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Assessing institutional sanitation and its impact at a citywide level: an exploration of school sanitation in the Accra Metropolitan Area, Ghana

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Introduction: Exploring sanitation at a city scale is crucial due to approaches such as Citywide Inclusive Sanitation (CWIS). Sanitation impacts individuals, households and the whole city, as recognised by CWIS. The Shit Flow Diagram Graphic (SFDG) is the primary tool for citywide situation analysis. However, current SFDGs assume that individuals use only home toilets, overlooking the complexity of toilet usage, including public and workplace facilities. Our understanding of citywide sanitation flows is incomplete if analyses ignore the other toilets that people use. This study explored the impact of one type of institutional sanitation, school sanitation, on citywide sanitation flows.

Methods: To do this an overview and analysis of school sanitation at a citywide level was needed and a method to split the school pupils' excreta flows was developed. Data was collected from secondary sources (e.g. from Ghana Statistical and Educational Services), structured observations (n = 26), and interviews with key informants (n = 15), headteachers (n = 26) and students (n = 39) from across Accra Metropolitan Area, Ghana. This data was used to construct three SFDGs, which were compared using Trend Graphs (graphs used to compare the state of sanitation across the different stages of the sanitation value chain).

Results and Discussion: The findings indicated that school sanitation was less safely managed than household sanitation and that SFDGs could be used assess school-level sanitation. Method development was crucial to accurately partition pupils' excreta flows. While annual flows from schools appeared insignificant citywide, this seasonal flow could adversely affect public and environmental health during school terms. Therefore, it may be more important to consider the school population as a whole when thinking about the impact of school sanitation. This study highlights the importance of understanding where people spend their day and how this is related to the different sanitation systems they use; it demonstrates the need to move beyond household sanitation. This study successfully demonstrates the level of information that is needed regarding people's sanitation practices which enables their excreta flows to be split between different facilities. It could be used as a guide for future studies and the further development of methods to explore this topic.

KEYWORDS

citywide inclusive sanitation, fecal sludge management, sanitation value chain, sanitation tools, shit flow diagram, urban sanitation

Introduction

The world is becoming increasingly urbanized with over 50% of the population now living in cities; this rate is expected to increase further to 66% by 2050 (Ritchie et al., 2024). The majority of this urban growth has occurred in low- and middle-income countries (Ritchie et al., 2024); such fast and continuous urban growth increases the pressure on urban services, such as sanitation. Sanitation systems in these cities can be onsite (non-sewered), offsite (sewered), or a mixture of both (Peal et al., 2020), which adds to the complexity of service delivery. Over the past few decades, the focus of urban sanitation has been on offsite infrastructure, which normally serves only a part of the city in low- and middle-income countries (Evans and Saywell, 2006); this means that onsite infrastructure and the needs of a majority of the population have been neglected. As past approaches have failed to meet the needs of these growing populations, new approaches are required. The citywide inclusive sanitation (CWIS) approach was developed in response to this challenge, and its foundation is the provision of equitable sanitation services at the citywide scale, although it is evolving in terms of what this entails (Gambrill et al., 2020; Lüthi et al., 2020; Mills et al., 2020; Schrecongost et al., 2020).

Before applying any approach at the citywide scale, city sanitation authorities need to understand the existing situation; however, this is not a straightforward task given that services are typically provided on an irregular basis without regulatory oversight or performance information (Baum et al., 2013; Sato et al., 2013; Peal et al., 2020). To assess the delivery of sanitation services in cities, Peal et al. (2014) explored the use of "fecal waste flow diagrams," which are now known as shit flow diagrams (SFDs). The SFD tool has a standard methodology and the outputs are the shit flow diagram graphic (SFDG) along with a report (SFD-PI, 2018). SFDGs have become a useful tool for assessing the sanitation conditions in urban areas (Scott and Cotton, 2020; Safi et al., 2022) and are popular for sanitation delivery context analysis at the citywide scale (Furlong, 2015). To date, over 340 SFDGs have been produced for cities around the world (SFD, 2024). The SFDG illustrates the amount of the populations excreta that is safely managed as it moves along the sanitation service/value chain (SSC or SVC) and the proportion that leaves the SSC safely or unsafely at each stage of the SVC (SFD PI, 2018). The SSC includes the provision of sanitation services by integrating collection, containment, conveyance, treatment, and disposal (Safi et al., 2022).

Although SFDs are produced at the citywide scale and allow for the exploration of different categories of origin, e.g., household and institutional (SFD PI, 2018), it is generally assumed that people use only one toilet throughout the day, namely, their "home toilet." However, actual toilet usage is more complex as people use several toilets throughout the day, such as those in medical facilities, offices, schools, and shopping malls. The importance of toilets beyond the household toilet has been acknowledged by the sustainable development goals (SDGs) through the inclusion of monitoring of toilets in both schools (WASHData, 2024a) and healthcare facilities (WASHData, 2024b), which are considered to be a part of the universal WASH access. Sanitation outside the home could have a disproportionate impact on the citywide conditions, as public and institutional facilities may be used more frequently than facilities at home. Without considering this complexity, and ignoring the other toilets that people frequently use throughout the city, our understanding of citywide sanitation is incomplete. Worryingly, this could mean that even if there is good household sanitation quality, coverage, and usage, the population may not be protected from fecal-oral diseases due to poor sanitation in other sectors, such as medical facilities, offices, and schools.

The complexity of collecting such data and splitting excreta flows is believed to be the main reason why this has not been explored, but there are often good datasets for institutions, such as schools, hospitals, and barracks. Schools are of great interest and significance, as currently over one-quarter of the global population is of school age (UNESCO Institute of Statistics, 2017; UN, 2019), and 78% of this population lives in low- and middle-income countries (UNESCO Institute of Statistics, 2024). As students spend nearly 80% of their waking time in schools (Reid et al., 2002; Nahmod et al., 2017), they may be using school sanitation systems more often than those in their homes. Additionally, given the global aim of inclusive and equitable education for all under SDG4 (UN, 2019), several countries have introduced compulsory free primary education, meaning that a large percentage of the population is in school. Schools have been traditionally excluded from SFDGs; in a study of 20 SFDGs, only six recognized the significance of schools, although no data were included in the SFDGs (Nkonde, 2022). This is because significant estimates and assumptions are needed to understand the utilization of school sanitation facilities (Boadi, 2019). As schools have clearly defined and relatively stable populations, with the amount of time spent in school known along with sanitation types and management strategies, they provide a good case study for investigating the impact of institutional sanitation on citywide sanitation.

This study aimed to explore the impact of institutional (school) sanitation on citywide sanitation. Hence, detailed information was required on both school sanitation and the usage patterns of students so that a method could be developed to split the excreta flows of school pupils between school and home. Therefore, this work also contains an overview and analysis of school sanitation at the citywide level, and a new methodology was developed to allocate the excreta flows of school pupils. SFDGs were used to explore this as it has been used extensively to assess sanitation service delivery at the citywide level across the SSC (SFD, 2024).

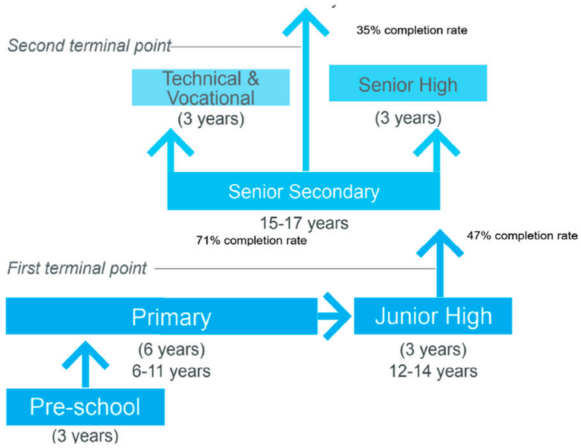

FIGURE 1
Education system in Ghana. Source: Decosas et al. (2018).

Methodology

Case study description

The Accra Metropolitan Area (AMA) in Ghana was chosen for this study due to the availability of data (GSS, 2021a), especially the level of information on the current city sanitation situation (Boadi, 2019), the high percentage of the school-aged population (GSS, 2021a; GSS, 2021c), and accessibility to institutions holding data. The AMA, commonly called Accra, is situated in the southern part of the Greater Accra region of Ghana (Boadi, 2019). It comprises an area of 140 km^2 and has 10 sub-metropolitan districts with a population of 1,281,570, of whom 25% are of school age (GSS, 2021a; GSS, 2021c).

In AMA, schools are differentiated by the age of the students (Figure 1) and their ownership. Private and public senior high schools along with basic schools (a combination of primary and junior high schools) are spread across all 10 sub-metropolitan districts, with an average of two private senior high schools and 123 private and public basic schools per district (GES, 2020). Two of the 10 districts have no private senior high school (Nkonde, 2022). In Ghana, education is managed by the Ministry of Education through the Ghana Education Service (GES), which formulates and implements policies in partnership with other organizations, such as the United Nations Children's Fund (GSS, 2019; African Union & UNICEF, 2020). The GES is currently implementing free compulsory basic and secondary education (FCUBE) (GSS, 2019).

Case study design

This case study used a mixed-methods approach, quantitative data was gathered from secondary data sources e.g. Ghana Statistical Service, structured observations and interviews, while qualitative data was gathered from secondary sources e.g. reports and interviews. This approach was used so that the data could be validated. Data collection was undertaken between July and September 2022 after obtaining ethical approval from the IHE, Delft, The Netherlands (IHE-RECO-2022-003).

The schools were selected using stratified convenience sampling, with one school chosen from each category of schools present in each district. Twenty six schools were selected: one public senior high school, one private senior high school, 17 public basic schools, and seven private basic schools. Secondary data were collected from the Ghana Statistical Service (GSS) and GES on the school population, school policies, and sanitation situation in the schools and cities (Table 1).

A total of 80 key informants were interviewed using a semi-structured approach. The headteachers of the selected schools were interviewed, and they also identified students who could be interviewed (Table 2). The School Health Education Program (SHEP) coordinators were interviewed from each district (Table 2). Other key informants were also purposively sampled based on their roles, responsibilities, and knowledge (Table 2), but harder-to-access key informants such as private operators and utility employees were sampled through snowball sampling (Table 2). All interviews were conducted in English, either at the offices of these individuals or at the schools; the interviews lasted between 30 and 45 min, and informed consent was obtained prior to participation. Interviews with the students were conducted in the presence of a parent, guardian, or headteacher, and informed consent was obtained from both the student and the adult present. Notes were taken during the interviews and analyzed using themes related to the objectives of this research. After each interview with the headteachers, structured observations of the school sanitation systems were conducted. The structured observation sheets were developed based on the WHO Sanitation Sanitary Inspection Forms (WHO, 2018) and is included in Supplementary Table S1.

Generation of SFDGs

SFDGs were generated using the online SFDG generator following the standard methodology in the SFD manual (SFD

TABLE 1 Secondary data sources used in the study.

Information source	Reference	Data used
Education Management Information System Data	Ghana Education Service (GES), 2020	Student enrollment and number of schools used for school SFDG
Implementation Model for WASH in Schools in Ghana	Ghana Education Service (GES), 2014	School sanitation policies for general overview of school sanitation in Ghana
Ghana Living Standards Survey	Ghana Statistical Service (GSS), 2019	FCUBE
Ghana 2021 Population and Housing Census: Population of Regions and Districts	Ghana Statistical Service (GSS), 2021a	Population used for the AMA SFDGs
Ghana 2021 Population and Housing Census: Water and Sanitation	Ghana Statistical Service (GSS), 2021b	Sanitation technologies used for the AMA SFDGs
Ghana 2021 Population and Housing Census: Age and Sex Profiles	Ghana Statistical Service (GSS), 2021c	Population age profile used to estimate the number of school-aged children in AMA
Greater Accra Sustainable Sanitation and Livelihoods Improvement Project	Colan-Consult (2020)	Household sanitation, city sanitation technologies, treatment options, school sanitation technologies, and student practices used for used for the AMA and school SFDGs

TABLE 2 Details of key informant interviews.

Code	Role	Organization	Interview themes and topics
KI-001	School sanitation expert	Local consultancy	- School sanitation policies - General school sanitation in AMA
KI-002	School sanitation officer	Local consultancy	- General school sanitation in AMA
KI-003	Program manager	Sanitation improvement project	- AMA sanitation status - Impact of project
KI-004	Association president	Private operator organization	- Role of private operator in AMA and school sanitation
KI-005	School health education program (SHEP) coordinator	Ghana Education Service	- School sanitation policies - General school sanitation in AMA
KI-006	SHEP coordinator	City education unit	- School statistics - State of school sanitation in each district - Sanitation systems and technologies - Operation and maintenance of toilets
KI-007–14	SHEP coordinators	District Educational Directorates	
KI-015	Sanitation expert	Ministry of sanitation and water resources	- AMA household sanitation technologies
HT-001 – HT-026	Headteacher	Various schools	- General school information and school sanitation
S-001 – S-039	Student	Various schools	- Students school sanitation practices

PI, 2018). Three SFDGs were developed to explore the impact of school sanitation on the excreta flows of the city. SFDG1 depicts the excreta flow of the current population in AMA; this was used to understand the city sanitation situation in 2022. SFDG2 depicts the current excreta flow from only the schools in AMA; this was generated to visualize the status of school sanitation. SFDG3 depicts the excreta flow of the city by including the inputs from the school sanitation; this SFDG was generated by removing the excreta flows of the students from their home toilets and incorporating the school sanitation excreta flows of the pupils from the school toilets.

To develop SFDG3, the students' excreta flows had to be split between their households and schools. The proportions of pupils' excreta disposed of at school were calculated using the number of waking hours per day (h) and the number of days in a year that a pupil is in school (d). This depends on the type of attendance, i.e., residential (R) or day (D). Not all students use toilets at school, so the proportion of students using school sanitation facilities (C) was needed. For each student using the school toilet, some excreta may still be deposited at home, so the proportion of excreta deposited in the school sanitation system (k) was needed. These data were used to calculate the school sanitation usage population equivalent (SUP_e) given by Equations 1–3

School sanitation usage population equivalent:

$$SUP_e = SUP_{eR} + SUP_{eD}. \quad (1)$$

School sanitation usage population equivalent for day (*D*) or residential (*R*) students:

$$SUP_{eD} = S_{pD} \times t_D \times C_D \times k_D$$

or

$$SUP_{eR} = S_{pR} \times t_R \times C_R \times k_R. \quad (2)$$

The proportion of time spent by the students in school in a year:

$$t_D = \frac{h_{sD}}{h_W} \times \frac{d_D}{365}$$

or

$$t_R = \frac{h_{sR}}{h_W} \times \frac{d_R}{365}, \quad (3)$$

Where:

- SUP_e = School usage population equivalents
- SUP_{eD} or SUP_{eR} = School usage population equivalents (D = day, R = residential)
- S_{pD} or S_{pR} = Student population of students (D = day, R = residential)
- t_D or t_R = Proportion of time the students spend at school per year (D = day, R = residential)
- d_D or d_R = Number of days students spend at school (D = day, R = residential)
- h_{SD} or h_{SR} = Total hours spent in school per day (D = day, R = residential)
- h_W = Total waking hours of the student
- C_D or C_R = Proportion of students who use the school toilets (D = day, R = residential)
- k_D or k_R = Proportion of day students' usage of school compared to home sanitation facilities (D = day, R = residential)

Data checking

The accuracy of the various data sources varied; to ensure that the results were not unduly influenced by inaccurate data, a two-step validation process was used. First, the data used to generate the SFDGs were color-coded based on the level of triangulation to show the level of confidence. Data with a wide range of sources were coded green, while data from a single source without triangulation were coded amber. Sensitivity analysis was performed using different scenarios to assess the impact of variations in the amber-coded data. The range of results was assessed, and if this range was large then the middle value was chosen; however, if there was little difference in the results, the value deemed by the authors to be most valid was chosen for generating the SFDGs.

The SFDGs were compared using trend graphs (Martinez, 2016). Trend graphs were developed to illustrate the differences in sanitation provision over time (Martinez, 2016; Safi et al., 2022); however, in the present study, they were used to compare differences in the safe management of sanitation services between households and schools in AMA (SFDG1 vs. SFDG2) and to explore the impact of school sanitation on citywide sanitation (SFDG1 vs. SFDG3).

Results and discussion

Current AMA sanitation status

Figure 2 shows the SFDG for AMA in 2022 based on household sanitation. In AMA, 1% of the population was practicing open defecation, and the excreta of approximately 99% of the population was safely contained through various sanitation technologies (Figure 2), including sewers, biodigesters, septic tanks, holding tanks, ventilated pit latrines, and ordinary pit latrines (Colan-Consult, 2020; GSS, 2021b). While 98% of the captured excreta was emptied (Figure 2) only 69% of this excreta reached the treatment facilities (Colan-Consult, 2020), which were approximately 85% efficient (KI-014; SSGL, 2017). This means that the excreta of only 62% of the population in AMA was safely managed (Figure 2).

Number of schools and student population

The number of school-aged children actually attending schools in AMA was 235,761 (Table 3), which was 74% of the school-aged population (GSS, 2021a; GSS, 2021c). School enrollment in AMA is higher than the average rate of 66% for Sub-Saharan African countries (African Union & UNICEF, 2020; White, 2021; Onukwue, 2022), and this is probably due to FCUBE (GSS, 2019). Ghana's education system has three levels (Figure 1), but the primary and junior levels are combined and collectively referred to as basic schools (KI-001; KI-005; GES, 2020). Schools are either managed by the state (public) or privately owned (private), and the financing, operation, and maintenance of school sanitation infrastructure differ between these two categories (KI-005; GES, 2020).

Only 3.5% of the overall school population in AMA are residential students (Table 3); this is important in terms of sanitation as they would use the school sanitation facilities more often than the day students who live at home during the school term. Five senior high schools had residential students who only returned home at the end of each term. It was estimated that the residential students spend 275 days per year in school, including weekends during the school term (GES, 2020; Sky News Gh (SNG), 2022), while the day students spend 185 days per year in school (HT-026; KI-012; Ghana Students, 2022). Residential students only account for 0.6% of the AMA population, so no adjustments were made to the population used to generate SFDG3. Knowing the amount of time that the day students spend in school is essential to understanding their sanitation practices. Typically, students in Ghana spend 9 h in school from 07:30 to 16:30 (GEO, 2022). Studies have shown that students under the age of 12 are awake for between 12 and 14 h a day, while those aged between 12 and 18 years of age are awake for between 14 and 16 h daily (Reid et al., 2002; Nahmod et al., 2017). If an average of 14 waking hours is considered, then the day students spend over 64% of their waking

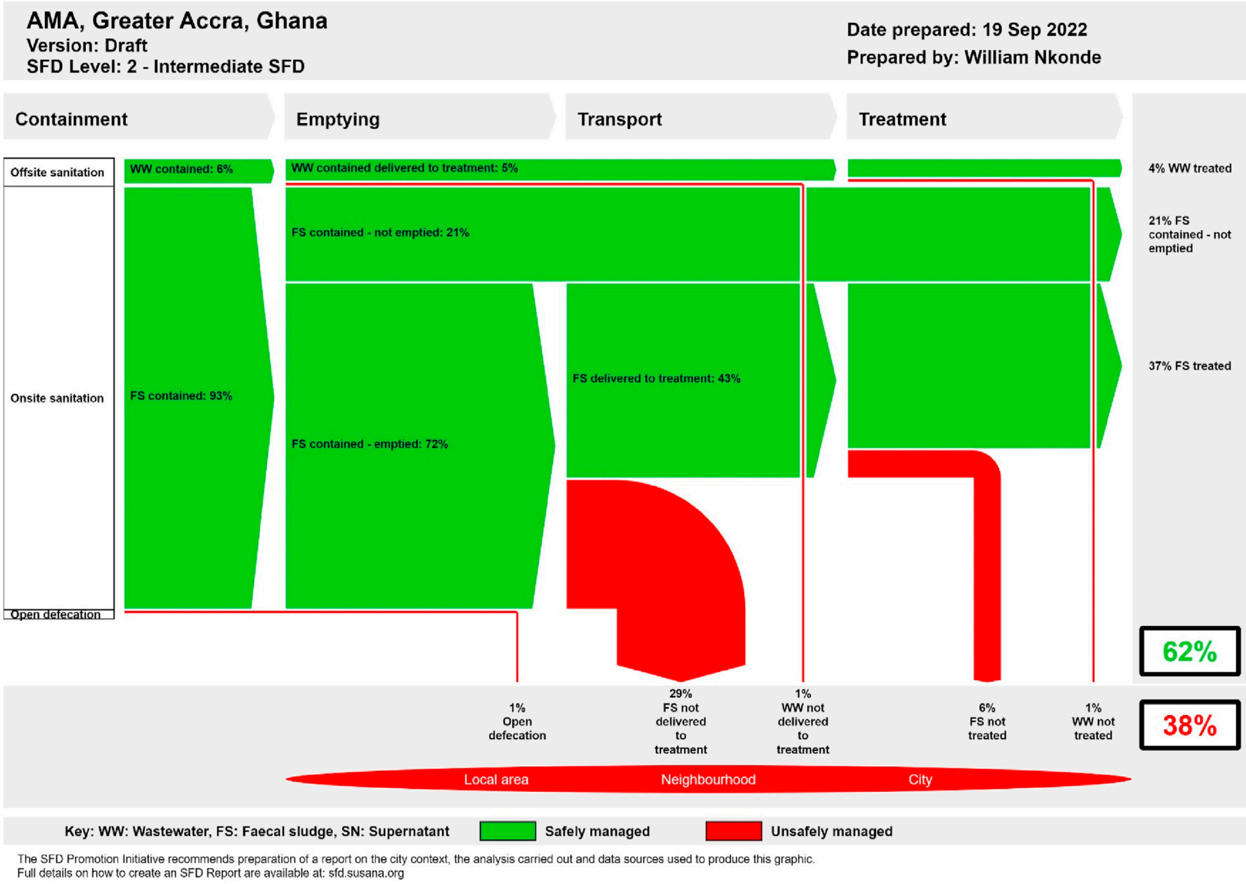

FIGURE 2
SFDG1 for AMA households for 2022.

TABLE 3 AMA school statistics.

School category	Number of schools		Enrollment	
	Public	Private	Day students	Residential students
Primary and Junior High	361	870	194,273	Null
Senior High	15	20	33,122	8,366

Source: Ghana Education Service (2020), Ghana Statistical Service (2019), Sky News Gh (SNG) (2022), KI-012, HT-026.

hours in school on school days (GEO, 2022; Reid et al., 2002; Nahmod et al., 2017).

School sanitation technology types

The GES policy provides guidelines for the use of adequate and safe sanitation facilities and recommends the use of specific technologies, such as septic tanks and ventilated improved pit (VIP) latrines (GES, 2014). In AMA, septic tanks and VIPs are the most common technologies for both schools and households (Figure 3). These are also typical sanitation technologies used in schools in Sub-Saharan Africa (Harvey and Adenya, 2009).

Student practices and operation and maintenance of school sanitation systems

Nearly half of the students reported using the school toilets only when needed, and approximately one-third of the students reported using the toilets either once or twice a day, but 28% of the students interviewed did not use the school toilets at all (Figure 4). Some headteachers (19%, $n = 26$) noted that not all school students used the school toilets (HT-001 to HT-026). Hence, as with household toilets, the availability of school toilets does not equate to usage. These data were fed into the estimation of the parameter C in Equations 2 for the day students (Table 4).

The students stated that their school toilet usage was dependent on the level of toilet cleanliness (64%, $n = 39$); the other factors

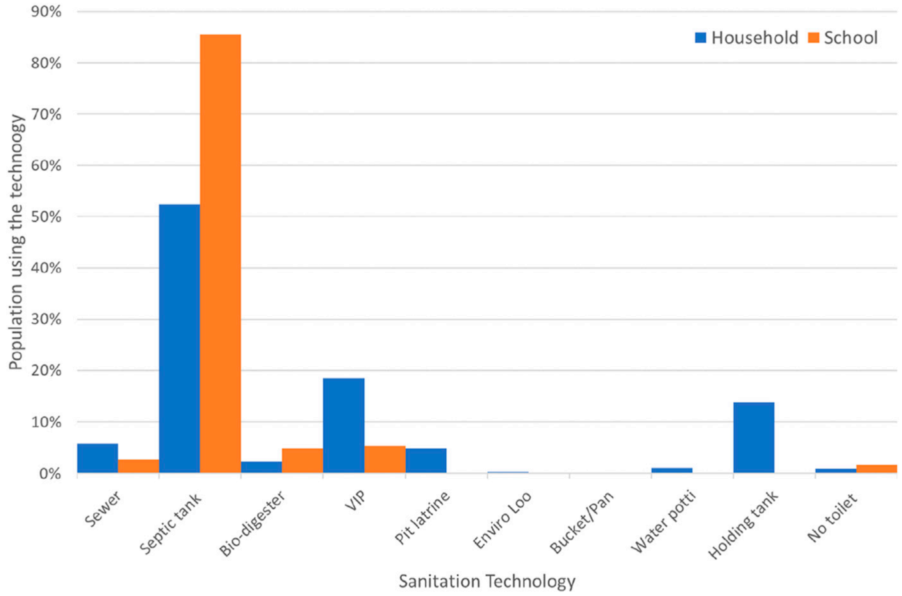

FIGURE 3
Sanitation technology types used in households and schools. AMA population data (GSS, 2021b) and school data were obtained from observations and interviews triangulated with Colan-Consult (2020).

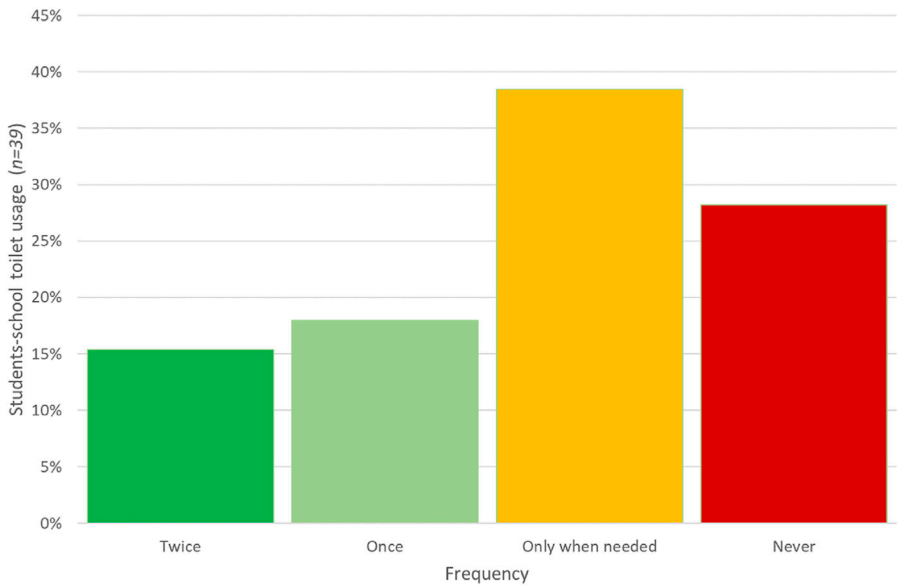

FIGURE 4
Student usage of school toilets.

highlighted by the students included security and privacy (8%, $n = 39$), student-to-toilet ratio (15%, $n = 39$), and type of toilet technology (49%, $n = 39$); it should be noted that many of these factors are interrelated (Garn et al., 2014; Schmitt et al., 2017; Shao et al., 2021). Similar findings have been reported based on studies in China and Nigeria, where one of the main barriers to school sanitation usage included toilet cleanliness (Abigail et al., 2012; Shao et al., 2021). This was supported by the structured observations cleanliness scored lower than all other parameters for public and private schools (Figure 5).

The structured observations (Figure 5) were categorized into two themes physical infrastructure (accessibility, menstrual health management (MHM) features, privacy, and security), and operation and maintenance (O&M) (water availability and cleanliness).

This is due to the differences in funding requirements. For parameters related to physical infrastructure, both private and public schools had fair to good scores ranging from 50% to 100%, while features related to O&M were rated low at <40% (Figure 5). The lack of funding for O&M was the reason given

TABLE 4 Data for SFDG2 and SFDG3.

Variable	Use of the data	Data and justification	Data sources	Data used in the SFD
Number of residential students (S_{pR})	SFDG3	Multiple sources of secondary data triangulated with key informant interviews.	Ghana students (2022), Sky News Gh (SNG) (2022), KI-012, and HT-026	S_{pR} = 11,155
Residential students' percentage of time in school per year (t_R)	SFDG3	Residential students spend 275 days a year, d_R = 275, and 14 h a day in school, h_{SR} = 14. Secondary data were triangulated with key informant interviews.	Nahmod et al. (2017), Reid et al. (2002), Ghana students (2022), KI-012, and HT-026	$t_R = \frac{14}{14} \times \frac{275}{365} = 0.753$
Proportion of school toilet usage compared to the usage of other toilets by residential students (C_R)	SFDG3	Residential students are obliged to stay on school premises, and they use the provided sanitation facilities during the entire term or semester. Secondary data were triangulated with key informant interviews.	Ghana students (2022), KI-012, and HT-026	C_R = 1
Proportion of residential students using the school toilets (k_R)	SFDG3	Residential students do not have access to other toilets when in school.	No data required	k_R = 1
Number of day students (S_{pD})	SFDG3	Secondary data were triangulated with key informant interviews.	GES 2020, GSS (2019), Sky News Gh (SNG) (2022), KI-012, and HT-001 to HT-026	S_{pD} = 224,606
Day students' number of days in school per year (t_D)	SFDG3	Day students spend 185 days a year, d_D = 185, and at least 9 h of their 14 waking hours per day in school, h_{SD} = 9. Secondary data were triangulated with key informant interviews.	Nahmod et al. (2017), Reid et al. (2002), Ghana Students (2022), Sky News Gh (SNG) (2022)	$t_D = \frac{9}{14} \times \frac{185}{365} = 0.33$
Proportion of school toilet usage compared to the usage of other toilets for day students (C_D)	SFDG3	Children are known to use the toilet between 4 and 7 times a day. Day students spend 64% (9/14 h) of their waking time in school during the school term.	Nahmod et al. (2017) Reid et al. (2002) DRI Sleeper (2017)	C_D = 0.5
Proportion of day students who claimed to be using school toilets (k_D)	SFDG3	38.5% of students use the toilet only when they need to, and 17.9% of students use the toilet once a day. 15.4% of students use the toilet twice a day. Although 38.5% of the day students stated that they used school toilets only when needed, it is believed that they used the school toilets at some point, and this proportion was added to the other (once and twice) usage frequencies to yield 72%.	S-001 to S-039, HT-001 to HT-026	k_D = 0.72
School sanitation containment type	SFDG3	The containment type at each school visited was identified through structured observations. This was triangulated via interviews with headteachers. These data, together with secondary data were used to extrapolate the containment type for schools across AMA. The data were scaled using the population equivalents for the excreta flows for all students in AMA.	HT-001 to HT026, Colan-Consult (2020), GSS (2019), Structured observations	The containment types used by the school population were estimated to be 85% septic tanks, 3% sewers, 5% biodigesters, 5% VIP toilets, and 2% open defecation.
Type of containment system used by day students at home	SFDG3	Population equivalents for the day school students were subtracted from the AMA SFDG1 based on the types of sanitation systems used at home. The data from the pupil interviews on their home sanitation systems were triangulated with data used to generate SFDG1. This was then extrapolated to the AMA school population.	S-001 to S-039, SFDG1	The sanitation systems used by the students at home represented as a percentage of the AMA population include 0.9% holding tanks, 2.6% septic tanks, 0.2% biodigesters, and 0.4% VIP toilets.
Impact of containment on groundwater	SFDGs 2 and 3	Triangulated with multiple secondary sources	Hagan, et al. (2022), Barakat (2020), Boadi (2019)	Groundwater pollution is not considered in the SFD matrix.

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TABLE 4 (*Continued*) Data for SFDG2 and SFDG3.

Variable	Use of the data	Data and justification	Data sources	Data used in the SFD
Transport of sewage and fecal sludge to the treatment plants	SFDGs 2 and 3	Secondary data were triangulated with key informant interviews.	Colan-Consult (2020), Boadi (2019), KI-003, and KI-014	90% of sewage and fecal sludge reaches the sewage treatment plant, and 10% leaks into the environment due to infrastructure failure
Emptying of fecal sludge from school sanitation systems	SFDGs 2 and 3	The emptying efficiency for households was 95% (SFDG1). It was known that there were issues with emptying in schools (multiple sources), so it was assumed that the emptying efficiency was lower for schools than households.	Colan-Consult (2020), KI-004, HT-002, HT-003, HT-013, and HT-014	80% of fecal sludge is emptied
Transport of fecal sludge from school sanitation systems to the FSTP	SFDGs 2 and 3	The transport efficiency for households was 60% (SFDG1). It was known that there were issues with the transportation of fecal sludge from public schools, so it was assumed that the transportation efficiency was lower for schools than households.	Colan-Consult (2020), KI-004, HT-002, HT-003, HT-013, and HT-014	50% is disposed of in the designated treatment plants.
Treatment efficiencies of sewage treatment plants	SFDGs 2 and 3	There are two sewage treatment plants. Mudor sewage treatment plant is considered to be 90% efficient (with 18,000 m^3/day capacity). The Legon sewage treatment plant is considered to be 80% efficient (with 9,000 m^3/day capacity). Secondary data were triangulated with interview data.	Sewage Systems Ghana Ltd. (2017), Boadi (2019), Holbech and Cobbinah (2021), Colan-Consult (2020), and KI-014	85% of sewage is treated.
Treatment efficiencies of fecal sludge treatment plants	SFDGs 2 and 3	85% of fecal sludge that reaches the wastewater treatment plants is treated. There are two FSTPs: Lavender Hill (2,000 m^3/day) and Adjen Kotoku (600 m^3/day). From the data, both FSTPs are considered to be 85% efficient. Secondary data were triangulated with interview data.	SSGL (2017), Boadi (2019), Holbech and Cobbinah (2021), Colan-Consult (2020), and KI-014	85% of fecal sludge is treated.

High confidence data (green).
Low confidence data requiring sensitivity analysis (yellow).

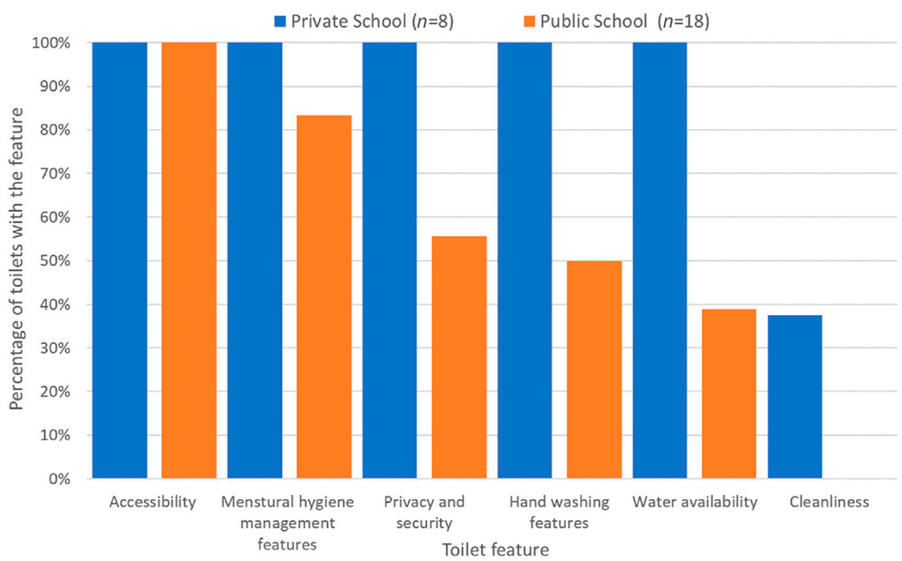

FIGURE 5
Structured observational scores of various features of school toilets.

TABLE 5 Summary of C_D sensitivity analysis.

Scenario	C_D	Population equivalent (SUP_e)	Proportion of SUP_e to total AMA population (%)
A	0.25	21,694	2.0
B	0.50	34,867	3.0
C	0.75	48,040	4.0

for the lack of cleanliness by headteachers from both public and private schools (HT-002; HT-003; HT-013; HT-014). This impacted the sanitation system in public schools as many were not emptied when full, resulting in leakage into the environment (KI-004). This was supported by the structured observations which noted that 38% (n = 18) of the sanitation systems in public schools was not emptied when full. Half of the headteachers from the public schools (n = 18) noted that their schools had experienced overflowing sanitation containment systems. This information fed into the estimates for the emptying and transportation of fecal sludge in Table 4.

Private schools outperformed public schools in every category, as shown in Figure 5 this was thought to be due to the lack of O&M funding in public schools and the additional pressure on their sanitation systems related to increased student numbers due to FCUBE (GSS, 2019). The low performance of the O&M-related features compared to the infrastructure features (Figure 5) illustrates that although thought and investment were put into building school sanitation infrastructure, the public schools were struggling to manage their O&M due to a lack of continuous funding. This is in line with a UNICEF and WHO (2022) study that found that although there has been significant capital investment in the construction of public-school sanitation, there is a lack of sustainability as emptying, transportation, and treatment of fecal sludge are often neglected due to a lack of continuous funding. Similar situations have been reported in other developing countries, where O&M could not be sustained over a long period of time despite using novel approaches, such as community involvement, preventive maintenance programs, and packaged operation and maintenance (Chatterley et al., 2013; Duijster et al., 2022).

School sanitation and its impact on city sanitation in AMA

The data in Table 4 were used to generate SFDG2 and SFDG3.

Flows from schools

The population equivalent for residential students SUP_{eR} was calculated using the data in Table 4 and Equations 2, 3. A sensitivity analysis was performed on the calculated population equivalent for day students SUP_{eD} (Equations 2, 3) due to the uncertainty of the data for the parameter C_D (proportion of children actually using sanitation whilst in school). The tested C_D values were related to the original assumption of C_D = 0.5 in Table 4. Three scenarios were tested by varying the C_D value, and the results are found in Table 5. Scenario C with C_D = 0.75 was used in SFDG3 rather than C_D = 0.5 as assumed in Table 4 as students are in school for 9 h out of their 14 waking hours (Table 4), which is equivalent to 64% of their waking time. Although AMA has a relatively high percentage of the population attending school (18.4%, Table 3), this only accounts for approximately 4% of the excreta flow from AMA owing to usage patterns, such as usage frequency and time spent in school.

Emptying and transport

Sensitivity analysis was performed on the assumptions made for the emptying and transportation of fecal sludge from schools in Table 4. Five scenarios were tested around these assumptions, and the results are shown in Table 6. The population used to test these scenarios was the total student population of 235,761. The baseline or reference values for these five scenarios were the SFDG1 emptying and transport efficiencies (Scenario 1, Table 6). In Scenarios 2 and 3 (Table 6), the emptying efficiency decreased by 10% and 20%, respectively, while the transport efficiency remained constant; this unexpectedly caused the percentage of safely managed excreta to increase from 54% to 65% because the unemptied fecal sludge was considered to be safely contained, which is related to groundwater contamination (Table 4) rather than the overall public health risk. The assumptions noted in Table 4 (Scenario 4, Table 6) related to emptying and transport resulted in a 50:50 split between safely and unsafely managed excreta. It was observed that for each drop of 10% in transport efficiency, the overall safe management rate dropped by 4% (Scenarios 1, 4, and 5, Table 6). After assessment, the data from Scenario 4 was used to generate the SFDGs.

Status of school sanitation in AMA

SFDG2 (Figure 6) shows the excreta flows from schools in AMA; 71% of the excreta deposited in schools was safely contained using onsite and offsite sanitation technologies. Very few of the schools were connected to sewers (Colan-Consult, 2020; Boadi, 2019, KI-003), as the sewer network mostly serviced the central business district (Colan-Consult, 2020; Boadi, 2019, KI-003), where few schools are located.

While 27% of the excreta deposited at the schools was not contained and leaked into the immediate environment (Figure 6). A total of 68% of the excreta was emptied, but 40% of this flow ended up in the environment untreated (Figure 6). Therefore, 29% of the excreta from schools reached a treatment plant, and only 41% of the excreta from the schools was safely managed (Figure 6).

Comparisons were performed between school (Figure 6) and household sanitation (Figure 2) in AMA for each stage of the SSC (Figure 7). This shows that school sanitation service delivery was

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TABLE 6 Summary of sensitivity analysis for the emptying and transport efficiencies of fecal sludge from school sanitation systems.

Scenario	Emptying efficiency (%)	Transport efficiency (%)	Overall SFD result	
			Safely managed (%)	Unsafely managed (%)
1	90[a]	60[a]	54	46
2	80	60	59	41
3	70	60	65	35
4	80[b]	50[b]	50	50
5	80	40	46	54

[a]data used to generate SFDG1.
[b]assumptions listed in Table 4.

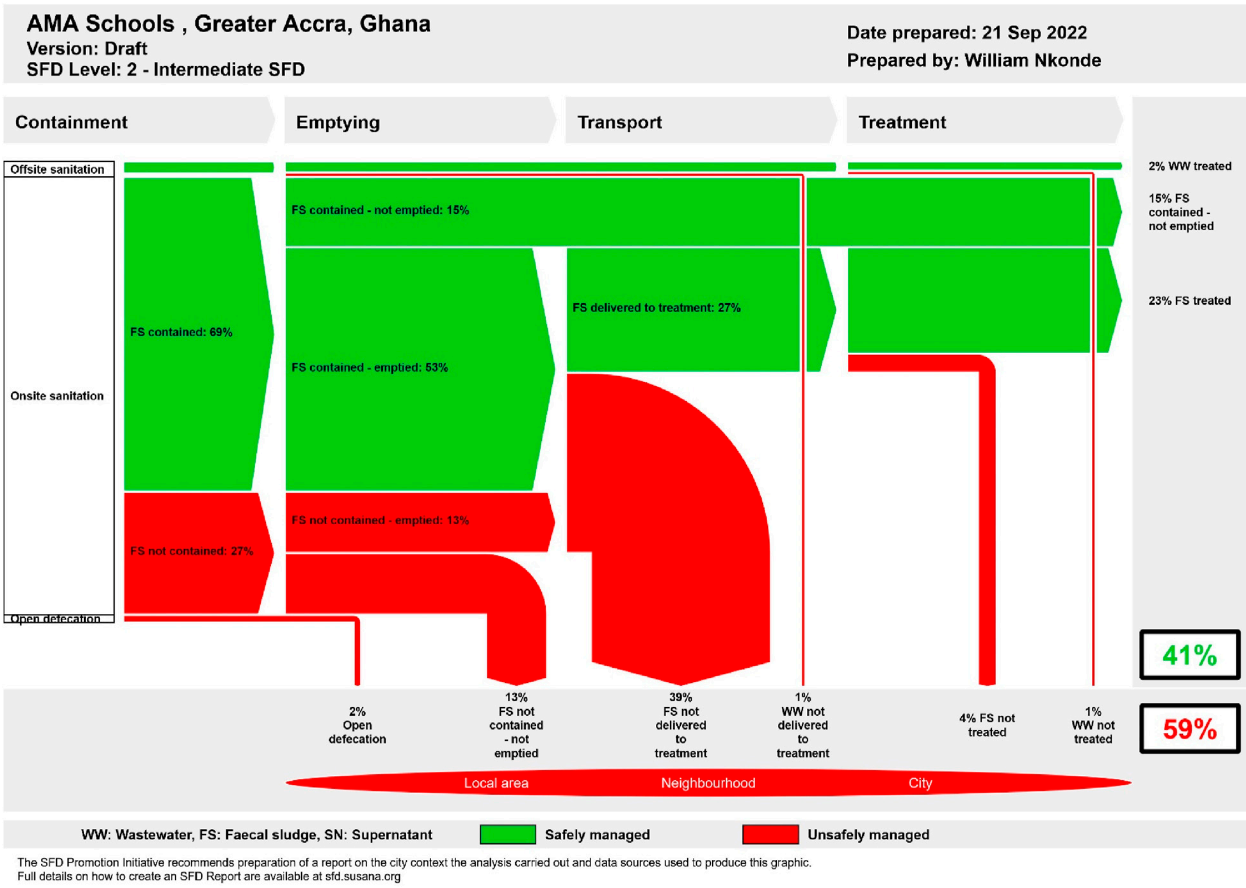

FIGURE 6
SFDG2 of AMA school sanitation.

worse at every stage of the SSC compared to household sanitation. Surprisingly, Figure 7 shows that open defecation in schools is higher than in households, as some schools do not have adequate sanitation facilities (Figure 3). The emptying and transport stages of the SSC are worse in schools than in households owing to a lack of continuous funding and investment for O&M. This means that (on average) the excreta disposed of in schools was less safely managed than that disposed of in households in AMA (Figure 7).

Impact of school sanitation on citywide sanitation flows

The data from SFDG2 were converted to school usage population equivalents using Equations 1–3. The final SFDG3 (Figure 8) shows the sanitation service delivery at the citywide level, including both household and school sanitation, using data from Table 4. Trend graphs (Figure 9) were then used to compare

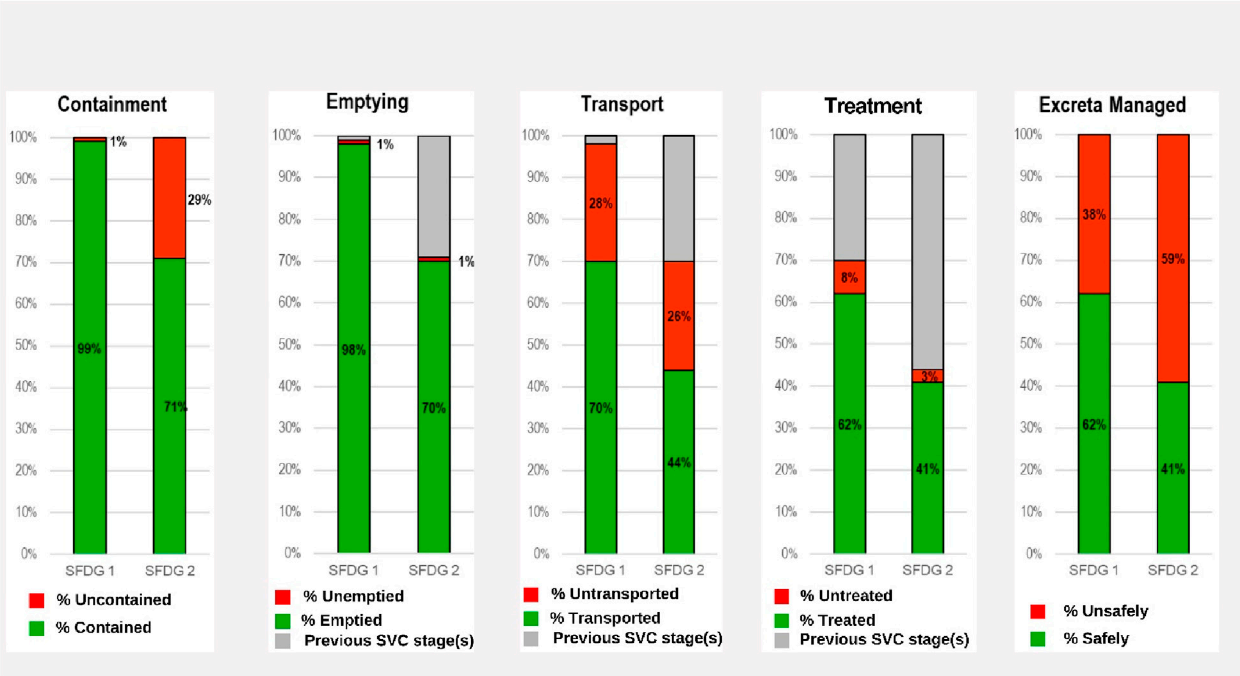

FIGURE 7
Comparison of AMA city and school sanitation along the SSC.

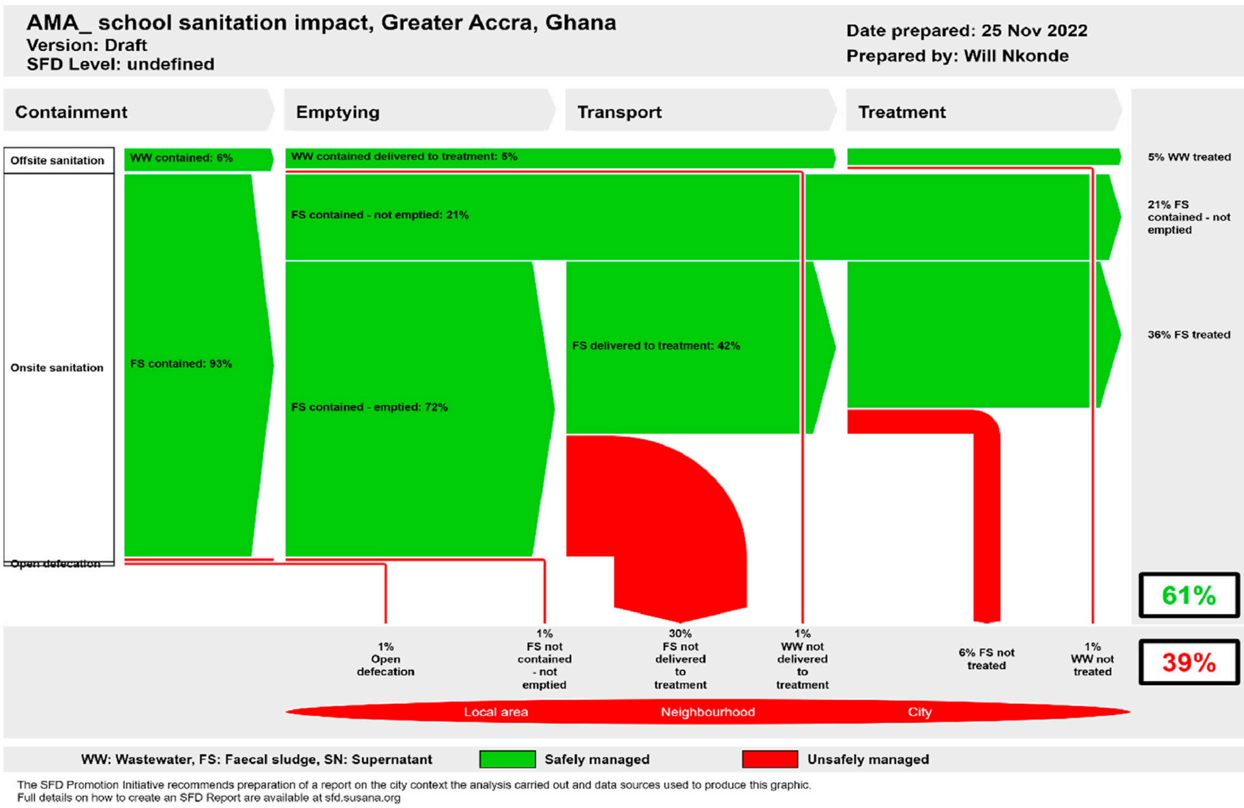

FIGURE 8
SFDG3 the impact of school sanitation on the sanitation in AMA at a citywide level.

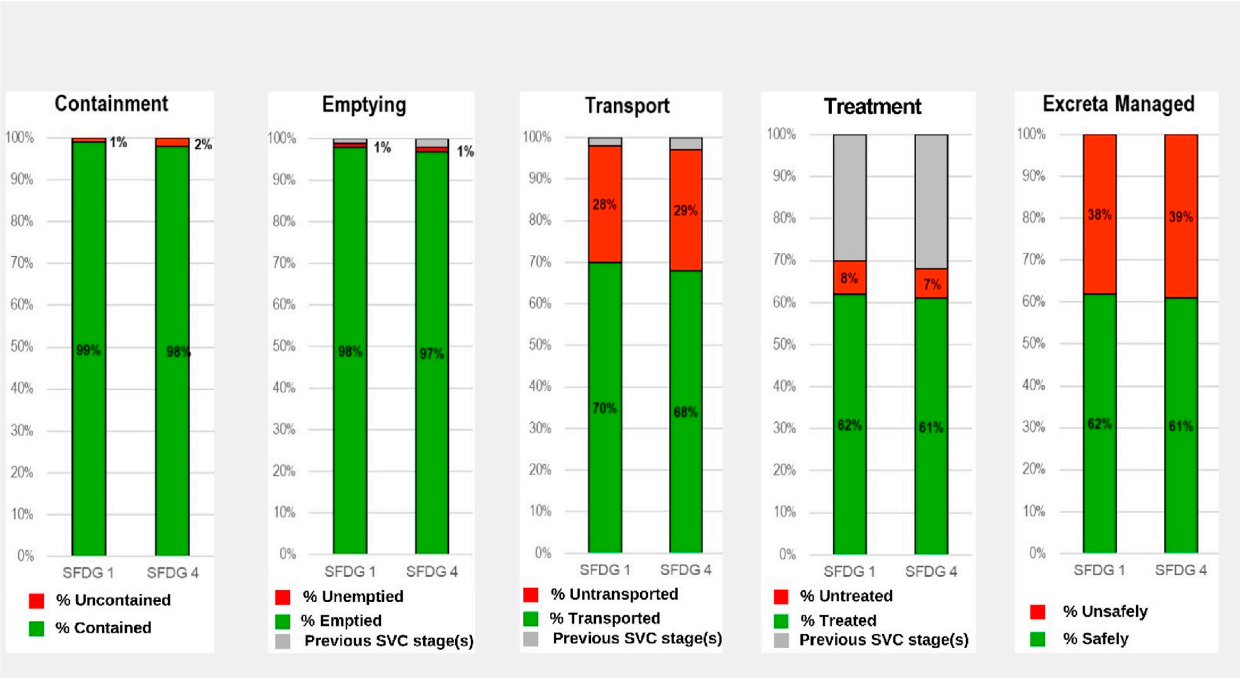

FIGURE 9
Comparison between SFDG1 (AMA city) and SFDG3 (AMA with impact from schools).

SFDG1 (Figure 2) to SFDG3 (Figure 8) to observe the impact of school sanitation on citywide sanitation. Impacts highlighted by the trend graphs (Figure 9) include the following:

- Uncontained excreta increased from 1% to 2% due to a lack of or poorly maintained containment in schools. It should be noted that the situation in the schools may be worse than that illustrated in the SFDG, as it was assumed that students who did not use the school toilets used their toilets at home and that fecal sludge is safely managed if it is not collected.
- Unemptied and uncontained excreta increased from the initial 2% to between 2% and 3% owing to a lack of O&M for school sanitation, which was related to funding.
- Excreta not delivered to the fecal sludge treatment plants (FSTPs) increased from 28% to 29% due to a lack of funds for O&M for school sanitation.
- Treated excreta decreased by 1% from 62% to 61% owing to the impact of school sanitation in the previous stages.

General discussion

Limited data were required to produce SFDG2 (Figure 6) for the schools (Table 3) compared to the data required to split the excreta flow and integrate it into the citywide SFDG (Table 3, SFDG3). SFDG2 (Figure 6) could be used to highlight the main challenges in assessing and monitoring the progress of school and healthcare sanitation facilities in relation to the SDGs across the SSC. The data collected and the process developed to split excreta flows highlights the complexity of exploring sanitation beyond a household level on a citywide scale. The process highlighted in this work could be used as a guide for future studies, as it could help reduce the time required for data collection and analysis.

Although 18.4% of the people in AMA attend school, and considering the state of school sanitation in the city, the citywide sanitation services were only adversely impacted by 1%, which is the sensitivity limit of the SFDG tool used. This means that in cities with a lower percentage of the population attending school and a low number of residential students, the impact will be insignificant at the citywide level. This is because the school excreta flows of the day students (SUP_{eD}, Equation 2) only account for between 6% and 16% (Scenarios A-C, Table 5) of their annual excreta flow. This is due to the time spent in school during the year (t_D = 0.34, Table 4). For residential students, this value was 76% of their annual excreta flow due to the time spent in school each year (t_R = 0.75, Table 4). Hence, there will be a higher impact of school sanitation in cities with a higher number of residential students compared to the total city population. This indicates that the main factors influencing the institutional impact on sanitation at the citywide level are the percentage of the population at the institution, and the proportion of time spent in the institution per year. This means that larger residential institutions, such as hospitals, barracks, and universities, will have a bigger impact on citywide sanitation. The present research demonstrates the effects of where people spend their day on city sanitation flows. As approximately 70% of the people in AMA are employed or involved in income-generating activities (AMA, 2020), with the majority of people working outside their homes, it is assumed that these people will not be using household sanitation for the majority of their waking hours. According to Mazeau et al. (2014), 63% of men and 41% of women in one area of Accra use two or three different toilets every day. It is hypothesized that this flow of excreta is likely to have the biggest impact on the sanitation landscape of the city in relation to non-household toilets.

The findings of this study hide the fact that the excreta flows in schools are seasonal. Although these flows are insignificant at the citywide level when considering annual flows, there will be significant health and environmental impacts during the school terms. Thus, it may be more important to consider the school population as a whole, as in SFDG2 (Figure 6), and compare it to the household city sanitation situation (Figure 7) with regard to impact.

Study limitations

Fieldwork for this study was conducted between August and September 2022 coinciding with the schools' summer holidays, which limited access to the schools, staff, and students. Gaining official data on private school sanitation was challenging as this information was not publicly available, so interview data were used. The SFD tool was designed for situational analysis at the citywide level and for use in advocacy and decision-making; it was not designed for accuracy or precision, so the sensitivity of the tool was only 1% of the population. The tool does not display decimal outputs but rather rounds them to the nearest integers. The SFDGs presented in this work are based on assumptions that have been justified (Table 4), which is linked to the use of SFDGs. More detailed information would therefore be required for an accurate or precise understanding of school sanitation flows at the city level. In this study, excreta was considered as a whole rather than its fractions, namely, urine and feces; if the patterns of defecation and urination were considered separately, the present findings may be significantly altered.

With regard to the residential students in AMA, no adjustments were required for the area's population. For large institutions, such as residential schools and regional hospitals that people commute to from outside the area, more data is required in regards to the locations of their homes so that the excreta flows can be added to the areas where they temporarily reside. It should be noted that some children from AMA also attended schools outside the study area, which was not considered in this analysis.

To obtain an overview of the sanitation conditions in schools across AMA, stratified convenience sampling was used with at least one school sample per district. In total, 18 public and 8 private schools were sampled, and the conditions of the school sanitation systems were very different for these two types of schools (Figure 5). This means that the school SFDGs and data will be skewed toward the poorer conditions in the public schools. Hence, we recommend that the different types of schools be taken into consideration when sampling in the future to replicate this study. The official statistical records may also be incorrect in some countries as there may be financial incentives for school registration, so the number of enrolled students may be inflated.

Conclusions

This study explores if the SFDG process can be used to map excreta flow originating from more than one source (households and schools) at a citywide level. This approach can give a more comprehensive understanding of the citywide sanitation landscape, which is currently limited to household sanitation only. This study shows that the SFDG process could be used to compare excreta flows from schools with those from households. Within the case study area, school sanitation was less safely managed than household sanitation at all stages of the SSC. This was attributed to the lack of continuous funding for O&M as the current focus was found to be on the construction of school toilets rather than maintaining the facilities. In the case study area and for school sanitation in low- and middle-income countries, there is a need to consider the entire SSC and use a systems approach in line with the SDGs. This study shows that the SFDGs can be used to assess the management of sanitation at the school level.

A new method was developed to avoid double counting of the pupils and to split the pupils' annual flows between their home and school. To do this an in-depth understanding of school sanitation and pupil usage was required for the case study area. The results showed that the level of school sanitation usage is linked to the cleanliness of the toilet facility. In turn, this is connected to the O&M and funding issues, again highlighting the need to focus beyond sanitation infrastructure, as the presence of a toilet facility does not equate to its usage.

The developed method highlights the importance of where people spend their time during the day and how this is related to the different sanitation systems they use. A greater understanding of this relationship is needed to obtain a complete picture of the citywide sanitation landscape. It has been hypothesized that flows from work-based sanitation systems may have the biggest impact on the city sanitation landscape in terms of non-household toilets. The focus of citywide sanitation needs to move beyond household sanitation. To do this, more information is needed on the population's sanitation practices. This would then enable their excreta flows to be split between different facilities. An example of such redistribution is presented in this paper. This work demonstrates how different flows from institutional facilities can be incorporated in SFDGs at the citywide level. Currently, the SFD tool cannot show where the excreta flows originate, which could be achieved using different colors in the graphic to indicate whether the source of the excreta flow is a household or an institution.

Data availability statement

The datasets presented in this study can be found in online repositories. The name of the repository and accession number can be found below: https://doi.org/10.25831/np66-xg34.

Ethics statement

The studies involving humans received ethical approval from the IHE, Delft, Netherlands (IHE-RECO-2022-003). The studies were conducted in accordance with all local legislations and institutional requirements. Written informed consent for participation in this study was provided by each participant's legal guardian/next of kin.

Author contributions

WN: data curation, formal analysis, investigation, methodology, visualization, writing–original draft, and writing–review and editing. CF: conceptualization, data curation, formal analysis, methodology, project administration, resources, supervision, visualization, writing–original draft, and writing–review and editing. BR: formal analysis, methodology, and writing–review and editing. DB: funding acquisition, supervision, and writing–review and editing.

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Conflict of interest

Author WN was employed by the Lusaka Water Supply and Sanitation Company.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2024.1473729/full#supplementary-material

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