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Review Paper

WASH and drinking water quality considerations in schools in reflection of the sustainable development goals – a review

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ABSTRACT

Poor drinking water quality has been linked to negative health outcomes across the world. Drinking water quality is an essential part of safe water, sanitation, and hygiene (WASH). Safe WASH in schools is linked with the achievement of sustainable development goals (SGDs), specifically, SDG 6. It is unclear whether water quality is always assessed as part of WASH in schools. This study focused on determining the consideration of water quality aspects during WASH assessment in schools by examining published studies. A systematic online review of the literature was conducted to identify studies that reported on the assessment of WASH facilities in schools. Titles, abstracts, and full text of retrieved articles were screened. Seventy-five studies were identified. Thirty-two studies considered drinking water quality analysis as part of WASH in schools. Chemical (66%), microbial (59%), and physical (38%) parameters were included in drinking water quality analysis, with lead (Pb), and *Escherichia coli* being mostly included. This study reveals that some studies did not include an evaluation of drinking water quality, though it reflects an important exposure pathway between WASH services and health outcomes. It is, therefore, recommended that routine water quality monitoring be included in school WASH to ensure learner's health is protected.

Key words: drinking water quality, *Escherichia coli*, schools, SDGs, systematic review, WASH

HIGHLIGHTS

- Most researchers neglect the analysis of water quality in school WASH programmes.
- The current study emphasizes the importance of drinking water quality analysis in schools.
- Concerns about water quality exist in both developed and underdeveloped countries.
- The relationship between WASH and achieving the sustainable development goals (SDGs) in schools is a necessity.
- WASH intervention for water quality is key to safeguard learner's health.

GRAPHICAL ABSTRACT

INTRODUCTION

A large proportion of communicable diseases in the world are related to contaminated drinking water. Contaminated drinking water causes morbidity and mortality worldwide, especially in low- and middle-income countries (Shilunga *et al.* 2018; Bain *et al.* 2021; Bolatova *et al.* 2021; Morgan *et al.* 2021; Ahmed *et al.* 2022). WASH refers to the provision of safe drinking water, effective disposal of faeces, and the promotion of healthy behaviour among impacted individuals (Antwi-agyei *et al.* 2017; World Health Organisation [WHO] 2017; Cronk *et al.* 2021; Williams *et al.* 2021). Safe WASH facilities are critical factors of human dignity and good health, and quality of life (Agol & Harvey 2018; Ngwenya *et al.* 2018; Morgan *et al.* 2021; Bolatova *et al.* 2021).

Drinking water quality is an essential part of WASH provision in schools (Scheili *et al.* 2015; Wen *et al.* 2020; Anthonj *et al.* 2021; Bolatova *et al.* 2021; Morgan *et al.* 2021). To ensure good health habits and a high quality of life for learners in school, it is critical that schools provide a favourable environment that includes safe WASH facilities (Maroneze *et al.* 2014; Bolatova *et al.* 2021). Since learners spend a significant amount of time each day on the school premises, adequate WASH facilities in schools are crucial for their well-being (Anthonj *et al.* 2021). Additionally, learners spend more of their formative years in school, which means that giving them basic access to sustainable WASH is not only necessary at home but also in their schools (WHO & the United Nations Children's Fund [UNICEF] 2018). The provision of safe WASH facilities in schools is linked with the achievement of sustainable development goals (SGDs) in particular, SDG 6, (Antwi-agyei *et al.* 2017). The global initiative aimed at achieving SDG 6 by 2030 has expanded beyond the household to institutional settings which includes schools. Global education for all approaches has reinforced this by emphasizing how WASH in schools increases access to education and learning outcomes, particularly for girls, by establishing a safe and equal learning environment for everyone (WHO & UNICEF 2018, 2021). Safe WASH facilities include access to safe drinking water for all and is among the first target of SDG 6 (Hung *et al.* 2020). When providing safe WASH facilities, one of the environmental health factors that should be considered is drinking water quality. The provision of safe drinking water is associated with global indicator 6.1.1, which means the use of well-managed water services (Bain *et al.* 2021).

Despite remarkable progress since the declaration of SDG 6 in 2015, ensuring access of all to safe drinking water quality worldwide still remains a concern (Nanseu-njiki *et al.* 2019; Winter *et al.* 2021). Drinking water quality continues to be a global issue (Addisie 2022), and this might affect the world's ambition to achieve universal access to safe drinking water by 2030 (Scheili *et al.* 2015; Wen *et al.* 2020; Anthonj *et al.* 2021; Bolatova *et al.* 2021). There is a consensus on a lack of capacity in the developing world to achieve the SDGs, among them, SDG 6 on ensuring the availability and sustainable management of water and sanitation for all (Nanseu-njiki *et al.* 2019). Access to clean and safe drinking water quality is a basic human need and a basic human right. However, utilization of contaminated water is increasing particularly in developing countries (Akram 2020). Because it is necessary to make sure that learners have access to safe drinking water at school, monitoring drinking water quality is essential during WASH assessments in schools. This is to determine whether water is safe for consumption and hygienic purposes (Scheili *et al.* 2015; Wen *et al.* 2020; Anthonj *et al.* 2021; Bolatova *et al.* 2021; Morgan *et al.* 2021). In addition, the assessment of drinking water quality in schools, specifically, microbial quality, is critical since it is linked to the prevention of infectious diseases. However, it is unclear whether water quality is always assessed as part of WASH in schools.

The purpose of this article is to examine through systematic literature review, the consideration of water quality aspects during the assessment of WASH in schools since the declaration of the SDGs. This study should stimulate a discussion on the subject to highlight the importance of providing safe WASH in schools in all of its forms focusing on the three objectives which include; to determine if drinking water quality is included during the assessment of WASH in schools, to identify the drinking water quality parameters that are mostly included during the assessment of WASH in schools, and to identify if there are any gaps that need to be addressed during the assessment of WASH in schools.

METHODOLOGY

Protocol

This study was conducted in adherence to Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines to review, analyse, and report (Anthonj *et al.* 2020). A PRISMA flow diagram (Figure 1) was developed to increase the transparency and accuracy of literature reviews (Liberati *et al.* 2009; Frampton *et al.* 2017; Pahlevan-sharif *et al.* 2019).

Search strategy

A systematic search which included data selection, screening, eligibility, and the final selection of journal articles was performed. Three online databases (ScienceDirect, ProQuest and Google Scholar) and manual search (Google, Bing, and Yahoo) were used to identify studies that reported assessment of WASH facilities in schools. The literature search was

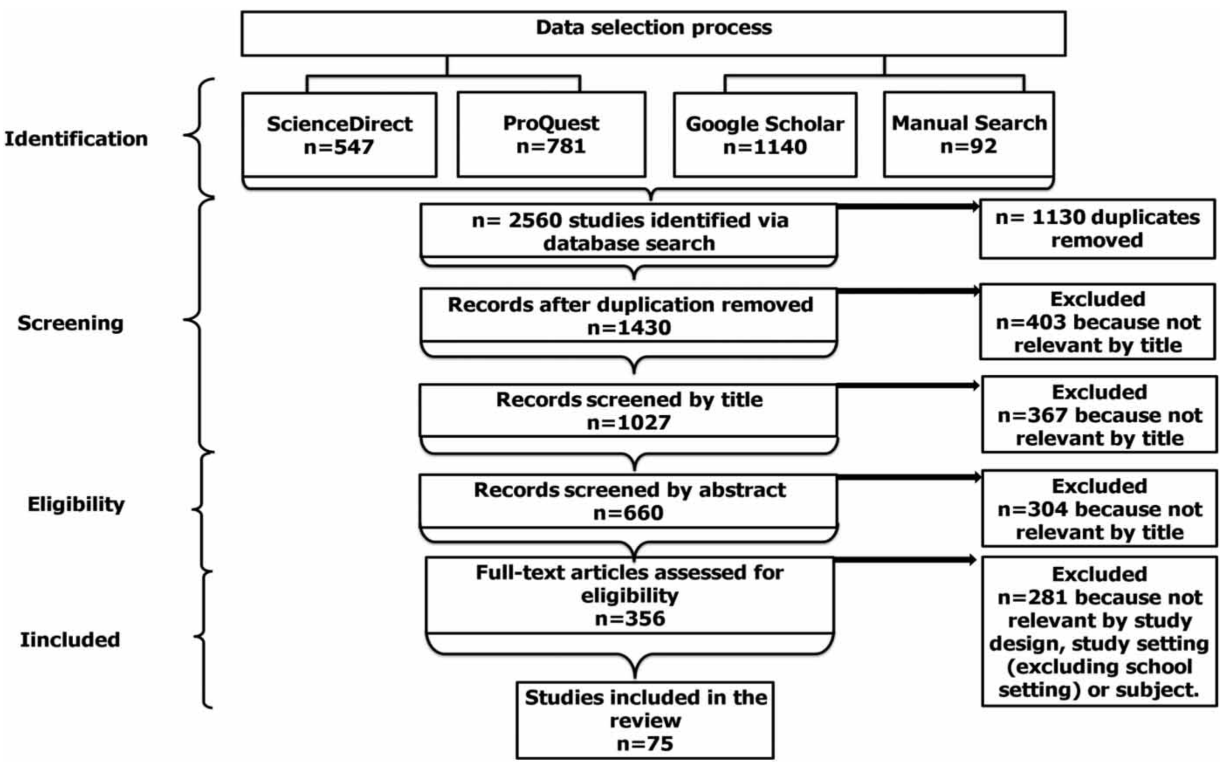

Figure 1 | Data selection process (Liberati *et al.* 2009; Pahlevan-sharif *et al.* 2019; Anthonj *et al.* 2020).

restricted to articles and papers published in English. The search strategy included the keywords 'Assessment of water, sanitation, and hygiene facilities in schools,' or 'WASH' in 'schools' or 'WaSH in schools' or 'water, sanitation and hygiene' or 'drinking water quality in schools' or 'drinking water quality' or 'drinking water and schools.' The data were firstly selected based on title and abstract (Pahlevan-sharif *et al.* 2019), thereafter, full-text articles were downloaded for further screening. The duplications of the articles and papers from all search engines were removed (Pahlevan-sharif *et al.* 2019; Anthonj *et al.* 2020). The total number of articles and papers after removing duplication was 1,430 ($n = 1{,}430$) as presented in Figure 1.

Study eligibility criteria and selection

Prior to conducting the full review of selected studies, further screening was conducted. Six hundred and sixty studies were screened to avoid bias (Pahlevan-sharif *et al.* 2019). Further screening was conducted considering inclusion and exclusion criteria (Table 1). Only journal articles and papers were included in this process. Guidelines, manuals, news stories, and blog posts were not included.

Study quality

The authors independently appraised the included studies for methodological quality using the upgraded version of Assessment of Multiple Systematic Reviews (AMSTAR) which is called AMSTAR 2 (Shea *et al.* 2017). The AMSTAR 2 appraisal checklist was adopted (https://amstar.ca/). A rating of high, moderate, low, and critically low was awarded to each study according to the number of 'yes', 'can't tell', and 'no' responses (Table 2). Where high means No or one non-critical weakness: the systematic review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest. Critically low indicates that the review has numerous significant faults or omissions, making it unreliable for giving a precise and thorough summary of the studies that are currently available (Perry *et al.* 2021).

Data extraction and analysis

Using a standardized checklist, data related to study characteristics were extracted. Data were collected from studies that met the inclusion criteria. Data on WASH variables, drinking water quality information, and drinking water quality parameters were gathered. Extracted data were manually entered into a Microsoft Excel database. The documents were coded into two cycles for the following: the consideration of drinking water quality during the assessment and drinking water variables that were included in the selected studies. Thereafter, statistical analysis in terms of percentage was calculated.

RESULTS

Search results

A total of 2, 560 studies were identified, but after de-duplication, only 1,430 remained (Figure 1). After title and abstract screening, 356 studies were included for full-text screening. Finally, 75 studies were identified for inclusion. Most studies were excluded because they did not meet the criteria for inclusion based on full-text review.

The 75 studies that were included in the analysis were classified by country, subregion, and country income level as determined by the World Bank (https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html)

Table 1 | Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Journal articles focusing only on assessment of WASH in schools.	• Journal articles that focus on the assessment of WASH in other institutions or setting such as household setting.
• The review covered research articles published in English.	• Research papers and articles published in languages other than English
• This review focused on research articles published in the digital libraries.	• Review articles, book chapters, and encyclopedia entries were not considered.
• Research articles that included all three WASH facilities.	• Research articles focused on sanitation and hygiene only.

Table 2 | Criteria for assessing confidence in AMSTAR-2 (Shea *et al.* 2017; Perry *et al.* 2021)

Rating overall confidence in the results of the review
1. **High** No or one non-critical weakness. The systematic review provides an accurate and comprehensive summary of the results of the available studies that address the question of interest.
2. **Moderate** More than one non-critical weakness. The systematic review has more than one weakness but no critical flaws. It may provide an accurate summary of the results of the available studies that were included in the review.
3. **Low** One critical flaw with or without non-critical weaknesses. The review has a critical flaw and may not provide an accurate and comprehensive summary of the available studies that address the question of interest.
4.**Critically low** (a) More than one critical flaw with or without non-critical weaknesses. The review has more than one critical flaw and should not be relied on to provide an accurate and comprehensive summary of the available studies.

(Tables 3 and 4). Most studies were carried out in the sub-Saharan Africa region (49%) in lower middle-income countries.

Drinking water quality monitoring for WASH in schools

The drinking water quality was not considered by many studies that looked at WASH in schools. Only 42% (32 studies) considered drinking water quality (Table 3). However, most of the studies focused on water supply in terms of availability and sufficiency (Table 4). The studies that considered drinking water quality were conducted mostly in lower middle-income countries (33%) and high-income countries (30%). Less studies were conducted in the upper middle-income and low-income countries. The physical, chemical, and microbial quality of drinking water was considered by all studies that considered drinking water quality.

The physical drinking water quality parameters that were examined were colour, taste, odour, pH, turbidity, temperature, electric conductivity, hardness, and salinity. The chemical drinking water quality parameters that were examined by the selected studies were aluminium (Al), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), Fe, Mn, molybdenum (MO), nickel (Ni), silicon (Si), strontium (Sr), vanadium (V), and zinc (Zn), fluoride (F^-), total dissolved solids (TDS), phosphate (PO_4^{3-}), chloride (Cl−), arsenic (As), cadmium (Cd), lead (Pb), dissolved oxygen (DO), iron (Fe), manganese (Mn), nitrates (NO_3^-), ammonia (NH3), nitrate (NO_3^-), phosphate (PO_4^{3-}) and sulphate (SO_4^2), nitrite (NO_2^-), ammonium (NH_4^+), permanganate ($KMnO_4$), free residual chlorine (FRC), cyanide (CN^-), chemical oxygen demand (COD), calcium (Ca^{+2}), and bicarbonate (HCO_3^-). The microbial water quality parameters that were analysed by the selected studies included *E. coli, Shigella, Salmonella, Vibrio cholerae, Campylobacter*, rotavirus, faecal coliforms, total coliforms, heterotrophic bacteria, *Pseudomonas*, colony-forming units (CFU), and parasites.

Of all the studies that considered drinking water quality, 66% of the studies included chemical parameters together with microbial and physical parameters, while 34% of the studies included chemical parameters only (Table 3). About 28% of the studies included microbial parameters alone, whereas the specific number of studies that used microbial parameters together with chemical and physical parameters was 59%. In 38% of the studies, physical parameters were included together with chemical and microbial parameters, while in 3% of the studies, physical parameters were included alone (Table 3). Only 16% of the studies were conducted in low-income countries and 9% of these studies included microbial parameters. This study revealed that lower middle-income countries considered the analysis of the microbial water quality, especially *E. coli* or faecal coliform. While the high-income countries focused primarily on chemical parameters, particularly Pb.

DISCUSSION

Importance of WASH in schools

Several studies reported that improved WASH in schools is crucial in improving health and education efficiency in schools (Olukanni 2013; Appiah-brempong *et al.* 2018; Cronk *et al.* 2021; Ahmed *et al.* 2022; Akoteyon 2022; Toleubekov *et al.* 2022). Facilitating the implementation of WASH interventions in schools settings is of particular importance because most of the

Table 3 | Identified studies that included drinking water quality

No.	Author, Year	Country	Country income level	Region	WASH variables	Drinking water quality variable
1.	Ahmed *et al.* (2020)	Pakistan	Lower middle-income	South Asia	WASH provision Drinking water quality	**Microbial:** *E. coli*, *Shigella*, *Salmonella*, *Vibrio cholerae*, *Campylobacter*, and *Rotavirus*.
2.	Ahmed *et al.* (2022)	Pakistan	Lower middle-income	South Asia	WASH provision	**Physical:** pH, turbidity, temperature, conductivity, and hardness **Chemical:** F^-, TDS, pH, PO_4^{3-}, Cl^-, As, Cd, Pb, DO, Fe, Mn, and NO_3^-. **Microbial:** Faecal coliforms.
3.	Al-saleh (1996)	Saudi Arabia	High income	Middle East & North Africa	Water quality analysis	**Chemical:** Al, Be, Cd, Co, Cr, Cu, Fe, Mn, MO, Ni, Si, Sr, V, and Zn.
4.	Cronk *et al.* (2021)	Ethiopia, Ghana, Honduras, India, Kenya, Malawi, Mali, Mozambique, Niger, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe.	Lower middle-income, low income	Sub-Saharan Africa; Latin America & Caribbean; South Asia	WASH facilities	**Microbial:** *E. coli*
5.	Bah *et al.* (2022)	Guinea	Low income	Sub-Saharan Africa	WASH facilities and practices	**Physical:** Water quality made their choices mainly in terms of the clarity of the water, i.e., if the water is clear, it was considered drinkable.
6.	Bolatova *et al.* (2021)	Kazakhstan	Upper middle-income	Europe & Central Asia	WASH provision	**Physical:** Turbidity, colour, odour, and pH. **Chemical:** Fe. **Microbial:** Total coliforms and faecal coliforms.
7.	Banu *et al.* (2018)	Ghana	Lower middle-income	Sub-Saharan Africa	Drinking water quality	**Microbial:** Heterotrophic bacteria, *Pseudomonas*, and total coliforms.
8.	Bouchard *et al.* (2018)	Canada.	High income	North America	Drinking water quality	**Chemical:** Mn, Cr, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb.
9.	Bouchard *et al.* (2011)	Canada	High income	North America	Drinking water quality.	**Chemical:** Mn, Pb, Fe, As, Zn, and Cu.
10.	Buajitti *et al.* (2021)	Canada	High income	North America	Drinking water quality.	**Chemical:** Pb.
11.	Cradock *et al.* (2019)	United States of America (USA)	High income	North America	Drinking water quality, availability, and education- related practices.	**Microbial:** Bacteria and coliforms (no specific details provided).

(*Continued.*)

Table 3 | Continued

No.	Author, Year	Country	Country income level	Region	WASH variables	Drinking water quality variable
12.	Ekenga *et al.* (2018)	USA	High income	North America	Drinking water analysis	**Chemical:** Pb.
13.	Hood *et al.* (2014)	USA	High income	North America	Drinking water availability and water quality.	**Physical:** Water analysis was based on physical appearance of drinking fountains. **Chemical:** Pb. **Microbial:** Bacteria (name not specified).
14.	Hossain *et al.* (2022)	Bangladesh	Lower middle-income	South Asia	Drinking water quality.	**Physical:** pH and salinity. **Chemical:** DO, NH3, NO_3^-, PO_4^{3-}, and SO_4^2. **Microbial:** *E. coli* and total coliforms.
15.	Hu *et al.* (2021)	China	Upper middle-income	East Asia & Pacific	Drinking water quality.	**Physical:** Turbidity. **Chemical:** FRC and COD. **Microbial:** CFU.
16.	Huang *et al.* (2018)	China	Upper middle-income	East Asia & Pacific	Drinking water quality.	**Physical:** Conductivity and hardness. **Chemical:** Ca^{+2}, Mn, and HCO_3^-.
17.	Hung *et al.* (2020)	Vietnam	Lower middle-income	East Asia & Pacific	Drinking water quality.	**Physical:** Colour, taste, odour, turbidity, pH, and hardness. **Chemical:** NO_2^-, NO_3^-, NH_4^+, Fe, $KMnO_4$, Cl-, Mn, SO_4^2, As. **Microbial:** Total coliforms, and *E. coli*.
18.	Alam & Mukarrom (2022)	Bangladesh	Lower middle-income	South Asia	Drinking water quality	**Microbial:** Total coliforms and faecal coliforms
19.	Borges-pedro *et al.* (2018)	Brazil	Upper middle-income	Latin America & Caribbean	WASH services	**Microbial:** *E. coli* and total coliforms.
20.	Khan *et al.* (2011)	Bangladesh	Lower middle-income	South Asia	Drinking water quality	**Chemical:** Mn and As.
21.	Lobo *et al.* (2022)	USA	High income	North America	Drinking water quality	**Chemical:** Pb.
22.	Machado *et al.* (2022)	Guinea-Bissau	Low income	Sub-Saharan Africa	Drinking water quality	**Physical:** Conductivity, DO, colour, and pH **Chemical:** NO_2^-, NO_3^-, NH_4^+, Al, As, Cu, Cr, CN –, and Fe. **Microbial:** Faecal coliforms and intestinal enterococci.
23.	Samie *et al.* (2011)	South Africa	Upper middle-income	Sub-Saharan Africa	Drinking water quality	**Microbial:** Faecal coliforms, total coliform, heterotrophic bacteria.
24.	Meschede *et al.* (2018)	Brazil,	Upper middle-income	Latin America & Caribbean	Drinking water quality	**Physical:** pH, turbidity, conductivity, and alkalinity. **Microbial:** Total coliform, *E. coli*,

						heterotrophic bacteria, and parasites. **Chemical:** Anions and trace elements (names not specified).
25.	Moreno *et al.* (2021)	USA	High income	North America	Drinking water access	**Chemical:** Pb.
26.	Morgan *et al.* (2021)	Mozambique and Uganda	Low income	Sub-Saharan Africa	Drinking water quality	**Microbial:** *E. coli.*
27.	Patel *et al.* (2011)	USA	High income	North America	Availability and consumption of water	**Chemical:** Pb
28.	Rahman & Hashem (2019)	Bangladesh	Low income	Sub-Saharan Africa	Drinking water quality	**Chemical:** As, Fe and Cl-
29.	Ribeiro *et al.* (2018)	Brazil	Upper middle-income	Latin America & Caribbean	Drinking water quality	**Physical:** Turbidity. **Chemical:** FRC. **Microbial:** *E. coli* and faecal coliforms.
30.	Sangalang *et al.* (2022)	Philippines	Lower middle-income	East Asia & Pacific	WASH facilities and hygiene practices.	**Microbial:** Total coliforms and *E. coli*.
31.	Yani *et al.* (2021)	Palu, Indonesia	Lower middle-income	East Asia & Pacific	Drinking water quality	**Chemical:** F^-.
32.	Kouamé *et al.* (2021)	Côte d'Ivoire	Lower middle-income	Sub-Saharan Africa	WASH accessibility	**Microbial:** *E. coli* and total coliforms.

Table 4 | Identified studies that excluded drinking water quality

No.	Reference	Country	Country income level	Region	WASH Variable
1.	Adhikari *et al.* (2017)	Nepal	Lower middle-income	South Asia	WASH funding
2.	Agol & Harvey (2018)	Zambia	Lower middle-income	Sub-Saharan Africa	Drinking water supply
3.	Akoteyon (2022)	Nigeria	Lower middle-income	Sub-Saharan Africa	Quality of WASH service delivery
4.	Oduor *et al.* (2015)	Kenya	Lower middle-income	Sub-Saharan Africa	Drinking water supply
5.	Altman *et al.* (2020)	USA	High income	North America	Drinking water supply
6.	Appiah-brempong *et al.* (2018)	Ghana	Lower middle-income	Sub-Saharan Africa	WASH provision
7.	Asumah *et al.* (2022)	Ghana	Lower middle-income	Sub-Saharan Africa	WASH provision
8.	Ngwenya *et al.* (2018)	Botswana	Upper middle-income	Sub-Saharan Africa	WASH functionality
9.	Tadesse & Hagos (2009)	Ethiopia	Lower middle-income	Sub-Saharan Africa	WASH impact on basic education
10.	Toleubekov *et al.* (2022)	Kazakhstan	Upper middle-income	Europe & Central Asia	WASH provision
11.	Chard *et al.* (2019)	Laos	Lower middle-income	Southeast Asia	WASH impact on basic education
12.	Cradock *et al.* (2012)	USA	High income	North America	Water-related policies
13.	Pandey *et al.* (2020)	India	Lower middle-income	South Asia	WASH intervention
14.	Ellis *et al.* (2016)	Philippines	Lower middle-income	East Asia & Pacific	Drinking water supply
15.	Erhard *et al.* (2013)	Malawi and Uganda	Low income	Sub-Saharan Africa	WASH provision
16.	Fadda *et al.* (2012)	Italy	High income	Europe & Central Asia	Drinking water supplements
17.	Franks *et al.* (2017)	Poland	High income	Europe & Central Asia	Water consumption
18.	Gomathi *et al.* (2018)	India	Lower middle-income	South Asia	Knowledge and practices regarding WASH
19.	Inah *et al.* (2020)	Nigeria	Lower middle-income	Sub-Saharan Africa	WASH provision
20.	Jordanova *et al.* (2015)	Nicaragua	Lower middle-income	Latin America & Caribbean	WASH provision
21.	Karon *et al.* (2017)	Indonesia	Lower middle-income	East Asia & Pacific	WASH sustainability
22.	Kaushik *et al.* (2007)	United Kingdom	High income	Europe & Central Asia	Drinking water supply
23.	Kenney *et al.* (2016)	USA	High income	North America	Drinking water supply
24.	Komarulzaman *et al.* (2019)	Indonesia	Lower middle-income	East Asia & Pacific	Water impact on basic education
25.	Kotingo *et al.* (2014)	Nigeria	Lower middle-income	Sub-Saharan Africa	Drinking water supply
26.	Loughridge & Barratt (2005)	United Kingdom	High income	Europe & Central Asia	Drinking water supply
27.	Mchenga *et al.* (2020)	Malawi	Low income	Sub-Saharan Africa	Sufficiency of sanitation facilities
28.	Muralidharan *et al.* (2015)	India	Lower middle-income	South Asia	Menstrual hygiene
29.	Olukanni (2013)	Nigeria	Lower middle-income	Sub-Saharan Africa	WASH provision
30.	Patel *et al.* (2014)	USA	High income	North America	Attitudes associated with intentions to drink water
31.	Dreibelbis *et al.* (2013)	Kenya	Lower middle-income	Sub-Saharan Africa	WASH conditions
32.	Roshini *et al.* (2020)	India	Lower middle-income	South Asia	

					Practices regarding WASH among leaners
33.	Sharma *et al.* (2021)	USA	High income	North America	Examine how language quality relates to school drinking water access
34.	Wada *et al.* (2022)	Nigeria	Lower middle-income	Sub-Saharan Africa	WASH conditions
35.	Wadan (2012)	Ghana, Sierra Leone, and South Africa	Lower middle-income, Low income and Upper middle-income	Sub-Saharan Africa	Understand knowledge about drinking water and impact on education
36.	Antwi-Agyei *et al.* (2017)	Tanzania	Lower middle-income	Sub-Saharan Africa	Drinking water supply
37.	Garn *et al.* (2017)	Mali	Low income	Sub-Saharan Africa	Drinking water supply
38.	Mushota *et al.* (2021)	India	Lower middle-income	South Asia	Drinking water supply
39.	Ohwo (2019)	Nigeria	Lower middle-income	Sub-Saharan Africa	Drinking water supply
40.	Olatunji & Thanny (2020)	Nigeria	Lower middle-income	Sub-Saharan Africa	WASH provision
41.	Shilunga *et al.* (2018)	Namibia	Upper middle-income	Sub-Saharan Africa	Drinking water supply
42.	Habtegiorgis *et al.* (2021)	Ethiopia	Low income	Sub-Saharan Africa	Menstrual hygiene practices
43.	Winter *et al.* (2021)	Zambia	Lower middle-income	Sub-Saharan Africa	Drinking water supply

children's time is spent in school and they are more susceptible to various WASH-related diseases than adults (Agol & Harvey 2018; Banu *et al.* 2018; Ahmed *et al.* 2020, 2022; Bolatova *et al.* 2021). Therefore, to reduce the prevalence of WASH-related diseases, effective interventions for adequate safe WASH in schools should be implemented (Patel *et al.* 2014; Chard *et al.* 2019; Pandey *et al.* 2020; Wada *et al.* 2022). Furthermore, safe WASH inclusive of water of good quality in schools is not only a prerequisite to health but contributes to livelihoods, school attendance, and dignity (Bolatova *et al.* 2021; Ahmed *et al.* 2022).

Several studies have demonstrated an important exposure pathway between WASH services and health outcomes (Jordanova *et al.* 2015; Ahmed *et al.* 2020, 2022; Cronk *et al.* 2021; Morgan *et al.* 2021; Sangalang *et al.* 2022). The assessment and monitoring of water quality, particularly the microbial and chemical quality, is necessary for preventing potential human risks associated with exposure to contaminated water. To protect learner's health, it is recommended that water quality, particularly microbial quality, monitoring be included in schools' WASH or routine water quality monitoring studies (Ahmed *et al.* 2020; Hung *et al.* 2020; Hossain *et al.* 2022).

Role of WASH in education

This review identified few studies that support the role of safe WASH in school's primary role of providing education and essential life skills to children (Chard *et al.* 2019; Cradock *et al.* 2019; Komarulzaman *et al.* 2019; Tadesse & Hagos 2009; Bolatova *et al.* 2021; Toleubekov *et al.* 2022). Approximately 443 million school days are lost each year due to water-related illnesses, making this a leading factor for school absences in the developing world (Karon *et al.* 2017; Agol & Harvey 2018; Chard *et al.* 2019; Komarulzaman *et al.* 2019). Tadesse & Hagos (2009) suggests that access to adequate WASH services in schools may contribute to improved education and health of children by reducing the number of days missed in schools due to menstrual periods or illness. Moreover, poor provision of WASH in schools can result in lower enrolment, absenteeism, and dropout among girls (Jordanova *et al.* 2015; Habtegiorgis *et al.* 2021). Therefore, the provision of safe WASH in schools is not only a prerequisite to health but also to promote educational performance (Karon *et al.* 2017; Chard *et al.* 2019; Komarulzaman *et al.* 2019). A correlation between water quality and educational outcomes has been shown in several studies (Ahmed *et al.* 2020; Bolatova *et al.* 2021; Buajitti *et al.* 2021; Cronk *et al.* 2021). These studies have demonstrated that providing schools with improved water quality can contribute to improved educational performance (Hood *et al.* 2014; Borges-pedro *et al.* 2018; Ribeiro *et al.* 2018; Rahman & Hashem 2019; Hu *et al.* 2021; Kouamé *et al.* 2021; Yani *et al.* 2021; Ahmed *et al.* 2022; Bah *et al.* 2022; Hossain *et al.* 2022).

Global WASH provisioning in schools

A global initiative has focused on improving access to WASH by increasing access to drinking water and sanitation (Erhard *et al.* 2013; Karon *et al.* 2017; Cronk *et al.* 2021). Yet studies also revealed that a lot of people in developing countries still do not have access to potable water and sanitation services (Ohwo 2019; Ahmed *et al.* 2020; Bolatova *et al.* 2021; Wada *et al.* 2022). While WASH provision has improved significantly over the world, progress in Sub-Saharan Africa has lagged that of other regions since Sub-Saharan Africa's rural areas have lower rates of access to WASH services and poorer health outcomes than metropolitan areas (Winter *et al.* 2021; Zerbo *et al.* 2021). This is because only 6% of the urban population in Sub-Saharan Africa uses unimproved sources of drinking water compared to more than 25% of the rural population (Winter *et al.* 2021; Zerbo *et al.* 2021; Wada *et al.* 2022). Consequently, many schools in low-income countries, especially sub-Saharan Africa, have inadequate access to WASH provision (Ohwo 2019; Akoteyon 2022). A study conducted in 14 low- and middle-income countries (Ethiopia, Ghana, Honduras, India, Kenya, Malawi, Mali, Mozambique, Niger, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe), revealed that not all schools have all three WASH facilities. Of the 2,690 rural schools, only 4% of schools had all basic water, sanitation, and hygiene facilities in all 14 low and middle-income countries (Bolatova *et al.* 2021; Cronk *et al.* 2021).

The drinking water quality in schools WASH

The deterioration in the drinking water quality in schools is mostly related to microbial water contamination. Several studies showed that schools in low- and middle-income countries are often deprived of microbial safe water (Banu *et al.* 2018; Ahmed *et al.* 2020, 2022; Bolatova *et al.* 2021; Cronk *et al.* 2021; Hossain *et al.* 2022). Some studies highlight that the supply of safe drinking water quality in schools has been compromised by the absence of adequate sanitary infrastructure (Cronk *et al.* 2021; Kouamé *et al.* 2021; Morgan *et al.* 2021). Whereas safe and adequate drinking water supply in schools is prerequisite aspects of the right to basic education for learners. Because contaminated drinking water poses health risks and lower level of academic success among learners (Meschede *et al.* 2018; Hung *et al.* 2020; Kouamé *et al.* 2021). Six of the selected studies (Borges-Pedro *et al.* 2018; Ahmed *et al.* 2020; Hung *et al.* 2020; Hossain *et al.* 2022; Kouamé *et al.* 2021; Alam & Mukarrom 2022) demonstrated through regular monitoring, poor water quality in schools. According to these investigations, the drinking water quality test results from the schools showed microbial contamination, primarily with *E. coli* and total coliforms.

A safe and adequate drinking water supply in schools is crucial (Antwi-agyei *et al.* 2017) and is essential for health and assisting learners in maintaining daily water intake. Several studies have shown that increasing water intake may improve hydration and cognitive performance among learners (Hood *et al.* 2014; Borges-pedro *et al.* 2018; Cradock *et al.* 2019; Rahman & Hashem 2019; Ahmed *et al.* 2020; Bolatova *et al.* 2021; Hu *et al.* 2021; Moreno *et al.* 2021; Morgan *et al.* 2021; Sangalang *et al.* 2022).

To ensure a safe water supply in schools, drinking water quality should be included during the evaluation of WASH provision (Bolatova *et al.* 2021). However, this study showed that there has only been a limited amount of research on drinking water quality in schools and that drinking water quality has not been fully researched in the context of WASH (Meschede *et al.* 2018; Cradock *et al.* 2019; Sangalang *et al.* 2022). Some studies have focused on the availability of water without determining the water the safety quality (Cronk *et al.* 2021; Morgan *et al.* 2021). However, it is necessary to make sure that students have access to safe drinking water at school. As mitigation intervention to improve drinking water quality, Ahmed *et al.* (2020), Hu *et al.* (2021), Cronk *et al.* (2021) and Bah *et al.* (2022), suggested that schools establish a routine water quality monitoring programme, as well as the implementation of cost-effective drinking water treatment methods such as solar disinfection and chlorination. Ahmed *et al.* (2022) suggested that Educational Monitoring and Information System (EMIS) should be implemented in schools to improve WASH. In addition, the assessment of drinking water quality in schools, in particular, microbial quality, is critical since it is linked to the prevention of infectious diseases. However, this study showed that in high-income countries, chemical analysis is given a greater priority than microbial and physical analysis. Since drinking water is a source of Pb exposure in North America, Pb has been primarily monitored in these schools. Leaching from plumbing system components has been identified as the main contributor to Pb water contamination in educational facilities (Al-saleh 1996; Bouchard *et al.* 2011, 2018; Patel *et al.* 2011; Ekenga *et al.* 2018; Buajitti *et al.* 2021).

Challenges associated with WASH in schools

Population growth and challenges in terms of water infrastructure coverage and portable water supply reliability, access to WASH provisions is lacking or limited, particularly in schools in rural areas in most developing countries (Ngwenya *et al.* 2018; Bolatova *et al.* 2021; Kouamé *et al.* 2021). Poor availability and access to water and sanitation are major health concerns and constitute a principal barrier to the achievement of quality education in schools (Agol & Harvey 2018). A study by Ngwenya *et al.* (2018) found that the three surveyed schools in northwest Botswana's Ngamiland District had unreliable water supply issues because they depended on the local water authority for water supply which also supplied water to many other educational institutions, small businesses, and residential areas. As a result, the three schools that were surveyed suffered from poor sanitation and hygiene. Moreover, a study by Garn *et al.* (2017) revealed a slight decline in the sustainability of the WASH programme in Mali over the 3-year period covered by the study (2012–2014) as evidenced that some of the schools appeared to face some challenges in sustaining their WASH programmes over time, and thus indicating the need for further improvements in ensuring that schools have the motivation and resources to maintain their WASH systems over time. Gaps in several vital aspects of WASH in schools, such as accessibility, maintenance, operation, lack of knowledge, and poor hygiene practices are noted occurrences (Bolatova *et al.* 2021). These gaps affect the achievement of SDGs, especially SDG 6, which focuses on ensuring 'the availability and sustainable management of water and sanitation for all' by 2030 (Bain *et al.* 2021; Cronk *et al.* 2021; Morgan *et al.* 2021; Asumah *et al.* 2022).

Successes and lessons learnt on WASH in schools

Significant global improvements in WASH access have been reported in some studies in the past two decades (Garn *et al.* 2017; Appiah-brempong *et al.* 2018; Winter *et al.* 2021). Efforts to increase access to improved water, sanitation, and hygiene globally including in rural areas have been noticed (Appiah-brempong *et al.* 2018). Since the 1990s, prior to the first adoption of WASH in 2001, a study by Al-Saleh (1996) revealed that learners in schools were at risk of ingesting chemically polluted water, and early intervention was suggested for remedial action. Even now during the 2020s, a study by Winter *et al.* (2021) has also reflected a significantly increased percentage of people worldwide who have access to improved water sources and adequate sanitation. It is noted however, the efforts have been primarily focused on WASH in the household or community, rather than at the institutional level, particularly in school settings (Cronk *et al.* 2021; Morgan *et al.* 2021; Winter *et al.* 2021). One of the successes of WASH is that WHO and UNICEF have produced the 'Surveillance of water, sanitation, and hygiene in schools' tool which could be used at the local and national level to monitor the holistic view of access to WASH and consequently could be used to cover SDG 6 in schools (Garn *et al.* 2017; Bolatova *et al.* 2021). The tool has primarily been used by the WHO/UNICEF Joint Monitoring Programme (JMP) to provide ongoing updates on the provision of WASH in schools around the world and is also available for use by researchers at the local level (Winter *et al.* 2021; Toleubekov *et al.* 2022). The JMP developed WASH service ladders for monitoring WASH services in schools around the world, classifying them as basic, limited, and no service. The service ladders are beneficial even locally, as researchers utilize them to evaluate the WASH status of schools (Toleubekov *et al.* 2022).

Role of WASH education in schools

Schools as learning environments have the potential to be places where pupils learn safe WASH practices (Morgan *et al.* 2021). WASH services alone are often not sufficient, they need to be combined with educational programmes (Mushota *et al.* 2021). Although often taken for granted, hand washing education is the most simple, effective, and inexpensive measure for interrupting the transmission of micro-organisms and slowing the spread of diseases (Ngwenya *et al.* 2018). Hence, most school-based WASH programmes are to increase student knowledge and practice of behaviours such as washing hands with soap (Winter *et al.* 2021). However, evidence of good WASH-related practices and knowledge at schools is scarce (Kouamé *et al.* 2021). This discrepancy of knowledge and practice might arise due to the lack of handwashing facilities or the unavailability of clean water. A study by Kouamé *et al.* (2021) in the south-central part of Côte d'Ivoire revealed that, although learners had knowledge about WASH, however, they do not practice hygiene. Therefore, effective hygiene education should be incorporated into the school curriculum, as this will help promote long-term positive behavioural changes among pupils (Mogaji *et al.* 2018). According to a study conducted by Egbinola & Amanambu (2015) and Thakadu *et al.* (2018), despite the fact that hygiene education was incorporated into the curriculum, learners did not practice hygiene.

WASH in light of SDGs

Several studies are done and as reviewed here contribute to information and practices towards the achievement of SDGs 3, 4, and 6, which are essential for ensuring safe WASH in schools (Karon *et al.* 2017; Agol & Harvey 2018; Appiah-brempong *et al.* 2018; Ngwenya *et al.* 2018; Bolatova *et al.* 2021; Cronk *et al.* 2021; Kouamé *et al.* 2021; Toleubekov *et al.* 2022). The SDGs 4 and 6 have to address the provision of safe water and sanitation for schools and increase schools' ability to offer an effective learning environment, including essential drinking water, sanitation, and hygiene (Appiah-brempong *et al.* 2018; Ngwenya *et al.* 2018; Bolatova *et al.* 2021; Cronk *et al.* 2021). SDG 3 aims to ensure healthier lives and encourage well-being at all ages to achieve sustainable growth. While Goal 4 seeks to improve the proportion of education facilities with access to an appropriate learning environment, including essential WASH. At the same time, Goal 6 aims at achieving access for all to potable water, sanitation, and hygiene (Karon *et al.* 2017; Ngwenya *et al.* 2018; Bolatova *et al.* 2021; Kouamé *et al.* 2021; Toleubekov *et al.* 2022). One notable strategy for achieving the related SDGs to safe water supply and sanitation by 2030 is to provide schools with sustainable, safe WASH (Agol & Harvey 2018). A study by Kouamé *et al.* (2021), indicates achieving SDG 6 will be difficult to reach by 2030 in 20 schools surveyed in the Taabo health and demographic surveillance systems in the south-central part of Côte d'Ivoire. This is because the findings of their study revealed that the drinking water of the surveyed schools did not comply with the set water quality standards, and sanitation infrastructure is lacking to a large extent and inadequate. Moreover, there was no provision of hygiene infrastructure such as handwashing stations, soaps, and menstrual hygiene management facilities.

CONCLUSIONS

The SDGs place a strong emphasis on ensuring that everyone has access to clean and safe water, sanitation, and hygiene as well as improving schools' ability to create a positive learning environment. This study, however, identified a gap where most studies just consider water availability and neglect including drinking water quality analyses, whereas, drinking water quality analysis are necessary to establish whether the water is safe to drink or not. Some investigations have also shown that drinking water quality in schools was microbially compromised by *E. coli* and total coliforms. Therefore, effective school-based WASH interventions are needed to better protect children's health. This must include drinking water quality assessment programmes in schools.

This study also revealed that most middle-income countries considered the analysis of the microbial water quality, especially *E. coli* or faecal coliforms. While the high-income countries focused primarily on chemical analysis, particularly, Pb. This suggests that the priorities of developing and developed countries differ in relation to the supply of WASH facilities. This does, however, show that there are concerns with drinking water quality in both developed and developing countries.

Drinking water quality has an impact on the availability of safe WASH. Even if water is provided in adequate quantities, if the quality is poor, it will still contribute to negative health effects and affect safe WASH. From the literature study as presented, as part of safe WASH, it is recommended that routine drinking water quality monitoring programmes be incorporated in schools, and that cost-effective water treatment procedures be implemented where appropriate. This should involve the implementation of EMIS. This study also discovered that there were limited studies that covered drinking water quality analysis in schools; as a result, this study recommends that additional water quality analysis studies be undertaken in schools to improve academic awareness and help the world achieve the SDGs by 2030.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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