. The data revealed a significant burden of WASH-related illnesses amongst students, with diarrhoeal diseases reported at a prevalence of 10%. These are commonly caused by contaminated water, poor sanitation or improper hygiene practices, leading to dehydration, malnutrition and potentially fatal outcomes if untreated. Typhoid fever, caused by *Salmonella typhi*, shows a prevalence of 8.3%, indicating severe issues with water quality and food safety in the school environment. Additionally, roundworm (*Ascaris lumbricoides*) infections, present at 5.8%, highlight a public health concern linked to poor hygiene and sanitation, typically transmitted through the ingestion of contaminated food or water. While students may wear shoes, the presence of these infections reflects environmental contamination that could include school areas and inadequate hygiene practices, such as insufficient handwashing. Hookworm infections (*Necator americanus*) also pose a risk, with a prevalence of 5.5%, often related to poor sanitation and hygiene practices. Even with shoes, the indirect transmission can occur through contaminated surfaces in playgrounds or communal areas. Eye infections, likely associated with poor hygiene or water quality, have a notably high prevalence of 14.3%, potentially stemming from inadequate access to clean water for washing. Lastly, skin infections, the most prevalent issue in this dataset at 15%, may arise from poor personal hygiene, limited water access or overcrowded living conditions that facilitate infection spread. The high prevalence of these diseases underscores the urgent need for improved water quality, sanitation and hygiene practices in schools to enhance student health and well-being. These findings highlight the critical relationship between WASH conditions and student health, emphasizing the importance of addressing these issues to reduce disease prevalence and improve overall health outcomes in the school population.

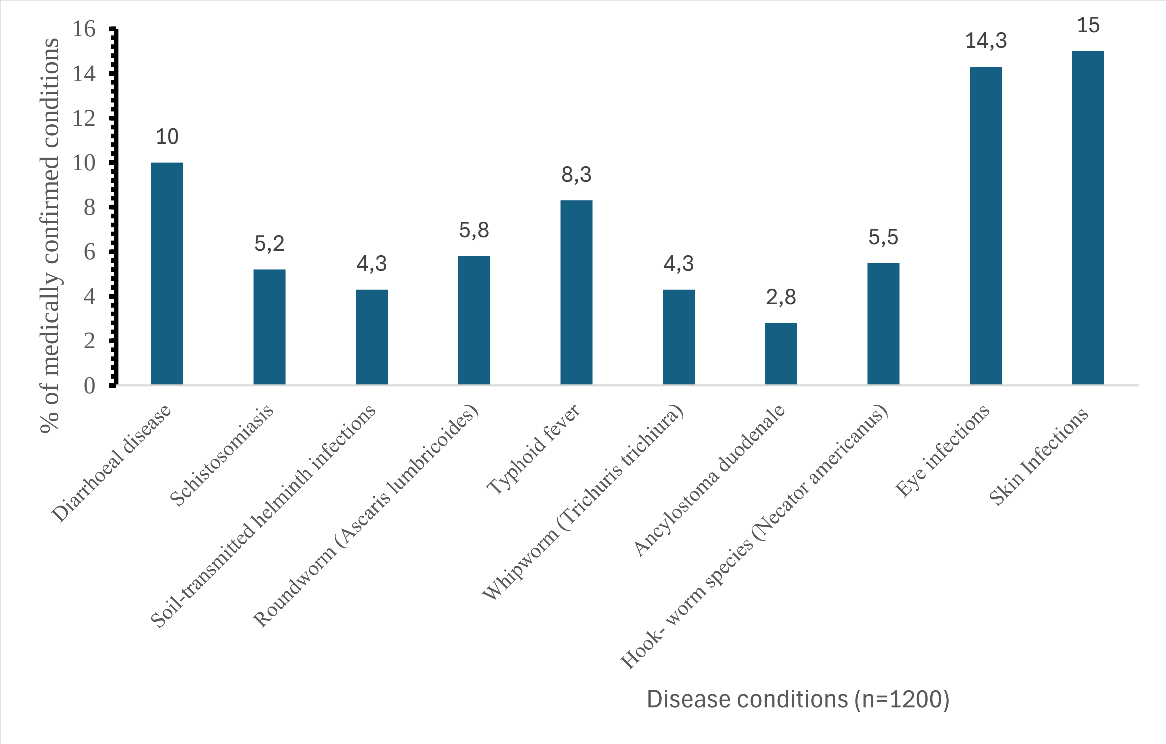

Figure 4.7: Prevalence of Clinically Confirmed WASH-Related Diseases amongst Students

4.6.6 Predictors of WASH-Related Illnesses: A Logistic Regression Analysis

In this analysis, diseases are separated into two tables based on a combination of epidemiological, statistical and public health considerations. This separation allows for a focused and clear interpretation of the effects of demographic variables on different groups of diseases associated with WASH.

Table 4.26 presents the binary logistic regression results for diseases primarily transmitted through direct ingestion or contact with contaminated water or soil, including diarrhoeal disease, schistosomiasis, soil-transmitted helminth infections, roundworm infection and typhoid fever. These diseases were selected for this table due to their acute impact on health and direct relationship with primary WASH interventions, making them critical targets for immediate public health actions.

Table 4.27 includes diseases such as whipworm, *Ancylostoma duodenale*, hookworm and additional conditions like eye and skin infections, which are also influenced by WASH factors but often manifest due to prolonged exposure to poor hygiene and sanitation conditions. These diseases were grouped in a separate table to address the more chronic and behavioural aspects of disease transmission, highlighting the need for sustained public health strategies and community education to manage these conditions effectively.

The analysis employed binary logistic regression to explore the associations between demographic variables (gender, age, grade, quintile and district) and various disease conditions. The age groups analysed include students typically in high school, specifically those aged 16-24 years, reflecting the demographic of the study population.

Males had 1.4 times higher odds of diarrhoeal disease compared to females, but this was not statistically significant (OR=1.4, 95% CI: 0.95-2.04, p = 0.085). Schistosomiasis, soil-transmitted helminth infections, roundworm and typhoid fever did not show significant differences based on gender, as all p-values were greater than 0.05.

Respondents aged 16-19 years, which includes students typically in high school, significantly had lower odds of diarrhoeal disease compared to the reference group (OR = 0.59, 95% CI: 0.39-0.89, p = 0.012). For other diseases, there was no significant association with this age group. No significant associations were found between the 20-24 age group and any of the diseases, as indicated by p-values greater than 0.05.

No significant associations across grades were found for the odds of having diarrhoeal disease. Grades 10 and 12 showed a trend towards significance (p = 0.072 and p = 0.101, respectively) for roundworm, suggesting possible increased odds compared to Grade 8, but the results were not statistically significant. There were no significant associations across grades for schistosomiasis, soil-transmitted helminth infections or typhoid fever.

No significant associations were found for Quintile 2. However, Quintile 3 showed a trend towards significance (OR = 0.33, 95% CI: 0.11-1.05, p = 0.061) for soil-transmitted helminth infections, while Quintile 4 had significantly lower odds of soil-transmitted helminth infections (OR = 0.20, 95% CI: 0.06-0.70, p = 0.012). Quintile 5 also had significantly lower odds of soil-transmitted helminth infections compared to the reference group (OR = 0.29, 95% CI: 0.09-0.97, p = 0.044). For other diseases, there were no significant associations across quintiles.

No significant associations were found between districts (Umlazi vs. Pinetown) and any of the diseases. Nevertheless, the odds of having these diseases were higher in the Umlazi district.

In summary, there was no strong evidence of gender differences in the prevalence of the listed diseases, except for a non-significant trend for diarrhoeal disease in males. The 16–19-year age group, primarily comprised of high school students, had significantly lower odds of diarrhoeal disease compared to the reference group. There was no significant association between school grade and the prevalence of the diseases, although there were some trends for roundworm infection in higher grades. Lower socio-economic groups (Quintiles 1 to 4) had significantly lower odds of soil-transmitted helminth infections compared to the reference group. No significant differences in disease prevalence were observed between Umlazi and Pinetown.

Table 4.27: Binary Logistic regression of Socio-Demographic Factors and Risks of WASH-related Diseases

Demographic variables	Disease conditions									
	Diarrhoeal disease		**Schistosomiasis**		**Soil-transmitted helminth infections**		**Roundworm (Ascaris lumbricoides)**		**Typhoid fever**	
	OR (95%CI)	**P-value**	**OR (95%CI)**	**P-value**	**OR (95%CI)**	**P-value**	**OR (95%CI)**	**P-value**	**OR (95%CI)**	**P-value**
Gender of student										
Female										
Male	**1.4 (0.95-2.04)**	**0.085**	**1.29(0.77-2.16**	**0.335**	**1.03 (0.58-1.83)**	**0.914**	**0.66(0.39-1.12)**	**0.124**	**0.84(0.54-1.29)**	**0.420**
Age										
12-15	**R[a]**		**R[a]**		**1[b]**				**R[a]**	
16-19	**0.59(0.39-0.89)**	**0.012**	**0.99(0.58-1.67)**	**0.957**	**0.90(0.51-1.59)**	**0.714**	**1.31(0.80-2.15)**	**0.287**	**1.26 (0.83-1.91)**	**0.269**

Demographic variables	Disease conditions									
	Diarrhoeal disease		Schistosomiasis		Soil-transmitted helminth infections		Roundworm (Ascaris lumbricoides)		Typhoid fever	
	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value
20-24	**1.36 (0.55-3.36)**	**0.501**	**0.99(0.23-0.426)**	**0.985**	**0.55(0.07-4.12)**	**0.559**	**1.57(0.49-5.36)**	**0.473**	**0.65(0.15-2.79)**	**0.565**
Grade										
8			**1[b]**		**1[b]**					
9	**0.81(0.48-1.38)**	**0.441**	**0.72(0.32-1.61)**	**0.424**	**1.17(0.51-2.68)**	**0.713**	**0.80(0.36-1.82)**	**0.603**	**0.71(0.36-1.40)**	**0.324**
10	**0.74(0.41-1.31)**	**0.301**	**1.26(0.61-2.58)**	**0.535**	**1.68(0.76-3.70)**	**0.201**	**1.88(0.94-3.73)**	**0.072**	**1.43(0.79-2.58)**	**0.238**
11	**0.69(0.40-1.19)**	**0.182**	**0.73(0.33-1.58)**	**0.419**	**0.84(0.35-2.03)**	**0.693**	**0.81(0.37-1.79)**	**0.604**	**0.96(0.53-1.76)**	**0.901**
12	**0.53(0.27-1.02)**	**0.057**	**1.05(0.40-2.29)**	**0.905**	**1.20(0.49-2.93)**	**0.681**	**1.81(0.89-3.69)**	**0.101**	**1.33(0.72-2.47)**	**0.362**
Quintile										
1	**R[a]**		**R[a]**		**R[a]**				**R[a]**	
2	**5.4 (0.17-1.73)**	**0.296**	**0.77(0.16-3.67)**	**0.747**	**0.26(0.72-0.91)**	**0.036**	**0.7(0.15-3.36)**	**0.656**	**0.64(0.17-2.38)**	**0.509**
3	**0.89(0.30-2.66)**	**0.836**	**0.64 (0.14-2.90)**	**0.561**	**0.33(0.11-1.05)**	**0.061**	**0.76(0.17-3.40)**	**0.716**	**0.92(0.26-3.17)**	**0.889**
4	**0.78(0.25-2.40)**	**0.667**	**0.88(0.19-4.04)**	**0.871**	**0.20(0.06-0.70)**	**0.012**	**0.77(0.17-3.54)**	**0.733)**	**0.76(0.21-2.71)**	**0.691**
5	**0.57(0.18-1.75)**	**0.323**	**0.79(0.17-3.61)**	**0.760**	**0.29(0.09-0.97)**	**0.044**	**1.16(0.26-5.19)**	**0.844**	**0.85(0.24-3.01)**	**0.806**
Districts										
Pinetown	**R[a]**		**R[a]**		**R[a]**				**R[a]**	
Umlazi	**1.03(0.71-1.51)**	**0.847**	**1.10(0.66-1.85)**	**0.705**	**1.47 (0.83-2.60)**	**0.184**	**1.12(0.68-1.82)**	**0.680**	**1.33(0.88-2.02)**	**0.175**

Note: a means reference category and refers to the reference category in each variable. OR refers to Odds Ratio and 95%CI refers to 95% Confidence Interval. b reference to empty data.

Males have higher odds of contracting Whipworm (*Trichuris trichiura*) (OR = 1.30, 95%C1: 00.58–1.83, p = 0.914), *Ancylostoma duodenale* (OR = 1.48, 95% CI: 0.75–2.94, p = 0.259) and Hookworm (*Necator americanus*) (OR =1.15, 95% CI: 0.69–1.91, p=0.568) compared to females. This result suggests that males may have a higher risk, but it is not statistically significant. However, the odds of contracting eye infections were lower amongst Males (OR=0.84, 95% CI: 0.60–1.78, p = 0.314). Nevertheless, no significant difference in the occurrence of eye infections between genders presented. Males show a significant decrease in odds with an OR of 0.71 (95% CI: 0.50–1.00), p = 0.047, suggesting that males are less likely to have skin infections compared to females.

Students within the 16-19 years brackets have lower odds of contracting Whipworm (OR= 0.80, 95% CI: 0.45–1.41, p = 0.439), Eye infections (OR= 0.73, 95% CI: 0.52–1.03, p = 0.071), and Skin infections (OR=0.81, 95% CI: 0.58–1.12, p = 0.195), showing no significant association. The odds of contracting *Ancylostoma duodenale* (OR= 1.47 95% CI: 0.74–2.91, p = 0.271) and Hookworm: (OR= 1.15, 95% CI: 0.70–1.90, p = 0.578) were however higher among students within the 16-19 years group, suggesting a potential increase in risk but was not statistically significant.

Grade 9 has lower odds of contracting Whipworm (OR =0.76, 95% CI: 0.32–1.78, p = 0.523), *Ancylostoma duodenale* (OR= 0.54, 95% CI: 0.14–2.00, p = 0.353), and Hookworm: (OR=0.73, 95% CI: 0.34–1.56, p = 0.414), with no significant association. Grade 11 has a significant reduction in odds of contracting Eye infections (OR= 0.58, 95% CI: 0.34–0.97, p = 0.037) and Skin infections (OR= 0.62, 95% CI: 0.39–1.00, p = 0.050), indicating a lower likelihood of these infections.

Quintile 2 has lower odds of contracting Whipworm (OR=0.70, 95% CI: 0.28–1.78, p = 0.458), indicating no significant association with infection while Quintile 3 has higher odds of contracting *Ancylostoma duodenale* (OR of 2.07, 95% CI: 1.05–4.11, p = 0.037), indicating a significant increase in risk compared to the reference group (Table 4.28).

There was no significant association in any quintile for Hookworm as all p-values are greater than 0.05, while Quintile 2 shows a near-significant association with Eye infections (OR= 0.60,95% CI: 0.34–1.04, p = 0.070). Quintile 3 shows a possible increased risk for Skin infections (OR=5.38, 95% CI: 0.72–40.21, p = 0.101), but this is not statistically significant.

Umlazi shows an OR of 1.35 (95% CI: 0.77–2.38, p = 0.295) for Whipworm, suggesting no significant difference compared to Pinetown. Umlazi has an OR of 2.22 (95% CI: 1.05–4.68, p = 0.037) for *Ancylostoma duodenale*, indicating a significantly higher risk in Umlazi.

No significant differences between districts for Hookworm and Eye infections.

Table 4.28: Results binary logistic regression of socio-demographic factors and risks of WASH-related diseases

Demographic variables	Disease Conditions									
	Whipworm (*Trichuris trichiura*)		*Ancylostoma duodenale*		Hook- worm species (Ne*cator americanus*)		Eye infections		Skin Infections	
	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value	OR (95%CI)	P-value
Gender of student										
Female										
Male	1.03 (0.58-1.83)	0.914	1.48(0.75-2.94	0.259	1.15 (0.69-1.91)	0.586	0.84(0.60-1.78)	0.314	0.71(0.50-1.00)	0.047
Age										
	R^a		R^a		1^b				R^a	
16-19	0.80(0.45-1.41)	0.439	1.47(0.74-2.91)	0.271	1.15(0.70-1.90)	0.578	0.73(0.52-1.03)	0.071	0.81 (0.58-1.12)	0.195
20-24	-	-	-	-	-	-	0.43(0.13-1.42)	0.168	0.58(0.20-1.68)	0.318
Grade										
8										
9	0.76(0.32-1.78)	0.523	0.54(0.14-2.00)	0.353	0.73(0.34-1.56)	0.414	0.97(0.61-1.55)	0.901	0.78(0.49-1.24)	0.294
10	1.25(0.57-2.72)	0.578	1.28(0.45-3.65)	0.645	0.77(0.35-1.70)	0.517	1.17(0.73-1.88)	0.501	0.84(0.52-1.35)	0.473
11	0.77(0.30-1.76)	0.538	0.98(0.35-2.79)	0.973	0.66(0.31-1.41)	0.280	0.58(0.34-0.97)	0.037	0.62(0.39-1.00)	0.050
12	0.86(0.35-2.10)	0.734	2.41(0.96-6.03)	0.061	1.47(0.74-2.90)	0.272	1.08(0.66-1.77)	0.768	0.82(0.50-1.35)	0.443
Quintile										
1	R^a		R^a		R^a				R^a	
2	0.70 (0.28-1.78)	0.458	0.42(0.04-4.18)	0.459	1.07(0.44-2.60)	0.873	0.60(0.34-1.04)	0.070	4.65(0.61-35.43)	0.138
3	1.22(0.61-2.43)	0.569	0.84 (0.10-6.75)	0.871	2.07(1.05-4.11)	0.037	1.37(0.92-2.05)	0.125	5.38(0.72-40.21)	0.101
4	0.70(0.30-1.65)	0.421	0.66(0.08-5.67)	0.704	1.31(0.60-2.89)	0.499	0.74(0.45-1.20)	0.218	4.75(0.63-35.91)	0.131
5	-	-	1.31(0.17-10.40)	0.796	-	-	-	-	5.94(0.70-1.32)	0.083
Districts										
Pinetown	R^a		R^a		R^a				R^a	
Umlazi	1.35(0.77-2.38)	0.295	2.22(1.05-4.68)	0.037	0.90(0.55-1.48)	0.676	1.08(0.78-1.49)	0.656	0.96(0.70-1.32)	0.808

WASH-related disease findings indicated a measurable burden amongst learners, with 63.6% reporting an illness in the preceding 12 months. At the district level, most conditions did not differ significantly. However, learners in Umlazi had higher odds of *Ancylostoma duodenale* than those in Pinetown (OR = 2.22, p = 0.037). In terms of socio-economic classification, learners in higher-quintile schools showed lower odds of soil-transmitted helminth infection compared to those in Quintile 1 (Quintile 4 OR = 0.20, p = 0.012; Quintile 5 OR = 0.29, p = 0.044). Additionally, learners aged 16–19 years had lower odds of diarrhoeal disease than those aged 12–15 years (OR = 0.59, p = 0.012). Taken together, these results identify priority sub-groups for school-centered WASH risk reduction.

4.7 Integrated Analysis and Implications of the Findings

The integrated analysis draws insights from qualitative aspects of the focus group discussions with school personnel and quantitative data from measured WASH indicators (observational checklists, KAP surveys, microbiological water quality assessments and structured health-related questionnaires). Together, these data sources enable a holistic appraisal of the environmental, behavioural and health dimensions of WASH within the participating schools and facilitates a deeper understanding of both perceived challenges and objectively measured challenges.

Focus group findings revealed that inconsistent water availability was a critical operational challenge affecting hygiene management. Schools frequently experienced disruptions in municipal water supply, which constrains handwashing and toilet flushing and severely affect the school day. Participants reported that these interruptions led to compromised hygiene practices and increased absenteeism amongst both learners and staff. The lack of alternative water storage solutions further amplifies vulnerability to service outages.

MHM was identified as a persistent issue, with major disparities observed across schools. While some institutions provided sanitary pads and private changing facilities, others lacked even minimal provisions for menstruating learners. These challenges affected girls in both lower-quintile and some higher-quintile schools, although they were more pronounced in under-resourced settings. This highlights the inadequate attention given to menstrual hygiene in current school WASH policies.

Quantitative data from observational checklists confirmed that many schools did not meet the recommended standards for WASH infrastructure. Facilities were often insufficient in number, poorly maintained or completely non-functional, with such deficiencies most common in lower-quintile schools. These findings aligned with staff perceptions and indicated systemic underinvestment in WASH services. The inadequacy of infrastructure also limited the ability of learners to engage in proper hygiene practices, regardless of awareness.

The KAP survey showed that while learners generally possessed a good knowledge of hygiene practices, the physical environment often restricted behavioural implementation. Students expressed a willingness to follow hygiene protocols, but the absence of clean water and soap rendered compliance unfeasible. This discrepancy between knowledge and practice indicates a structural rather than behavioural deficit. The findings underscore the necessity of addressing environmental constraints alongside educational interventions.

Microbiological testing of drinking water indicated overall compliance with safety standards at the time of collection, although several samples contained *E. coli*, suggesting episodic contamination. These results suggest that while baseline water quality may be acceptable, it is compromised by inconsistent supply and storage practices. The QMRA revealed elevated infection risks during periods of interrupted water service. These risks undermine the protective potential of otherwise safe water sources.

Health-related questionnaires administered to learners revealed frequent reporting of symptoms consistent with waterborne illnesses, such as diarrhoea, fever, and gastrointestinal discomfort. These symptoms were most prevalent amongst the students in studied schools with the poorest WASH infrastructure, reinforcing the association between environmental settings inadequacy and adverse health outcomes. Learners also reported limited access to medical attention, exacerbating the impact of preventable infections. These findings strengthen the causal link between deficient WASH conditions and compromised learner health.

The synthesis of these qualitative and quantitative findings demonstrates the multidimensional nature of WASH-related risks to students. Structural inequities, behavioural constraints, and health vulnerabilities interact to create complex challenges that cannot be resolved through infrastructure alone. Addressing these issues requires integrated strategies that include sustainable service provision, behavioural reinforcement and policy reform. The implications of this analysis extend beyond the individual school level and speak to broader educational and public health priorities.

4.8 Chapter Summary

This chapter presented a mixed-methods analysis of WASH conditions in selected high schools in Durban. Qualitative data from the focus group discussions revealed challenges such as intermittent water supply, inadequate sanitation infrastructure and poor menstrual hygiene support. These insights reflected systemic gaps and underscored inequities disproportionately affecting lower-quintile schools. Stakeholder voices provided an understanding of how resource limitations lead to daily hardships for learners and educators.

Quantitative evidence from the observational checklists and KAP surveys confirmed widespread infrastructural inadequacies. Learners demonstrated sufficient knowledge of hygiene principles, yet the lack of supporting infrastructure inhibited the application of this knowledge. Microbiological assessments revealed compliance and isolated contamination cases, indicating variability in water safety linked to supply inconsistencies. Moreover, the QMRA results reinforced the need for reliable water provision as a public health priority.

Data from the health-related questionnaires established the association between WASH conditions and learner morbidity. Reports of diarrhoeal symptoms were frequent amongst students, particularly in under-resourced schools, often linked to poor household environments. These findings highlighted how inadequate WASH access contributes to diminished well-being, reduced attendance and impaired educational outcomes. Health and education are deeply intertwined within the school WASH context.

This chapter demonstrated that WASH challenges are systemic, inequitable and embedded in the operational fabric of schools. The integration of qualitative and quantitative data provided a platform for identifying intervention priorities. These findings lay the groundwork for the following chapter, which synthesizes key insights and proposes strategic recommendations, including a context-specific WASH Risk Reduction Framework tailored to the South African educational environment.

CHAPTER 5: STUDY DISCUSSION AND THE DEVELOPMENT OF WASH RISK REDUCTION FRAMEWORK

5.1 Introduction

This chapter presents a detailed discussion of the study findings, as informed by data from focus group discussions with school personnel, the WASH infrastructure survey, student hygiene knowledge and practice questionnaires, and the microbiological analysis of drinking water. It explores structural limitations, operational weaknesses and behavioural patterns that contribute to disparities in WASH provision across different school quintiles. Particular attention is given to the availability and condition of WASH infrastructure, school-based hygiene management practices, menstrual hygiene support and institutional response systems.

The interpretation of findings is guided by both national and international frameworks, including SDG 6; the UNICEF & WHO (2020) JMP; the National Environmental Health Norms and Standards for Premises (Department of Health, 2015); and SANS 241 Drinking Water Standards SABS (2015). By critically engaging with these policy benchmarks, the chapter highlights how systemic and governance-related constraints continue to undermine safe, equitable and sustainable WASH service delivery in the school environment. It concludes by introducing a context-specific WASH Risk Reduction Framework, developed as a strategic response to the identified challenges, thereby offering a pathway toward improved service planning, implementation and long-term sustainability.

The findings of this study revealed widespread and persistent disparities in the availability, functionality and management of WASH infrastructure across schools in different quintiles in Durban. While some high-quintile schools demonstrated relatively better access to water and sanitation services, intermittent supply interruptions and maintenance issues remained a challenge. In contrast, schools in the lower quintiles experienced significantly more severe infrastructural deficiencies, including a lack of functional toilets, limited handwashing facilities, and irregular access to safe drinking water. These inequities reflect broader socio-economic patterns and have direct implications for learners' health, dignity and educational engagement.

In addition to infrastructure, the study identified considerable gaps between learners' hygiene knowledge and their daily practices. Although most students demonstrated an awareness of the importance of handwashing and sanitation, behavioural change was constrained by environmental limitations, such as the unavailability of soap and dysfunctional handwashing stations. These findings suggest that health education alone is insufficient unless it is accompanied by the necessary enabling conditions. The presence of waterborne illnesses and hygiene-related infections highlights the urgent need to contain and prevent the further spread of WASH-related infections, particularly in resource-limited schools.

MHM emerged as another critical area of concern. The absence of private, clean and well-maintained sanitation facilities, coupled with a lack of sanitary products and disposal systems, limited the ability of menstruating learners to manage their hygiene with dignity. Although some lower-quintile schools benefited from government or donor support in providing menstrual products, challenges related to privacy and waste management were reported across all quintiles. These findings underscore the need for gender-sensitive WASH interventions that go beyond product provision to include supportive infrastructure and education.

Furthermore, the absence of routine water quality monitoring in most schools highlighted a key vulnerability in preventive health management. Although the microbiological analysis indicated that the water was generally within safety limits during supply periods, the potential for unnoticed contamination, especially during supply disruptions, presents a significant health risk. The reliance on alternative and often unsafe water sources during shortages exacerbates this risk and points to the urgent need for resilient water systems and school-level surveillance mechanisms.

5.1.1 Disparities in WASH Infrastructure and Service Delivery

This study found marked disparities in the provision of WASH infrastructure across schools, largely aligned with the quintile classification system. Schools in lower quintiles (1 to 3) experienced widespread infrastructure deficits, including non-functional or insufficient toilets; an unreliable water supply; and inadequate handwashing stations. By contrast, high-quintile schools (4 and 5) were generally better resourced but still encountered problems such as maintenance delays and occasional water supply interruptions. These patterns are consistent with findings reported in previous studies, including the Iringa region of Tanzania, where Magwe (2025) reported that only 40.6% of poor rural schools met basic WASH criteria compared to 87.5% in developed urban schools. This disparity underscores the urgent need to address the inequalities in WASH access, particularly in low-income areas. Similarly, Wada et al. (2022) identified stark disparities between public and private schools in Nigeria, with the underfunded public institutions lacking safe drinking water and adequate sanitation facilities. These findings reflect broader trends that align with the UN SDGs, particularly SDG 6, which aims to ensure the availability and sustainable management of water and sanitation for all (Okesanya et al., 2024; De Wit et al., 2024). Biswas et al. (2024) emphasize that achieving SDG 6 in India requires increased government initiatives and investments to improve the availability, accessibility and affordability of WASH facilities, especially in the western and north-eastern districts. De Wit et al. (2024) argue that despite progress, universal access to safe WASH by 2030 remains a distant prospect, necessitating a critical re-evaluation of WASH sector strategies and a focus on addressing social inequalities.

The disparities in WASH access are not only a matter of health but also intersect with economic development and poverty alleviation efforts. Victor et al. (2025) state that inadequate WASH facilities can hinder educational outcomes by increasing absenteeism due to illness, thereby perpetuating cycles of poverty. Schools in resource-limited settings often face systemic barriers, such as insufficient funding and the lack of infrastructure investment, which further exacerbate these challenges (Byansi et al., 2025; Magwe, 2025).

Addressing these issues is crucial for achieving SDG 4 (Quality Education) and SDG 1 (No Poverty), as improved WASH conditions can enhance learning environments and contribute to better health outcomes. Investing in WASH infrastructure in schools is not just a health imperative but also a strategic economic development priority that can yield long-term benefits for communities (Kumar et al., 2023; Bick et al., 2024; Adane et al., 2025). However, significant infrastructural inequalities persist, particularly in resource-limited areas, which further exacerbate the disparities in access to essential WASH services (John & Ajibade, 2024).

These infrastructural inequalities contribute to broader systemic disadvantages for learners in lower-resourced schools. Poor access to functional toilets and safe water increases the risk of exposure to disease and undermines students' ability to engage meaningfully in their education. The present findings also reinforce the conclusions of Mokgwathi et al. (2023) and Köhler (2020), who argue that despite policy frameworks designed to allocate more resources to low-quintile schools, implementation failures have limited progress in addressing infrastructure backlogs. The consequences of these gaps are evident in the learning environment, where overcrowding, poor hygiene and operational inefficiencies persist. In their study of South African schools, Lombo and Subban (2024) noted that lower-quintile schools frequently struggle to meet even minimum WASH standards due to poor investment and ineffective policy enforcement, thus reinforcing health inequities and limiting educational opportunities. These inequities directly challenge the realisation of SDG 6.1 and 6.2, which aim to ensure universal access to safe water and adequate sanitation. The urgent need for targeted investment and effective policy enforcement in the education sector is further underscored by this study's findings.

While government efforts have introduced standardised infrastructure projects in some schools, the sustainability of these interventions remains questionable. Infrastructure alone cannot address the layered nature of WASH disparities if it is not accompanied by sufficient maintenance plans, monitoring systems and community involvement. As observed in other developing countries, one-time infrastructural inputs often fail to achieve long-term impact without embedded management and accountability frameworks (Magwe, 2025; Wada et al., 2022).

Therefore, addressing infrastructure gaps require not only capital investment but also the establishment of enduring operational systems tailored to the needs and contexts of individual schools.

5.1.1.1 Implications of Inadequate WASH in Schools

The consequences of inadequate WASH provision in schools are far-reaching and extend beyond mere discomfort or inconvenience. This study found that schools lacking basic infrastructure, such as functional toilets, handwashing stations and a reliable water supply, created environments that undermined student well-being, particularly in lower-quintile schools. Learners in these contexts were often exposed to unhygienic conditions that discouraged the use of sanitation facilities and impeded consistent hygiene practices. As a result, students faced the increased risk of WASH-related illnesses, missed school days and reduced academic performance.

These findings align with international evidence showing that poor school WASH conditions contribute directly to elevated rates of diarrhoeal disease, parasitic infections and skin conditions among learners (Bick et al., 2024; Method et al., 2024; Sharma et al., 2024; Adane et al., 2025). Health-related absences disrupt learning continuity, while the psychosocial stress associated with using unclean or unsafe facilities negatively affects students' concentration and participation. Girls face additional challenges during menstruation as the absence of private and hygienic sanitation spaces leads many to stay home during their menstrual cycle, further widening educational disparities.

Similar patterns have been observed in other developing countries, including Tanzania and Rwanda, where WASH inadequacies in lower-income schools compromise students' safety and dignity (Chidakwa, 2024; Method et al., 2024; Bazakare et al., 2025). This study reinforces those concerns by demonstrating that even within relatively urbanised areas like Durban, quintile-based inequalities produce vastly different school conditions. The impact of WASH deficits is not only physical but also psychological, as learners internalise these challenges and adjust their behaviour in ways that reduce their educational engagement and confidence.

Addressing the consequences of inadequate WASH therefore demands more than infrastructure upgrades alone. A comprehensive approach must recognise the interrelationship between health, hygiene and educational outcomes, particularly for vulnerable learner populations. Prioritising equitable WASH access is essential for creating school environments that are not only hygienic and functional, but also inclusive and supportive of student success (Sharma & Adhikari, 2022; Sharma et al., 2024; Bick et al., 2024).

5.1.1.2 Factors Contributing to WASH Disparities

The findings of this study revealed that several structural and systemic factors contribute to the unequal distribution of WASH resources across schools. One of the most pressing issues identified was funding inequality. Schools in lower quintile (1-3) often receive insufficient financial support for the development and maintenance of sanitation infrastructure, which limits their ability to provides consistent, safe and hygienic facilities. This finding is consistent with broader trends observed in the literature, where resource constraints and governance challenges have been linked to disparities in WASH service delivery in under-resourced schools (Abrams et al., 2021; Pu et al., 2022; Bazaanah et al., 2024; Magwe, 2025).

For instance, a study by Wada et al. (2022) in Nigeria found that when adequate funding was allocated for WASH facilities in public schools, there was a significant improvement in the availability of safe drinking water and functional sanitation facilities, leading to higher student attendance and better health outcomes. This highlights the direct impact of financial support on WASH infrastructure. Similarly, a recent study by Byansi et al. (2025) across various low-income schools indicated that schools with dedicated budgets for WASH maintenance reported fewer health-related absences and improved overall student performance. The absence of sustained government investment means that these schools struggle to maintain functional water and sanitation facilities, further deepening existing inequalities (Pu et al., 2022; Bazaanah et al., 2024). A global assessment of budgeting and financing for WASH in schools emphasizes that the mobilization of public finance is crucial for ensuring that schools have the necessary resources for infrastructure, maintenance and hygiene promotion. However, even with available funding, policy gaps and enforcement challenges often hinder effective implementation, leaving many schools unable to meet essential WASH standards.

Policy gaps and enforcement challenges further compound the problem, particularly in schools in lower quintiles (1-3). Although national WASH policies are in place, they are often not effectively enforced, resulting in inconsistent service delivery across schools. Pereira et al. (2024) found that many regions in sub-Saharan Africa lack the necessary infrastructure and personnel to implement WASH policies effectively, leading to significant disparities in service delivery. Similarly, Poague et al. (2025) highlighted that the lack of local government accountability exacerbates these issues, with many schools receiving inadequate support for compliance with established standards. Many schools also lack accountability mechanisms to ensure adherence to WASH standards, and in some instances, there is a disconnect between policy development and implementation on the ground (WHO & UNICEF, 2023). For example, a study by Karim et al. (2024) in Bangladesh highlighted that despite the existence of national WASH policies, many schools reported inadequate access to clean water and sanitation facilities due to insufficient monitoring and support from local authorities. This disparity leads to a situation where policies exist on paper but fail to translate into practice. In the absence of robust monitoring and evaluation systems, compliance remains low, and students continue to experience the adverse effects of inadequate WASH provisions (Jahan et al., 2025). This lack of effective oversight not only jeopardizes student health but also undermines educational outcomes, perpetuating a cycle of inequality. Another critical aspect to consider is the sustainability of WASH infrastructure in schools.

Another major factor influencing WASH outcomes in schools is the sustainability of infrastructure. Even when new facilities are constructed, they often deteriorate rapidly due to inadequate maintenance and the absence of effective school-based management structures. In the absence of routine inspections, timely repairs and consistent resource allocation, schools frequently regress to unsanitary conditions, hence undermining the impact of prior investments. Research by Poague et al. (2022b) indicates that without sustained support and engagement, school-based WASH facilities struggle to deliver long-term benefits, as their studies reveal that facilities with regular maintenance programs saw a 40% increase in functionality over three years compared to those that lacked such support. Similarly, Byansi et al. (2025) found that schools in regions with dedicated WASH management teams reported significantly better hygiene practices and student health outcomes, highlighting the importance of ongoing oversight. Forro and Besa (2025) further emphasize that effective community involvement in maintenance efforts can lead to a 30% reduction in facility deterioration, reinforcing the need for local engagement. These studies collectively illustrate that without a commitment to sustainable practices, the cycle of inadequate service provision continues, ultimately affecting student well-being and educational outcomes.

5.1.1.3 Critique of Existing Interventions and Policy Gaps

Although various national and NGO-led WASH interventions have been introduced in schools, this study found that their impact was often limited by poor contextual alignment and a lack of engagement with school communities. For example, Munyugi and Nteere (2024) investigated the effectiveness of NGO-led interventions in rural schools and found that these initiatives often failed to meet local needs due to a lack of community involvement in the planning stages. Their study showed that when schools were not consulted, the interventions resulted in low usage rates and minimal improvement in hygiene practices. Similarly, Etiaba et al. (2025) argue that successful WASH programs are those that are tailored to the specific contexts of the schools they serve. They affirm that interventions which incorporate feedback from school personnel and adapt to local conditions lead to better sustainability and student engagement.

Several school personnel engaged in this study expressed that WASH interventions were externally driven, with little consultation or adaptation to their specific needs. In some cases, schools received standardized infrastructure solutions that did not consider constraints such as overcrowding, staffing limitations or student usage patterns, thus making them difficult to sustain or integrate into daily routines. For instance, a study by Forro and Besa (2025) highlighted that externally-driven and standardized infrastructure solutions often face significant challenges in implementation as they overlook essential factors such as local resource availability and maintenance capabilities. Their findings indicate that without a nuanced understanding of the local context, these interventions struggle to achieve their intended outcomes thus further perpetuating a cycle of inadequate service provision.

Building on the previous findings regarding the challenges of WASH interventions, the limited involvement of school-based stakeholders in the planning and implementation of these programs emerged as a significant constraint. School principals and educators in lower quintile schools indicated that they were often expected to manage or maintain new facilities without having been consulted in the planning phase. As a result, many schools received infrastructure that did not adequately account for contextual challenges such as poor maintenance capacity, high student-to-facility ratios, or environmental limitations.

These findings suggest that the absence of participatory planning compromises both the sustainability and functionality of school WASH investments. This concern is corroborated by previous research. For instance, Okesanya et al. (2024) conducted a comprehensive evaluation of WASH interventions in Nigerian schools and found that when local stakeholders were involved in the design process, the facilities were more effectively utilized and better maintained. Their study highlighted that schools with stakeholder input reported a 30% increase in student engagement with the facilities compared to those with no input.

Similarly, Barrington et al. (2025) explored WASH programs in rural areas of Kenya and found that a lack of community consultation led to infrastructure that did not fit the specific needs of the schools. Their research showed that schools that implemented participatory planning processes experienced a significant reduction in maintenance issues, as local knowledge contributed to more sustainable and contextually appropriate solutions. Radebe et al. (2025) further emphasized this point by demonstrating that externally driven interventions that overlooked local conditions resulted in poor uptake and maintenance. Their findings indicated that schools receiving standardized infrastructure solutions faced a 50% higher likelihood of reported functionality issues over time, underscoring the critical importance of involving school personnel in the planning stages. Together, these studies illustrate that engaging local stakeholders is essential for developing effective and sustainable WASH programmes as it ensures that interventions are tailored to the specific challenges and needs of each school context.

Another key limitation was the lack of investment in behaviour change and hygiene education components. Participants reported that while physical facilities were occasionally delivered, hygiene promotion activities, such as handwashing campaigns, menstrual hygiene education, or training for school staff, were either minimal or absent. Such discrepancies between infrastructure provision and behavioural reinforcement contributed to the inconsistent usage and maintenance of facilities.

These findings support the arguments by Ngwenya et al. (2018) and Sharma et al. (2024), who emphasized that the success of WASH interventions depends not only on the physical infrastructure but also on the promotion of hygiene-supportive environments. For instance, a study by Wolf et al. 2023) investigated the impact of comprehensive hygiene education programs in schools and found that schools implementing regular hygiene training sessions saw a 40% increase in handwashing practices amongst students. The researchers noted that consistent engagement in hygiene education led to an increased awareness and ownership of hygiene practices, which directly correlated with an improved maintenance of facilities.

Additionally, Betsu et al. (2024) examined the effectiveness of menstrual hygiene education initiatives in peri-urban schools and found that when schools actively promoted menstrual hygiene management, students reported greater confidence and comfort in using WASH facilities. Their study highlighted that schools with integrated hygiene education programs experienced a reduction in absenteeism due to menstrual-related issues, demonstrating the crucial link between hygiene education and effective WASH usage. Together, these studies illustrate that without a robust emphasis on hygiene promotion and education, physical infrastructure alone is insufficient to ensure the effectiveness and sustainability of WASH interventions.

5.1.1.4 Practical Solutions for Bridging the WASH Gap

To address the gaps identified in this study, particularly in lower-quintile schools, targeted policy and intervention strategies should be prioritized. Increased funding is also essential to ensure that these schools receive adequate support for both sanitation infrastructure and reliable water supply. While lower-quintile schools may receive relatively greater financial allocations compared to their higher-quintile counterparts, the current levels remain insufficient to meet their significant WASH needs (Cronk et al., 2020; Girmay et al., 2023). Notably, Victor et al. (2025) highlighted disparities in WASH deprivation based on household wealth quintiles, emphasizing that children from the poorest households face higher deprivation in WASH facilities. This aligns with findings by Haque and Freeman (2021) and Kucici and Shettima (2025), who emphasized the importance of tailored, context-specific interventions in promoting sustainable WASH outcomes. Moreover, the reliance on short-term project models without sustained financial mechanisms has been shown to undermine the long-term functionality of WASH facilities (John and Ajibade, 2024). Therefore, government budgets must make provisions not only for initial infrastructure development but also for ongoing maintenance and monitoring, as echoed by previous studies highlighting the need for durable investment strategies in WASH programming.

In this study, integrating hygiene education into the school curriculum emerged as a crucial strategy in improving WASH outcomes. Participants highlighted that the students lacked consistent guidance on hygiene practices, including proper handwashing and menstrual hygiene management. Embedding structured hygiene education within the curriculum can reinforce behavioural change and promote sustainable hygiene habits over time (Enkel et al., 2025). These programmes should actively involve students, educators and community members to foster a school-wide culture of sanitation and health.

Community and school-based WASH management initiatives are recognised in the literature as effective pathways to improving sustainability and accountability (Winter et al., 2021; Mushota et al., 2021; Bick et al., 2024; Jahan et al., 2025 Poague et al., 2025). However, this study found that such structures were largely absent in the schools assessed. There was no evidence of student-led WASH clubs, designated sanitation officers or structured school-based sanitation teams. This lack of internal WASH governance contributed to inconsistent maintenance and limited engagement with WASH responsibilities. Establishing these initiatives, such as appointing sanitation champions or involving learners in peer-led hygiene promotion, could help foster a culture of shared responsibility and improve compliance with national standards. Moreover, involving parents and local stakeholders in school WASH governance may enhance accountability and promote the long-term ownership of WASH infrastructure (Nelson et al., 2021; John & Ajibade, 2024; Barrington et al., 2025).

Finally, gender-sensitive WASH interventions must be central to any improvement efforts. This study found that the lack of safe, private and adequately maintained toilet facilities for girls was a recurring concern, particularly in schools in lower quintiles (1–3). These conditions created significant barriers to MHM and undermined the dignity, comfort and attendance of female learners. Providing separate, well-maintained toilets; ensuring access to sanitary products; and fostering a supportive environment for menstruating learners are essential measures (Ngonyani and Kamando, 2023). Addressing these gender-specific challenges, especially in lower-quintile schools where the needs are most acute, is critical for promoting inclusive and equitable learning environments (Bick et al., 2024; Pereira et al., 2024; Byansi et al., 2025).

5.1.2 Intermittent Water Supply and Hygiene Risks

Despite microbiological analysis confirming that available drinking water in the schools generally met safety standards during periods of regular supply, the qualitative findings of this study revealed a more pressing challenge, namely intermittent water availability. Many schools reported frequent and sometimes prolonged water shortages, which left learners and staff without a reliable source of safe water. This is not a new challenge as previous studies have similarly shown that even when water meets microbiological guidelines, irregular access significantly compromises the safety and effectiveness of school WASH services (Poague et al., 2022b; Pu et al., 2022; Radebe et al., 2025).

The responses from participants indicated that during periods of water interruption, schools were forced to rely on alternative water sources such as rainwater tanks, unprotected wells and stored water, options that pose considerable risks. These coping mechanisms echo the concerns raised by Singh et al. (2024) and Obong'o et al. (2024), who highlight that such alternative sources often lack adequate protection and increase vulnerability to microbial contamination, particularly when storage practices are unhygienic or inconsistent with safety protocols (Pu et al., 2025).

The findings of this study suggest that intermittent water availability may in fact pose a greater health risk than microbial contamination observed during normal supply periods. During disruptions, learners and staff are compelled to adopt unsafe practices, such as collecting water in open or unclean containers and storing it for extended periods without proper safeguards. This observation is consistent with the study of Sharma et al. (2024), who found that in school environments in Nepal where water access is unreliable, the risk of waterborne diseases tends to rise, not necessarily because of source contamination, but due to unsafe handling and compromised hygiene behaviours.

Taken together, these findings underscore the urgent need for sustainable water resilience strategies in schools. Backup water storage systems, borehole installations and improved municipal water service reliability were amongst the suggestions raised by participants as critical to ensuring uninterrupted access to safe water. Addressing intermittent supply is not simply a technical concern but a matter of protecting learners' health, dignity and their right to a safe and conducive learning environment.

5.1.2.1 Health Consequences of Intermittent Water Supply in Schools

This study found that intermittent water supply remains a major concern across schools in lower quintiles (1–3), significantly impacting students’ ability to maintain basic hygiene. Participants described how water shortages frequently rendered toilets unusable due to the inability to flush, leading to foul odours, blocked sanitation units and discomfort amongst learners. Handwashing stations often became non-functional, and in several cases, schools resorted to storing water in open containers or buckets, which raised concerns about contamination and unsafe handling. Participants voiced concern that these conditions not only increased the likelihood of infections but also compromised learners’ dignity, particularly for girls managing menstruation under these circumstances.

These findings echo observations from other studies showing that an intermittent or unreliable water supply in schools contributes to higher incidences of gastrointestinal infections, diarrhoea and other waterborne diseases (Sangalang et al., 2020; Wami et al., 2022; Shayo et al., 2023; Bick et al., 2024). Research also confirms that limited water availability disrupts essential hygiene behaviours such as handwashing and menstrual hygiene management, especially in under-resourced settings (Azupogo et al., 2023; Tlhabudugwane et al., 2024; Wilbur et al., 2024; Kucici & Shettima, 2025). The situation observed in this study is consistent with findings by Borah (2025) and Hussain et al. (2024), who emphasised that infrastructure alone cannot ensure health security if water supply remains inconsistent. Taken together, these findings point to the need for integrated water resilience strategies in schools, including adequate water storage; sustainable backup systems; and reliable municipal supply to ensure the continuity of basic sanitation and hygiene practices, which are often severely compromised during periods of water interruption.

5.1.2.2 Impact on Sanitation and Hygiene Practices

This study revealed that water supply interruptions disrupted sanitation and hygiene practices in schools across all quintiles. However, the effects were more pronounced in lower-quintile schools (1–3). While some high-quintile schools (4–5) reported occasional disruptions, they were often better equipped to cope, either through backup water systems, quicker municipal response or school funds to secure temporary solutions. In contrast, schools in lower quintiles experienced more frequent and prolonged water shortages, which severely compromised their ability to maintain basic hygiene standards. Participants described how toilets were often left unflushed due to insufficient water, resulting in unpleasant odours, blocked systems and a reluctance amongst learners to use the facilities. In some cases, toilets were locked altogether to avoid further deterioration or misuse, forcing students to delay or avoid using them entirely during school hours. These findings are consistent with research by Pereira et al. (2024) and Radebe et al. (2025), who observed that poor water availability in schools leads to unhygienic and unsafe sanitation conditions, contributing to discomfort and reduced use of facilities.

Handwashing practices were severely compromised during periods of water supply interruption, with significant implications for personal hygiene amongst learners. This study found that in the absence of running water, many schools resorted to storing water in buckets or plastic containers. However, these improvised solutions were often unhygienic, frequently left uncovered, shared between classes and rarely disinfected. In some cases, water was scooped using communal cups or students' bare hands, increasing the risk of cross-contamination. As a result, learners were often unable or unwilling to wash their hands, especially after using the toilet or before eating. These findings raise serious concerns about the breakdown of basic hygiene routines in the school setting and align with earlier research by Rakesh (2023), who observed that stored water, when not handled properly, becomes a vector for secondary contamination. Similarly, Azupogo et al. (2023) note that water scarcity in schools disrupts hygiene behaviours and leads to increased vulnerability to infections.

The absence of clean water and soap made it challenging for learners to practise good hygiene, even though they were aware of proper handwashing procedures (Theoneste & Robert, 2024; Trandafir & Lotrean, 2025). This gap between knowledge and practice may be partly attributed to the demotivating effect of repeated supply failures, which discouraged both students and staff from maintaining hygiene standards. Furthermore, the burden of improvising and managing water use often fell on school personnel, who were required to oversee rationing, enforce limited hygiene protocols or request that learners bring water from home. As reported in similar studies by Kulkarni (2020) and Nchor and Ukam (2024), these coping mechanisms are not only unsustainable but also inequitable as they depend on household capacity to provide additional resources. Ultimately, the disruption of handwashing facilities contributed to a broader erosion of personal hygiene practices and increased the risk of water-related diseases within the school community.

Collectively, the findings demonstrate that intermittent water supply not only undermines the functionality of sanitation infrastructure but also compromises basic hygiene behaviours and the overall learning environment. The impact is most severe in schools with limited financial and infrastructural capacity, highlighting the urgent need for context-specific WASH management strategies that prioritise sustainability, dignity and equity. These observed challenges in maintaining basic sanitation and hygiene practices, particularly during periods of water interruption, point to deeper systemic issues rooted in inadequate infrastructure and policy implementation. These findings are consistent with those of Wilbur et al. (2024) and Pham (2025), who emphasise that in low-income settings, school WASH systems remain weak and unequal without long-term investment in infrastructure and clearly defined responsibilities for maintenance and oversight.

5.1.2.3 Infrastructure Challenges and Policy Implications

The sanitation and hygiene issues discussed in the previous section cannot be separated from the broader infrastructural and policy limitations that underpin them. This study found that many schools, particularly those in lower quintiles (1–3), operate with outdated or poorly maintained infrastructure systems, leaving them ill-equipped to manage water-related disruptions. While some high-quintile schools (4–5) were able to buffer the impact through on-site solutions such as water tanks, schools in lower quintiles faced frequent infrastructure breakdowns and limited repair support. Participants described leaking pipes, dysfunctional toilets, non-operational taps and deteriorating water tanks that compromised WASH service delivery. These observations are consistent with findings from Barrington et al. (2025), who reported that even where WASH infrastructure exists, its effectiveness is often short-lived due to inadequate maintenance and thew lack of dedicated operational budgets.

The persistent issue of intermittent water supply in these schools reflects systemic weaknesses in both physical infrastructure and governance. As Tshona et al. (2025) note, water supply systems in many developing contexts are structurally weak, outdated, and incapable of meeting growing demand. This problem is further exacerbated by poor infrastructure planning and financial constraints, particularly in low-income settings where rationed water distribution is common and schools are left vulnerable to frequent service interruptions (Poague et al., 2022a; Pu, C. J. et al., 2022; Borah, 2025). Participants in this study expressed similar concerns, explaining that delays in municipal response, unclear repair responsibilities and inadequate support from local authorities often left schools without water for extended periods, reinforcing infrastructural inequities between schools across different quintiles.

Addressing these challenges requires a deliberate and long-term policy commitment. Governments must prioritise resilient water infrastructure investment within the education sector, particularly in schools serving marginalised communities. The findings of this study reinforce recommendations by De Bernardi and Annesi (2025) and Magwe (2025), who advocate for context-specific infrastructure planning, integrated maintenance systems, and cross-sector collaboration as key components for sustainable WASH delivery in schools.

Furthermore, the study underscores the importance of strengthening municipal water supply planning and interdepartmental co-ordination. The Norms and Standards for School Infrastructure provide a foundational policy framework in South Africa. However, the disconnect between policy and practice remains a key barrier to progress. As John and Ajibade (2024) argue, without enforcement mechanisms and regular oversight, even well-formulated policies fail to produce equitable WASH outcomes. School staff in this study expressed a desire for more inclusive planning processes, where educators and local stakeholders are not only consulted but actively involved in infrastructure design, budgeting, and monitoring.

Overall, the infrastructure challenges observed highlight the urgent need for a shift from reactive, infrastructure-focused approaches to preventive and participatory WASH strategies. Sustainable improvements must be grounded in the realities faced by schools, particularly those in lower quintiles, and should be supported by stronger governance, adequate funding models and clear accountability across all levels of implementation. Whilst addressing infrastructure and policy gaps is essential for improving WASH outcomes in schools, this study also revealed that the presence of facilities alone do not guarantee effective hygiene practices, highlighting a persistent gap between knowledge and behaviour amongst learners and staff.

5.1.3 Knowledge-Behaviour Gap in Hygiene Practices

Although KAP assessments indicate a high level of awareness regarding hygiene, infrastructural and environmental constraints hinder behaviour change. Students understand the importance of handwashing and sanitation, but the lack of soap, functional handwashing stations and adequate sanitation facilities limits their ability to practice proper hygiene. This knowledge-behaviour gap suggests that awareness campaigns alone are insufficient. They must be accompanied by tangible improvements in infrastructure and access to hygiene resources.

These findings align with the Health Belief Model (HBM), which suggests that individuals are more likely to adopt preventive health behaviours when they recognise the seriousness of health risks. Behavioural change is also more likely when people have access to the resources and support needed to act (Nasiri et al., 2024; Rajapakshe et al., 2024). However, in the absence of proper sanitation facilities, even strong health awareness does not translate into improved hygiene behaviours (Habtu et al. 2025). Therefore, interventions must integrate infrastructure development with behavioural change initiatives, ensuring that hygiene education is reinforced by accessible WASH facilities.

5.1.3.1 Health Behaviour Change and Hygiene Practices

The findings of this study highlight a persistent knowledge-behaviour gap in hygiene practices amongst students, whereby an awareness of proper sanitation and handwashing does not always translate into consistent hygienic behaviours. This discrepancy is widely documented in the literature and underscores the limitations of awareness campaigns when they are not accompanied by adequate infrastructure and resources (Nelson et al., 2021; Kumar et al., 2023; John & Ajibade, 2024; Sharma et al., 2025; Habtu et al., 2025). In line with the HBM, students may recognise the health risks associated with inadequate hygiene and express positive attitudes towards preventive practices, yet systemic barriers such as the lack of soap, functional handwashing stations and adequate sanitation facilities inhibit behaviour change (Macleod et al., 2025).

5.1.3.2 KAP in Hygiene Behaviour

A study by Admasie et al. (2022) in the Damote Woide District of South Ethiopia reinforces these findings, revealing that although students were well-informed about the importance of hand hygiene, their ability to practice proper hygiene was restricted by infrastructural shortcomings. The absence of soap and non-functional handwashing stations created a situation in which knowledge alone was insufficient to drive behavioural change. Similar challenges have been observed in various low- and middle-income countries, where students' awareness of hygiene practices is not matched by the availability of the necessary resources (Bick et al., 2024; Dibaba et al., 2024; Jahan et al., 2024). While KAP assessments indicate high awareness, the gap in translating this knowledge into action suggests that motivation and behavioural reinforcement are equally critical.

5.1.3.3 Barriers to Hygiene Behaviour Adoption

The issue is not solely related to the presence of handwashing stations but also their functionality and accessibility. A study in Addis Ababa, Ethiopia, found that while 86.7% of the surveyed schools had handwashing facilities, very few provided soap and water simultaneously (Melaku & Addis, 2023). This highlights a key challenge as the presence of infrastructure alone does not guarantee proper hygiene practices, especially when essential supporting resources are lacking. Furthermore, the lack of health education programs and trained co-ordinators in schools diminishes the effectiveness of hygiene promotion efforts, thus reducing students motivation to engage in consistent handwashing (Pearson et al., 2024; Pradhan et al., 2025). Socio-economic constraints and cultural norms further contribute to these challenges, limiting the impact of hygiene education programs.

5.1.3.4 The Influence of School Environments on Hygiene Practices

The literature also suggests that cultural and socio-economic factors influence hygiene behaviours. For instance, a study conducted in Mogadishu, Somalia, research found that low awareness of handwashing practices was exacerbated by cultural influences and insufficient education (Mohamed & Ahmed, 2021). In environments where hygiene promotion is limited and cultural practices do not prioritize handwashing, students may not develop consistent habits despite their awareness of its benefits. The availability of soap and structured hygiene training were identified as key determinants in promoting hand hygiene and preventing the spread of communicable diseases (Pieters et al., 2025).

Similarly, a study in Nepal revealed that although students intend to maintain proper hygiene, infrastructural deficiencies severely hinder their ability to do so (Sharma et al., 2024). In this study, the participants also reported that handwashing facilities were insufficient, with the absence of soap and other hygiene materials. Additionally, an inadequate number of wash-hand basins further limited students' ability to practice proper hand hygiene. These findings align with research from other regions, which consistently demonstrates that even when students understand the importance of hygiene, resource constraints act as significant barriers to behaviour change (Carry et al., 2024).

5.1.3.5 Policy and Governance in Hygiene Promotion

The study demonstrated the need for a comprehensive and co-ordinated approach to addressing hygiene challenges in schools. Bridging the knowledge–behaviour gap requires an integrated strategy that combines health education with the provision of enabling infrastructure. This aligns with the conclusions of Karim et al.

(2024) and Sharma et al. (2024), who emphasise that sustainable hygiene outcomes in schools depend on the simultaneous presence of knowledge, motivation and access to basic hygiene facilities. However, translating these principles into sustained behavioural change requires the backing of strong institutional policies and governance mechanisms that ensure consistent delivery and support at the school level (Admasie et al., 2022; Theoneste & Robert, 2024; Magwe, 2025).

Ultimately, government policies and school-based interventions play a pivotal role in ensuring the long-term success of hygiene promotion efforts. Policies must move beyond awareness-raising and infrastructure provision to include mechanisms for implementation, monitoring and accountability at the school level. This recommendation echoes the work of Kenny et al. (2023) and Al-Thani (2024), who highlight the importance of policy frameworks that link national goals to school-level practice through dedicated funding, institutional oversight and inclusive planning. When well-resourced and locally adapted, such policies have the potential to create school environments that not only support hygiene behaviour but also promote dignity, equity and health for all learners (Mcmichael, 2019; Olaboye et al., 2024; Poague et al., 2025).

5.1.4 Menstrual Hygiene Management Inequities

The study highlights critical deficiencies in MHM, particularly in lower-quintile schools, where inadequate sanitation facilities and the absence of proper menstrual waste disposal systems negatively impact female learners. Although free menstrual products were more readily available in these schools, the lack of sanitary bins and an organised waste management plan undermined their effectiveness. In higher-quintile schools, the challenges differed slightly; while some infrastructure, such as private restrooms and access to running water, existed, issues such as frequent water interruptions, a lack of free menstrual products, and poor disposal planning continued to limit effective MHM. For instance, although some schools provided bins for menstrual waste, many lacked a defined process for disposing of this waste, leading to accumulation and potential health hazards. This often resulted in learners resorting to improper disposal methods, such as flushing products down toilets or discarding them in general waste, which further exacerbated the existing sanitation issues.

These findings support global evidence indicating that poor MHM is a significant factor contributing to gender disparities in education (Habtegiorgis et al., 2021; Betsu et al., 2024; Chidakwa, 2024; Shrestha et al., 2025). To address this, schools must integrate MHM-specific interventions within broader WASH frameworks, including free sanitary product provision, private disposal options and gender-sensitive sanitation designs (Bick et al., 2024; Al-Mamum et al., 2025; Ikogho & Onoharigho, 2025).

The study confirms that lower-quintile schools lack the basic WASH infrastructure necessary for effective MHM, consistent with findings by Chidakwa (2024) and Assefa et al. (2025). The absence of clean, private and functional sanitation facilities forces students to use unhygienic alternatives, exacerbating discomfort and increasing the risk of infections (Wada et al., 2022; Azupogo et al., 2023;). Underhill et al. (2025) emphasize that inadequate sanitation, particularly in under-resourced settings, is a major contributor to gendered educational disparities.

A study by Bazakare et al. (2025) found that the unavailability of lockable, private toilets discourages adolescent girls from attending school during menstruation. Similarly, this study found that the lack of privacy and functional disposal mechanisms causes embarrassment and undermines learners' well-being. This aligns with research by Betsu et al. (2024), who argue that the design and functionality of school sanitation facilities significantly influence girls' educational experiences and retention rates.

Another significant finding of this study is the lack of access to menstrual products, particularly in higher-quintile schools. Schmitt et al. (2024) highlighted that the absence of free or subsidized menstrual products in schools leads to significant discomfort and stress. These findings are consistent with this study, where participants from lower-quintile schools expressed frustration over the lack of access to menstrual products. Interventions such as government-sponsored menstrual product distribution programs have been shown to improve school participation and student well-being (Schmitt et al., 2021).

Inadequate disposal facilities combined with a lack of privacy force students to use unhygienic disposal methods, such as flushing sanitary pads down toilets or wrapping them in plastic bags. Even in higher-quintile schools, this study found that challenges related to the disposal of menstrual waste persist. In many schools, there were no dedicated bins for menstrual waste, and even where bins existed, there was no structured waste management plan in place. These gaps often resulted in blocked plumbing, unsanitary conditions and discomfort amongst learners. This finding aligns with Abdurraheem et al. (2024), who highlight the need for gender-sensitive sanitation infrastructure in schools to support effective MHM.

Research by Shrestha et al. (2025) emphasises that MHM must be integrated into broader school sanitation policies, including the provision of private disposal bins; separate latrines for boys and girls; and regular waste collection. Failure to address these infrastructural deficiencies perpetuates the stigma around menstruation and discourages girls from full participation in educational activities (Schmitt et al., 2024; Åkerman et al., 2024) .

The findings of this study also align with literature emphasising the influence of socio-cultural beliefs on MHM. Tomlinson (2024) argues that menstrual stigma, particularly in conservative societies, exacerbates gender inequalities by reinforcing silence and misinformation about menstruation. Medina-Perucha et al. (2024) further note that socio-economic conditions shape how menstrual health is perceived and managed in different communities.

The impact of menstrual stigma was evident in the focus group discussion, where students reported feeling embarrassed to discuss menstruation or seek assistance when experiencing difficulties. Similar findings have been reported in a study undertaken in the states of Bihar and West Bengal in India, where menstrual taboos limit girls' access to necessary resources (Dutta et al., 2024). Efforts to normalise menstruation through comprehensive menstrual education programs could help mitigate these challenges and empower girls to manage their menstrual health with confidence (Ikogho & Onoharigho, 2025).

5.1.4.1 Addressing MHM Through Policy and Practice

The inequities identified in MHM within schools point to critical shortcomings in both policy formulation and practical implementation. Addressing the challenges identified in this study requires the integration of MHM within broader school-based WASH policies, with particular attention to ensuring equitable access across all school quintiles. This approach is supported by Shah et al. (2022) and Bwalya et al. (2025), who argue that school-based MHM must be both inclusive and comprehensive, reaching all learners regardless of their socio-economic background. Integrating MHM into national WASH strategies is essential to realising the right to education, health and dignity for menstruating learners.

A notable finding of this study was that the provision of free menstrual products was more commonly reported in lower-quintile schools (1–3), often supported by government-led or donor-funded initiatives. In contrast, several high-quintile schools (4–5) lacked such programmes, suggesting a gap in universal provision. This reveals that while efforts to support under-resourced schools have shown progress, MHM interventions are not yet consistent or systematised across the education system. Studies in similar contexts have shown that the absence of universal provision can lead to exclusion and stigma, even in relatively better-resourced schools (Macleod et al., 2020; Ahmed et al., 2023). It is therefore critical that national policies support the universal distribution of menstrual products to all learners who need them, regardless of school quintile.

Finally, policy and governance frameworks must be strengthened to ensure sustained and standardised MHM implementation across all schools. As revealed in this study, the current landscape is marked by uneven coverage, limited co-ordination and inadequate monitoring. Embedding MHM within national school health and WASH policies, backed by earmarked funding and accountability structures, is essential to achieving the targets of SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality) and SDG 6 (Clean

Water and Sanitation) (Bick et al., 2024; Sharma et al., 2024; Radebe et al., 2025). Without this systemic integration, menstrual health risks being marginalised despite the growing recognition of its centrality to gender equity in education.

5.1.5 Water Quality Monitoring and the Risk of Contamination

Although the majority of drinking water samples appeared microbiologically safe, the absence of routine water quality monitoring in schools represents a significant oversight in preventive public health measures. The isolated detection of *E. coli*, even if infrequent, highlights a potential contamination risk that often remains unnoticed in the absence of regular surveillance. Adugna et al. (2024) and Udiba et al. (2025) suggested that even low-level or episodic contamination in drinking water systems can pose serious risks, especially in environments with young or immunocompromised individuals.

The lack of systematic monitoring makes it difficult for schools to identify deteriorating water quality in time to respond. Without consistent testing, there is no early warning system to prevent outbreaks or to trace the sources of contamination when illnesses arise. As observed in similar studies by Hossain et al. (2022) and Bautista et al. (2024), schools that do not regularly assess their water supply often underestimate exposure risks, leaving learners vulnerable to episodic but serious health threats.

These findings suggest that school WASH interventions should integrate simple but routine water quality monitoring protocols, ideally supported by local health authorities. Empowering school administrators and educators with basic water testing tools and training could help bridge this gap and ensure that safe water is not only assumed but verified. This preventive approach aligns with risk-based water safety planning frameworks promoted globally to strengthen resilience and protect vulnerable populations.

5.1.6 WASH-Related Diseases and their Implications

The interpretation of illness patterns reported symptoms and disease distribution considered differences across socio-demographic and school-level contexts. While little variation was observed between Umlazi and Pinetown, disparities were more pronounced across school quintiles, pointing to the role of socio-economic factors in shaping health outcomes.

More than 63% of learners reported recent illness, with symptoms such as headache (55.4%), fever (46.5%) and fatigue (30.5%) suggesting environmentally-related health issues. Despite this, 67.4% of students did not seek medical care, raising concern about access barriers, health literacy and the possible normalisation of poor health in affected communities (Wang et al., 2025). These findings align with global evidence showing that inadequate WASH access in schools contributes to increased public health concerns (Jahan et al., 2024; Sharma et al., 2024; Wilbur et al., 2024; Magwe, 2025). Skin (15%) and eye infections (14.3%) were reported more frequently than diarrhoeal diseases, which challenges the conventional focus in WASH literature (Rhodes-Dicker et al., 2021). This shift in disease profile highlights hygiene-related gaps, particularly in handwashing and access to water for personal cleanliness.

Analyses by age and gender showed some variation, such as significantly lower odds of diarrhoeal disease amongst learners aged 16–19 years and lower odds of skin infections amongst male learners. However, the most notable disparities were associated with school quintiles. Learners from higher quintiles (4 and 5) had significantly lower odds of helminth infections, suggesting that improved infrastructure and resources offer a protective effect. In contrast, learners from lower quintiles (1–3) experienced a higher disease burden, pointing to persistent inequalities in WASH access. These findings align with arguments by Egede et al. (2023) that health outcomes are closely tied to structural inequities.

Geographically, no substantial disparities were observed between Umlazi and Pinetown. Although students in Umlazi had slightly higher odds of certain infections, such as *Ancylostoma duodenale*, the overall disease patterns were largely comparable between the two districts. This suggests that geographic location alone was not a significant factor. Rather, school-level socio-economic differences were more impactful in determining WASH-related health outcomes.

The prevalence of infections such as whipworm, schistosomiasis, hookworm and typhoid reinforced the complex nature of WASH-related disease transmission. These findings echo global patterns of exposure to unsafe water and inadequate sanitation (Okesanya et al., 2024; Garba et al., 2025; Habtu et al., 2025). Despite this, only 26.1% of learners reported knowing others with similar symptoms, indicating limited awareness that could hinder early detection and response to outbreaks (Yimer et al., 2024). These findings underscore the need for comprehensive and context-sensitive policy responses. Interventions should go beyond infrastructure to include behaviour change communication, deworming programmes, and regular health screenings. Furthermore, efforts should prioritise lower quintile schools to ensure equity and align with SDG 6 (Pereira et al., 2024; Robinson et al., 2024; Wilbur et al., 2024; Magwe, 2025).

5.1.7 Opportunities for Improvement in School WASH Interventions

Whilst numerous efforts have been made to improve WASH conditions in South African schools, this study found that many existing interventions remain fragmented, reactive and insufficiently tailored to the contextual realities of schools, particularly those in lower quintiles. Participants consistently noted that while some schools had benefited from government infrastructure programmes or external donor support, these initiatives were often short-term, narrowly focused or poorly maintained after initial implementation. Moreover, the lack of long-term planning, monitoring and community involvement significantly limited the sustainability and impact of such interventions.

Many WASH programmes prioritised hardware installation, such as building new toilets or installing water tanks, without ensuring the availability of supporting systems for maintenance, hygiene education or behavioural reinforcement. This aligns with critiques by Chidakwa (2024) and Magwe (2025), who argue that infrastructure-based approaches, while necessary, are insufficient when implemented in isolation. In the absence of maintenance plans, training for users, and adequate funding for consumables such as soap or cleaning supplies, the utility of these facilities deteriorates over time. This pattern was observed in several schools where toilets were constructed but later locked due to damage, misuse or water shortages.

Furthermore, WASH interventions often failed to take into account the unique needs of different learner groups. Gender-specific requirements, such as menstrual hygiene support for girls, were commonly overlooked, and there was little evidence of disability-inclusive design in sanitation facilities. These gaps reflect a broader issue of generic, one-size-fits-all programming that does not adequately engage school communities in planning and decision-making. Studies by Pereira et al. (2024) and Bick et al. (2024) support this finding, highlighting the importance of needs-based and participatory approaches to WASH implementation.

Another critical shortfall observed was the limited co-ordination between stakeholders involved in school WASH delivery. Participants cited poor communication between the departments responsible for education, water provision and environmental health, resulting in delayed responses to service breakdowns and unclear accountability for repairs and upgrades. This fragmentation not only undermines intervention outcomes but also demoralises school personnel who are left to manage crises without external support. Tshona et al. (2025) similarly argue that intersectoral disconnects contribute to the failure of WASH programmes to produce lasting results, particularly in under-resourced settings.

Moreover, the study found that WASH interventions were rarely monitored or evaluated beyond their initial rollout. There was little evidence of follow-up visits, impact assessments or feedback mechanisms to track functionality or learner outcomes. As a result, even well-intentioned initiatives failed to adapt to emerging challenges or correct implementation flaws. This lack of systematic monitoring reflects concerns raised by Bazakare et al. (2025), who argue that evaluation is critical for ensuring that WASH programmes meet their intended objectives and remain responsive to local needs.

Finally, the study reveals that existing WASH interventions often fall short due to narrow scope, weak coordination and insufficient sustainability planning.

Addressing these limitations requires a shift toward holistic, inclusive and community-informed programming that integrates infrastructure with behavioural support, stakeholder alignment and ongoing evaluation. Without such a shift, WASH improvements risk being temporary fixes that fail to address the deeper systemic issues affecting school health and educational equity.

5.1.8 Strengthening the Institutional Framework for School WASH

The need to reinforce the institutional framework governing WASH delivery in schools was noted. Despite the existence of national policies and infrastructure standards, such as the Norms and Standards for School Infrastructure and the National Environmental Health Norms and Standards for Premises, their implementation remains uneven, especially in under-resourced schools. Participants repeatedly noted that school administrators were unclear about which departments held responsibility for WASH-related infrastructure, maintenance and supply. This confusion led to delays in addressing urgent WASH issues and perpetuated a reactive rather than preventive approach to service delivery. These concerns mirror those raised by Tshona et al. (2025), who argue that fragmented institutional roles and poor accountability mechanisms weaken WASH provision in educational settings.

A significant barrier to effective WASH management is the lack of dedicated personnel and budget lines within schools. Principals and school governing bodies often have to re-allocate limited funds meant for teaching and learning to address urgent WASH needs. This situation is particularly dire in lower-quintile schools, where budgetary constraints are most severe. As observed by De Bernardi and Annesi (2025), without designated funding and personnel for WASH operations, schools remain vulnerable to service gaps, and interventions cannot be sustained. This study also found that very few schools had staff trained in WASH operations, and even fewer had established systems for monitoring service levels or maintenance schedules.

Another challenge is the weak integration between national and local governance systems. While the Department of Basic Education may set national guidelines, local implementation often depends on municipal water services and district health or infrastructure support. In many cases, participants described a lack of responsiveness from municipalities when schools reported water supply interruptions or sanitation failures. The absence of formalised channels of engagement between schools and local service providers further delays response times and discourages reporting. These findings support those of Radebe et al. (2025), who recommend formal service-level agreements and communication protocols to ensure that schools receive timely and appropriate support.

The study also emphasises the importance of multi-sectoral collaboration. Effective WASH in schools depends on the coordinated efforts of education, health, infrastructure and environmental departments. However, participants described minimal collaboration between these sectors and highlighted a lack of shared accountability. Theoneste and Robert (2024) have similarly argued that without collaborative governance, WASH services tend to be piecemeal and unsustainable. A strong institutional framework would include clear role definitions, shared objectives and performance monitoring across all relevant stakeholders.

Community and parental engagement were also found to be underutilised. Although school governing bodies are legally empowered to participate in school management, their involvement in WASH-related planning, budgeting and oversight was limited. Enhancing the capacity of school governance structures to understand and support WASH functions could improve accountability and resource mobilisation. As noted by Chidakwa (2024), empowering communities to co-manage WASH facilities fosters greater ownership and sustainability, especially when combined with transparency in budget use and infrastructure development.

In summary, strengthening the institutional framework for school WASH requires clear governance structures, adequate resourcing, cross-sector collaboration and meaningful community engagement. Without addressing these foundational weaknesses, WASH interventions will continue to be constrained by disjointed efforts, unclear responsibilities and limited resilience to ongoing operational challenges.

5.2 WASH Risk Reduction Framework

Drawing on the thematic findings discussed in the previous sections, this study developed a WASH Risk Reduction Framework to guide schools, policymakers and stakeholders in strengthening WASH systems in high schools. The framework responds to the systemic challenges identified throughout the research, including infrastructure gaps, behavioural limitations and institutional weaknesses. It is informed by both quantitative and qualitative data and is structured into five sections: the rationale for its development; the key risk areas addressed; implementation and monitoring strategies; policy alignment mechanisms; and integration with the study's findings. The framework is intended to support context-sensitive, inclusive and sustainable WASH improvements aligned with national priorities and SDG 6.

5.2.1 Rationale for the Framework

The findings presented in the preceding discussion have demonstrated that WASH-related risks in schools are systemic, multifaceted and deeply interwoven with infrastructural, behavioural, institutional and policy-level challenges. Inadequate water supply, unreliable sanitation infrastructure, insufficient menstrual hygiene support and weak institutional accountability collectively compromise the safety, dignity and health of learners, particularly in lower-quintile schools. These risks not only hinder daily educational participation but also exacerbate broader inequalities in the school system.

In response to these findings, this study proposes a WASH Risk Reduction Framework as a structured, context-sensitive tool to support schools and relevant stakeholders in identifying, prioritising and managing WASH risks in a sustainable and participatory manner. The framework is designed to move schools from reactive, crisis-driven WASH responses toward a more proactive, integrated, and prevention-oriented approach. It draws directly from the themes and gaps identified in this study and aligns with international guidance. Its development process was informed by principles from the UNICEF and Global Water Partnership (GWP) Climate-Resilient Water Safety Planning Toolkit UNICEF & GWP (2017), as well as by recommendations from a recent study (De Bernardi & Annesi, 2025). These authors advocate for the use of the European Sustainability Reporting Standards (ESRS) governance framework to evaluate and enhance the integration of climate change considerations into organizational governance structures. They emphasize the importance of fostering collaboration amongst stakeholders, including water managers and policymakers, to create a cohesive and adaptive WASH system. Additionally, their focus on developing hybrid governance models, combining proactive and reactive strategies, supports the framework's goal of encouraging transformative and resilient approaches to WASH risk management. By adopting these principles, the WASH Risk Reduction Framework aims to promote continuous monitoring, strategic adaptation and resilience practices, ultimately leading to a more effective and sustainable approach to managing WASH-related risks.

Importantly, the framework is grounded in a rights-based and equity-driven perspective, ensuring that the most vulnerable learners, particularly girls, those in lower-resourced schools and learners with disabilities, are prioritised in WASH planning and interventions. It also reflects the need for systemic change by combining technical, behavioural, and governance strategies into a unified and adaptable tool. Informed by both quantitative and qualitative evidence from this study, the WASH Risk Reduction Framework offers a practical model that can be applied, monitored, and refined by schools in collaboration with education, health and infrastructure stakeholders.

5.2.2 Key WASH Challenges and Risk Analysis

This section presents the key WASH-related risks identified in the study as the foundation for developing the WASH Risk Reduction Framework. Drawing on the empirical findings, six critical domains were examined to highlight how infrastructural shortcomings, management gaps and behavioural constraints shape WASH vulnerabilities across both lower and higher quintile schools. These domains represent the core areas requiring targeted intervention and are presented in the sub-sections below.

5.2.2.1 Infrastructure Availability

Schools in lower quintiles (1 to 3) face severe deficiencies in infrastructure, including a lack of functional toilets, handwashing stations and reliable water supply. These inadequacies hinder the ability of students and staff to maintain proper hygiene, increasing the risk of disease transmission. Although higher quintile schools (4 to 5) generally have better facilities, they still experience intermittent water shortages and maintenance issues, which can compromise hygiene and sanitation standards. Across all quintiles, handwashing facilities remain insufficient, further limiting effective hygiene practices.

5.2.2.2 Quality of Drinking Water

Water quality is a critical issue in many schools, particularly in lower quintiles. While *E. coli* analysis indicates that most schools maintain acceptable drinking water quality, intermittent supply interruptions pose a significant contamination risk. Schools in lower quintiles are more vulnerable to prolonged water shortages, often leading them to rely on unsafe alternative water sources, which increases the likelihood of waterborne diseases and other health-related concerns.

5.2.2.3 WASH Management Practices

Inconsistent WASH monitoring and maintenance further exacerbate sanitation challenges in schools. School personnel report that a lack of routine inspections and upkeep has led to deteriorating hygiene conditions over time. Limited budget allocations and weak governance structures also contribute to ineffective WASH service delivery, particularly in lower quintile schools. Without proper oversight, schools struggle to maintain essential WASH infrastructure, leaving students and staff in unsanitary conditions.

5.2.2.4 Menstrual Hygiene Management

Menstrual hygiene remains a significant challenge, especially in lower quintile schools. While some schools provide adequate MHM resources, disparities persist, with many lacking the necessary sanitary products and private disposal facilities. These deficiencies negatively impact student attendance, as menstruating students may miss school due to inadequate hygiene facilities. Even in higher quintile schools, issues such as disposal challenges and lack of privacy continue to affect students' ability to manage menstruation with dignity.

5.2.2.5 Sanitation Facility Conditions

The overall condition of sanitation facilities in schools is a growing concern. Many schools, particularly in lower quintiles, lack adequate infrastructure, including non-functional toilets and overcrowded sanitation facilities. Poor maintenance and a lack of necessary supplies, such as soap and toilet paper, further contribute to an unsanitary learning environment. These challenges disproportionately affect students in lower quintile schools, where basic toilet structures may be absent, thus leaving students with no choice but to resort to unhygienic alternatives.

5.2.2.6 Knowledge, Attitudes and Practices

Despite a high level of awareness regarding the importance of hygiene, inadequate infrastructure prevents students from practicing proper hygiene behaviours. Many students understand the significance of handwashing and sanitation, yet a lack of reliable water access and soap renders these practices difficult to implement. Lower quintile students face even greater barriers, as unreliable water supply and insufficient sanitation facilities leave them unable to maintain consistent hygiene, further increasing their susceptibility to infections and hygiene-related illnesses.

5.2.3 Risk Mitigation Strategies and Intervention Plan

This section outlines practical strategies developed to mitigate the key WASH-related risks identified in the study. These strategies form a core component of the WASH Risk Reduction Framework and aim to address both immediate service delivery gaps and long-term systemic challenges. They are rooted in the empirical findings of the study and draw on international standards and national guidelines to ensure contextual relevance and sustainability. The proposed interventions target infrastructure deficits; inadequate sanitation management; menstrual hygiene challenges; and weak governance structures that collectively undermine safe and equitable WASH provision in schools.

The framework promotes a multi-stakeholder approach, encouraging collaboration between school leadership, government departments, local municipalities, civil society and development partners. Such collaboration is essential to coordinate resources, share responsibilities and sustain progress over time. It is also intended to build the capacity of schools to take ownership of WASH interventions while ensuring support and oversight from relevant authorities. This shared responsibility approach enhances the resilience of school WASH systems and reduces dependence on crisis-driven responses.

To ensure alignment with broader policy goals, the intervention strategies reflect the principles outlined in the National Environmental Health Norms and Standards for Premises and the WHO/UNICEF JMP for WASH in Schools. These frameworks provide benchmarks for evaluating service quality and coverage and have been adapted in this study to suit the local context. The alignment ensures that the proposed interventions contribute to national development objectives and global targets such as SDG 6, particularly in promoting inclusive and equitable access to water and sanitation. Table 5.1 provides a structured summary of these interventions, detailing the specific WASH challenges, contributing factors, proposed solutions and responsible implementing stakeholders. The table serves as a practical planning tool that can guide schools and support partners in prioritising and sequencing WASH improvements. Each intervention is designed to be feasible and scalable within the constraints of school environments, particularly in under-resourced settings. The use of this table allows for context-driven adaptation, enabling flexibility while maintaining strategic focus on risk reduction and service sustainability.

Table 5.1: WASH Risks, Challenges and Intervention Strategies

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
	Low-Quintile Schools (1-3)			
Infrastructure Availability **Hazard:** Facilities often non-functional **Risk Classification:** Medium--High	Insufficient toilets and handwashing stations.	Insufficient funding and resource allocation.	Sustainable funding & resource allocation.	National & Provincial Government (Department of Water and Sanitation, Department of Basic Education, National Treasury)
	Limited functional toilets and handwashing stations.	Limited government and school budgets for WASH infrastructure.	Establish public-private partnerships (PPPs) to secure additional funding.	Allocate budgetary resources for WASH infrastructure in schools.
	Lack of reliable water supply, particularly in rural areas.	Dependence on government finding.	Increase government budget allocations for WASH improvements in schools.	National & Provincial Government (Department of Water and Sanitation, Department of Basic Education, National Treasury)
	Poorly maintained or aging infrastructure.	Poor Infrastructure planning and maintenance Rural and remote schools facing logistical challenges in accessing water and sanitation services.	Establish community-led maintenance teams to support infrastructure upkeep.	School Governing Bodies (SGBs): Encourage community involvement in maintaining sanitation and hygiene facilities.
	Overcrowded or poorly maintained facilities.	Schools not designed with adequate WASH facilities. High student-to-facility ratio (overcrowding).	Addressing overcrowding & resource constraints.	Department of Basic Education (Infrastructure Development): Oversee the expansion of school facilities to accommodate growing student populations.

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
	Inadequate planning or maintenance.	Environmental and geographic challenges	Expand school facilities to accommodate growing student populations.	National & Provincial Government (Department of Water and Sanitation, Department of Basic Education, National Treasury)
	High-Quintile schools (4-5)			
	Water supply interruptions despite having better infrastructure.	Infrastructure and Maintenance Issues	Reliable continuous water monitoring systems. Establish a preventive maintenance system with scheduled inspections and prompt repairs to address wear and tear in school WASH infrastructure.	Department of Education. Department of Health. Department of Water and Sanitation. Municipal authority. Ensures routine monitoring and timely reporting of faults.
	Occasional lapses in maintenance (for example, faulty taps, blocked toilets	Despite having better infrastructure, schools depend on unreliable municipal water services. Aging Infrastructure, even well-developed schools experience wear and tear, leading to frequent breakdowns in taps, toilets, and piping.	Install alternative on-site water storage systems, such as tanks to be filled by potable water supply, to ensure water availability during service interruptions.	The municipality is responsible for maintaining consistent water service delivery, while school principals and SGBs coordinate short-term alternatives and advocate for reliable supply.
Quality of Drinking Water **Hazard:** High likelihood of contamination	**Low-Quintile Schools (1-3)**			
	No routine water quality monitoring.	Absence of a structured water quality monitoring plan.	Establish structured water quality monitoring programs. Strengthening Institutional Capacity and Support	The Department of Water and Sanitation (DWS) should develop national water monitoring frameworks and guidelines. Environmental Health Practitioners to conduct

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
Risk Classification: High	Water interruption increase vulnerability to contamination.	Insufficient government oversight and enforcement of water quality standards in schools. Inadequate Policy Implementation and Enforcement Inconsistent application of national water quality standards in schools	Improving Policy Implementation and Enforcement Mandate regular inspections by environmental health practitioners to check compliance with water safety regulations.	regular water monitoring, including water testing and risk assessments to ensure compliance with safety standards.
	Isolated detection of *E. coli* indicates potential contamination risk.	Reliance on alternative water sources, such as rainwater tanks and nearby rivers, during supply interruptions increases the risk of contamination.	Implement regular cleaning, treatment, and water quality monitoring protocols for rainwater tanks to ensure stored water remains safe for use.	School management is responsible for routine tank maintenance and basic water quality checks, while the municipality and provincial health authorities provide technical support and periodic testing.
	Schools relying on rivers, unprotected wells, and untreated boreholes during water shortages.	Lack of intervention through education on how to treat water from unsafe sources.	Establish clear accountability frameworks with defined roles, reporting structures, and compliance monitoring to ensure the provision of safe water in schools.	The provincial education department must enforce accountability measures, while school principals are responsible for implementing and reporting on water access compliance.
	High-Quintile Schools (4-5)			

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
	No routine water quality monitoring.	Water Supply & Quality Concerns No Routine Water Quality Monitoring	Establish regular water testing routines	The Department of Water and Sanitation (DWS) should develop national water monitoring frameworks and guidelines.
	Intermittent water supply increase vulnerability to contamination.	Inconsistent municipal water supply leads to reliance on unsafe alternative sources or use of compromised storage practices during interruptions.	Develop school-level contingency plans that include safe water storage protocols and emergency water supply arrangements to reduce contamination risks during disruptions.	The municipality must ensure timely restoration of water services, while school management is responsible for implementing safe interim water handling and storage practices.
WASH Management Practices **Hazard:** Facilities degrade quickly without management **Risk Classification:** Medium	**Low-Quintile Schools (1-3)**			
	Lack of clear accountability for WASH facilities maintenance. .	Absence of a designated authority responsible for WASH facility upkeep.	Establish Clear Accountability for WASH Facilities Maintenance.	Schools must implement a reporting system for identifying and addressing WASH-related issues in a timely manner.
	Shortages of cleaning supplies impacting hygiene standards	Inadequate funding for cleaning and maintenance.	Leverage partnerships with NGOs, private sector, and donors to secure additional resources.	The Provincial Department of Education must lead partnership coordination, while schools ensure local implementation and accountability.
	Absence of standardised guidelines for cleaning and maintenance procedures.	Lack of structured Standard Operating Procedures (SOPs) to regulate facility management.	Assign a WASH coordinator at each school to oversee sanitation, hygiene promotion, and facility maintenance.	School principals, in collaboration with the SGB, are responsible for appointing and supporting WASH coordinators, while district offices provide oversight and guidance.

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
	Overreliance on general workers for WASH-related tasks without proper guidelines for effective management.	No appointed WASH coordinator to oversee implementation and ensure compliance with hygiene standards.	Develop a clear accountability framework assigning specific roles for cleaning, maintenance, and monitoring. Train general workers and staff on WASH best practices, including proper cleaning protocols and facility management. Ensure the WASH coordinator liaises with local authorities and health departments to address issues effectively.	Department of Education. Department of Health. Department of Water and Sanitation must develop and Enforce Standard Operating Procedures (SOPs), ensuring consistency and adherence to hygiene standards.
	High-Quintile Schools (4-5)			
	Lack of formalized maintenance contracts with external providers leads to inconsistent facility upkeep.	Reliance on reactive rather than preventive maintenance – Repairs are often only done when issues arise, rather than through	Formalise maintenance contracts with external providers, to ensure consistent and high-quality facility upkeep.	The Provincial Education Department handles contract approval, while principals and SGBs oversee school-level implementation.

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
		scheduled inspections and servicing.		
	Absence of a dedicated WASH coordinator results in inadequate oversight and monitoring of hygiene standards.	No designated responsibility for WASH management	Assign a dedicated WASH coordinator to oversee sanitation, water supply, and facility maintenance.	Principals and SGBs appoint and support the coordinator; the district office provides oversight and support.
	Low-Quintile Schools (1-3)			
MHM **Hazard:** Poor MHM leads to infections, absenteeism **Risk Classification**: Medium--High	Inadequate or no private toilets for girls. Irregular supply of sanitary products.	Many schools lack the budget or resources to build sufficient toilet facilities for girls, resulting in overcrowding.	Establish partnerships with private companies to secure long-term agreements for product donations. Advocate for policy changes to establish government-supported menstrual health programs that allocate free menstrual products in schools.	The provincial education department initiates and manages partnerships, while school principals and SGBs coordinate distribution and ensure proper use at the school level. National and Provincial Education Departments are responsible for policy development and budgeting, while NGOs, civil society, and school leadership advocate and provide evidence from the school level to support policy reform.
	Lack of proper disposal facilities (bins, incinerators)	The absence of a structured menstrual hygiene waste disposal system, due to inadequate policies, results	Increase the number of private toilets for girls to ensure they have adequate space and privacy for	The Provincial Education Department is responsible for planning and funding infrastructure upgrades, while schools identify needs

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
		in improper waste management.	managing menstrual hygiene effectively.	and ensure facilities are maintained and accessible.
	High-Quintile Schools (4-5)			
	High demand and cost of menstrual hygiene products, yet provision is dependent on the school's budget.	Insufficient funding in some high quintile schools hinders the consistent provision of resources for all students in need	Integrate menstrual hygiene into school health policies, ensuring sustainable budget allocation. Establish partnerships with NGOs and corporate sponsors to secure free or subsidized sanitary products.	The National and Provincial Education Departments are responsible for integrating menstrual hygiene into official school health policies and securing dedicated funding within education budgets. The Provincial Education Department facilitates strategic partnerships, while school principals and SGBs coordinate local distribution and ensure equitable access for learners.
Sanitation Facility Conditions **Hazard:** Potential pathogen spread in unclean toilets **Risk Classification**: Medium	**Low-Quintile Schools (1-3)**			
	Poor cleaning and maintenance. Lack of cleaning supplies, leading to unhygienic conditions. .	Inadequate funding for regular cleaning supplies and equipment. No structured cleaning schedules or Standard Operating Procedures (SOPs).	Ensure consistent supply of cleaning materials by including them in school budgets. Develop and enforce cleaning schedules to maintain hygiene standards.	School principals and SGBs are responsible for budgeting for cleaning materials and ensuring the development and enforcement of regular cleaning schedules to maintain hygiene standards.

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
	Broken locks compromising privacy. Community vandalism, including damaging roofs and breaking into schools to steal toilet infrastructure and basins. Students misusing facilities, such as putting toilet paper in sinks, leading to blockages. Some toilets filled with refuse and general waste, making them unusable.	Lack of ownership and responsibility for school infrastructure – Students and community members do not perceive school facilities as their own, leading to misuse (for example, students putting toilet paper in sinks) and vandalism (for example, community break-ins resulting in the theft of basins, plumbing, and other WASH infrastructure).	Promote a culture of ownership and responsibility by engaging both students and the community in WASH facility management	School principals and SGBs, in collaboration with Life Orientation educators, are responsible for promoting a culture of ownership by involving students and the wider school community in the management and upkeep of WASH facilities.
	Improper disposal of sanitary products, causing blockages. Unsafe Waste Disposal and Drainage Issues Inadequate waste management resulting in clogged drains and overflowing waste.	No proper waste collection system, leading to accumulation of refuse.	Develop waste disposal policies and train students on proper waste management.	School principals and SGBs, supported by the provincial education department and local health authorities, are responsible for developing school-specific waste disposal policies and ensuring that students receive training on proper waste management practices.

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
	Insufficient water for lushing (where flush systems exist) Water shortages making flush toilets non-functional. Poor water pressure or broken pipes, preventing proper flushing.	Inconsistent water supplies due to municipal shortages or broken pipes. Aging or faulty plumbing infrastructure leading to leaks and inefficiencies.	Install backup water storage tanks connected to ablution facilities for flushing and hygiene, as well as separate tanks for safe drinking water supply.	The Provincial Education Department is responsible for funding and overseeing the installation of backup water storage systems, while school principals and SGBs ensure proper usage, maintenance, and separation of tanks for hygiene and drinking purposes.
	High-Quintile Schools (4-5)			
	Water supply interruptions causing flush toilets to become non-functional.	Unreliable water supply and lack of backup systems	Set up backup water storage tanks linked to ablution facilities for flushing and hygiene, along with dedicated tanks for a safe drinking water supply.	The Provincial Education Department is responsible for providing infrastructure support and funding, while school principals and SGBs are responsible for coordinating installation, ensuring proper maintenance, and monitoring the safe use of separate tanks for hygiene and drinking purposes.
KAP	**Low-Quintile Schools (1-3)**			

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
Hazard: Risk of disease transmission through poor hygiene **Risk Classification:** Low--Medium	Students aware of hygiene but do not always practice it.	Limited access to hygiene facilities (for example, soap, handwashing stations).	Encourage students to practice hygiene regularly through awareness campaigns and structured handwashing routines. Introduce hygiene champions or peer educators to promote consistent hygiene habits. Conduct interactive hygiene education sessions using interactive digital education tools and guest speakers to emphasise the importance of personal hygiene.	School principals and Life Orientation educators, in collaboration with the SGB and school health teams, are responsible for promoting hygiene practices by ensuring access to handwashing stations, organising regular awareness campaigns, training peer educators, and facilitating interactive hygiene education sessions using digital tools and guest speakers.
	Low handwashing frequency	Lack of monitoring and reinforcement of hygiene behaviour.	Ensure accessibility of handwashing stations with soap and clean water.	School principals and SGBs are responsible for ensuring that handwashing stations are functional, accessible, and regularly stocked with soap and clean water, with support from the provincial education department for infrastructure and supply funding.
	High-Quintile Schools (4-5)			
	Students are aware of the importance of hygiene but do not give it much attention in their daily routines, even in schools where handwashing facilities are provided.	Lack of engagement in hygiene education.	Use behavioural nudges such as posters, digital reminders, and peer-led initiatives to make hygiene a daily habit. Implement hygiene accountability programs,	School principals and Life Orientation educators, in collaboration with the SGB and school health teams, are responsible for promoting hygiene practices by ensuring access to handwashing stations,

WASH Domain	Key challenges Identified	Risk Contributing Factors	Strategies to Address Challenges	Key Responsibilities
			where student hygiene ambassadors promote and monitor good hygiene practices. Conduct interactive hygiene education sessions using interactive digital education tools and guest speakers to emphasise the importance of personal hygiene.	organising regular awareness campaigns, training peer educators, and facilitating interactive hygiene education sessions using digital tools and guest speakers.

5.2.4 WASH Implementation and Monitoring Framework

Ensuring the effective implementation and monitoring of WASH interventions requires a structured framework that enables systematic tracking of progress, evaluation of impact, and accountability for WASH improvements. This framework provides a set of suggested strategies for addressing key WASH challenges in schools, recognizing that successful implementation depends on the coordination of multiple stakeholders, adequate funding and continuous assessment.

The proposed framework emphasizes infrastructure development, water quality monitoring, sanitation management, menstrual hygiene support and behavioural change interventions. Each component is designed to address specific WASH risks while aligning with national and international standards, including the National Environmental Health Norms and Standards and WHO/UNICEF JMP service ladders for schools.

5.2.4.1 Infrastructure Improvement and Sustainable Maintenance

The availability and functionality of WASH infrastructure are crucial for improving hygiene conditions in schools. Schools in lower quintiles often experience deficiencies in sanitation facilities, handwashing stations and water supply systems. Upgrading and maintaining these facilities is essential for ensuring long-term sustainability. Regular facility inspections by Environmental Health Practitioners (EHPs) can help track compliance with hygiene standards and inform necessary improvements. Community participation in facility upkeep can further enhance the sustainability of WASH infrastructure.

5.2.4.2 Water Quality Monitoring and Compliance

Maintaining safe drinking water in schools requires structured monitoring programme that ensure compliance with safety standards. Schools should conduct routine water quality assessments, ensuring that water meets SANS 241:2015 Drinking Water Quality Standards. Establishing a school water quality surveillance program, supported by a centralized database for monitoring test results, can facilitate timely identification of risks and corrective action. Additionally, institutional capacity should be strengthened by training school-based WASH teams to oversee daily water safety practices and report contamination issues.

5.2.4.3 WASH Facility Accountability and Governance

Effective governance and accountability mechanisms are essential for ensuring that WASH services are consistently maintained. Schools should appoint dedicated WASH co-ordinators responsible for facility oversight, hygiene promotion and issue reporting. Implementing structured reporting systems for sanitation concerns, hygiene supply shortages, and infrastructure repairs will facilitate prompt response by relevant authorities. The development and enforcement of Standard Operating Procedures can further ensure consistency in WASH facility management across schools.

5.2.4.4 Menstrual Hygiene Management and Support Services

Access to menstrual hygiene products and appropriate disposal facilities remains a challenge in many schools. Strengthening partnerships between government agencies, private sector stakeholders, and NGOs can help secure sustainable supplies of menstrual hygiene products. Regular school inspections can assess the availability of menstrual hygiene facilities, while policy advocacy efforts can drive increased funding for menstrual health programs. Schools should integrate menstrual health education into hygiene promotion activities to ensure that students receive adequate support and information.

5.2.4.5 Sanitation Infrastructure and Wastewater Drainage Maintenance

Ensuring functional sanitation systems requires ongoing maintenance and proactive measures to prevent infrastructure failures. Schools should implement regular inspections of plumbing systems and wastewater drainage systems, including toilet facilities. Developing scheduled cleaning protocols and ensuring the availability of hygiene supplies are critical for maintaining hygienic conditions. The installation of backup water storage systems can provide a contingency measure to sustain hygiene services during water supply disruptions.

5.2.4.6 Hygiene Promotion and Student Behaviour Change

Encouraging students to adopt positive hygiene behaviours requires structured awareness programs, peer-led initiatives and behavioural reinforcement strategies. Schools can integrate hygiene education into their curriculum, supported by digital education tools and interactive campaigns. Handwashing promotion should be reinforced through the availability of functional handwashing stations and hygiene accountability programs. Regular assessments of student hygiene practices before and after awareness campaigns can help evaluate the effectiveness of these interventions.

5.2.4.7 Monitoring and Evaluation Mechanisms

To ensure effective oversight, structured monitoring mechanisms should be incorporated into the WASH framework. Schools should conduct regular audits, track compliance with hygiene and sanitation standards, and integrate mobile-based reporting tools for real-time updates on WASH conditions. Performance indicators such as the percentage of schools with functional WASH infrastructure, reductions in waterborne disease reports, and compliance with WHO/UNICEF JMP standards can serve as key benchmarks for assessing progress (WHO & UNICEF, 2023).

Table 5.2 outlines the proposed implementation and monitoring framework for addressing WASH challenges in schools. It presents key focus areas, recommended actions, responsible entities, monitoring approaches and measurable indicators. These recommendations are aligned with national and international WASH standards to enhance accountability and improve service delivery. The suggested actions align with national and international standards, emphasizing the need for sustainable investments, stakeholder collaboration and ongoing assessment to ensure safe and hygienic learning environments.

Table 5.2: WASH Implementation and Monitoring Framework

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
Infrastructure Availability	**Infrastructure Improvement**	Upgrade (construction or refurbishment) sanitation and handwashing facilities to meet hygiene standards.	Department of Basic Education (Infrastructure Development).	Monthly facility inspections by EHPs Check compliance with National Norms and Standards of Environmental Health.	Number of sanitation and handwashing stations upgraded or provided.
	Sustainable Funding & Resource Allocation	- Establish public-private partnerships (PPPs) to secure additional funding. - Increase government budget allocations for WASH improvements in schools.	Department of Basic Education. Private Sector, NGOs.	Impact of secured funding on WASH infrastructure improvements. Comparison of pre- and post-allocation WASH infrastructure and services.	Amount of funding secured through PPPs % increase in government budget allocation for WASH
	Community Engagement & Participation	- Establish community-led maintenance teams to support infrastructure upkeep. - Involve parents, local communities, and school management committees in maintaining WASH facilities.	Schools, Local Authorities, NGOs, School Management Committees	Effectiveness of community engagement in ensuring facility upkeep. Number of maintenance activities completed with community involvement.	- Number of active community-led maintenance teams Frequency of community engagement initiatives in WASH maintenance
	Addressing Overcrowding & Resource Constraints	- Expand school facilities to accommodate growing student populations.	Government (Department of Education & Public Works), Donor Organizations	Impact of expansion on WASH accessibility and quality. Student satisfaction and usage of new facilities.	Number of schools with expanded infrastructure. Reduction in student-to-facility ratio

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
Quality of Drinking Water	Strengthening Water Quality Monitoring and Compliance	Mandate regular inspections by environmental health practitioners to monitor and enforce compliance with water safety and sanitation regulations.	eThekwini Metropolitan Municipality (Department of Health),	Water Quality Risk Assessment in Schools.	- % of schools meeting SANS 241 microbiological, physical and chemical safety standards.
		Establish a nationwide school water quality surveillance programme to ensure consistent monitoring, assessment, and reporting of school drinking water safety in alignment with SANS 241: Drinking Water Quality Standards.	Provincial and National Department of Health, eThekwini Metropolitan Municipality (Department of Health), Department of Basic Education,	Develop a centralised school water quality compliance database to track water quality test results, identify non-compliant schools, and implement corrective actions. The database should integrate real-time reporting, trend analysis, and enforcement mechanisms to ensure accountability and continuous improvement.	- Frequency of water quality testing per school per year (Target: At least 4 times annually). - Number of non-compliant schools and enforcement actions taken annually.
	. Strengthening Policy Implementation and Compliance	Establish structured water quality compliance indicators to assess whether schools meet national drinking water safety standards, including SANS 241: Drinking Water Quality	eThekwini Metropolitan Municipality (Department of Health); Department of Water and Sanitation, School Governing Bodies	Monthly water quality compliance report	- % of schools meeting SANS 241 standards for microbial, physical, and chemical safety.

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
		Standards. These indicators should track microbial contamination, chemical safety, water availability, and continuity of supply			
	Strengthening Institutional Capacity and Support for Water Quality Management in Schools.	Develop WASH management teams within schools to oversee daily water-related issues, ensure safe drinking water practices, and liaise with local authorities (for example, Department of Health, Department of Water and Sanitation, and municipal water service providers).	Department of Basic Education in collaboration with School Governing Bodies; eThekwini Metropolitan Municipality (Department of Health),	- Establish structured training programs for WASH management teams on water quality issues, risk identification, and emergency response protocols. - Create a reporting system where schools can report any water supply or contamination issues to the municipality and health authorities. - Conduct periodic audits to assess the functionality and effectiveness of school-based WASH management teams in handling water quality concerns. - Develop a performance review system to measure how effectively teams identify and escalate	- % of schools with trained WASH management teams capable of identifying and reporting water quality issues. - % of schools submitting water-related issue reports to the municipality within required timeframes. - Number of school WASH management teams trained annually on water safety protocols.

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
				water-related risks to authorities for corrective action.	
WASH Management Practices	Strengthening Accountability and Maintenance of WASH Facilities in Schools	- Assign a dedicated WASH Coordinator at each school to oversee sanitation, hygiene promotion, and facility maintenance. - Develop a clear accountability framework defining roles for cleaning, maintenance, and monitoring of WASH facilities. - Implement a structured reporting system where schools document and report WASH-related issues (for example, broken toilets, water shortages, hygiene supply needs) to relevant authorities. - Develop and enforce Standard Operating Procedures (SOPs) to ensure consistent sanitation, hygiene, and facility upkeep practices. - Train school staff and general workers on proper sanitation, hygiene promotion, and facility	Department of Basic Education & School Governing Body; eThekwini Metropolitan Municipality (Department of Health).	- Monitor the number of schools with active WASH Coordinators and track their effectiveness through periodic performance reviews. - Conduct biannual WASH audits to assess maintenance practices and facility conditions. - Ensure schools submit monthly maintenance reports, tracking resolution times for reported issues.	- % of schools with assigned WASH Coordinators. - % of schools submitting maintenance reports on time. - % of reported WASH issues resolved within 3 months. - % of schools meeting sanitation maintenance standards.

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
		management best practices. - Ensure WASH Coordinators liaise with local authorities (municipal water services, health departments) for prompt response to water and sanitation concerns.			
MHM	Ensuring the continuous and adequate supply of menstrual products to schools to support girls' menstrual health needs. Strengthening government commitment to menstrual health by advocating for policies and funding allocations for free menstrual products in schools. Improving school sanitation facilities to ensure privacy, comfort, and hygiene for menstruating girls.	Establish partnerships with private companies for long-term agreements on menstrual product donations. Advocate for policy changes to establish government-supported menstrual health programs that allocate free menstrual products in schools. Increase the number of private toilets for girls to ensure adequate space and privacy. Implement maintenance and sustainability plans for menstrual hygiene facilities.	Department of Basic Education and School Governing Bodies; Private Sector Department of Basic Education. Department of Basic Education and School Governing Bodies.	Track signed agreements with private sector partners. Track policy proposals and government funding allocations. Conduct periodic school sanitation facility inspections to monitor availability of hygiene products and disposal mechanisms	Number of active private sector partnerships. % of schools with consistent menstrual product supply. % of schools implementing menstrual health education. % of schools provided with proper menstrual hygiene facilities or products.

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
Sanitation	Sanitation Infrastructure (Plumbing & Toilets)	Repair or upgrade plumbing infrastructure (pipes, taps, toilet fixtures) to improve water flow and toilet functionality.	Department of Basic Education and School Governing Bodies.	Conduct routine inspections of toilets and plumbing; maintain a log of repair needs and actions taken; promptly address leaks or malfunctions; involve authorities for major upgrades.	% of functional toilets. Number of plumbing repair requests addressed within a set timeframe.
	Drainage System Maintenance	Conduct regular maintenance of school drainage systems to prevent blockages and flooding.	Department of Basic Education and School Governing Bodies.	Schedule periodic inspections of drainage infrastructure.	% of drains maintained in functional condition.
	Cleaning & Hygiene Maintenance	Ensure consistent supply of cleaning materials. Develop and enforce cleaning schedules to maintain hygiene standards.	Department of Basic Education and School Governing Bodies.	Regularly inspect cleanliness of facilities.	% of ablution facilities regularly inspected and found compliant with school hygiene standards.
	Water Supply & Storage	Install backup water storage tanks connected to ablution facilities to ensure flushing and hygiene even during water outages.	Department of Basic Education and School Governing Bodies.	Monitor water availability daily and check functionality of ablution facilities even during water outages.	Backup water tanks provided uninterrupted water supply for hygiene and sanitation needs."
Knowledge, Attitudes, and Practices (KAP) of Students	Hygiene Awareness and Behaviour Change	Encourage students to practice hygiene regularly through awareness campaigns and structured	Department of Basic Education and WASH Committee. eThekwini Metropolitan	Conduct pre- and post-campaign assessments to evaluate changes in	% of students demonstrating improved hygiene

WASH Domain	Focus Area	Proposed Action	Responsible Entity	M&E Approach	Monitoring Indicator
		handwashing interactive hygiene education sessions using digital tools and guest speakers.	Municipality (Department of Health).	students' hygiene behaviour.	practices after hygiene campaign sessions.
	Handwashing Infrastructure and Access	Ensure accessibility of handwashing stations with soap and clean water.	Department of Basic Education and WASH Committee.	Conduct regular inspections of handwashing stations; monitor soap refills and water availability.	Number of functional handwashing stations per student ratio.
	Peer-Led Hygiene Promotion	Introduce hygiene champions or peer educators to promote consistent hygiene habits	Department of Basic Education and WASH Committee.	Observe peer-led hygiene promotion sessions; conduct feedback surveys with students.	Number of trained student hygiene champions per school Frequency of peer-led hygiene promotion sessions.
	Hygiene Behaviour Reinforcement	Use behavioural nudges such as posters, digital reminders, and peer-led initiatives to make hygiene a daily habit	Department of Basic Education and WASH Committee.	Evaluate the visibility and effectiveness of hygiene nudges	Number of hygiene reinforcement materials (posters, digital reminders) installed and active.

5.2.5 WASH Policy Implementation and Compliance Framework

This framework presents a structured approach for improving the implementation and enforcement of WASH-related policies in schools. Grounded in national standards and informed by international best-practices, it identifies key areas where regulatory action, institutional accountability and policy alignment are essential to achieve equitable access to safe WASH services across all school quintiles. It begins by outlining the foundational role of policy in WASH governance, followed by proposed mechanisms to enhance compliance and accountability within the school environment.

5.2.5.1 Role of Policy in Strengthening WASH Governance

Effective WASH service delivery in schools depends on well-defined policy frameworks, regulatory enforcement and systematic compliance monitoring. While national and international guidelines provide a foundation for setting WASH standards, inconsistent implementation and inadequate enforcement mechanisms have led to disparities in service provision, particularly in lower-quintile schools. Addressing these gaps requires a structured compliance framework that ensures policies are effectively translated into measurable improvements in school WASH conditions.

The alignment of WASH policies with the National Environmental Health Norms and Standards for Premise by the Department of Health (2015), WHO/UNICEF JMP service ladders UNICEF & WHO (2020) and SANS 241:2015 Drinking Water Quality Standards SABS (2015) is crucial to ensuring that schools meet the minimum health and safety requirements. However, ensuring universal compliance remains a challenge, particularly in tracking the functionality of WASH systems across different school quintiles.

This framework emphasizes school-based WASH management plans, water supply resilience, MHM and improved monitoring mechanisms to ensure that policies lead to tangible improvements. Aligning with WHO/UNICEF JMP service ladders for school WASH, the National Environmental Health Norms and Standards for

Premises and the adoption of WHO/UNICEF recommendations on MHM will ensure that national policies reflect global best practices. Strengthening institutional accountability, financial investment, and regular audits is essential for achieving sustainable WASH service delivery in schools to ensure that policies lead to tangible improvements. Strengthening institutional accountability, financial investment and regular audits is essential for achieving sustainable WASH service delivery in schools.

5.2.5.2 Strengthening Policy Compliance and Monitoring

For WASH policies to be effective, it is essential to establish clear accountability mechanisms, organized enforcement strategies, and dependable compliance indicators. Schools should be monitored against national WASH standards, with those failing to comply receiving targeted interventions. Developing school-specific WASH management plans can enhance governance, while investments in resilient water infrastructure ensure continuous WASH services during supply interruptions. Additionally, integrating MHM policies into school WASH programs supports gender-inclusive practices. This integration aligns with UNICEF guidance on menstrual health and hygiene, emphasizing the need for policy cohesion across education, health and WASH sectors for systematic support in schools (UNICEF & WHO, 2024).

Regular monitoring and audits should track compliance with key WASH indicators, as highlighted in (UNICEF & WHO, 2020). Strengthening governance and accountability mechanisms, such as funding incentives and independent audits, can enhance enforcement and improve transparency in service delivery (Chandratreya, 2023). Performance evaluations should assess the percentage of schools meeting WASH standards and the effectiveness of management plans in sustaining improvements. Table 5.3 outlines key WASH policies, regulatory actions, responsible entities and compliance indicators. This framework provides a structured approach to aligning WASH strategies with legal frameworks while defining mechanisms to track implementation and impact.

Table 5.3: WASH Policy Implementation and Compliance Framework

Policy	Regulatory or Strategic Action	Responsible Entity	Indicator for Compliance
National WASH Policy	Implement uniform national WASH standards in line with National Environmental Health Norms and Standards, and WHO/UNICEF JMP service ladders.	Department of Basic Education	(%) of schools meeting the National Environmental Health Norms and Standards for WASH. (%) of schools classified as meeting the "Basic" service level for drinking WASH, as per WHO/UNICEF JMP service ladders.
School-based WASH Management Plans	Develop, adopt, and enforce school-specific WASH management plans aligning with national standards.	Department of Basic Education	(%) of schools with officially approved and operational WASH management plans
Water Supply Resilience	Establish resilient water backup systems ensuring continuous WASH services aligned to SANS 241 Drinking Water Quality Standards.	Department of Basic Education (Infrastructure Development). eThekwini Municipality (Water and Sanitation Department).	(%) of schools with functional backup water supply systems meeting drinking water quality standards
MHM Policy	• Ensure provision and accessibility of free sanitary products and suitable disposal facilities. • Adopt WHO/UNICEF recommendations on MHM, which advocate for policy integration within the education, health, and WASH sectors to ensure a systematic approach. • Provide adequate, private, and functional MHM-friendly sanitation facilities in schools.	Department of Basic Education. National Department of health	% of schools consistently providing sanitary products and appropriate disposal facilities. % of schools with private, functional MHM-friendly sanitation facilities. Number of schools implementing WHO/UNICEF MHM recommendations within education, health, and WASH policies.
WASH Monitoring & Audits	Conduct regular WASH compliance inspections based on WHO/UNICEF JMP Service Ladders for WASH in schools. • Quantitatively measure WASH outcomes against defined JMP service levels (Basic, Limited, No Service). • Ensure drinking water quality meets SANS 241 Drinking Water Quality Standards and sanitation/hygiene adequacy aligns with National Environmental Health Norms and Standards.	eThekwini Metropolitan Municipality (Department of Health).	% of schools meeting "Basic" JMP service level criteria for WASH. % distribution of schools across Basic, Limited, and No Service categories. • Frequency and % of schools inspected annually for WASH compliance.

5.2.6 Integration of Framework with Study Findings

The WASH Risk Reduction Framework was developed as a direct response to the empirical findings of this study, which highlighted significant deficiencies in school sanitation infrastructure, water security, governance and MHM. The study demonstrated that lower-quintile schools face severe sanitation deficits, while even higher-quintile schools struggle with inconsistent water supply and maintenance issues. Additionally, the absence of structured WASH governance mechanisms was identified as a major contributor to deteriorating hygiene conditions. These challenges underscore the need for a systematic, risk-based intervention strategy to ensure sustainable, equitable improvements in school WASH services.

Rather than presenting disparate, isolated interventions, the framework consolidates evidence-based solutions into an integrated, multi-level governance model. This approach ensures that policy interventions are not just reactive but preventive, addressing both immediate infrastructure needs and long-term systemic improvements in WASH management.

A key contribution of this framework is its emphasis on risk-informed decision-making. By classifying WASH challenges according to risk severity, exposure likelihood, and potential impact on student health, the framework allows for targeted, priority-driven interventions. This structured approach is particularly relevant in addressing infrastructure gaps in low-quintile schools, where resource constraints require a phased, high-impact investment strategy.

Furthermore, the framework advances policy implementation by bridging the gap between regulatory standards and actual practice. While national policies such as the National Environmental Health Norms and Standards for Premises provide WASH guidelines, gaps between standards and practice were evident at the school level, particularly in lower quintile schools (1-3), where there was no routine water quality monitoring. This was reflected in variable compliance and non-systematic monitoring within sampled schools. By integrating school-based WASH management plans, structured monitoring protocols, and independent audits, the framework strengthens institutional compliance, ensuring that WASH improvements are sustained beyond short-term interventions.

The framework also expands on global best-practices, aligning with WHO/UNICEF JMP service ladders and SANS 241 Drinking Water Quality Standards. However, it extends these frameworks to account for school-specific governance structures, ensuring that interventions are contextually relevant and adaptable to South African school environments.

In summary, the WASH Risk Reduction Framework translates the study findings into a structured action plan, offering a scalable, evidence-based solution for improving school WASH services. By integrating policy-driven enforcement mechanisms, targeted infrastructure investments and behaviour change strategies, the framework ensures that WASH service delivery is not only improved in the short- term but sustained over time through institutional resilience and accountability.

5.3 Chapter Summary

This chapter presented a critical discussion of the study findings, examining the Knowledge, attitudes and student awareness of wash and the multiple challenges affecting the provision of WASH in selected high schools in Durban. The analysis drew on survey responses from students and insights from focus group discussions with school personnel to explore infrastructure availability, hygiene practices and WASH-related management systems. Schools in lower quintiles were found to have significant deficits in water and sanitation infrastructure, such as inadequate access to functional toilets, insufficient handwashing stations and a lack of menstrual hygiene support. Even schools in higher quintiles experienced intermittent service disruptions and poor maintenance, pointing to systemic weaknesses across the education sector.

Informed by these findings, the chapter introduced a WASH Risk Reduction Framework developed to guide improvement efforts in school WASH conditions. The framework responds directly to the challenges observed and aligns with national regulations and international guidance for safe and equitable WASH provision in schools. It is organised into four interconnected phases: risk assessment; risk prioritisation; intervention planning; and monitoring and evaluation. Each phase addresses specific issues identified in the study, aiming to improve service delivery, accountability and sustainability.

The chapter further elaborated on six key domains of WASH risk, namely infrastructure availability, water quality, management practices, menstrual hygiene, sanitation conditions, and hygiene knowledge and behaviour. Within each domain, detailed challenges were identified alongside contributing factors and practical interventions. These strategies promote a multi-stakeholder approach that includes school management teams, municipal officials and community partners to ensure coordinated, inclusive responses tailored to school-specific contexts.

In summary, this chapter progressed from an analysis of school-level WASH challenges to the design of a structured, evidence-informed framework. The WASH Risk Reduction Framework offers a practical tool to support schools and stakeholders in improving WASH provision. It also lays the groundwork for ongoing monitoring and policy alignment, contributing to safer, more equitable school environments and improved learner well-being.

CHAPTER 6: STUDY SUMMARY, CONCLUSION, AND RECOMMENDATIONS

6.1 Introduction

This study investigated the provision and challenges of WASH services across 40 high schools in Durban, categorized by different quintiles. Insights were gathered from focus group discussions with school personnel, a WASH infrastructure checklist, student hygiene surveys and microbiological analyses of drinking water. The findings reveal significant differences in access to WASH services across school quintiles, with schools in lower quintiles facing more serious challenges than those in higher quintiles. These challenges arise from structural, infrastructural and governance related issues that affect the daily functioning of WASH services in schools. Inadequate and unreliable WASH provision compromises learners' health, dignity and ability to fully engage in educational activities (UNICEF & WHO, 2020).

The current chapter also explores the broader implications of these findings in relation to SDG 6, which focuses on access to clean water and sanitation for all (UN, 2015). The study shows that many schools, especially those in disadvantaged communities, fall short of this target due to limited resources and weak support systems. The gaps identified highlight the importance of strengthening WASH planning, budgeting and monitoring within the Education sector. Addressing these challenges is essential for creating safe and supportive learning environments that protect learners' health and uphold their right to education (WHO, 2018).

In addition to presenting the main conclusions of the study, this chapter reflects on how factors such as infrastructure, hygiene behaviour and school-level management have influenced WASH service delivery, based on the findings of the study. Understanding how these elements interact is important for identifying practical solutions that are relevant to schools across different quintiles. The chapter also outlines key recommendations for the education department, school authorities and public health stakeholders to support the improvement and sustainability of WASH services in schools. These recommendations are based on the challenges identified during the study and respond to the practical needs of school communities.

The final section presents actionable recommendations and directions for future research based on the empirical evidence. These include targeted strategies for policymakers, school administrators and public health stakeholders to improve the design, implementation and monitoring of school WASH interventions. Special attention is given to the WASH Risk Reduction Framework, which offers a context-specific model for addressing the identified challenges. Together, the components of this chapter provide a roadmap for building safer, healthier and more equitable school environments through comprehensive WASH provision.

6.2 Summary of the Key Findings Based on Study Objectives and Novelty of the Study

Objective 1: To determine the students' KAP about WASH, as well as the incidence and prevalence of WASH-related diseases

The findings indicated that students possessed basic hygiene knowledge and generally positive attitudes towards WASH. However, significant environmental and infrastructural barriers, such as non-functional handwashing stations, unreliable water supply and a lack of soap, hindered the effective translation of this knowledge into practice. While WASH-related illnesses, including gastrointestinal and skin diseases, were reported amongst students, these cannot be directly attributed to school WASH conditions alone. Instead, they highlight a critical need for robust preventive measures and effective hygiene practices to control the spread of infections from various sources, including those within the school environment.

This study reveals a clear "knowledge-behaviour gap" and provides new empirical evidence within the Durban high school context, illustrating that student KAP is critically constrained by infrastructural deficits. This contribution is significant as it identifies the infrastructural barriers affecting hygiene practices and emphasizes the necessity for concurrent infrastructure investment and behaviour change communication. By illuminating the interplay between knowledge, attitudes and infrastructural conditions, the study enriches the understanding of WASH challenges in educational settings and offers actionable insights for policymakers and educators.

Objective 2: To examine the state of WASH at each of the selected school, including MHM

The findings revealed widespread deficiencies in WASH infrastructure, particularly in lower-quintile schools, where clean and functional toilets, handwashing stations and reliable water supply were lacking. Notably, these deficiencies were not confined to the lowest quintile, even higher-quintile schools experienced intermittent water supply issues and inadequate facilities.

This study provides a differentiated infrastructure profile across quintiles, challenging the assumption that only the poorest schools face WASH constraints. While MHM facilities were compromised due to insufficient private spaces, sanitary bins and access to water, the broader implications of these inadequacies extend to all students. This contribution is crucial as it explicitly documents the link between inadequate WASH infrastructure and overall student well-being, reinforcing the call for gender-sensitive and inclusive WASH solutions essential for fostering educational equity across all school environments.

Objective 3: To determine the quality of water in terms of *E. coli* and prevalence of virulence genes in all diarrhoeagenic *E. coli* (DEC) strains isolated in drinking water

The study found that while water generally met safety standards during regular supply periods, some samples detected *E. coli*, indicating episodic faecal contamination linked to infrastructural degradation and poor sanitation. Notably, no virulence genes for diarrhoeagenic *E. coli* strains were found, suggesting a low prevalence of acute pathogens. However, the lack of routine monitoring meant that episodic contamination often went unnoticed, posing significant health risks.

This study contributes groundbreaking microbiological evidence of the risks associated with intermittent water supply, highlighting the necessity for regular monitoring to ensure safety. It underscores the critical gap between compliance with safety standards and actual water quality, emphasizing that routine assessments are essential for safeguarding public health in school settings.

Objective 4: To assess the microbiological risks associated with each school's drinking water quality through a QMRA, informing interventions to improve WASH provision

The QMRA findings revealed that under intermittent supply and single-hit model assumptions, the annual infection risk approached 100% in maximum infectivity scenarios, particularly in lower-quintile schools where infrastructure was weakest. These estimates explicitly highlight the health consequences of unreliable water systems, transforming engineering reliability into a decision-relevant risk metric.

This study's novel contribution lies in its policy-ready translation of water supply intermittency into quantifiable health risks. By providing a framework that equips planners with transparent, scenario-based bounds for prioritizing resilience investments and interim protective measures, it enables informed decision-making. This analysis underscores the urgent need for targeted interventions in educational settings and offers actionable insights to guide resource allocation and operational targets, addressing the critical health vulnerabilities faced by students in disadvantaged areas.

Objective 5: To compare and contrast WASH status and conditions at different school quintiles

The findings revealed clear disparities in WASH conditions across school quintiles, with lower-quintile schools experiencing the greatest infrastructural and operational challenges. Schools in Quintiles 1 to 3 were more likely to report inadequate sanitation facilities, non-functional handwashing stations and inconsistent water supply, whereas higher-quintile schools generally demonstrated better infrastructure provision and maintenance. However, the study also revealed that WASH challenges such as intermittent municipal water supply and inadequate hygiene education programmes, were not limited to lower-quintile schools and occasionally affected higher-quintile institutions as well.

This comparative analysis provides empirical evidence that socio-economic inequalities significantly influence the availability and functionality of WASH services within schools. By systematically examining variations across quintiles, the study contributes to a deeper understanding of how infrastructural investment, governance capacity and resource allocation shape WASH outcomes in educational settings. These findings highlight the need for targeted policy interventions and resource prioritisation to address the disproportionate burden experienced by schools serving disadvantaged communities.

Objective 6: To develop a risk reduction framework that facilitates the adequate provision of WASH in schools

Based on the findings, this study developed an evidence-based WASH Risk Reduction Framework that integrates infrastructural, behavioural, and governance elements. The framework prioritises water supply reliability, sanitation maintenance, menstrual hygiene management, surveillance, and cross-sector collaboration to support sustainable improvements. By producing a context-specific and actionable framework tailored to the realities of Durban high schools, the study advances understanding of how evidence can be translated into practical interventions for educational settings. Importantly, the framework also offers adaptability to broader school contexts, providing a structured and policy-ready tool for strengthening WASH provision and accelerating progress toward SDG 6. The comprehensive mixed-methods approach utilised in this research provides a robust foundation for future interventions and reinforces the importance of addressing WASH inequities to achieve this global target.

6.3 Conclusions

This study examined WASH conditions in selected high schools in Durban through a comprehensive mixed-methods approach. The findings revealed significant disparities in WASH provision, highlighting the challenges faced by learners in lower-quintile schools compared to their higher-quintile counterparts. The comparative analysis demonstrated that schools in Quintiles 1 to 3 consistently experienced greater infrastructural deficits, including inadequate sanitation facilities, limited handwashing infrastructure and unreliable water supply, whereas schools in Quintiles 4 and 5 generally reported better facility availability and maintenance. These disparities were linked to infrastructural inadequacies, including unreliable water supply and insufficient sanitation facilities, which hindered access to safe WASH services. The assessment of students' KAP revealed a critical knowledge-behaviour gap, where despite awareness of hygiene principles, environmental limitations restricted effective practices. Furthermore, microbiological analyses indicated that intermittent water access and occasional contamination posed serious health risks, with the microbial risk assessment underscoring the potential for a 100% annual infection risk in vulnerable settings.

In conclusion, the systemic nature of WASH deficiencies in Durban high schools calls for an integrated approach that addresses not only infrastructural needs but also school management, hygiene promotion and policy enforcement. By investing in policy-driven strategies, strengthening routine monitoring and applying evidence-based solutions, stakeholders can ensure that all learners, regardless of socio-economic status, gain access to safe, reliable and sustainable WASH services. Such commitment is essential for advancing SDG 6 and for fostering healthier, more equitable learning environments across the education system. The evidence gathered in this study provides a solid foundation for developing a context-specific WASH Risk Reduction Framework aimed at fostering sustainable improvements and ensuring equitable access to safe WASH services for all students.

6.4 Study Recommendations

Addressing the challenges identified in this study requires a combination of policy-driven interventions, practical actions and future research to ensure the sustainability of WASH improvements in schools.

- **Policy Interventions:** There is an urgent need for increased investment in WASH infrastructure, particularly in lower-quintile schools where deficiencies are most pronounced. Government agencies should allocate dedicated budgets for upgrading water supply systems, sanitation facilities and menstrual hygiene infrastructure. Routine maintenance must be prioritized to prevent deterioration. Additionally, the Department of Basic Education should establish a national school WASH audit system to allow for annual assessments and rankings based on hygiene compliance, complemented by regular inspections from environmental health practitioners.

- **Integration into National Policies:** The WASH Risk Reduction Framework should be integrated into national school health policies, ensuring that schools develop structured WASH management plans aligned with national guidelines. Structured planning and monitoring are essential for effective WASH service delivery.
- **Practical Interventions**: Immediate actions should focus on remediating existing infrastructure deficiencies. Schools should collaborate with local municipalities and NGOs to repair and upgrade essential WASH facilities, including toilets and handwashing stations. Emergency hygiene kits with soap, sanitary products and disinfectants should be available in schools facing acute shortages.
- **Hygiene Education:** Enhancing hygiene education programs through peer-led campaigns, digital tools and school-wide initiatives is vital. Teachers and staff should receive training on best practices in WASH management and hygiene education.
- **MHM:** The Department of Basic Education should establish an MHM Support Programme to ensure that all schools provide free sanitary products and private disposal facilities. Incorporating private, gender-sensitive sanitation spaces into school infrastructure plans is essential for promoting dignity and safety.

6.4.1 Recommendations for Future Research

Building upon the foundational work of this study, the following strategic areas are recommended for future research and project implementation to enhance the effectiveness, relevance and sustainability of WASH interventions:

i. Longitudinal Impact Studies

Future studies should adopt a longitudinal approach to evaluate the long-term sustainability and impact of WASH interventions in school environments. Such research would be instrumental in monitoring infrastructure performance, hygiene behaviour trends and seasonal fluctuations in water supply. Capturing data over extended periods would allow for a more nuanced understanding of how interventions perform across different climatic conditions and educational cycles, thereby supporting adaptive management strategies.

ii. *Comparative Regional Studies*

It is important to undertake comparative research across varied geographic contexts, urban, peri-urban and rural schools within South Africa and beyond. This approach would help identify both shared and unique WASH challenges faced by different regions, facilitating the development of policy interventions that are sensitive to contextual disparities. Insights from such studies could help shape more inclusive and responsive national strategies for WASH in education.

iii. Context-Specific Intervention Models

Building on the Risk Abatement Plan developed in this study, future projects should prioritise the co-design and piloting of context-specific intervention models. These models should be developed in partnership with school communities, local health authorities and the Department of Education, thereby ensuring alignment with existing programmes and infrastructural constraints. Interventions must also account for socio-cultural norms and behavioural dynamics that influence WASH practices in school environments.

iv. Monitoring and Evaluation Frameworks

Future initiatives should embed rigorous monitoring and evaluation (M&E) frameworks from inception. Drawing from the M&E approach conceptualised in this study, future projects should integrate both process indicators (for example, resource deployment, stakeholder involvement) and outcome indicators (for example, reduction in WASH-related illness, improved hygiene behaviours). These frameworks would support continuous learning, allow for mid-course corrections and promote accountability.

v. Verification of Reported Health Outcomes

Future studies should consider verifying WASH-related illnesses reported by students through medical or clinic records to improve the reliability and accuracy of health outcome data associated with school WASH conditions.

vi. Scaling and Replication of the WASH Risk Reduction Framework

There is considerable potential to adapt and scale the WASH Risk Reduction Framework developed in this study for use in other regions. Its participatory, risk-informed structure offers a replicable model for addressing WASH challenges in educational settings. Future work should evaluate the framework's applicability and effectiveness in diverse contexts and refine it for broader implementation. By addressing these research gaps, future work can ensure that school WASH interventions are not only evidence-based but also sustainable, equitable and responsive to both current and emerging challenges in public health and education.

References

Abdulhadi, R., Bailey, A., & Van Noorloos, F. (2024). Access inequalities to WASH and housing in slums in low- and middle-income countries (LMICs): A scoping review. *Global Public Health, 19*(1), 2369099. https://doi.org/110.1080/17441692.2024.2369099.

Abrams, A. L., Carden, K., Teta, C., & Wågsæther, K. (2021). Water, Sanitation, and Hygiene Vulnerability among Rural Areas and Small Towns in South Africa: Exploring the Role of Climate Change, Marginalization, and Inequality. *Water, 13*(20), 2810. https://doi.org/110.3390/w13202810.

Abuzerr, S. (2025). Challenges and Innovations in WASH and Disease Surveillance in Conflict Zones: Lessons from the Gaza Strip. *Intech Open,* 1–20 https://doi.org/10.5772/intechopen.1008876.

Acheampong, A. O., Opoku, E. E. O., & Tetteh, G. K. (2024). Unveiling the effect of income inequality on safe drinking water, sanitation and hygiene (WASH): Does financial inclusion matter? *World Development,178, 106573. https://doi.org/178*10.1016/j.worlddev.2024.106573.

Achuo, E. D., & Asongu, S. A. (2024). The impact of public spending on water, sanitation and hygiene adoption: Governance thresholds for complementary policies. *International Social Science Journal*, 75(255), 27–60. https://doi.org/10.1111/issj.12535.

Adane, Y., Ambelu, A., Yenesew, M. A., Mekonnen, Y., & Kassahun, T. (2025). Effect of menstruation on school attendance of girls along with water, sanitation, and hygiene services in Northwest Ethiopia. *Pan African Medical Journal, 50, 28. https://doi.org/50*10.11604/pamj.2025.50.28.45413.

Addie, O. (2025). The Status of Water and Sanitation Facilities in Public Primary Schools in Oyo State, Nigeria: Progress toward Achieving the SDG

6. *Environmental Health Insights*, *19*, 11786302251332045. https://doi.org/10.1177/11786302251332045.

Adugna, D. (2023). Challenges of sanitation in developing counties - Evidenced from a study of fourteen towns, Ethiopia. *Heliyon, 9*(1), https://doi.org/10.1016/j.heliyon.2023.e12932.

Agyei -Sarpong, K., & Agyei-Sarpong, K. (2025). Examining Socio-Economic and Parental Influences on Menstrual Hygiene Practices and Knowledge Accuracy: Implications for Counselling, Policy and Education. *International Journal of Research and Innovation in Applied Science, X*(I), 482. https://doi.org/10.51584/ijrias.2025.1001038.

Ahiabor, W. K., & Donkor, E. S. (2025). Microbial Safety of Sachet Water in Ghana: A Systematic Review. *Environmental Health Insights, 19*, https://doi.org/10.1177/11786302241307830.

Ahmed, J., Wong, L. P., Chua, Y. P., Hydrie, M. Z. I., & Channa, N. (2021). Drinking water, sanitation, and hygiene (WASH) situation in primary schools of Pakistan: the impact of WASH-related interventions and policy on children school performance. *Environmental Science and Pollution Research, 29*(1), 1259. https://doi.org/10.1007/s11356-021-15681-w.

Ahmed, Z., Ahmed, M. N. Q., Hussain, A. H. M. B., Alam, R., Ambinakudige, S., Kamal, M. M., & Chowdhury, M. A. (2023). Do Socio-demographic Factors Influence Water-fetching Practices? Evidence from the Southwestern Coastal Region of Bangladesh. *Society &Amp; Natural Resources, 36*(12), 1491–1509. https://doi.org/10.1080/08941920.2023.2234872.

Akanzum, J., & Pienaah, C. K. A. (2023). Review of the effects of adequate sanitary facilities on the participation and performance of the school girl child in Ghana. *ISABB Journal of Health and Environmental Sciences, 8*(1), 1–14 https://doi.org/10.5897/isaab-jhe2021.0073.

Åkerman, E., Wängborg, A., Persson, M., Sörensdotter, R., & Klingberg-Allvin, M. (2024). Navigating menstrual stigma and norms: a qualitative study on young people's menstrual experiences and strategies for improving menstrual health. *BMC Public Health*, 24(1), 3401. https://doi.org/10.1186/s12889-024-20936-5.

Al-Hamawi, H., Davies, P. A., Mayouf, M., & Nikologianni, A. (2025). Sustainability of Water, Sanitation, and Hygiene (WASH) in Post-Emergency Contexts: A Conceptual Framework. *Water, 17*(2), 280. https://doi.org/10.3390/w17020280.

Ali, M., Shahreen, T., & Alam Sarker, R. (2024). Towards Climate-Resilient WASH Services: A Critical Evaluation of Bangladesh's Policy Landscape. *International Journal of Research and Scientific Innovation, XI*(XI), 121. https://doi.org/10.51244/ijrsi.2024.11110011.

Alkali, F. M. (2024). Menstrual Period Poverty And Sustainable Development Goals Assessment In Lapai Local Government AREA. *South East Political Science Review, 9*(2), 273–290.

Al-Mamum, M., Kalam, A., Karim, M. Z., Alam, M., & Khan, T. H. (2025). Menstrual hygiene management in flood-affected Bangladesh: addressing socio-cultural barriers, infrastructure gaps, and policy responses. *Frontiers in Public Health, 13*, 1–13. https://doi.org/10.3389/fpubh.2025.1538447.

Amatobi, D. A., & Agunwamba, J. C. (2022). Improved quantitative microbial risk assessment (QMRA) for drinking water sources in developing countries. *Applied Water Science*, *12*(3), 49. https://doi.org/10.1007/s13201-022-01569-8.

Amin, H. A. (2024). The sample size determination strategy in the simple random sampling design. *Tikrit Journal of Administrative and Economic Sciences*, *20*(68), 493–505. https://doi.org/10.25130/tjaes.20.68.2.26.

Andleeb, &., Gul Irsa, Rafiq, N., Ateeq-Ur-Rehman, M., Ansari, L., & Ehtisham Ilyas, M. (2025). Impact of Environmental Education on Knowledge and Hygiene Practices Among School Children in the Potohar Region: A Step Towards

Sustainable Environmental Change. *Journal of Asian Development Studies, 14*(1), 433–446. https://doi.org/10.62345/jads.2025.14.1.33.

Andrés, L., Joseph, G., & Rana, S. (2021). The Economic and Health Impacts of Inadequate Sanitation. In *Oxford research encyclopedia of environmental science*. https://doi.org/10.1093/acrefore/9780199389414.013.561.

Angelakis, A. N., Capodaglio, A. G., Passchier, C. W., Valipour, M., Krasilnikoff, J., Tzanakakis, V. A., ... & Dercas, N. (2023). Sustainability of Water, Sanitation, and Hygiene: From Prehistoric Times to the Present Times and the Future. *Water, 15*(8), 1614. https://doi.org/10.3390/w15081614.

Angelakis, A. N., & Zheng, X. Y. (2015). Evolution of Water Supply, Sanitation, Wastewater, and Stormwater Technologies Globally. *Water, 7*(2), 455. https://doi.org/10.3390/w7020455.

Anjimoon, S., R J, A., Singh, N., Parmar, A., Sharma, N., & Mohammad, Q. (2024). Comprehensive Review on Low-Cost, Solar-Powered Water Purification Technologies for Remote Areas. *E3S Web of Conferences, 505, 02005*. https://doi.org/1051/e3sconf/202450502005.

Anthonj, C., Stanglow, S. N., & Grunwald, N. (2024). Co-defining WASH (In)Security challenges among people experiencing homelessness. A qualitative study on the Human Right to Water and Sanitation from Bonn, Germany. *Social Science &Amp; Medicine, 342*10, 116561. https://doi.org/1016/j.socscimed.2024.116561.

Anthonj, C., Githinji, S., Höser, C., Stein, A., Blanford, J., & Grossi, V. (2021). Kenyan school book knowledge for water, sanitation, hygiene and health education interventions: Disconnect, integration or opportunities? *International Journal of Hygiene and Environmental Health, 235*, 113756. https://doi.org/1016/j.ijheh.2021.113756.

Antoniou, G., Kathijotes, N., Spyridakis, D. S., & Angelakis, A. N. (2014). Historical development of technologies for water resources management and rainwater harvesting in the Hellenic civilizations. *International Journal of Water Resources Development, 30*(4), 680. https://doi.org/10.1080/07900627.2014.900401.

Antoniou, G. P., De Feo, G., Fardin, F., Tamburrino, A., Khan, S., Tie, F., ... & Angelakis, A. N. (2016). Evolution of toilets worldwide through the millennia. *Sustainability, 8*(8), 779. https://doi.org/10.3390/su8080779.

Assefa, G. M., Stulz, V., Mengie, G., Atnafe, L., Gezahegn, W., Smet, E., & Muluneh, M. D. (2025). Assessing the effects of menstrual hygiene, water, and sanitation on girls' academic performances in public schools, Ethiopia. *Journal of Water, Sanitation and Hygiene for Development, 15*(3), 192. https://doi.org/10.2166/washdev.2025.233.

Atangana, E., & Oberholster, P. J. (2022). Assessment of water, sanitation, and hygiene target and theoretical modeling to determine sanitation success in sub-Saharan Africa. *Environment, Development and Sustainability, 25*(11), 13353. https://doi.org/10.1007/s10668-022-02620-z.

Aydamo, A. A., Gari, S. R., & Mereta, S. T. (2023). Access to Drinking Water, Sanitation, and Hand Hygiene Facilities in the Peri-Urban and Informal Settlements of Hosanna Town, Southern Ethiopia. *Environmental Health Insights, 17*, https://doi.org/1177/11786302231193604.

Ayelazuno, R. A., & Tetteh, S. (2025). Sanitation struggles and public health concerns in Ghana: insights from Sodom and Gomorrah slum. *SN Social Sciences, 5*(4), 10. https://doi.org/10.1007/s43545-025-01063-3.

Ayembilla, D., Musa, A., Ayanwale, & Musa. (2024). Quality Education in Second Cycle Institutions: The Role of the Private Sector. *Journal of Education and Practice, 8*(4), https://doi.org/10.7176/jep/10-9-17.

Azupogo, U. W., Dassah, E., & Bisung, E. (2023). Promoting safe and inclusive water and sanitation services for students with physical disabilities in primary schools:

a concept mapping study in Ghana. *Journal of Water, Sanitation and Hygiene for Development, 13*(6), 453. https://doi.org/10.2166/washdev.2023.029.

Azupogo, U. W., Dassah, E., & Bisung, E. (2025). Navigating water and sanitation environments in schools: Exploring health risk perceptions of children with physical disabilities using drawing. *Wellbeing, Space and Society*, *8*, 100255. https://doi.org/10.1016/j.wss.2025.100255.

Bailey, E. S., Beetsch, N., Wait, D. A., Oza, H. H., Ronnie, N., & Sobsey, M. D. (2021). Methods, Protocols, Guidance and Standards for Performance Evaluation for Point-of-Use Water Treatment Technologies: History, Current Status, Future Needs and Directions. *Water, 13*(8), 1094. https://doi.org/10.3390/w13081094.

Barrett, C. A., Sleesman, D. J., & Amin, T. (2024). A Mixed Methods Examination of Decision-Making During Program Exploration and Implementation in Schools. *Prevention Science, 25*(3), 459. https://doi.org/10.1007/s11121-024-01655-0.

Barrington, D. J., Sindall, R. C., Chinyama, A., Morse, T., Sule, M. N., Beale, J., ... & Evans, B. E. (2025). The persistence of failure in water, sanitation and hygiene programming: a qualitative study. *BMJ Global Health*, *10*(2). https://doi.org/10.1136/bmjgh-2024-016354.

Barros Leal Farias, D. (2024). Unpacking the 'developing'country classification: origins and hierarchies. *Review of International Political Economy*, *31*(2), 651-673. https://doi.org/10.1080/09692290.2023.2246975.

Basit, A., Antu, O. S., Mithun, M., & Islam, M. S. (2025). Navigating the currents: understanding awareness, attitudes, and menstrual hygiene management challenges in Bangladesh's Haor Region. *Journal of Biosocial Science, 57*(1), 128. https://doi.org/10.1017/s0021932024000415.

Bazaanah, P., & Mothapo, R. A. (2023). Sustainability of drinking water and sanitation delivery systems in rural communities of the Lepelle Nkumpi Local Municipality, South Africa. *Environment, development and sustainability*, 1. https://doi.org/10.1007/s10668-023-03190-4.

Bennett, C., Khangura, S., Brehaut, J. C., Graham, I. D., Moher, D., Potter, B. K., & Grimshaw, J. M. (2011). Reporting guidelines for survey research: An analysis of published guidance and reporting practices. *PLoS Medicine*, *8*(8), e1001069. https://doi.org/10.1371/journal.pmed.1001069.

Betsu, B. D., Medhanyie, A. A., Gebrehiwet, T. G., & Wall, L. L. (2023). “Menstruation is a fearful thing”: a qualitative exploration of menstrual experiences and sources of information about menstruation among adolescent schoolgirls. *International Journal of Women's Health*, 881-892. https://doi.org/0.2147/ijwh.s407455.

Betsu, B. D., Medhanyie, A. A., Gebrehiwet, T. G., & Wall, L. L. (2024). Menstrual hygiene management interventions and their effects on schoolgirls’ menstrual hygiene experiences in low and middle countries: A systematic review. *Plos one*, *19*(8), e0302523. *https://doi.org/*10.1371/journal.pone.0302523.

Bhakta, A., Mansuri, A., Jaiswal, J., & Iyer, M. (2024). The need of the hour: Providing water in shared toilet facilities for menstrual hygiene management in urban India. *Journal of Water, Sanitation and Hygiene for Development, 14*(2), 113. https://doi.org/10.2166/washdev.2024.265.

Bick, S., Ezezew, A., Opondo, C., Leurent, B., Argaw, W., Hunter, E. C., ... & Dreibelbis, R. (2024). Impact of a school-based water and hygiene intervention on child health and school attendance in Addis Ababa, Ethiopia: a cluster-randomised controlled trial. *BMC Medicine, 22*(1), 348. https://doi.org/10.1186/s12916-024-03558-x.

Bick, S., Davies, K., Mwenge, M., MacLeod, C., Braun, L., Chipungu, J., ... & Dreibelbis, R. (2025). WASH and learn: a scoping review of health, education and gender equity outcomes of school-based water, sanitation and hygiene in low-income and middle-income countries. *BMJ global health*, *10*(5). https://doi:10.1136/ bmjgh-2024-018059.

Bishoge, O. K. (2021). Challenges facing sustainable water supply, sanitation and hygiene achievement in urban areas in sub-Saharan Africa. *Local Environment*, *26*(7), 893-907. https://doi.org/10.1080/13549839.2021.1931074.

Biswas, S., Adhikary, M., Alam, A., Islam, N., & Roy, R. (2024). Disparities in access to water, sanitation, and hygiene (WASH) services and the status of SDG-6 implementation across districts and states in India. *Heliyon,10(18),* *https://doi.org/10*(18)10.1016/j.heliyon.2024.e37646.

Blake, S. C., Hopper, K. J., Nguyen, A. M., Maroko, A. R., Wyss, N., Sugita, E., ... & Sommer, M. (2025). When the basic seems like a luxury: Menstrual friendly public toilets in six cities. *Health & Place*, *93*, 103436. https://doi.org/1016/j.healthplace.2025.103436.

Blose, S. (2024). Influence of school contexts on leadership practices: Putting deputy principals under the microscope. *Sage Open*, *14*(1), 21582440241237875. https://doi.org/10.1177/21582440241237875.

Bolatova, Z., Tussupova, K., Toleubekov, B., Sukhanberdiyev, K., Sharapatova, K., & Stafström, M. (2021). Challenges of Access to WASH in Schools in Low- and Middle-Income Countries: Case Study from Rural Central Kazakhstan. *International Journal of Environmental Research and Public Health, 18*(18), 9652. https://doi.org/10.3390/ijerph18189652.

Borah, G. (2025). Urban Water Stress: Climate Change Implications for Water Supply in Cities. *Water Conservation Science and Engineering, 10*(1), 20. https://doi.org/10.1007/s41101-025-00344-5.

Bourne, M. P., & Ahsan, K. Z. (2025). Parallel Plights in Advancing Menstrual Equity: A Scoping Review of Period Poverty in India and the United States. *Health Promotion Practice, https://doi.org/*10.1177/15248399241308901.

Burton, J., Patel, D., Landry, G., Anderson, S. M., & Rary, E. (2021). Failure of the "Gold Standard": The Role of a Mixed Methods Research Toolkit and Human-Centered Design in Transformative WASH. SAGE Publications. 15, 11786302211018391. https://doi.org/10.1177/11786302211018391.

Bute, J. B., Gupta, T. M., & Chinchodkar, K. N. (2023). Basic Water, Sanitation and Hygiene (WASH) practices among school adolescents of rural area, Indore: A comparative study. *Magna Scientia Advanced Research and Reviews, 8*(1), 173–181. https://doi.org/10.30574/msarr.2023.8.1.0059.

Buthelezi, S. S., Tshibalo, A. E., & Tshimbana, T. P. (2025). Evaluating the implementation of environmental education and waste awareness in Pinetown District schools, eThekwini Municipality, South Africa. *Discover Education*, 4, 301. https://doi.org/10.1007/s44217-025-00752-8

Byansi, J. Z., Semiyaga, S., Kansiime, F., & Kulabako, R. N. (2025). Factors enhancing operation and maintenance of sanitation facilities for improved service levels in Kampala Schools. *BMC Public Health, 25*(1), 562. https://doi.org/10.1186/s12889-025-21789-2.

Cairncross, S., Bartram, J., Cumming, O., & Brocklehurst, C. (2010). Hygiene, Sanitation, and Water: What Needs to Be Done? *PLoS Medicine, 7*(11), e1000365. https://doi.org/10.1371/journal.pmed.1000365.

Cavill, S., Francis, N., Grant, M., Huggett, C., Leahy, C., Leong, L., ... & Rankin, T. (2020). A call to action. *Waterlines*, *39*(2&3), 219–237. http://dx.doi.org/10.3362/1756-3488.20-00004.

Clements, E., van der Nagel, C., Crank, K., Hannoun, D., & Gerrity, D. (2025). Review of quantitative microbial risk assessments for potable water reuse. *Environmental Science: Water Research & Technology, 11*, 542–559. https://doi.org/10.1039/d4ew00661e.

Chandratreya, A. (2023). Financing Strategies for Water, Sanitation, And Hygiene (Wash) Initiatives: A Comprehensive Review. *Community Practitioner,* 20(10), 394–416. https://doi.org/0000-0001-9403-2094.

Chatterley, C., Slaymaker, T., Badloe, C., Nouvellon, A., Bain, R., & Johnston, R. (2018). Institutional WASH in the SDGs: data gaps and opportunities for national monitoring. *Journal of Water, Sanitation and Hygiene for Development, 8*(4), 595. https://doi.org/10.2166/washdev.2018.031.

Chidakwa, N., & Student, P. (2024). Menstrual Hygiene Management Among Vulnerable Rural Adolescent Schoolgirls in South Africa's Rural Learning Ecologies. *Futurity Education, 4*(3), 18–41. https://doi.org/10.57125/fed.2024.09.25.02.

Chirgwin, H., Cairncross, S., Zehra, D., & Sharma Waddington, H. (2021). Interventions promoting uptake of water, sanitation and hygiene (WASH) technologies in low- and middle-income countries: An evidence and gap map of effectiveness studies. *Campbell Systematic Reviews, 17*(4) https://doi.org/10.1002/cl2.1194.

Choudhuri, P., & Desai, S. (2021). Lack of access to clean fuel and piped water and children’s educational outcomes in rural India. *World Development, 145*10. https://doi.org/1016/j.worlddev.2021.105535.

Chouhan, S. N., Oledzka Nielsen, M., Singh, P., Manchikanti, S., Pandey, V., Walters, J. P., & Kadyan, K. (2022). A systems approach to improving access to water, sanitation, and hygiene (WASH) in schools in Odisha, India. *H2Open Journal, 5*(3), 396–411. https://doi.org/10.2166/h2oj.2022.044.

Crawfurd, L., Hares, S., & Todd, R. (2023). The Impact of Private Schools, School Chains and PPPs in Developing Countries. *The World Bank Research Observer, 39*(1), 97. https://doi.org/10.1093/wbro/lkad005.

Cronk, R., Guo, A., Fleming, L., & Bartram, J. (2020). Factors associated with water quality, sanitation, and hygiene in rural schools in 14 low- and middle-income countries. *Science of the Total Environment, 761*10. https://doi.org/1016/j.scitotenv.2020.144226.

Dakhode, S. U., Gaidhane, A. M., & Choudhari, S. G. (2022). Policy, programs, and activities for promotion of water, sanitation and hygiene practices in schools of India. *Journal of Family Medicine and Primary Care, 11*(8), 4310. https://doi.org/10.4103/jfmpc.jfmpc_2102_21.

Dalisay, S. N. M., Lumangaya, C. R., de Guzman, L. M. C., Leong, R. N. F., Siao, T. G., Leonardia, J. A., ... & Belizario, V. Y. (2024). A qualitative analysis of the implementation of the water, sanitation, and hygiene in schools program in the Philippines using the One Health lens. *International Journal of One Health*, *10*(1), 1-11. https://doi.org/10.14202/ijoh.2024.1-11.

Das, S., Khondakar, K. R., Mazumdar, H., Kaushik, A., & Mishra, Y. K. (2025). AI and IoT: Supported sixth generation sensing for water quality assessment to empower sustainable ecosystems. *ACS ES&T Water*, *5*(2), 490–510. https://doi.org/10.1021/acsestwater.4c00360.

Dassah, E., & Bisung, E. (2023). Access to water, sanitation and hygiene (WASH) for persons with disabilities in school settings: A call for research. *Disability & Society, 38*(5), 893–898. https://doi.org/10.1080/09687599.2023.2181770.

Davis, J., Macintyre, A., Odagiri, M., Suriastini, W., Cordova, A., Huggett, C., ... & Kennedy, E. (2018). Menstrual hygiene management and school absenteeism among adolescent students in Indonesia: evidence from a cross-sectional school-based survey. *Tropical Medicine &Amp; International Health, 23*(12), 1350–1363. https://doi.org/10.1111/tmi.13159.

De Feo, G., Antoniou, G., Fardin, H. F., El-Gohary, F., Zheng, X. Y., Reklaityte, I., ... & Angelakis, A. N. (2014). The historical development of sewers worldwide. *Sustainability*, *6*(6), 3936–3974. https://doi.org/10.3390/su6063936.

De Guzman, K., Stone, G., Yang, A. R., Schaffer, K. E., Lo, S., Kojok, R., ... & Kayser, G. L. (2023). Drinking water and the implications for gender equity and empowerment: A systematic review of qualitative and quantitative evidence. *International Journal of Hygiene and Environmental Health*, *247*, 114044. https://doi.org/1016/j.ijheh.2022.114044.

Delair, Z., Schoeman, M., Reyneke, B., Singh, A., & Barnard, T. G. (2024). Assessing the impact of *Escherichia coli* on recreational water safety using quantitative microbial risk assessment. *Journal of Water and Health, 22*(10), 1781–1792. https://doi.org/10.2166/wh.2024.081.

De Wit, S., Luseka, E., Bradley, D., Brown, J., Bhagwan, J., Evans, B., ... & Chandler, C. I. (2024). Water, sanitation and hygiene (WASH): the evolution of a global health and development sector. *BMJ global health*, *9*(10), e015367. https://doi.org/10.1136/bmjgh-2024-015367.

Dhoba, L. (2022). Strengthening water, sanitation and hygiene governance: a critical review of Zimbabwe's WASH sector institutional arrangements. *H2Open Journal, 5*(2), 248. https://doi.org/10.2166/h2oj.2022.063.

Dibaba, D. B., Alemu, B. M., & Debela, S. A. (2024). Impact of water, sanitation, and hygiene (WASH) interventions on gender-specific school attendance and learning outcomes: A systematic review and meta-analysis protocol. *PLoS One*, *19*(8), e0308144. https://doi.org/10.1371/journal.pone.0308144.

Dickin, S., & Gabrielsson, S. (2023). Inequalities in water, sanitation and hygiene: Challenges and opportunities for measurement and monitoring. *Water Security*, *20*, 100143. https://doi.org/1016/j.wasec.2023.100143.

Dimpor, J. J., Lucky, O. P., Kwarkye, D. F., Watts, S., Oguayo, C. P., Ojewole, C. O., & Kusi, J. (2024). Identifying spatiotemporal patterns and drivers of fecal indicator bacteria in an urban lake for water quality assessment and management. *Heliyon, 11*(1), https://doi.org/10.1016/j.heliyon.2024.e40955.

D'Mello-Guyett, L., Heylen, C., Rohm, E., Falconer, J., Lapegue, J., Dreibelbis, R., ... & Lantagne, D. (2024). Research priorities for water, sanitation and hygiene (WASH) in humanitarian crises: A global prioritisation exercise. *PLoS Water*, *3*(3), e0000217. https://doi.org/10.1371/journal.pwat.0000217.

Donde, O. O., Atoni, E., Muia, A. W., & Yillia, P. T. (2021). COVID-19 pandemic: Water, sanitation and hygiene (WASH) as a critical control measure remains a major challenge in low-income countries. *Water Research*, *191*, 116793. https://doi.org/1016/j.watres.2020.116793.

Donkor, F. K. (2021). Gendered Water, Sanitation, and Hygiene (WASH) equality: challenges and opportunities. *Clean Water and Sanitation*, 1–12. https://doi.org/10.1007/978-3-319-95846-0.

Dutta, A., Chakraborty, A., & Sarkar, O. (2024). Experiences of menstrual restrictions: Freedom lost and never regained. *International Journal of Educational Research Open*, *7*(1), 100347. https://doi.org/1016/j.ijedro.2024.100347.

Ejairu, U., Aderamo, A. T., Olisakwe, H. C., Esiri, A. E., Adanma, U. M., & Solomon, N. O. (2024). Eco-friendly wastewater treatment technologies (concept): Conceptualizing advanced, sustainable wastewater treatment designs for industrial and municipal applications. *Comprehensive Research and Reviews in Engineering and Technology,* *2*(1), 083–104. https://doi.org/10.57219/crret.2024.2.1.0063.

Ekolu, S. O., & Quainoo, H. (2019). Reliability of assessments in engineering education using Cronbach's alpha, KR and split-half methods. *Global journal of engineering education*, *21*(1), 24-29.

Evaristo, J., Jameel, Y., Tortajada, C., Wang, R. Y., Horne, J., Neukrug, H., ... & Biswas, A. (2023). Water woes: the institutional challenges in achieving SDG 6. *Sustainable Earth Reviews*, *6*(1), 13. https://doi.org/10.1186/s42055-023-00067-2.

Fabian, P. S., Kwon, H. H., Vithanage, M., & Lee, J. H. (2023). Modeling, challenges, and strategies for understanding impacts of climate extremes (droughts and floods) on water quality in Asia: A review. *Environmental Research*, *225*, 115617. https://doi.org/1016/j.envres.2023.115617.

Forro, R. D., & Besa, A. S. (2025). Water, Sanitation, And Hygiene In Schools Wins Program, Partners Commitment And Accomplishments Of Integrated Schools In Banga South Cotabato. https://doi.org/10.5281/zenodo.15130941.

Fouad, M. M., El-Gendy, A. S., Khalil, M. M. H., & Razek, T. M. A. (2021). Aluminum sulfate regeneration from surface water treatment waste in Cairo, Egypt. *Environmental Science and Pollution Research, 28*(43), 61450. https://doi.org/10.1007/s11356-021-15140-6.

Francis, J., Sachan, P., Waters, Z., Trapp, G., Pearce, N., Burns, S., ... & Cross, D. (2022). Gender-neutral toilets: A qualitative exploration of inclusive school environments for sexuality and gender diverse youth in Western Australia. *International Journal of Environmental Research and Public Health*, *19*(16), 10089. https://doi.org/10.3390/ijerph191610089.

Freeman, M. C., Ogden, S., Jacobson, J., Abbott, D., Addiss, D. G., Amnie, A. G., ... & Utzinger, J. (2013). Integration of water, sanitation, and hygiene for the prevention and control of neglected tropical diseases: a rationale for inter-sectoral collaboration. *PLoS neglected tropical diseases*, *7*(9), e2439. https://doi.org/10.1371/journal.pntd.0002439.

Gaiffe, M., Dross, C., Malembaka, E. B., Ross, I., Cumming, O., & Gallandat, K. (2023). A fuzzy inference-based index for piped water supply service quality in a complex, low-income urban setting. *Water research*, *243*, 120316. https://doi.org/1016/j.watres.2023.120316.

Gallandat, K., Hutchins, C., Malembaka, E. B., Jeandron, A., Saidi, J. M., Rumedeka, B. B., ... & Cumming, O. (2024). Process evaluation of an urban piped water supply infrastructure improvement programme in Uvira, Democratic Republic of the

Congo. *PLOS Water*, *3*(10), e0000185. https://doi.org/10.1371/journal.pwat.0000185.

Gallardo-Albarrán, D. (2024). The global sanitary revolution in historical perspective. *Journal of Economic Surveys, 39*(2), 567. https://doi.org/10.1111/joes.12607.

Garrison, F. H. (1929). The History of Drainage, Irrigation, Sewage-Disposal, and Water Supply. *Journal of Urban Health, V*(10), 887–938.

Gebremichael, S. G., Yismaw, E., Tsegaw, B. D., & Shibeshi, A. D. (2021). Determinants of water source use, quality of water, sanitation and hygiene perceptions among urban households in North-West Ethiopia: A cross-sectional study. *Plos one*, *16*(4), e0239502. https://doi.org/10.1371/journal.pone.0239502.

George-Williams, H. E. M., Hunt, D. V. L., & Rogers, C. D. F. (2024). Sustainable Water Infrastructure: Visions and Options for Sub-Saharan Africa. *Sustainability, 16*(4), 1592. https://doi.org/10.3390/su16041592.

Giné-Garriga, R., Delepiere, A., Ward, R., Alvarez-Sala, J., Alvarez-Murillo, I., Mariezcurrena, V., ... & Jiménez, A. (2021). COVID-19 water, sanitation, and hygiene response: Review of measures and initiatives adopted by governments, regulators, utilities, and other stakeholders in 84 countries. *Science of the Total Environment*, *795*, 148789. https://doi.org/1016/j.scitotenv.2021.148789.

Giné-Garriga, R., Flores-Baquero, Ó, Jiménez-Fdez De Palencia, A., & Pérez-Foguet, A. (2016). Monitoring sanitation and hygiene in the 2030 Agenda for Sustainable Development: A review through the lens of human rights. *Science of the Total Environment, 580*, 1108. https://doi.org/10.1016/j.scitotenv.2016.12.066.

Ginja, S., Gallagher, S., & Keenan, M. (2019). Water, sanitation and hygiene (WASH) behaviour change research: why an analysis of contingencies of reinforcement is needed. *International Journal of Environmental Health Research, 31*(6), 715. https://doi.org/10.1080/09603123.2019.1682127.

Girmay, A. M., Kenea, M. A., Mengesha, S. D., Wagari, B., Weldetinsae, A., Alemu, Z. A., ... & Tollera, G. (2023a). Level of JMP ladders for water, sanitation, and hygiene (WASH) services among healthcare facilities of Bishoftu Town, Ethiopia: An implication of healthcare-associated infection prevention status. *Journal of Water, Sanitation and Hygiene for Development*, *13*(6), 415-423. https://doi.org/10.2166/washdev.2023.230.

Girmay, A. M., Weldegebriel, M. G., Mengesha, S. D., Serte, M. G., Weldetinsae, A., Alemu, Z. A., ... & Tollera, G. (2023b). Factors influencing access to basic water, sanitation, and hygiene (WASH) services in schools of Bishoftu Town, Ethiopia: a cross-sectional study. *Discover Sustainability*, *4*(1), 5.https://doi.org/10.1007/s43621-023-00122-0.

Goshu, G., Koelmans, A. A., & de Klein, J. J. M. (2021). Performance of faecal indicator bacteria, microbial source tracking, and pollution risk mapping in tropical water. *Environmental Pollution*, *276*, 116693. https://doi.org/1016/j.envpol.2021.116693.

Gouge, D. H., Lame, M. L., Stock, T. W., Rose, L. F., Hurley, J. A., Lerman, D. L., ... & Green, T. A. (2023). Improving environmental health in schools. *Current Problems in Pediatric and Adolescent Health Care*, *53*(4), 101407. https://doi.org/10.1016/j.cppeds.2023.101407.

Grant, M. L., Nguyen, T. T., Vieira, A., Niner, S. L., & Roche, C. (2023). Working together: A study of civil society partnerships between WASH (water, sanitation, and hygiene) and GESI (gender equality and social inclusion) organisations in Timor-Leste. *Frontiers in Water,* 1–15. https://doi.org/10.3389/frwa.2023.1047955.

Gul, S., Fatima, B., & Akhtar, N. (2025). Gender Equality in Education: Addressing Structural Barriers and Social Norms Asian Context. *The Critical Review of Social Sciences Studies,* 3(1), 2839-2854. https://doi.org/10.59075/6bgnrq69.

Gwimbi, P., George, M., & Ramphalile, M. (2019). Bacterial contamination of drinking water sources in rural villages of Mohale Basin, Lesotho: exposures through neighbourhood sanitation and hygiene practices. *Environmental Health and Preventive Medicine, 24*(1), 33. https://doi.org/10.1186/s12199-019-0790-z.

Habtegiorgis, Y., Sisay, T., Kloos, H., Malede, A., Yalew, M., Arefaynie, M., ... & Adane, M. (2021). Menstrual hygiene practices among high school girls in urban areas in Northeastern Ethiopia: A neglected issue in water, sanitation, and hygiene research. *PloS one*, *16*(6), e0248825. https://doi.org/10.1371/journal.pone.0248825.

Habtu, Y., Kumie, A., Selamu, M., Harada, H., Kaneko, M., Kaba, M., & Girma, E. (2025). Perceptual link between inadequate water, sanitation, and hygiene (WASH) stressors and common mental symptoms in Ethiopian health workers: A qualitative study. *PloS one*, *20*(1), e0314170. https://doi.org/10.1371/journal.pone.0314170.

Hafeez, A., Shamair, Z., Shezad, N., Javed, F., Fazal, T., ur Rehman, S., ... & Rehman, F. (2021). Solar powered decentralized water systems: a cleaner solution of the industrial wastewater treatment and clean drinking water supply challenges. *Journal of Cleaner Production*, *289*, 125717. https://doi.org/1016/j.jclepro.2020.125717.

Hamilton, K. A., Harrison, J. C., Mitchell, J., Weir, M., Verhougstraete, M., Haas, C. N., Nejadhashemi, A. P., Libarkin, J., Aw, T. G., Bibby, K., Bivins, A., Brown, J., Dean, K., Dunbar, G., Eisenberg, J. N. S., Emelko, M., Gerrity, D., Gurian, P. L., Hartnett, E., … Rose, J. B. (2024). Research gaps and priorities for quantitative microbial risk assessment (QMRA). *Risk Analysis, 44*, 2521–2536. https://doi.org/10.1111/risa.14318.

Handayani, I. M., & Supriatna, N. (2024). Systematic Literature Review: Analysis Implementation of Water, Sanitation, and Hygiene (WASH) Programs in Elementary Schools. Paper presented at the *6th International Conference on*

Elementary Education, Universitas Pendidikan Indonesia. *6*(1) 206–214. https://proceedings.upi.edu/index.php/icee/article/view/3603.

Haque, S. S., & Freeman, M. C. (2021). The Applications of Implementation Science in Water, Sanitation, and Hygiene (WASH) Research and Practice. *Environmental Health Perspectives, 129*(6), 065002. https://doi.org/10.1289/ehp7762.

Hardigan, P. C., Popovici, I., & Carvajal, M. J. (2016). Response rate, response time, and economic costs of survey research: A randomized trial of practicing pharmacists. *Research in Social and Administrative Pharmacy, 12*(1), 141–148. https://doi.org/10.1016/j.sapharm.2015.07.003.

Head, A., Lim, M. S. C., Orozco, A., Dunstan, L., Kirwan, A., & Hennegan, J. (2025). "Basically, my answer is, there needs to be options!" Recommendations for the delivery of free menstrual products to the public: A qualitative exploration among marginalised groups in Victoria, Australia. *Australian and New Zealand Journal of Public Health, 49*(1), 100219. https://doi.org/10.1016/j.anzjph.2024.100219.

Herath, N., Duffield, C., & Zhang, L. (2022). Public-school infrastructure ageing and current challenges in maintenance. *Journal of Quality in Maintenance Engineering, 29*(2), 401. https://doi.org/10.1108/jqme-06-2021-0043.

Hlongwa, N., Nkomo, S. L., & Desai, S. A. (2024). Barriers to water, sanitation, and hygiene in Sub-Saharan Africa: a mini review. *Journal of Water, Sanitation and Hygiene for Development, 14*(7), 497. https://doi.org/10.2166/washdev.2024.266.

Howard, A. K., Holyfield-Moss, B., & S. Murty, K. (2022). Health Disparities for Rural Youth. *Journal of Public Health Issues and Practices, 6*(1), 1–6. https://doi.org/10.33790/jphip1100207.

Howard, G., Nijhawan, A., Flint, A., Baidya, M., Pregnolato, M., Ghimire, A., ... & Wondim, T. (2021). The how tough is WASH framework for assessing the climate resilience of water and sanitation. *NPJ Clean Water*, *4*(1), 39. https://doi.org/10.1038/s41545-021-00130-5.

Hussain, M. M., Iqbal, A., & Abbas, S. J. (2025). Water, Sanitation, Hygiene Facilities and Economic Well-Being: A Multilevel and Spatial Analysis in Punjab, Pakistan. *Journal of International Development*, *37*(2), 405–419. https://doi.org/10.1002/jid.3964. .

Hussein, J., Gobena, T., & Gashaw, T. (2022). The practice of menstrual hygiene management and associated factors among secondary school girls in eastern Ethiopia: The need for water, sanitation, and hygiene support. *Womens Health (Lond).18. https://doi.org/*10.1177/17455057221087871.

Hutton, G., & Chase, C. (2017). *Water Supply, Sanitation, and Hygiene*. The World Bank. https://doi.org/10.1596/978-1-4648-0522-6_ch9.

Ikogho, D. E., & Onoharigho, F. D. (2025). Menstrual waste management practices among female students in Niger delta development commission hostels in educational institutions in Niger delta, Nigeria. *BMC women's health, 25(1), 60.* https://doi.org/10.1186/s12905-025-03549-x.

Iqbal, M., Samiullah, M., & Aslam, S. (2023). Role of Nudges in Personal Hygiene Habits Among Early Graders. *Educational Research and Innovation (Eri), 3*(2), 130–137.

Islam, M. M. M., Bondelind, M., Bergion, V., & Sokolova, E. (2025). Changing climate and socio-economic conditions as part of quantitative microbial risk assessment of surface drinking water sources: A review. *Journal of Water and Health, 23*(4), 507–528. https://doi.org/10.2166/wh.2025.486.

Jafari, S., Naeeni, S. K., & Nouhi, N. (2024). Decision-Making Under Uncertainty: Lessons from Renewable Energy Sector Professionals. *Journal of Resource Management and Decision Engineering,* *3*(2), 32–40. https://doi.org/10.61838/kman.jrmde.3.2.5.

Jahan, F., Shuchi, N. S., Shoab, A. K., Alam, M. U., Bashar, S. M. K., Islam, K., ... & Rahman, M. (2024). Changes in the menstrual hygiene management facilities and usage among Bangladeshi school girls and its effect on school absenteeism from 2014 to 2018. *Global Health Action*, *17*(1), 2297512. https://doi.org/10.1080/16549716.2023.2297512.

Jahan, F., Shuchi, N. S., Yeamin, A., Sen, T., Shoab, A. K., Alam, M. U., ... & Rahman, M. (2025). Improving WASH facilities and practices in Bangladeshi schools: progress and challenges from 2014 to 2018. *Global Health Action*, *18*(1), 2466896. https://doi.org/10.1080/16549716.2025.2466896.

Jama, P., Buka, A. M., Naidoo, S., & Moloi, T. J. (2024). Exploring school support stakeholders' perceptions in identifying learning barriers: the case study of selected rural schools in the Eastern Cape. *Perspectives in Education, 42*(2), 171. https://doi.org/10.38140/pie.v42i2.7108.

Jasper, C., Le, T., & Bartram, J. (2012). Water and Sanitation in Schools: A Systematic Review of the Health and Educational Outcomes. *International Journal of Environmental Research and Public Health, 9*(8), 2772. https://doi.org/10.3390/ijerph9082772.

Jitu, H. I., & Masud, M. S. (2025). Demographic, socioeconomic and regional disparities in the coverage of water, sanitation and hygiene facilities in four South Asian Countries. *Plos One, 20*(3), e0319754. https://doi.org/10.1371/journal.pone.0319754.

Johannessen, Å, Rosemarin, A., Thomalla, F., Gerger Swartling, Å, Axel Stenström, T., & Vulturius, G. (2014). Strategies for building resilience to hazards in water, sanitation and hygiene (WASH) systems: The role of public private partnerships. *International Journal of Disaster Risk Reduction, 10*, 102. https://doi.org/10.1016/j.ijdrr.2014.07.002.

John, C. K., & Ajibade, F. O. (2024). Exploring the dynamics of WASH services: challenges, enablers, and strategies for improvement. *Discover Civil Engineering, 1*(1), https://doi.org/10.1007/s44290-024-00085-9.

Johnson, G., Espàrza, A., Stevenson, E., Stadler, L., Ensor, K., Williams, S., ... & Hopkins, L. (2025). Schools and Wastewater Surveillance: Practical Implications for an Emerging Technology to Impact Child Health. *Health Promotion Practice, 26*(1), 104–113. https://doi.org/10.1177/15248399231196857.

Jones, S. C., & Baldwin, M. K. (2025). Menstrual Health Education: School Health Curriculum Topics by Grade Level Recommended by Specialized Medical Professionals in Menstrual Health Clinics. *Journal of Pediatric and Adolescent Gynecology, 38*(1), 39. https://doi.org/10.1016/j.jpag.2024.09.003.

Jordanova, T., Cronk, R., Obando, W., Medina, O. Z., Kinoshita, R., & Bartram, J. (2015). Water, Sanitation, and Hygiene in Schools in Low Socio-Economic Regions in Nicaragua: A Cross-Sectional Survey. *International Journal of Environmental Research and Public Health, 12*(6), 6197. https://doi.org/10.3390/ijerph120606197.

Joshi, K., & Mendhe, D. (2025). Navigating Menstrual Health and Hygiene: Challenges and Solutions for Adolescent Girls. *Journal of Pharmacy and Bioallied Sciences,* 1, https://doi.org/0.4103/jpbs.jpbs_1637_24.

Joshi, P., Sharma, R., Jain, G., Kaur, G., & Jelly, P. (2024). Status, gaps and challenges in menstrual health in India: A systematic review. *Preventive Medicine: Research & Reviews*, 2(3), 129–137. https://doi.org/10.4103/PMRR.PMRR_74_24.

Kagurusi, P., Luyima, M., Comfort, H. M., Nagawa, E., Sematimba, I., Okar, A. E., & Nankanja, M. (2025). Impact of solar powered mini water systems on WASH service delivery among schools in Pader district, Uganda. *International Journal of Hygiene and Environmental Health, 266*, 114558. https://doi.org/10.1016/j.ijheh.2025.114558.

Kalbar, P. P., & Lokhande, S. (2023). Need to adopt scaled decentralized systems in the water infrastructure to achieve sustainability and build resilience. *Water Policy, 25*(4), 359. https://doi.org/10.2166/wp.2023.267.

Karim, M. R., Shariar, S., Rahadujjaman, M., Hasan, R., Islam, M. T., Faysal, A., ... & Khan, M. H. R. B. (2024). Evaluating water, sanitation, and hygiene in schools of Bangladesh: progress toward SDG compliance. *Journal of Water and Health*, *22*(10), 1942–1955. https://doi.org/10.2166/wh.2024.223.

Karon, A. J., Cronin, A. A., Cronk, R., & Hendrawan, R. (2017). Improving water, sanitation, and hygiene in schools in Indonesia: A cross-sectional assessment on sustaining infrastructural and behavioral interventions. *International Journal of Hygiene and Environmental Health, 220*(3), 539. https://doi.org/10.1016/j.ijheh.2017.02.001.

Kennedy-Shaffer, L., & Hughes, M. D. (2020). Sample size estimation for stratified individual and cluster randomized trials with binary outcomes. *Statistics in Medicine*, *39*(11), 1489–1513. https://doi.org/10.1002/sim.8492

Khan, A. W., Rasool, A., Awais, M., Altaf, M., Siddique, M., Bajwa, N., ... & Afzal, S. (2023). Water, Sanitation and Hygiene (WASH) in Schools of Asia. *Journal of Society of Prevention, Advocacy and Research KEMU, 2*(3), 203–214.

Khan, H. F. (2025). Why do some informal settlements fare better than others? A mixed-methods analysis of water and sanitation inequities across informal settlements. *Environmental Research: Infrastructure and Sustainability, 5*(1), 015014. https://doi.org/10.1088/2634-4505/adb453.

Khan, H., Anum, H., Yan, Z., & Chunjie, Q. (2024). Modernizing Rural Water Governance: A Systematic Review of Transitions, Dynamics, Influential Factors, and Challenges. *Water Resources Management, 39*(3), 979. https://doi.org/10.1007/s11269-024-04014-4.

Kim, J., Hagen, E., Muindi, Z., Mbonglou, G., & Laituri, M. (2022). An examination of water, sanitation, and hygiene (WASH) accessibility and opportunity in urban informal settlements during the COVID-19 pandemic: Evidence from Nairobi, Kenya. *Science of the Total Environment, 823*10. https://doi.org/1016/j.scitotenv.2022.153398.

Kirira, P., Oyatsi, F., Waudo, A., & Mbugua, S. (2023). Improving Access to Safe Water in Rural Schools of Kenya: Qualitative Multisectoral Insights. *Cureus,*15(11), https://doi.org/10.7759/cureus.49174.

Konteh, F. H. (2009). Urban sanitation and health in the developing world: Reminiscing the nineteenth century industrial nations. *Health &Amp; Place, 15*(1), 69. https://doi.org/10.1016/j.healthplace.2008.02.003.

Kothari, A., Phutane, V. S., Bajaj, S., Mukherjee, R., & Tawar, S. (2022). Impact of Health Education on Knowledge, Attitude and Practices Regarding Hand-Hygiene amongst School Children aged 10-12 Years in Pune: An Interventional Study. *Journal of Marine Medical Society, 25*(1), S36. https://doi.org/10.4103/jmms.jmms_81_22.

Koua, E. L., Moussana, F. H., Sodjinou, V. D., Kambale, F., Kimenyi, J. P., Diallo, S., ... & Gueye, A. S. (2025). Exploring the burden of cholera in the WHO African region: patterns and trends from 2000 to 2023 cholera outbreak data. *BMJ Global Health*, *10*(1). https://doi.org/10.1136/bmjgh-2024-016491.

Kouassi, H. A. A., Andrianisa, H. A., Traoré, M. B., Sossou, S. K., Momo Nguematio, R., Ymélé, S. S. S., & Ahossouhe, M. S. (2023). Review of the slippage factors from open defecation-free (ODF) status towards open defecation (OD) after the Community-Led Total Sanitation (CLTS) approach implementation. *International Journal of Hygiene and Environmental Health, 250*10. https://doi.org/1016/j.ijheh.2023.114160.

Kuandyk, U., Kazakhstan, Karaganda, G., & St. (2024). Strategies for enhancing hygiene culture among students in secondary educational institutions: A literature review. *Journal of Health Development, 4*(59), 29–36. https://doi.org/10.32921/2225-9929-2024-4-59-29-36.

Kuandyk, U., & Omarova, A. (2024). Strategies for enhancing hygiene culture among students in secondary educational institutions: A literature review. *Journal of Health Development, 4*(59), 29–36. https://doi.org/10.32921/2225-9929-2024-4-59-29-36.

Kucici, M. A., & Shettima, K. A. (2025). Addressing Water, Sanitation and Hygiene (Wash) Challenges in Yobe State. *International Journal of African Sustainable Development Research, 7*(2), 1–14. https://doi.org/10.70382/tijasdr.v07i2.016.

Kulkarni, T. (2020). The lucid dream of achieving equitable water distribution in India: A critique. *International Journal of Multidisciplinary Research and Growth Evaluation, 1*(4), 44. https://doi.org/10.54660/.ijmrge.2020.1.4.44-49.

Kumar, G. M., Chaturvedi, P., Rao, A. K., Vyas, M., Sethi, V. A., Swathi, B., & Jabbar, K. A. (2023). Flowing Futures: Innovations in WASH for Sustainable Water, Sanitation, and Hygiene. *E3S Web of Conferences, 453, 01040*. https://doi.org/1051/e3sconf/202345301040.

Kumar, P., Hasan, N., & Rajak, R. (2024). Socio-economic disparities in the utilization of improved sanitation facilities among Indian households. *Scientific Reports, 14*(1), 31659. https://doi.org/10.1038/s41598-024-80949-3.

Kurniati, E., Cahyo, F. T. F., & Romadona, F. (2025). Microbiological Quality of Packaged Tea Beverages Using the 3M Petrifilm Rapid *E. coli*/Coliform Count Plate. *Bioeksperimen: Jurnal Penelitian Biologi*, *11*(1), 9–15.

Kusumaningtiar, D. A., Veronika, E., Azteria, V., & Rendi Anggara, T. (2024). Water, Sanitation, and Hygiene in Indonesia School: Facilities and Infrastructure Availability. *Journal of Research and Health, 14*(03), 291. https://doi.org/10.32598/jrh.14.3.2255.2.

Libanda, B., Rand, E., Gyang, G. N., Sindano, C. T., Simwanza, L., & Chongo, M. (2024). Recent and future exposure of water, sanitation, and hygiene systems to climate-related hazards in Zambia. *Journal of Water and Climate Change, 15*(3), 958. https://doi.org/10.2166/wcc.2024.392.

MacArthur, J., Carrard, N., Mott, J., Raetz, S., Siscawati, M., & Willetts, J. (2023). Gender equality approaches in water, sanitation, and hygiene programs: Towards gender-transformative practice. *Frontiers in Water, 5*, 1–15. https://doi.org/10.3389/frwa.2023.1090002.

Madzivanyika, C., Utete, B., Mabvure, T. J., & Sango, I. (2026). Fiscal policies intertwined to public-private partnership investment in water and sanitation for achieving SDG 6: a systematic literature review. *Frontiers in Water*, *8*, 1703548. https://doi.org/10.3389/frwa.2026.1703548.

Magwe, E. A. (2025). Rural-Urban Disparities in Water, Sanitation, and Hygiene (WASH) Infrastructure in Primary and Secondary Schools: A Case of Iringa Region, Tanzania. *Afro-Egyptian Journal of Infectious and Endemic Diseases*, *15*(1), 36–47. https://doi.org/10.21608/aeji.2024.335372.1427.

Mahfuz, M. T., Sultana, F., Hunter, E. C., Jahan, F., Akand, F., Khan, S., ... & Winch, P. J. (2021). Teachers' perspective on implementation of menstrual hygiene management and puberty education in a pilot study in Bangladeshi schools. *Global health action*, *14*(1), 1955492. https://doi.org/10.1080/16549716.2021.1955492.

Manjong-Kofete, M. A., Yongabi, K. A., & Mbacham, W. F. (2021). Wash Practices in Schools, Cameroon. *European Journal of Medical and Health Sciences, 3*(1), 28. https://doi.org/10.24018/ejmed.2021.3.1.625.

Marsiati, H., Wuryanti, S., Hadi, R. S., Parwanto, E., Amalia, H., Digambiro, R. A., ... & Purnamasari, E. (2025). Community-Based Nutrition and Sanitation Education Using a Local Asset-Oriented Approach in Mandalamekar Village, Cimenyan

Sub-district. *ABDIMAS: Jurnal Pengabdian Masyarakat*, *8*(4), 1651-1665. https://doi.org/10.35568/abdimas.v8i4.7037.

Matte, T., Lane, K., Tipaldo, J. F., Barnes, J., Knowlton, K., Torem, E., ... & Yuan, A. (2024). *NPCC4: Climate change and New York City's health risk* 1539(1), 185–240). https://doi.org/10.1111/nyas.15115.

Matthews, S. (2018). School sanitation–returning dignity to South African schools. *Water Wheel*, 17(3), 26–29. https://hdl.handle.net/10520/EJC-f09bf6165.

Mcdonald, L. (2020). Florence Nightingale: The Making of a Hospital Reformer. *HERD: Health Environments Research &Amp; Design Journal, 13*(2), 25. https://doi.org/10.1177/1937586720918239.

Mchenga, J., Phuma-Ngaiyaye, E., & Kasulo, V. (2020). Do sanitation facilities in primary and secondary schools address Menstrual Hygiene needs? A study from Mzuzu City, Malawi. *Physics and Chemistry of the Earth, Parts A/B/C*, *115*, 102842. https://doi.org/1016/j.pce.2020.102842.

McMichael, C. (2019). Water, sanitation and hygiene (WASH) in schools in low-income countries: a review of evidence of impact. *International Journal of Environmental Research and Public Health, 16*(3), 359. https://doi.org/10.3390/ijerph16030359.

Mdhluli, S. K. (2025). The Implications of the Progression Policy and the Multiple Examination Opportunity Policy in Rural High Schools, South Africa. *Journal of African Education and Traditional Learning Systems*, 6(1), 47–69. https://doi.org/10.31920/2633-2930/2025/v6n1a3.

Mensah, J., Amoah, J. O., Mattah, P. A. D., & Mensah, A. (2022). Causes and effects of weak enforcement of environmental sanitation laws in Ghana. *Journal of Human Behavior in the Social Environment, 33*(5), 663. https://doi.org/10.1080/10911359.2022.2080146.

Method, A., Hassan, J., Assenga, O., Kamugisha, P., Kawishe, T., Luchagura, F., ... & Bintabara, D. (2024). Challenges faced by adolescent girls on menstrual hygiene management: School-based study, Siha, Kilimanjaro, Tanzania. *PLOS Global Public Health*, *4*(6), e0002842. https://doi.org/10.1371/journal.pgph.0002842.

Michael, S. L., Barnes, S. P., & Wilkins, N. J. (2023). Scoping Review of Family and Community Engagement Strategies Used in School-Based Interventions to Promote Healthy Behaviors. *Journal of School Health, 93*(9), 828. https://doi.org/10.1111/josh.13367.

Miiro, G., Rutakumwa, R., Nakiyingi-Miiro, J., Nakuya, K., Musoke, S., Namakula, J., ... & Weiss, H. A. (2018). Menstrual health and school absenteeism among adolescent girls in Uganda (MENISCUS): a feasibility study. *BMC women's health*, *18*(1), 4. https://doi.org/10.1186/s12905-017-0502-z.

Milgroom, M. G. (2023). The germ theory paradigm. In Biology of infectious disease: from molecules to ecosystems Cham: *Springer International Publishing*, 9–22.

Miller, T., Durlik, I., Kostecka, E., Kozlovska, P., Łobodzińska, A., Sokołowska, S., & Nowy, A. (2025). Integrating artificial intelligence agents with the internet of things for enhanced environmental monitoring: applications in water quality and climate data. *Electronics*, *14*(4), 696. https://doi.org/10.3390/electronics14040696.

Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies*, *4*(3), 1–78. https://doi.org/10.37745/bjmas.2022.0207.

Mo, J., & Morris, G. (2024). Investigating the employment motivation, job satisfaction, and dissatisfaction of international high school teachers in China: the impact of the COVID-19 pandemic. *Frontiers in Psychology*, *15*, 1271604. https://doi.org/10.3389/fpsyg.2024.1271604.

Moe, C. L., & Rheingans, R. D. (2006). Global challenges in water, sanitation and health. *Journal of water and health*, *4*(S1), 41–57. https://doi.org/10.2166/wh.2005.039.

Montgomery, M. A., & Elimelech, M. (2007). Water and sanitation in developing countries: including health in the equation. *Environmental science & technology*, 41(1), 17–24.

Msovela, J., Shija, A. E., Ntuyeko, H., Imeda, C., Mugula, A., Mgina, E., & Egidio, A. A. (2025). Puberty and menstruation knowledge, information sources and needs among secondary school adolescent girls and boys in Kibaha, Tanzania. *PLOS Global Public Health*, *5*(3), e0004176. https://doi.org/10.1371/journal.pgph.0004176.

Muktar, A. M., Saba, C. K. S., & Adzo, D. D. (2024). Knowledge, attitudes and practices (KAP) towards community-led total sanitation (CLTS) behaviours among communities in Northern Ghana. *Journal of Health and Environmental Research*, *10*(3), 65-77. https://doi.org/10.11648/j.jher.20241003.12.

Mulopo, C., & Chimbari, M. J. (2021). Water, sanitation, and hygiene for schistosomiasis prevention: a qualitative analysis of experiences of stakeholders in rural KwaZulu-Natal. *Journal of Water, Sanitation and Hygiene for Development, 11*(2), 255. https://doi.org/10.2166/washdev.2021.182.

Mumin, A. A., Mohammed, A. R., Issahaku, T., & Musah, B. I. (2024). How has community-led total sanitation (CLTS) affected open defecation in urban communities in the Tamale Metropolis?. *Environment, Development and Sustainability*, *26*(8), 21353–21368. https://doi.org/10.1007/s10668-023-03533-1.

Murei, A., Kamika, I., & Momba, M. N. B. (2023). Selection of a diagnostic tool for microbial water quality monitoring and management of faecal contamination of water sources in rural communities. *Science of the Total Environment, 906*10. https://doi.org/1016/j.scitotenv.2023.167484.

Mushota, O., Mathur, A., & Pathak, A. (2021). Effect of school-based educational water, sanitation, and hygiene intervention on student's knowledge in a resource-limited setting. *BMC Public Health*, *21*(1), 2258. https://doi.org/10.1186/s12889-021-12279-2.

Mustapha, A., Laniyan, T., Reigns, A., Birke, W., & Zawide, F. (2024). Pathway to equity in water, sanitation, and hygiene (WASH) in Africa: challenges and opportunities. *Environmental Epidemiology*, *8*(4), e315. https://doi.org/10.1097/EE9.0000000000000315.

Nabwera, H. M., Shah, V., Neville, R., Sosseh, F., Saidykhan, M., Faal, F., ... & Torondel, B. (2021). Menstrual hygiene management practices and associated health outcomes among school-going adolescents in rural Gambia. *PloS one*, *16*(2), e0247554. https://doi.org/10.1371/journal.pone.0247554.

Naz, L. H., Zafar, J. M., & Ullah, N. (2024). Effectiveness of Monitoring and Evaluation System in Improving Educational Facilities at Secondary School Level in Punjab (Pakistan). *Journal of Asian Development Studies, 13*(3), 175. https://doi.org/10.62345/jads.2024.13.3.15.

Naz, S., Hossain, M. Z., & Rahaman, K. R. (2025). Assessing the effectiveness of a rights-based approach for pro-poor WASH services: A study in urban poor settlements in Khulna, Bangladesh. *World Development Perspectives, 37*10. https://doi.org/1016/j.wdp.2025.100663.

Nelson, S., Drabarek, D., Jenkins, A., Negin, J., & Abimbola, S. (2021). How community participation in water and sanitation interventions impacts human health, WASH infrastructure and service longevity in low-income and middle-income countries: a realist review. *BMJ open*, 11(12), e053320. https://doi.org/10.1136/bmjopen-2021-053320.

Ngcongo, M. T., & Tekere, M. (2023). WASH and drinking water quality considerations in schools in reflection of the sustainable development goals – a review. *Journal of Water, Sanitation and Hygiene for Development, 13*(8), 566. https://doi.org/10.2166/washdev.2023.028.

Ngure, F. M., Reid, B. M., Humphrey, J. H., Mbuya, M. N., Pelto, G., & Stoltzfus, R. J. (2014). Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. *Annals of the New York Academy of Sciences, 1308*(1), 118. https://doi.org/10.1111/nyas.12330.

Nguyen, T. T., Rahut, D. B., Timilsina, R., Do, M. H., Sonobe, T., & Manchanda, N. (2025). Improving the health of the rural population in India through bundling WASH practices. *Frontiers in Health Services,* 510. https://doi.org/3389/frhs.2025.1500504.

Ngwenya, B. N., Thakadu, O. T., Phaladze, N. A., & Bolaane, B. (2018). Access to water and sanitation facilities in primary schools: A neglected educational crisis in Ngamiland district in Botswana. *Physics and Chemistry of the Earth, Parts A/B/C, 105*, 231. https://doi.org/10.1016/j.pce.2018.03.006.

Njee, R. M., Imeda, C. P., Ali, S. M., Mushi, A. K., Mbata, D. D., Kapala, A. W., ... & Malebo, H. M. (2024). Menstrual health and hygiene knowledge among post menarche adolescent school girls in urban and rural Tanzania. *PLoS One*, *19*(3), e0284072. https://doi.org/10.1371/journal.pone.0284072.

Nkonde, W., Furlong, C., Reed, B., & Brdanovic, D. (2025). Assessing institutional sanitation and its impact at a citywide level: an exploration of school sanitation in the Accra Metropolitan Area, Ghana. *Frontiers in Environmental Science*, *12*, 1473729. https://doi.org/10.3389/fenvs.2024.1473729.

Nunbogu, A. M., & Elliott, S. J. (2022). Characterizing gender-based violence in the context of water, sanitation, and hygiene: A scoping review of evidence in low- and middle-income countries. *Water Security*, *15*, 100113. https://doi.org/1016/j.wasec.2022.100113.

O'Brien, L. A., Files, K., Snyder, J. S., Rogers, H., Cumming, O., Mills, J. E., ... & Wolfe, M. K. (2025). Minimum material requirements for hand hygiene in community settings: A systematic review. *medRxiv*, 2025–03. https://doi.org/10.1101/2025.03.12.25323858.

Okesanya, O. J., Eshun, G., Ukoaka, B. M., Manirambona, E., Olabode, O. N., Adesola, R. O., ... & Chowdhury, A. A. (2024). Water, sanitation, and hygiene (WASH) practices in Africa: exploring the effects on public health and sustainable development plans. *Tropical medicine and health*, *52*(1), 68. https://doi.org/10.1186/s41182-024-00614-3.

Olatunji, R. W., & Taiwo, N. T. (2021). Availability And Adequacy Of Water, Sanitation And Hygiene (Wash) Facilities In Secondary Schools In Lagos State, Nigeria. *Journal of Environmental Science and Sustainable Development, 4*(2), 177–194. https://doi.org/10.7454/jessd.v4i2.1079.

Olson, M. M., Alhelou, N., Kavattur, P. S., Rountree, L., & Winkler, I. T. (2022). The persistent power of stigma: A critical review of policy initiatives to break the menstrual silence and advance menstrual literacy. *PLOS Global Public Health*, *2*(7), e0000070. https://doi.org/10.1371/journal.pgph.0000070.

Otieno, A., Mwangi, D., & Kariuki, P. (2024). Gender equality in education: Progress and barriers in secondary school enrollment. *International Journal of Educational Development*, *1*(1), 26–30. https://doi.org/10.61132/ijed.v1i1.125.

Palgunadi, N. P. G. S., Wesnawa, I. G. A., & Sudiana, I. K. (2024). I Bring Home My Used Menstrual Pad: Water, Sanitation, Hygiene, and Menstrual Hygiene Management in Middle Schools with Limited Sanitation Access. *Edunity: Social and Educational Studies, 3*(11), 1052–1063.

Palmares, A. J., Rongalirios, J. J., Santos, M., Siggaoat, M. J., Sucgang, P. L., Tipa, N. N., ... & Gellecanao, F. (2024). The Antibiotic Resistance Profile of Escherichia coli from Selected Estuaries in the City of Manila, Philippines. *Asian Journal of*

Water, Environment and Pollution, *21*(6), 15–22. https://doi.org/10.3233/AJW240068.

Panagiotou, C. F., Stefan, C., Papanastasiou, P., & Sprenger, C. (2023). Quantitative microbial risk assessment (QMRA) for setting health-based performance targets during soil aquifer treatment. *Environmental Science and Pollution Research, 30*, 14424–14438. https://doi.org/10.1007/s11356-022-22729-y.

Pereira, C. T., Sorlini, S., Sátiro, J., & Albuquerque, A. (2024). Water, Sanitation, and Hygiene (WASH) in Schools: A Catalyst for Upholding Human Rights to Water and Sanitation in Anápolis, Brazil. *Sustainability, 16*(13), 5361. https://doi.org/10.3390/su16135361.

Pereira, M. A., & Marques, R. C. (2021). Sustainable water and sanitation for all: are we there yet? *Water Research*, *207*, 117765. https://doi.org/1016/j.watres.2021.117765.

Pieters, M. M., Fahsen, N., Craig, C., McDavid, K., Ishida, K., Hug, C., ... & Lozier, M. J. (2025). Changes in Hand Hygiene Knowledge, Attitudes, and Practices Among Primary School Students: Insights from a Promotion Program in Guatemala. *International Journal of Environmental Research and Public Health*, *22*(3), 424. https://doi.org/10.3390/ijerph22030424.

Pietz, D. A., & Zeisler-Vralsted, D. (2021). Water and Human Societies Historical and Contemporary Perspectives. *Springer Nature*. https://doi.org/10.1007/978-3-030-67692-6.

Piper, J. D., Chandna, J., Allen, E., Linkman, K., Cumming, O., Prendergast, A. J., & Gladstone, M. J. (2017). Water, sanitation and hygiene (WASH) interventions: effects on child development in low- and middle-income countries. *Cochrane Database of Systematic Reviews, 2017*(3), https://doi.org/10.1002/14651858.cd012613.

Poague, K. I. H. M., Blanford, J. I., & Anthonj, C. (2022a). Water, Sanitation and Hygiene in Schools in Low- and Middle-Income Countries: A Systematic Review and Implications for the COVID-19 Pandemic. *International Journal of Environmental Research and Public Health, 19*(5), https://doi.org/10.3390/ijerph19053124.

Poague, K. I. H. M., Blanford, J. I., Martínez, J. A., & Anthonj, C. (2022b). Water, sanitation and hygiene (WASH) in schools in Brazil pre-and peri-COVID-19 pandemic: Are schools making any progress? *International Journal of Hygiene and Environmental Health, 247*, 114069. https://doi.org/1016/j.ijheh.2022.114069.

Poague, K. I. H. M., Blanford, J. I., Martínez, J. A., & Anthonj, C. (2024). Preparing schools for future pandemics: Insights on water, sanitation and hygiene solutions from the Brazilian school reopening policies. *International Journal of Hygiene and Environmental Health, 257,* 114325. https://doi.org/1016/j.ijheh.2024.114325.

Poague, K. I. H. M., Ramos, A. P., De S. Lopes, C. B., Gonçalves, G. V. L., Damasceno, M. B. R., …& Anthonj, C. (2025). WASH-friendly schools for whom? Integrating the perception of different school stakeholders in Brazil. *Social Science &Amp; Medicine, 367*10. https://doi.org/1016/j.socscimed.2025.117753.

Prasad, B. A. (2013). Urban Sanitation: Health Challenges of the Urban Poor. *Research Journal of Family, Community and Consumer Sciences, 1*(3), 1–6.

Prüss-Ustün, A., Wolf, J., Bartram, J., Clasen, T., Cumming, O., Freeman, M. C., ... & Johnston, R. (2019). Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: an updated analysis with a focus on low-and middle-income countries. *International journal of hygiene and environmental health*, *222*(5), 765–777. https://doi.org/10.1016/j.ijheh.2019.05.004.

Pu, C. J., Patel, P., Hornsby, G., Darmstadt, G. L., & Davis, J. (2022). Necessary conditions for sustainable water and sanitation service delivery in schools: A systematic review. *Plos One, 17*(7), e0270847. https://doi.org/10.1371/journal.pone.0270847.

Quon, H., & Jiang, S. (2024). Quantitative microbial risk assessment of antibiotic-resistant *E. coli*, *Legionella pneumophila*, and mycobacteria in nonpotable wastewater reuse applications. *Environmental Science & Technology, 58*, 12888–12898. https://doi.org/10.1021/acs.est.4c01690.

Radebe, L. C., Mokgobu, M. I., Molelekwa, G. F., & Mokoena, M. M. (2025). Assessment of the Status of Water, Sanitation and Hygiene (WASH) Services at Primary Schools in uMfolozi Local Municipality, Kwa-Zulu Natal, South Africa. *International Journal of Environmental Research and Public Health, 22*(3), 360. https://doi.org/10.3390/ijerph22030360.

Rahman, M., Alam, M. U., Luies, S. K., Ferdous, S., Mamun, Z., Rahman, M. J., ... & Ahmed, T. (2024). Institutional capacity assessment in the lens of implementation research: Capacity of the local institutions in delivering WASH services at Cox's Bazar district, Bangladesh. *Plos one*, 19(2), e0297000. https://doi.org/10.1371/journal.pone.0297000.

Rajapakse, J., Otoo, M., & Danso, G. (2023). Progress in delivering SDG6: Safe water and sanitation. *Cambridge Prisms: Water*, *1* (e6), 1–15. https://doi.org/10.1017/wat.2023.5

Rautanen, S. L., Luonsi, A., Nygard, H., Vuorinen, H. S., & Rajala, R. P. (2010). Sanitation, Water and Health. *Environment and History, 16*(2), 173. https://doi.org/10.3197/096734010X12699419057250.

Rhodes-Dicker, L., Brown, N. J., & Currell, M. (2025). Lessons learnt from the localisation of WASH programs for those most overlooked in Cambodia. *Development in Practice, 35*(3), 430–445. https://doi.org/10.1080/09614524.2025.2460912.

Riviwanto, M., Edwin, V. A., Dwiyanti, D., & Nindrea, R. D. (2026). Analysis Case Control Under-Sanitation and History of Infection Disease with Stunting in Climate-Vulnerable Areas in Indonesia: A Meta-Analysis. *Journal of Environmental Health*, *18*(1). https://doi10.20473/jkl.v18i1.2026.19-25.

Robinson, H. J., Barrington, D., Evans, B., Hutchings, P., & Narayanaswamy, L. (2024). An analysis of gender inclusion in Water, Sanitation and Hygiene (WASH) projects: Intention vs. reality. *Development Policy Review, 42*(2),1. https://doi.org/0.1111/dpr.12741.

Rose, I., Powell, L., King, A., Murray, C. C., Rasberry, C. N., Pampati, S., ... & Lee, S. (2025). Facilitators and barriers to implementing COVID-19 prevention strategies in K-12 public schools. *The Journal of School Nursing*, *41*(2), 246–257. https://doi.org/10.1177/10598405231191282.

Rosenthal, J., Arku, R. E., Baumgartner, J., Brown, J., Clasen, T., Eisenberg, J. N., ... & Yadama, G. N. (2020). Systems science approaches for global environmental health research: enhancing intervention design and implementation for household air pollution (HAP) and water, sanitation, and hygiene (WASH) programs. *Environmental Health Perspectives*, *128*(10), 105001. https://doi.org/10.1289/ehp7010.

Roux, F., Chih, H., Hendriks, J., & Burns, S. (2023). Mixed method evaluation of my vital cycles®: a holistic school-based ovulatory menstrual health literacy program. *International Journal of Environmental Research and Public Health*, *20*(11), 5964. https://doi.org/10.3390/ijerph20115964.

Royo, G. M., Parrott, E., Pacheco, E., Ahmed, I., Meilianda, E., Kumala, I., …& Parikh, P. (2022). A Structured Review of Emotional Barriers to WASH Provision for Schoolgirls Post-Disaster. *Sustainability, 14*(4), https://doi.org/10.3390/su14042471.

Salleh, N. A., Mohamad, M., Hubadillah, S. K., Ismail, N., Abdul Nasir, M. H., Abdul Nasir, A. S., & Abdul Aziz, N. S. A. (2025). Study of design elements of toilets for the visually impaired on the campus. *Environmental Quality Management*. https://doi.org/10.1002/tqem.70142.

Samia, A., & Azharia, J. (1999). From Clarifying Pearls and Gems to Water Coagulation with Alum. History, Surviving Practices, and Technical Assessment.*94*(4/6), 419–430. https://www.jstor.org/stable/40465012.

Sangalang, S. O., Medina, S. A. J., Ottong, Z. J., Lemence, A. L. G., Totanes, D., Valencia, J. C., ... & Kistemann, T. (2021). Protocol for a trial assessing the impacts of school-based WASH interventions on Children's Health Literacy, handwashing, and nutrition status in low-and middle-income countries. *International Journal of Environmental Research and Public Health*, 18(1), 226. https://doi.org/10.3390/ijerph18010226.

Sardar, A., & Behera, D. K. (2024). Wash Practices of School-Going Children in South Asia. *International Research Journal of Economics and Management Studies IRJEMS*, 3(1), https://doi.org/10.56472/25835238/IRJEMS-V3I1P128.

Satterthwaite, D. (2016). Missing the Millennium Development Goal targets for water and sanitation in urban areas. *Environment and Urbanization, 28*(1), 99. https://doi.org/10.1177/0956247816628435.

Schmitt, M. L., Hagstrom, C., Gruer, C., Nowara, A., Keeley, K., Adenu-Mensah, N. E., & Sommer, M. (2022). "Girls May Bleed Through Pads Because of Demerits": Adolescent Girls' Experiences with Menstruation and School Bathrooms in the U.S.A. *Journal of Adolescent Research, 39*(2), https://doi.org/10.1177/07435584221139342.

Schmitt, M. L., Wood, O. R., Clatworthy, D., Rashid, S. F., & Sommer, M. (2021). Innovative strategies for providing menstruation-supportive water, sanitation and hygiene (WASH) facilities: learning from refugee camps in Cox's bazar, Bangladesh. *Conflict and Health, 15*(1), https://doi.org/10.1186/s13031-021-00346-9.

Shah, V., Nabwera, H., Sonko, B., Bajo, F., Faal, F., Saidykhan, M., ... & Torondel, B. (2022). Effects of menstrual health and hygiene on school absenteeism and drop-out among adolescent girls in rural Gambia. *International journal of environmental research and public health*, *19*(6), 3337. https://doi.org/10.3390/ijerph19063337.

Shama, A. T., Terefa, D. R., Geta, E. T., Cheme, M. C., Biru, B., Feyisa, J. W., ... & Gebre, D. S. (2023). Latrine utilization and associated factors among districts implementing and not-implementing community-led total sanitation and hygiene in East Wollega, Western Ethiopia: A comparative cross-sectional study. *PLoS One*, *18*(7), e0288444. https://doi.org/10.1371/journal.pone.0288444.

Shanazarov, O. (2025). Improvement Of the Methodology for The Formation of a Health Culture in Primary School Students. *Educator Insights: A Journal of Teaching Theory and Practice, 1*(3), 629–643.

Shanmugasundaram, B. L., & Luthra, A. (2024). Between choice and sustainability: Navigating menstrual waste management in India through feminist political ecology and ecological modernization. *Journal of Cleaner Production, 483*10. https://doi.org/1016/j.jclepro.2024.144304.

Sharma, M. K., & Adhikari, R. (2022). Effect of School Water, Sanitation, and Hygiene on Health Status Among Basic Level Students' in Nepal. *Environmental Health Insights, 16*10. https://doi.org/1177/11786302221095030.

Sharma, M. K., Adhikari, R., Van Tejlingen, E., Devkota, B., & Khanal, S. P. (2024). Improved water, Sanitation and Hygiene Facilities at School and their effect on educational achievement in basic level students in Nepal. *International Journal of Health Promotion and Education,* 1–12. https://doi.org/10.1080/14635240.2024.2314459.

Sharma, S., Das, A., & Bhattacharya, S. P. (2025). Strengthening WASH resilience in flood-affected urban poor communities: Insights from Patna. *Cities, 159*10. https://doi.org/1016/j.cities.2025.105758.

Shayo, G. M., Elimbinzi, E., Shao, G. N., & Fabian, C. (2023). Severity of waterborne diseases in developing countries and the effectiveness of ceramic filters for improving water quality. *Bulletin of the National Research Centre, 47*(1), https://doi.org/10.1186/s42269-023-01088-9.

Shoab, A. K., Nasim, M. I., Sen, T., Jahan, F., Alam, M. U., Sarker, S., ... & Rahman, M. (2026). Great strides, yet a long way to go: a comparative analysis of WASH conditions and associated sociodemographic factors from national hygiene surveys, 2014 and 2018. *Global Health Action*, *19*(1), 2611646. https://doi.org/10.1080/16549716.2025.2611646.

Shomuyiwa, D. O., Odey, G. O., Ndep, A. O., Ekerin, O., Amesho, J. N., Luvindao, E., Manirambona, E., & Lucero-Prisno Iii, D. E. (2024). Transforming adolescent menstrual health through policy: the role of value added tax exemptions in improving access to sanitary products. *Global Health Research and Policy*, *9*(1), 19. https://doi.org/10.1186/s41256-024-00358-x.

Shrestha, A., Bhattarai, T. N., Acharya, G., Timalsina, H., Marks, S. J., Uprety, S., & Paudel, S. R. (2023). Water, Sanitation, and Hygiene of Nepal: Status, Challenges, and Opportunities. *American Chemical Society (ACS)*, *3*(6), 1429–1453. https://doi.org/10.1021/acsestwater.2c00303.

Shrestha, S., Thapa, S., Bucha, B., Kunwar, S., Subedi, B., Singh, A. R., Chapagain, D. D., Dhital, R., & Caws, M. (2025). Effectiveness of menstrual hygiene management training to enhance knowledge, attitude, and practice among adolescents in Sindhupalchowk, Nepal. *Plos one, 20(1), e0313422.* https://doi.org/10.1371/journal.pone.0313422.

Sidle, A. A., Suedi, A., Schwarz, H., Swai, M., Kafanabo, E., & Oulo, B. (2025). 'She has become Brave:' the role of menstrual health education in building girls' agency. *International Journal of Adolescence and Youth, 30*(1), https://doi.org/10.1080/02673843.2025.2467116.

Sifullah, M. K., Sohel, M. S., Jamil, S., Hasan, M. M., Anika, J., Swadhin, H. R., ... & Sohag, S. M. (2024). Assessment of water, hygiene, and sanitation practice and associated factors among Bihari refugee camp in Bangladesh: A cross-sectional study. *Health Science Reports*, *7*(2), e1910. https://doi.org/10.1002/hsr2.1910.

Sinharoy, S. S., Pittluck, R., & Clasen, T. (2019). Review of drivers and barriers of water and sanitation policies for urban informal settlements in low-income and middle-income countries. *Utilities Policy, 60*10. https://doi.org/1016/j.jup.2019.100957.

Skhosana, R. M. (2025). Harnessing local strengths: Asset-based community development and sustainable livelihoods in South Africa. *Inkanyiso*, *17*(1), 151. https://doi.org/10.4102/ink.v17i1.151.

Sravanthi, B., Singh, S. V., Rao, A. K., Vyas, M., Sethi, V. A., Anandhi, R. J., & Lafta, A. M. (2023). AquaLives: Navigating the Interplay of Water, Sanitation, and Hygiene for Global Health. *E3S Web of Conferences, 453*10. https://doi.org/1051/e3sconf/202345301041.

Ssekyanzi, G., Ahmad, M. J., & Choi, K. (2024). Sustainable Solutions for Mitigating Water Scarcity in Developing Countries: A Comprehensive Review of Innovative Rainwater Storage Systems. *Water, 16*(17), https://doi.org/10.3390/w16172394.

Stauber, C. E., Walters, A., De Aceituno, A., & Sobsey, M. D. (2013). Bacterial Contamination on Household Toys and Association with Water, Sanitation and Hygiene Conditions in Honduras. *International Journal of Environmental Research and Public Health, 10*(4), 1586. https://doi.org/10.3390/ijerph10041586.

Strand, M. (2018). Public Health as a Matter of Concern: Victorian England, 1834-1848. *Science, Technology, &Amp; Human Values, 44*(3), 399. https://doi.org/10.1177/0162243918800575.

Sugita, E. W. (2022). Water, Sanitation and Hygiene (WASH) in Japanese elementary schools: Current conditions and practices. *Pediatrics International, 64*(1), https://doi.org/10.1111/ped.15062.

Tadesse, G., Wuletaw, Y., Mekete, K., Sime, H., Yard, E., Appleby, L., ... & Drake, L. (2024). Investigating the effect of a school-based WASH intervention on soil-transmitted helminth and schistosome infections and nutritional status of school children in Ethiopia: a quasi-experimental study. *Parasites & Vectors*, *17*(1), 130. https://doi.org/10.1186/s13071-024-06155-2.

Tandoh, M. A., Owusu, P., Nkrumah, C. N., Annaful, V. T., Asare, C. Y., & Attu, S. S. (2025). Comparative Analysis of Hydration Status and Microbial Quality of Tap Water Between Urban and Rural Settings in the Ashanti Region of Ghana. *International Journal of Food Science*, 2025(1), 4773110. https://doi.org/10.1155/ijfo/4773110.

Thomas, C., & Melendez-torres, G. J. (2024). The experiences of menstruation in schools in high income countries: A systematic review and line-of-argument synthesis. *Psychology in the Schools, 61*(7), 2820. https://doi.org/10.1002/pits.23192.

Thurairasu, V. (2023). Menstrual Hygiene Management (MHM) and the Way Forward-A Brief Review. *European Journal of Medical and Health Sciences, 5*(1), 1. https://doi.org/10.24018/ejmed.2023.5.1.1629.

Tomes, N. (1990). The Private Side of Public Health: Sanitary Science, Domestic Hygiene, and the Germ Theory, 1870-1900. *Bulletin of the History of Medicine, 64*(4), 509–539. https://www.jstor.org/stable/44443182.

Tortajada, C., & Biswas, A. K. (2018). Achieving universal access to clean water and sanitation in an era of water scarcity: strengthening contributions from academia. *Current Opinion in Environmental Sustainability, 34*, 21. https://doi.org/10.1016/j.cosust.2018.08.001.

Tsekleves, E., Fonseca Braga, M., Abonge, C., Santana, M., Pickup, R., Yongabi Anchang, K., ... & Roy, M. (2022). Community engagement in water, sanitation and hygiene in sub-Saharan Africa: does it WASH? *Journal of Water, Sanitation and Hygiene for Development*, *12*(2), 143–156. https://doi.org/10.2166/washdev.2022.136.

Tumwebaze, I. K., Sseviiri, H., Bateganya, F. H., Twesige, J., Scott, R., Kayaga, S., ... & Howard, G. (2023). Access to and factors influencing drinking water and sanitation service levels in informal settlements: Evidence from Kampala, Uganda. *Habitat International*, *136*, 102829. https://doi.org/1016/j.habitatint.2023.102829.

UN. (2015). Resolution adopted by the General Assembly on 25 September 2015 A/RES/70/1.

UN. (2024). A/79/79-E/2024/54 General Assembly Economic and Social Council Progress towards the Sustainable Development Goals.

Underhill, H., Sylvester, R. E., & Meehan, K. (2025). Water, sanitation, and hygiene inequities in high-income countries: an introduction and agenda. *Journal of Water, Sanitation and Hygiene for Development, 15*(3), iii–xii. https://doi.org/10.2166/washdev.2025.001.

UNICEF. (2012). Raising even more clean hands: Advancing health, learning and equity through WASH in schools. *New York.* UNICEF & GWP. (2017). WASH Climate Resilient Development: Risk assessments for WASH.

UNICEF & WHO. (2020). Progress On Drinking Water, Sanitation and Hygiene in Schools Progress on drinking water, sanitation and hygiene in schools Special focus on COVID-19.

UNICEF & WHO. (2024). Progress on drinking water, sanitation and hygiene in schools 2015–2023: special focus on menstrual health. United Nations Children's Fund (UNICEF) and World Health Organization (WHO).

UNICEF South Africa. (2019). WASH Thematic Report, January - December 2018. UNICEF. Retrieved from https://open.unicef.org/sites/transparency/files/2020-06/South-Africa-TP6-2018.pdf.

Vanderslott, S., Phillips, M. T., Pitzer, V. E., & Kirchhelle, C. (2019). Water and Filth: Reevaluating the First Era of Sanitary Typhoid Intervention (1840–1940). *Clinical Infectious Diseases, 69*(5), S377. https://doi.org/10.1093/cid/ciz610.

Victor, C., Kupoluyi, J. A., Oyinlola, F. F., & Sule, V. O. (2025). Prevalence and factors associated with water, sanitation and hygiene (WASH) facilities deprivation among children in Nigeria. *BMC Pediatrics, 25*(1), 102. https://doi.org/10.1186/s12887-025-05463-5.

Wada, O. Z., Olawade, D. B., Oladeji, E. O., Amusa, A. O., & Oloruntoba, E. O. (2022). School water, sanitation, and hygiene inequalities: a bane of sustainable development goal six in Nigeria. *Canadian Journal of Public Health, 113*(4), 622. https://doi.org/10.17269/s41997-022-00633-9.

Wada, O. Z., & Oloruntoba, E. O. (2021). Safe Reopening of Schools during COVID-19: An Evaluation of Handwash Facilities and Students' Hand Hygiene Knowledge and Practices. *European Journal of Environment and Public Health, 5*(2), em0072. https://doi.org/10.21601/ejeph/9704.

Wami, M., Fisher, J., Akpila, S., & Radu, T. (2022). Current water, sanitation and hygiene (WASH) conditions in selected schools in Port Harcourt, Nigeria. *International Development Planning Review, 44*(4), 436–455. https://doi.org/10.3828/idpr.2022.6.

Wang, D., Chen, Y., Jarin, M., & Xie, X. (2022). Increasingly frequent extreme weather events urge the development of point-of-use water treatment systems. *Npj Clean Water, 5*(1), 36. https://doi.org/10.1038/s41545-022-00182-1.

Weaver, E. R., Agius, P. A., Veale, H., Dorning, K., Hlang, T. T., Aung, P. P., ... & Hellard, M. E. (2016). Water, sanitation, and hygiene facilities and hygiene practices associated with diarrhoea and vomiting in monastic schools, Myanmar. *The American journal of tropical medicine and hygiene*, *95*(2), 278. https://doi.org/10.4269/ajtmh.15-0290.

Weets, C. M., & Katz, R. (2024). Global approaches to tackling antimicrobial resistance: a comprehensive analysis of water, sanitation and hygiene policies. *BMJ Global Health, 9*(2), https://doi.org/10.1136/bmjgh-2023-013855.

Weststrate, J., Dijkstra, G., Eshuis, J., Gianoli, A., & Rusca, M. (2018). The Sustainable Development Goal on Water and Sanitation: Learning from the Millennium Development Goals. *Social Indicators Research, 143*(2), 795. https://doi.org/10.1007/s11205-018-1965-5.

Whittington, D., Lauria, D. T., Choe, K., Hughes, J. A., & Wright, A. M. (1993). Household demand for improved sanitation services in Kumasi, Ghana: A contingent valuation study. Water resources research, 29(6), 1539–1560. https://doi.org/10.1029/93WR00184.

WHO (2017). Water, Sanitation and Hygiene: Health Emergency and Disaster Risk Management Fact Sheets. Geneva: *World Health Organization*, December.

WHO. (2018). Guidelines On Sanitation and Health. World Health Organization.

WHO. (2019). Surveillance of water, sanitation and hygiene in schools A practical tool. *World Health Organization*.

WHO. (2023). Addressing climate change: Supplement to the WHO Water, Sanitation and Hygiene strategy 2018-2025. *World Health Organization*.

WHO. (2024). Guidelines for drinking-water quality: Small water supplies. *World Health Organization.*

WHO & UNICEF. (2017). Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines

WHO & UNICEF. (2021). Progress On Household Drinking Water, Sanitation and Hygiene *2000-2020: five years into the SDGs.*

WHO & UNICEF. (2023). Water, sanitation, hygiene, waste and electricity services in health care facilities: progress on the fundamentals. 2023 global report.

WHO, UNICEF, & World Bank. (2022). State of the world's drinking water: an urgent call to action to accelerate progress on ensuring safe drinking water for all. *World Health Organization.*

Wilbur, J., Dreibelbis, R., & Mactaggart, I. (2024). Addressing water, sanitation and hygiene inequalities: A review of evidence, gaps, and recommendations for disability-inclusive WASH by 2030. *PLOS Water, 3*(6), e0000257. https://doi.org/10.1371/journal.pwat.0000257.

Win, C. Z., Daniel, D., Dwipayanti, N. M. U., & Jawjit, W. (2024). Development of integrated assessment tool for water, sanitation and hygiene (WASH) services in non-household settings under climate change context. *Heliyon, 10*(18), https://doi.org/10.1016/j.heliyon.2024.e37645.

Winter, J. C., Darmstadt, G. L., Lee, S. J., & Davis, J. (2021). The potential of school-based WASH programming to support children as agents of change in rural Zambian households. *BMC Public Health, 21*(1), https://doi.org/10.1186/s12889-021-11824-3.

Wolf, J., Johnston, R. B., Ambelu, A., Arnold, B. F., Bain, R., Brauer, M., ... & Cumming, O. (2023). Burden of disease attributable to unsafe drinking water, sanitation, and hygiene in domestic settings: a global analysis for selected adverse health outcomes. *The Lancet*, *401*(10393), 2060–2071. https://doi.org/10.1016/s0140-6736(23)00458-0.

WRC. (2015). Exploring the Issues around Rural On-Site School Sanitation in South Africa (WRC Report No. 2381/P/15). *Water Research Commission*.

WRC. (2018). The Internet of things: Opportunity for Water, Sanitation and Hygiene (WASH) Management (WRC project No. K5/2779*).* South Africa: *Water Research Commission.*

Yannopoulos, S., Yapijakis, C., Kaiafa-Saropoulou, A., Antoniou, G., & Angelakis, A. N. (2017). History of sanitation and hygiene technologies in the Hellenic world. *Journal of Water, Sanitation and Hygiene for Development, 7*(2), 163. https://doi.org/10.2166/washdev.2017.178.

Yasmin, T., Dhesi, S., Kuznetsova, I., Cooper, R., Krause, S., & Lynch, I. (2022). A system approach to water, sanitation, and hygiene resilience and sustainability in refugee communities. Informa UK Limited. https://doi.org/10.1080/07900627.2022.2131362.

Yillah, R. M., Sah, R. K., Bash-Taqi, A., & Osborne, A. (2025). Bridging the gap: exploring students' needs, knowledge, and preferences for delivering comprehensive sexuality education in Sierra Leone. *BMC Public Health, 25*(1), https://doi.org/10.1186/s12889-025-21866-6.

Yimenu, A. A., Gemechu, M. T., Shimber, E. T., & Ndugga, P. (2026). Barriers to water, sanitation, and hygiene (WASH) cluster coordination during emergencies in sub-Saharan Africa: A scoping review. *PLOS Water*, *5*(2), e0000434. https://doi.org/10.1371/journal.pwat.0000434.

Zadock, H. B., Muasya, D., & Gichuhi, D. (2024). The Relationship Between Reliability of Improved Water Service and Pupil's Hand Washing Practices in Lurambi Sub County, Kakamega County, Kenya. *African Journal of Emerging Issues*, 6(18), 70–82. https://ajoeijournal.org/sys/index.php/ajoei/article/view/704.

Zegeye, M. (2024). Water, Sanitation, and Hygiene (WASH) in Ethiopia: An International Human Rights Framework. *Journal of Health and Human Services Administration, 47*(1–2), 37. https://doi.org/10.1177/10793739241277608.

Zimmermann, K. (2023). The Water Sector Was Born and Raised with Big-Impact Water Data. *ACS ES&T Water, 4*(3), 764. https://doi.org/10.1021/acsestwater.3c00104.

Zuin, V., Delaire, C., Peletz, R., Cock-Esteb, A., Khush, R., & Albert, J. (2019). Policy Diffusion in the Rural Sanitation Sector: Lessons from Community-Led Total Sanitation (CLTS). *World Development, 124*10. https://doi.org/1016/j.worlddev.2019.104643.

Zyoud, S. H., & Zyoud, A. H. (2023). Water, sanitation, and hygiene global research: evolution, trends, and knowledge structure. *Environmental Science and Pollution Research*, *30*(56), 119532-119548. https://doi.org/10.1007/s11356-023-30813-0.

List of Appendices

Appendix 1: Observation Checklist for WASH and MHM

UNISA
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College of Agriculture and Environmental Sciences

Tittle of the research study: Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa.

Water, Sanitation and Hygiene (WASH) means the supply of potable drinking water appropriate for domestic use, disposing of feaces in a safe manner and promoting healthy behavior in affected citizens (UNICEF & WHO, 2020; WHO, 2017).

Purpose of the study: The proposed study is aimed at examining the current WASH conditions and menstrual hygiene practices at 40 high schools in Durban. The findings will assist in developing a framework that will enhance the provision of safe WASH to the selected schools and potentially beyond. The provision of safe WASH to school would help to achieve Sustainable Development Goal (SDG) 6.

Confidentiality: "This checklist contains confidential information and is only for use in the research study titled "*Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa.*" You should not disseminate, distribute, or copy this document or its contents if you are not an intended participant and obtained it by error. Participants should not mention their names anywhere in this checklist to preserve confidentiality."

Target Respondent: To be completed by the researcher on behalf of the school personnel.

General information on the school

School name: __________________/ School identification number: ____________

School location: ____________/ What type of area is the school located in:_______

Date of the inspection (dd/mm/yy): ____/______/_____/ Time of the inspection (hh/mm): ____/___

Section A: Water Supply

Water: availability; functionality	
Questions	**Response's option(s)**
Tick (✓) your response next to the correct option	

Question: W 1. What is the main source of drinking water provided by the school?		Currently available?			
W. 1.1 Piped water supply into school building?		Yes		No	
W. 1.2 Piped water supply into school yard/plot?		Yes		No	
W. 1.3 Public tap/standpipe out of school yard/plot?		Yes		No	
W. 1.4 Protected well/spring?		Yes		No	
W. 1.5 Rainwater?		Yes		No	
W. 1.6 Unprotected well/spring?		Yes		No	
W. 1.7 Packaged bottled water?		Yes		No	
W. 1.8 Tanker-truck or cart?		Yes		No	
W 1.9 Surface water (lake, river stream)?		Yes		No	
W. 1.10 No water source available?		N/A			

W.2. 1. How many drinking-water points are at the school	Total number =			Number of functional water points=	
W. 3 Is at least one drinking water point accessible for students with limited mobility?	Yes		No		
W.4.1 If drinking-water points are not accessible, what barriers are present?					
W.4.1.1 No access (for example stairs, narrow door)	Yes		No		
W.4.1.2 Inadequate tap height	Yes		No		
W.4.1.3 No handrail	Yes		No		
W.4.1.4 Water point difficult to open/close	Yes		No		
Water accessibility					
W.5. Where are the drinking-water points (intended for drinking) located?					
W.5.1 In the school building on each floor?	Yes		No		
W.5.2 In the school building, not on each floor?	Yes		No		
W.5.3 In the toilet facilities?	Yes		No		

W.5.4 Outside of the toilet facilities (common areas or in class)?	Yes		No			
W.5.5 Near the canteen?	Yes		No			
W.5.6 Outside or in a separate building?	Yes		No			
Water: quality of services, operation, and maintenance						
W.6.What quality characteristics apply to the drinking-water on the premises?						
W.6.1 Water has no colour?	True		False		NA	
W.6.7.2 Water has no odour?	True		False		NA	
W.6.3 Water has no taste?	True		False		NA	
W.6.4 Water is clear?	True		False		NA	
W.7. Are there signs of measures taken at the school level with respect to drinking-water?	True		False		NA	
W.7.1 Functioning means for water treatment?	True		False		NA	
W.7.2 No damage or crack of the water system or source?	True		False		NA	
W.7.3 Clean area around the water source?	True		False		NA	
W.7.4 Means for protection of water source (fence, cover, sealing)?	True		False		NA	
W.7.5 Other (please specify):__________________	True		False		NA	
W.8. Are records available for tracking performance of regular maintenance of the water points?	True		False		NA	
Water: education and practices						
W.9 Are informative/educational materials about water and hydration available on the school premises?	True		False		NA	
W.10 Is information on water quality easily accessible for school personel and pupils?	True		False		NA	

Section B Sanitation

Sanitation: availability, functionality, privacy

S.1 What kind of lavatory/latrines available for schoolchildren?						
S.1 Flush/pour-flush toilets?	True		False			
S.2 Pit latrines with slab?	True		False			
S.3 Composting toilets?	True		False			
S.4 Pit latrines without slab?	True		False			
S.5 Hanging latrines?	True		False			
S.6 No toilets or latrines	True		False			
S.2. How many lavatories cubicles/latrines available for schoolchildren						
S.2.1 Total number?	Boys		Girls		Unisex	
S.2.2 Number that are available?	Boys		Girls		Unisex	
S.2.3 Number that are functional?	Boys		Girls		Unisex	
S.2.4 Number that are private?	Boys		Girls		Unisex	
S.2.5 Number that are usable?	Boys		Girls		Unisex	
S.3. Are there toilet facilities for personnel (separate from school childrens' toilet facilities)?	Yes		No		NA	
Sanitation: accessibility						
S.4 Where are the pupils' toilet facilities located?						
S.4. Within the school building on each floor						
S.4.2 Outside the school building, but on the premises						
S.4.3 Some within the school building and some outside the building						
S.4.4 Not applicable						
S.5. If yes, what usability requirements are met?	Yes		No		NA	
S.5.1 The cubicle is available?	Yes		No		NA	
S.5.2 The cubicle is functional?	Yes		No		NA	
S.5.3 The cubicle is private?	Yes		No		NA	
S.6 Is there at least one toilet for the disabled?	Yes		No		NA	

S.7 If yes, what usability requirements are met?	Yes		No		NA	
S.7.1 The cubicle is available?	Yes		No		NA	
S.7.2 The cubicle is functional?	Yes		No		NA	
S.7.3 The cubicle is private?	Yes		No		NA	
Sanitation: quality of services, operation, and maintenance						
S.8 Are there any records of cleaning and maintenance schedules of the toilet facilities?						
S.8.1 All or more than half of the facilities are clean?						
S.8.2 All or more than half of the facilities are somewhat clean?						
S.8.3 All or more than half of the facilities are not clean?						
S.8.4 Not applicable?						
S.9 Is lighting in the toilet facilities adequate and functional?						
S.9.1 All toilets have functional lighting?						
S.9.2 Half or more of the toilets have functional lighting?						
S.9.3 Very few or none of the toilets have functional lighting?						
S.9.4 Not applicable						
S.10 Are there signs of adequate ventilation in the toilet facilities?						
S.10.1 Yes, in all toilet facilities?						
S.10.2 In a half or more than half of the toilet facilities						
S.10.3 In very few or none of the toilet facilities						
S.10.4 Not applicable						
S.11 Are means for anal cleansing provided in pupils’ toilet cubicles?						
S.11.1 Yes, in all toilet cubicles?						

S.11.2 Yes, in a half of or more of the toilet cubicles?						
S.11.3 In a few or none of the toilet cubicles?						
S.11.4 Not applicable						
S.12 Are there waste bins in the pupils' toilet facilities?						
S.12.1 Yes, there are waste bins in all toilet facilities?						
S.12.2 There are waste bins in a half or more of the toilet facilities?						
S.12.3 Waste bins can be found in a few or none of the toilet facilities?						
S.12.4 Not applicable						
S.1 If general waste bins are provided, are they adequate to prevent accumulation of litter on the floor?	Yes		No		NA	
S.15 Are there any posters promoting healthy and/or hygienic use of the toilets/latrines?	Yes		No		NA	

Section C: Hygiene and Menstrual Hygiene Management

Hygiene and Menstrual Hygiene Management: Availability, Functionality		
H.1 How many handwashing facilities are at the school?		
H.1.1 Total number of handwashing facilities		
H.1.2 Number that are functional		
H.1.3 Number of functional facilities with soap		
H.2 If handwashing facilities are not functional, what are the reasons?		
H.2.1 No water?		
H.2.2 Broken/missing faucet?		
H.2.3 Broken basin?		
H.2.4 Clogged sinks?		
H.2.5 No drainage in place?		

H.2.6 Other, please specify: ______________________						
H.3 Is hot/warm running water provided at handwashing facilities?						
H.3.1 Yes, at all or more than half of handwashing facilities?						
H.3.2 Yes, at less than half?						
H.3.3 No						
H.3.4 Not applicable						
H.4 Where are handwashing facilities located?						
H.4.1 Near the toilets						
H.4.2 In food preparation areas						
H.4.3 In food consumption areas						
H.4.4 In classrooms						
H.4.5 In school yard						
H.4.6 Other, please specify: ______________________						
H.5 Are handwashing facilities accessible to those with limited mobility?	Yes		No		NA	
H.6 Are there any records of cleaning and maintenance schedule?						
H.6.1 Yes, satisfactory?						
H.6.2 Yes, but incomplete or outdated?						
H.6.3 No						
H.7 Are any cleaning materials present on school premises?						
H.7.1 Yes, sufficient?						
H.7.2 Yes, but insufficient?						
H.7.3 There are no cleaning materials present on the premises						
H.8 Are the handwashing facilities clean?						

H.8.1 All or more than half of the handwashing facilities are clean?						
H.8.2 All or more than half of the handwashing facilities are somewhat clean?						
H.8.3 All or more than half of the handwashing facilities are not clean?						
H.9 What hand drying materials are provided?						
H.9.1 Disposable paper towels?						
H.9.2 Reusable fabric hand towels?						
H.9.3 Individual towels?						
H.9.4 Air dryer/electric hand dryer?						
H.9.5 Other, please specify ______________________________						
H.10 Is any information about handwashing/hand hygiene visible at the school?	Yes		No		NA	
H.11 Is a private space available for MHM at the school?	Yes		No		NA	
H.12 Does the private space have soap and water available for menstrual hygiene management?						
H.12.1 Water only						
H.12.2 Soap only						
H.12.3 Water and soap						
H.12.4 Not applicable						
H.13 Is there a sanitary container in the girls' restroom to dispose of used sanitary products during menstruation?						
H.13.1 Yes, in all girls' toilet cubicles?						
H.13.2 Yes, more than half of girls' toilet cubicles?						
H.13.3 Yes, in few girls' toilet cubicles?						
H.13.4 There are no sanitary bins in the girls' toilet cubicles?						
H.13.5 Not applicable?						

H.14 Does the girls have clear instructions on how to discard waste of menstruation in the suitable container?	Yes		No		NA	
H.15 Are sanitary bins emptied regularly?	Yes		No		NA	
H.16 Are menstrual hygiene products freely available at the school?						
H.16.1 Yes, available free of charge in the toilet facilities or a dedicated area?						
H.16.2 Yes, available for purchase in the toilet facilities or a dedicated area?						
H.16.3 Not observed?						

Adopted from WHO (2019)

Appendix 2: KAP including WASH Related Diseases Questionnaire

<u>College of Agriculture and Environmental Sciences</u>

Tittle of the research study: Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."

Water, Sanitation and Hygiene (WASH) means the supply of potable drinking water appropriate for domestic use, disposing of feaces in a safe manner and promoting healthy behavior in affected citizens (UNICEF & WHO, 2020; WHO, 2017).

Purpose of the study: The proposed study is aimed at examining the current WASH conditions and menstrual hygiene practices at 40 high schools in Durban. The findings will assist in developing a framework that will enhance the provision of safe WASH to the selected schools and potentially beyond. The provision of safe WASH to school would help to achieve Sustainable Development Goal (SDG) 6.

Confidentiality: "This questionnaire contains confidential information and is only for use in the research study titled "*Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa*." You should not disseminate, distribute, or copy this questionnaire or its contents if you are not an intended participant and obtained it by error. Participants should not mention their names anywhere in this questionnaire to preserve confidentiality.

Target respondent: To be completed by the researcher on behalf of the school student

Please Note:

- Please complete the questionnaire only after you have read and understood the participant information sheet and signed the participant informed consent form.
- Completing this questionnaire is totally voluntary.
- Please bear in mind that the information will be kept confidential.
- Please be truthful in your answer.

Section A: Knowledge, attitude, and practice.

Questions	**Response's option(s)**			
General information				
A.1 Interview date				
A.2 Online or physical contact interview				
A.4 Name of the school				
A.8 Does the person responsible of the child consent to the student to be interviewed?	Yes		No	
A.9 If yes at question A8, is the student willing to participate?	Yes		No	
Student information (student's identity needs to be checked prior the interview)				
A.11 Gender	Male		Female	
A.12 Age				
A.14 Grades				
Source of Knowledge – Water, Sanitation, Hygiene				
Knowledge towards water, sanitation, and hygiene				
Tick (✓) the correct option between A, B, C, and D				
C.1 To your knowledge, why is it important to boil water?	i.	Kills germs.	A. i only	
	ii.	Makes water safe to drink	B. i & iii	
	iii.	Reduces the chances of getting diarrhoea	C. iv only	
	iv.	Gives water a better taste	D. i, ii, iii & iv	

C.2 To your knowledge, how long does water need to be boiled to ensure that it is free of disease-causing organisms?	i. Less than one minute	A. i, & iv	
	ii. Between one and five minutes	B. ii only	
	iii. More than five minutes	C. iii & iv	
	iv. More than 10 minutes	D. i, iii & iv	
C.3 To your knowledge, why human faeces should be disposed of in a proper way (as opposed to be left in natural areas)?	i. Contains germs.	A. i only	
	ii. Avoids contaminating water supplies and the environment	B. i, ii, iii & iv	
	iii. Smell purposes	C. iv only	
	iv. To promote hygiene	D. i, iii & iv	
C.4 What material should you use for bathing?	i. Water	A. i, ii &iii	
	ii. Soap	B. i & iii	
	iii. Towel	C. iv only	
	iv. Water only without soap	D. i, ii, iii & iv	
C.5 What material should you used for anal cleansing?	i. Paper	A. iii	
	ii. Water and soap	B. ii	
	iii. Nothing	C. iv only	
	iv. Water without soap	D. i, & iv	
C.6 In your opinion, why is it important to be cleaned?	i. Health purpose	A. i only	
	ii. Smell purpose	B. i & iii	
	iii. Importance in family/ society	C. iv only	
	iv. Because it is a bad habit to be dirty	D. i, ii, iii & iv	
Knowledge towards hand washing practices			
Tick (✓) the correct option between A, B, C, and D			
C.7 To your knowledge, what are the critical times to wash your hands?	i. After playing, coughing and sneezing	A. i only	
	ii. When wake up from sleep	B. i & iii	

	iii.	All the time after visiting the toilet and taking care of pets or farm animals	C. iv only	
	iv.	Before touching food	D. i, ii, iii & iv	
C.8 To your knowledge, why is it important to wash your hands using water and soap? C	i.	Reduces the chances of getting diarrhoea	A. i only	
	ii.	Minimises chances for contracting diseases/ infections	B. i & iii	
	iii.	To make sure that hands are cleaned properly	C. iv only	
	iv.	For religious purposes	D. i, ii, iii & iv	
Knowledge towards WASH related diseases				
Tick (✓) the correct option between A, B, C, and D				
C.9 To your knowledge, how can you protect yourself against stomach-ache and diarrhoea?	i.	Eat washed fruits and vegetables	A. i only	
	ii.	Avoid eating spoiled and contaminated food	B. i & iii	
	iii.	Ensure to use tidy toilet all the time	C. i,ii,iii &iv	
	iv.	Ensure to drink water that is fit for human consumption	D. iii only	
C.10 To your knowledge, how can you protect others against stomach-ache and diarrhoea?	i.	Clean hands thoroughly after playing	A. i only	
	ii.	Ensure to clean hands before/ after handling children	B. i & iii	
	iii.	Clean hands thoroughly before touching food	C. iv only	
	iv.	Properly washing of hands after visiting toilet	D. i, ii, iii & iv	
Attitudes towards the provision of Water, Sanitation and Hygiene Facilities				
Write your answer next to the question, choosing one of the following options: 1, 2, 3, 4, or 5.; where				

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree	
D. 1 Within the school environment, access to clean water, sanitation, and handwashing facilities is critical.	
Attitudes towards the provision of Water	
Write your answer next to the question, choosing one of the following options: 1, 2, 3, 4, or 5.; where 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Stro Agree	
D.2 Water should be safe to drink in a school environment.	
D.3 Your school provides enough drinking water.	
D.4 Your school provides enough drinking water.	
Attitudes towards Sanitation	
Write your answer next to the question, choosing one of the following options: 1, 2, 3, 4, or 5.; where 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Stro Agree	
D.5 It is important to clean up after yourself after using the toilet.	
D.6 Your school's toilets provide enough privacy.	
D.7 Toilets are always in good functioning order.	
Attitudes towards hand washing facilities at school	
Write your answer next to the question, choosing one of the following options: 1, 2, 3, 4, or 5.; where 1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Stro Agree	
D.8 In a school environment, hand washing facilities should be available?	
D.9 Your school have enough clean water and soap for hand washing?	
D. 10 Do you frequently wash your hands in the school's hand washing facilities?	

Practices related to Water, Sanitation and Hygiene		
Tick (✓) one of the following options regarding your water, sanitation, and hygiene practices between A, B and C		
E.1 How do you usually drink water at school?	A. Using your own cup or bottle not sharing with other students?	
	B. Using hands, directly by mouth (mouth under tap); using bottles or cups sharing with other students?	
	C. Unable to drink water in the school premises due to lack of water supply?	
	D. Not drinking water from the school since the water supply is of poor quality?	
	A. Between 0.5L ≥ 1L?	

E.2 How much water E.3 consumption do you take per day while you are at school	B. Between 0.1L ≤ 0.5?	
	C. No water consumption due to unavailability of water supply?	
	D. No consumption of water due to poor quality?	
E.4 How often do you utilise toilet while you are at school	A. As need arise?	
	B. Not utilising the school toilet because I don't feel comfortable?	
	C. Not utilising the toilet due to unavailability of toilets facilities?	
	D. Not utilising the toilet due to bad conditions?	
E.5 Do you attend hygiene education that are offered in your school	A. Yes?	
	B. No?	
	C. There is no hygiene education offered?	
	D. No, it is not offered to all students, only for specific grades?	
E.6 Do you urinate behind the school toilet	A. No?	
	B. Yes?	
	C. Yes, because the toilets are not sufficient?	
	D. Yes, because the toilets are not in good condition?	
E.7. Do you clean up after yourself at the school toilets after using them?	A. Yes; all the time?	
	B. No; sometimes?	
	C. Unable to use toilets in the school premises due to lack of toilets provision?	
	D. Not using the school toilets because they are in bad condition?	
E.8 Do you wash hands after going to the bathroom	A. Yes, all the time?	
	B. No, sometimes?	
	C. Not applicable, hand washing facilities are not provided?	
	D. Not applicable, hand washing facilities are not in a good condition?	
Only if « Female » at question E9 to E11.		
E.9 Do you and your girls' friends feel comfortable using your school	A. Yes?	
	B. No?	
	C. No, menstrual hygiene facilities are not provided?	

toilets during your menstrual cycles?	D. No, toilets are not in good condition?	
E.10 Do you miss school during menstruation period	A. No?	
	B. Yes?	
	C. Yes, menstrual hygiene is not manageable at school?	
	D. Yes, controlling menstruation at school is not possible.	
E.11 Do you maintain personal hygiene during menstruation while you are at school	A. Yes?	
	B. No?	
	C. No, facilities to maintain hygiene during menstruation are not provided	
	D. No, hygiene facilities are not provided	

Adopted from(UNICEF, 2018).

Section B: WASH Related Diseases

Questions	**Response's option(s)**			
Have you recently been ill?	Yes		No	
Did you have any of the following symptoms?				
Diarrhoea?	Yes		No	
Nausea?	Yes		No	
Abdominal cramps?	Yes		No	
Worms?	Yes		No	
Vomiting?	Yes		No	
Bloody diarrhoea?	Yes		No	
Chills?	Yes		No	
Sweats?	Yes		No	
Headache?	Yes		No	
Fatigue?	Yes		No	
Fever?	Yes		No	
Do you know of anyone with similar symptoms in past two weeks?	Yes		No	
Did you see a doctor?	Yes		No	
Did doctor confirm any of the following diseases?				
Diarrhoeal disease?	Yes		No	
Schistosomiasis?	Yes		No	
Soil-transmitted helminth infections?	Yes		No	
Roundworm (Ascaris lumbricoides)?	Yes		No	
Typhoid fever?	Yes		No	
Whipworm (Trichuris trichiura)?	Yes		No	
Ancylostoma duodenale?	Yes		No	

Hook- worm species (Necator americanus)?	Yes		No	
Eye infections?	Yes		No	
Skin Infections?	Yes		No	

Appendix 3: Focus group discussion questionnaire

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Tittle of the research study: "Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."

Water, Sanitation and Hygiene (WASH) means the supply of potable drinking water appropriate for domestic use, disposing of feaces in a safe manner and promoting healthy behavior in affected citizens (WHO, 2017; WHO & UNICEF, 2020)(UNICEF & WHO, 2020; WHO, 2017).

Purpose of the study: The proposed study is aimed at examining the current WASH conditions and menstrual hygiene practices at 40 high schools in Durban. The findings will assist in developing a framework that will enhance the provision of safe WASH to the selected schools and potentially beyond. The provision of safe WASH to school would help to achieve Sustainable Development Goal (SDG) 6.

Confidentiality: "This questionnaire contains confidential information and is only for use in the research study titled "*Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."* You should not disseminate, distribute, or copy this questionnaire or its contents if you are not an intended participant and obtained it by error. Participants should not mention their names anywhere in this questionnaire to preserve confidentiality."

Target respondent: To be completed by the researcher on behalf of the school personnel

Date of a discussion meeting:

Name of the school:

Questions

Water: availability, functionality

1. Who is responsible for the school's potable water supply?
2. Does the school pay the water bill for water usage?
3. If there are interruptions in the previous two weeks, when and for how long have they happened?
4. Is potable water always available from the main source during the school year?
5. If water from the main source is available but there have been interruptions, how often did this happen in the last 12 months?
6. If the main source is not always available, is there an alternative source of drinking water available at the school?

Water: quality of services, operation, and maintenance

1. What is the provider of the main drinking water supply?
2. When the main drinking water supply is efficient, does this provide sufficient water for the requirements of the school?
3. Has the quality from the main water source ever been tested on the school premises for compliance with national standards for drinking-water?
4. If the water from the main source has been tested within the last 12 months, what parameters have been tested?
5. According to the latest tests, was the water from the main source meet national drinking water quality standards?
6. In the past 12 months, have there been complaints about the quality and/or availability of drinking-water at the school?
7. In case of complaints, what measures are taken at the school?
8. Who is responsible for identifying and reporting about issues with drinking-water system and facilities?

9. Who is responsible for the operation and maintenance of the drinking-water provision on the school premises?
10. What measures are taken at the school level regarding drinking-water?
11. What drinking-water treatment method is used on the premises of the school?
12. Is there a written operation and maintenance plan?

Water: education and practice

1. When are pupils allowed to drink water at school?
2. Where do pupils get their drinking water from at school?
3. Is a written school policy or rule in place to ensure accessible drinking water?

Sanitation

1. If the school has an onsite sanitation system, is there a schedule for emptying and disposing of the sludge?
2. In your opinion, what is needed to improve toilet facilities in the school?

Hygiene and menstrual hygiene management: quality of services, operation, and maintenance

1. Are records for the cleaning schedule of the toilet facilities available?
2. How often are checks made during the day to ensure that toilet facilities remain clean, and that soap, drying facilities and anal cleansing materials are provided?
3. Have cleaning staff been trained on cleaning procedures, safe and adequate use of cleaning materials and protective equipment?
4. What cleaning materials are available at the school in case of need?
5. What activities are undertaken for hygiene promotion at the school?
6. If there is MHM education at the school, from what age and grade do girls receive this knowledge?
7. Are menstrual hygiene management linked materials for knowledge available to schoolgirls?
8. When can girls access menstrual hygiene products at the school?

9. Is potable water always available from the main source during the school year?
10. Are you aware of girls missing classes because of menstruation?
11. In your opinion, what could the school do to make it easier for girls to attend school during menstruation?

Appendix 4: Letter of Informed Consent

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Letter of Informed Consent

Dear Participants

My name is Thulisile Ngcongo. I am presently registered as a student at the University of South Africa doing PhD Environmental Science. The proposed tittle of my research project is: *"Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."*

Water, Sanitation and Hygiene (WASH) means the supply of potable drinking water appropriate for domestic use, disposing of feaces in a safe manner and promoting healthy behavior in affected citizens (WHO, 2017; WHO & UNICEF, 2020)(UNICEF & WHO, 2020; WHO, 2017).

You are invited to participate in a research project entitled. The aim of this study is to examine the current WASH conditions and menstrual hygiene practices at high schools in Durban that are serving the poorest and wealthiest communities in order to identify the best methods for improving the provision of safe WASH practices in schools and moving toward achieving SDG 6.

Participants have a right to reject to take part and to leave the study at any time without the adverse effects. There will not be a cash rewards for taking part in this study. The secrecy and anonymity of the information that detect you as a participant will not be revealed. The questionnaire ought to take you approximately 10 to 15 mins to finish.

If you would like to partake in this study, you will need to fill in this form. If you are less than 18 years of age you will need your parent /guardian's permission.

- I verify that I am aware of the scope and potential of this study.
- I understand that the research findings will be used in a research article and study report without mention of my name.

____________________	______________	____________	______________
Full name of the participant	Date	Time	Signature

I ______________________ a guardian for __________________________ (name of a leaner) who

is studying at ______________________ (name of school), give a permission for him/her to

participate in the study. Guardian's signature: _________________ Date: ______________________

I ______________________________ (name of the researcher) herewith confirm that the above

participant has been fully informed about the nature of the study.

________________________ ________________ _______________

Signature Date Time

Appendix 5: Participants Information Sheet

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Participant Information Sheet

Tittle of the research study: "Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."

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Dear Prospective Participants

My name is Magareth Thulisile Ngcongo a student researcher and I am doing research with Professor M. Tekere in the Department of Environmental Sciences towards a degree title, PhD (Doctor of Philosophy) in Environmental Sciences at the University of South Africa. We have funding from Mangosuthu University of Technology. We are inviting you to participate in a study entitled *"Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."*

Purpose of the study: The proposed study is aimed at examining the current WASH conditions and menstrual hygiene practices at 40 high schools in Durban. The findings will assist in developing a framework that will enhance the provision of safe WASH to the selected schools and potentially beyond. The provision of safe WASH to school would help to achieve Sustainable Development Goal (SDG) 6.

Why Have You Been Invited to Take Part?

You have been invited to participate in this study because you are one of the prospective participants who met the study's inclusion criteria. In order to fulfil the study's goal, high school students studying in the selected Durban high schools, as well as staff members working in the selected Durban high schools, are being targeted. Students will fill out semi-structured questionnaires, while staff members will participate in a focus group discussion. Students will be questioned on their knowledge, attitudes, and practices in the area of WASH. A questionnaire should take no more than 10 to 15 minutes to complete. Staff members will be questioned on the availability of WASH in the chosen schools. It will take 45 to 60 minutes to hold a focus group meeting. The project will take place across four seasons of the year.

Can I Withdraw from This Study Even After Having Agreed to Participate?

Participating in this study is voluntary and you are under no obligation to consent to participation. There will be no penalty or loss of benefit for non-participating. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. You are free to withdraw at time before the information is collected as it would not be easy to withdraw the information once it is collected since there will be no identification.

Benefit to participate in the study?

There will be no benefits to participants or others who are partaking in the study.

Benefit of the study?

The outcomes of this research would also be helpful to the Department of Education, as the study will create a new framework that will be used to improve the provision of safe WASH to the selected schools and potentially beyond. The findings of the study will be used to develop a risk-reduction framework that may enhance the provision of safe WASH to schools. This will contribute to the improvement of Standard Development Goals (SDGs) 3,4,5 and 6 by 2030, thereby preventing or controlling the incidence of WASH-related diseases and improving school performance and attendance.

Are There any Negative Consequences for Me If I Participate in The Research Project?

The study will gather non-sensitive data, such as opinions, rather than personally identifiable information. You will not be asked to reflect on traumatic or bad experiences that could cause discomfort, emotional anguish, or harm, nor will they be asked to divulge personal/sensitive information or experiences that they would not typically share with a stranger. Despite the fact that the study will involve children under the age of 18, parents or guardians will be approached to give their approval if their children choose to participate.

Will The Information That I Convey to The Researcher and My Identity Be Kept Confidential?

The information of the participants will be kept secure at all times to guarantee that no unauthorised individuals get access. The hard copies of the data will be kept in a locked cabinet. Only the researcher will have access to the cabinet. The electronic copies will be kept on a secured laptop that will only be used by the researcher. To protect the participants' anonymity, no personally identifiable information will be collected throughout the data collection procedure. The participants' names and contact details will not be written anywhere in the questionnaire, however, it would be impossible to ensure confidentiality in terms of focus group because everyone will be present during discussions.

Will I Receive Payment or Any Incentives for Participating in This Study?

Participating in this study is voluntarily. There will not be a cash rewards for taking part in the study. Participating in the study is also free, you will not have to pay money to take part in the study.

How Will I Be Informed of the Findings/Results of The Research?

The findings will be shared with the participating schools as well as the Department of Education. One of the study's objectives is to develop a risk-reduction approach that will improve WASH service provision in schools. Meetings will be scheduled with each school to discuss the findings and the proposed risk reduction strategy for that school. The information will be stored in a secure, lockable office. It will be kept on file for the duration of the research. The data will be discarded once the study is concluded. Once the study is finished, there are no intentions to reuse the data.

Thank you for taking time to read this information sheet and for participating in this study.

Signature of the researcher: Magareth Thulisile Ngcongo________

Person to contact in the event of any problem

1. Researcher: Magareth Thulisile Ngcongo
   Contact Numbers – 031 819 9373/ 0744691746
   Email address – 56736762@mylife.unisa.ac.za
2. Supervisor: Prof M Tekere
   Contact number – 011 471 2270
   Email address – Tekerem@unisa.ac.za

Appendix 6: Letter of Informed Consent for the Adults

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College of Agriculture and Environmental Sciences

Letter of Informed Consent for Adult Participants

Dear Participants

My name is Thulisile Ngcongo. I am presently registered as a student at the University of South Africa doing PhD Environmental Science. The proposed tittle of my research project is: *"Safe Water, Sanitation, and Hygiene Practices and Challenges in Selected Durban High Schools, KwaZulu-Natal Province, South Africa."*

Water, Sanitation and Hygiene (WASH) means the supply of potable drinking water appropriate for domestic use, disposing of feaces in a safe manner and promoting healthy behavior in affected citizens (WHO, 2017; WHO & UNICEF, 2020)(UNICEF & WHO, 2020; WHO, 2017).

You are invited to participate in a research project entitled. The aim of this study is to examine the current WASH conditions and menstrual hygiene practices at high schools in Durban that are serving the poorest and wealthiest communities in order to identify the best methods for improving the provision of safe WASH practices in schools and moving toward achieving SDG 6.

Participants have a right to reject to take part and to leave the study at any time without the adverse effects. There will not be a cash rewards for taking part in this study. The secrecy and anonymity of the information that detect you as a participant will not be revealed. The questionnaire ought to take you approximately 10 to 15 mins to finish.

If you would like to partake in this study, you will need to fill in this form.

I verify that I am aware of the scope and potential of this study.

- I understand that the research findings will be used in a research article and study report without mention of my name.

______________	______________	______________	______________
Full name of the participant	Date	Time	Signature

I ______________________________(name of the researcher) herewith confirm that the above

participant has been fully informed about the nature of the study.

______________ ______________ ______________

Signature Date Time

Appendix 7: Approved Ethical Clearance

2021_CAES_HREC_166 RS.pdf (Command Line)

Appendix 8: Examples of the consent forms used in the study.

Examples of Consent Forms Used.pdf (Command Line)