

Fecal Sludge Management and Sanitation Safety: An Assessment in Addis Ababa, Ethiopia

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ABSTRACT

BACKGROUND: Sanitation safety practices and risks associated with fecal sludge management are crucial for public health and the environment. This study assessed sanitation safety practices and risks in Addis Ababa, Ethiopia, at different stages of fecal sludge management. The research aimed to understand the current state of sanitation facilities, practices, and associated risks and identify areas for improvement.

MATERIALS AND METHODS: A mixed methods/approach was employed, utilizing household surveys, risk assessments, and sanitary inspections. A total of 384 study subjects were interviewed using face-to-face interviews and observations.

RESULTS: The findings revealed that the majority of households (97.7%) had consistent access to toilets, with flush/pour flush toilets being the most common type (47.4%). Factors such as odors in toilets or septic tanks, open defecation by children, and the use of untreated wastewater for food production were significantly associated with sociodemographic factors. Risk assessments indicated that 67% of households fell into the low-risk category, while 33% were classified as intermediate risk. The study identified non-compliance issues during sanitary inspections at transfer stations (45%), a wastewater treatment and disposal facility (61.5%), and in the management of wastewater and sludge in the sewer line (64%). These findings call for urgent actions to address improper feces disposal, inadequate maintenance of sanitation facilities, and unsafe practices in fecal sludge management.

CONCLUSION: This study identified concerning issues in fecal sludge management, including improper feces disposal, inadequate facility maintenance, and non-compliance with safety standards during emptying, transport, treatment, and disposal. Urgent action is needed to address these risks. Promoting proper disposal techniques, improving facility maintenance, education programs, strengthening regulations, providing training and protective equipment, and investing in enhanced sanitation facilities and wastewater treatment methods are essential for improving sanitation safety practices.

KEYWORDS: Faecal sludge management, safety standards, sanitation safety, sanitation facilities, service chain, unsafe practices

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Introduction

The lack of safely managed sanitation services is a global issue that affects billions of people worldwide. Global studies and reports have shed light on the extent of this problem, highlighting the challenges faced in providing adequate sanitation facilities and services. According to WHO/UNICEF JMP 2023 Progress on household drinking water, sanitation and hygiene 2000 to 2022: special focus on gender shows that, 43% of the global population, or 3.5 billion people, lacked safely managed sanitation, including 24% (1.9 billion) with basic services, 7% (570 million) with limited services, 7% (545 million) with unimproved services, and 5% (419 million) who practiced open defecation.¹

While the sanitation crisis is a global concern, specific regions face unique challenges. Numerous studies conducted in Asian countries have shed light on the shortcomings in fecal sludge management practices. For instance, research conducted in Thailand revealed that only 30% of fecal sludge generated from on-site sanitation systems is safely managed, while the remaining 70% is unsafely handled.² Other report also showed, the inadequate practices contribute to health risks and

environmental contamination.³ Similarly, studies conducted in Bangladesh have highlighted the lack of access to basic personal protective equipment (PPE) for sanitation workers involved in fecal sludge management activities.⁴

Africa, too, grapples with the sanitation crisis, particularly in sub-Saharan regions.⁵ The lack of access to safely managed sanitation services is a pressing issue that affects millions of people. According to global studies, nearly half of the population without adequate sanitation services resides in sub-Saharan Africa, including countries like Ethiopia.⁶ The challenges faced in providing safe sanitation systems and managing fecal sludge in these regions are immense. The risks to public health, the environment, and groundwater sources are significant.^{7,8} As of 2022, Ethiopia's sanitation service levels show significant room for improvement, with only 6% of the population having access to safely managed sanitation services, 17% using basic sanitation facilities, 9% relying on limited sanitation, 20% using unimproved facilities, and a concerning 48% practicing open defecation, particularly in rural areas, highlighting serious health and environmental challenges.¹



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Addis Ababa, the capital city of Ethiopia, faces its own set of sanitation challenges. With a predominantly on-site sanitation system, comprising unsewered latrines and septic tanks, the majority of Addis Ababa's residents rely on these facilities for excreta and wastewater disposal. However, the lack of proper sanitation infrastructure and the limited connection to wastewater treatment facilities create unsanitary conditions and health hazards for the city's inhabitants and surrounding areas.^{9,10}

In the city, the management of fecal sludge along the entire service chain remains a critical challenge. Despite efforts to improve sanitation infrastructure, gaps persist in the effective containment, collection, transportation, treatment, and disposal of fecal sludge. These gaps result in untreated fecal sludge contaminating the environment, posing risks to public health and safety. Furthermore, research on the implementation of safety measures, standards, and approaches in the entire fecal sludge management service chain is limited. Therefore, a comprehensive assessment of existing practices is essential to identify weaknesses, bottlenecks, and opportunities for enhancing the fecal sludge management system. In response to this need, the World Health Organization (WHO) has developed the Sanitation Safety Planning framework¹¹ as a comprehensive approach to ensure the safe handling and disposal of wastewater, greywater, and excreta. This framework emphasizes rigorous risk assessment, effective risk management strategies, and continuous monitoring and evaluation throughout the sanitation service chain. By systematically applying this framework, municipalities and sanitation authorities can identify potential health hazards associated with inadequate FSM practices, implement targeted interventions to mitigate these risks, and improve overall sanitation safety. This study aims to investigate the current state of the fecal sludge management service chain in Addis Ababa using the WHO Sanitation Safety Planning framework, evaluate sanitation safety measures, and propose evidence-based recommendations for sustainable and safe fecal sludge handling. The findings of this research are expected to contribute significantly to improving sanitation safety planning by providing empirical insights into the strengths and weaknesses of current practices in Addis Ababa. Moreover, it can enhance the existing WHO framework by offering practical recommendations for addressing identified gaps and strengthening sanitation safety measures in urban settings.

Summary of Literature Review and Policy Document Review on Sanitation and Faecal Sludge in Ethiopia

Summary of literature review

Fecal sludge management (FSM) is crucial for urban sanitation, especially in developing countries. The FSM service chain includes containment, emptying, transport, treatment, and safe disposal of fecal sludge. Effective FSM prevents environmental contamination and protects public health. The

WHO's Sanitation Safety Planning (SSP) framework offers a comprehensive approach to managing sanitation-related health risks.¹¹

Inadequate sanitation affects approximately 2.0 billion people globally.¹ Many low- and middle-income countries rely on onsite sanitation solutions like pit latrines and septic tanks, which require safe management to prevent public health risks. Poorly managed fecal sludge can spread diseases such as cholera and dysentery.¹² The WHO SSP framework guides the improvement of sanitation systems and safe FSM practices.¹³

The SSP framework is a risk-based approach to ensure sanitation safety, involving system description, hazard identification, risk assessment, risk management plans, implementation, and monitoring. Studies in Kenya and Bangladesh show that SSP improves sanitation safety and reduces pathogen exposure.

Addis Ababa faces FSM challenges due to rapid urbanization and inadequate infrastructure. Only 12.6% of the population relies on sewer systems.¹⁴

Applying the SSP framework in Addis Ababa involves improving poorly constructed and maintained pit latrines and septic tanks to prevent leakage, using mechanized emptying methods and protective equipment to reduce health risks, investing in secure transport vehicles to prevent spillage, and expanding and upgrading treatment facilities to handle fecal sludge safely.¹⁵

Sanitation and faecal sludge management policy in Ethiopia

The Sanitation and Faecal Sludge Management (FSM) policy and strategies in Ethiopia addresses the country's significant sanitation challenges and aims to improve public health by ensuring universal access to safe and sustainable sanitation by 2030. This policy aligns with the Sustainable Development Goals (SDGs), particularly Goal 6, which focuses on clean water and sanitation for all.¹⁶

The policy aims to improve sanitation access, promote hygienic practices, and establish effective FSM systems through infrastructure development, capacity building, and financial mechanisms, involving multi-stakeholder engagement and addressing challenges like financial constraints, technical barriers, cultural practices, and weak M&E systems by recommending increased funding, technical training, behavioral change campaigns, and robust M&E frameworks.¹⁷

Materials and Methods

Description of study area and sampling sites

This study was conducted in Addis Ababa, which is home to approximately 5 703 628 people. The city spans an area of 527 km² and has an altitude ranging from 2000 to 2800 m. As the seat of both federal and regional governments, Addis Ababa

is surrounded by the Oromia National Regional State and is divided into 11 sub-cities and 116 woredas (Districts).

Due to urbanization and massive infrastructure development, the city is growing rapidly. Addis Ababa is home to over 2000 industries, including potable water, cement, textile, beverage and alcohol, tobacco, leather, tannery, plastic, and food factories. The metropolis serves as the country's industrial, cultural, administrative, commercial, and modern hub. It is also one of the central hubs in Africa with many international organizations and institutions.¹⁸ The African Union, United Nations Economic Commission for Africa, and more than a hundred embassies are in Addis Ababa. It is said to be Africa's diplomatic capital and a beacon of humanitarian progress on the African continent nowadays.

However, the city faces significant sanitation challenges. About 75% of the population relies on pit latrines that discharge waste by illegally connecting with open drains. About 15% of the population has access to flush toilets and septic tanks, which also frequently discharge into open drains. A notable minority, approximately 5%, practices open defecation.¹⁹

The sanitation safety practice assessment was conducted on 23 woredas of 384 HHs, field observations on the operations of fecal sludge collection, transport operations, fecal sludge transfer stations, disposal, and treatment centers.

Study design, and population selection

A community-based cross-sectional study was conducted in Addis Ababa city to gather necessary information from the community members and fecal sludge management service provision actors who are involved in the sludge management service chain.

The study employed both qualitative and quantitative data collection methods, adapted from the WHO water and sanitation safety guidelines.^{20,21} Data were gathered through primary sources, tracing the entire fecal sludge management chain from initial collection to final disposal and treatment sites.

The study employed comprehensive household survey involving 384 households and 13 key actors along the fecal sludge management service chain. Additionally, 13 observations were conducted to assess sanitation safety practices at various stages of the fecal sludge management process. Subsequently, 2 woredas were selected from each of the 23 sub-cities for further analysis and investigation.

Purposefully chosen actors within the fecal sludge management service chain, who operate across all components of the fecal sludge management and operational service chain, were selected for key informant interviews (KIIs) and observations. This was intended to gate primary information and understand the sanitation safety practices and risks across the fecal sludge management service chain processes. Households that handle fecal sludge at household level were randomly selected for the households survey.

Ethical considerations

The study received ethical approval from the Ministry of Education National Research Ethics Review committee, in accordance with the Ethiopia National Research Ethics Review Guideline (5th Edition). Written informed consent was obtained from all participants who took part in the study, after explaining the purpose and significance of the research. Data collection proceeded only after obtaining fully informed verbal consent from the participants, and confidentiality measures were implemented to protect their privacy by excluding their names and personal identification information.

Sample size determination, sampling technique, and sampling procedure

Sample size for the household survey. The sample size was computed by taking 95% confidence level ($Z=1.96$), 50% proportion, 5% margin of error (d) and 5% non-response rate using the single population proportion formula as follows:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Where, n = the required sample size

p = the average proportion of in different settings

Z = the critical value at 95% confidence level = 1.96

d = precision (margin of error) = 5%

Since there was no previous study on sanitation safety along the faecal sludge management service chain in Addis Ababa, and no time for conducting a pilot study, we assumed $P=.5$ as the most conservative estimate. Using this formula, the sample size was estimated to be 384. Adding a 5% non-response rate, the final sample size was 403.

Sampling technique and procedure

The sampling technique for the quantitative data was a simple random and cluster sampling. Figure 1 shows the sampling procedures utilized. The sampling technique for the qualitative data was purposive sampling.

Data collection methods and tools

The risk assessment methodology employed in this study follows a semi-quantitative approach adapted from the WHO Sanitation Safety Planning Manual, Second Edition. The methodology aims to evaluate the level of safe sanitation practices and risk associated with various sanitation safety practices along the faecal sludge management system/service chain.²⁰

Identification of Risk Factors: initially, a comprehensive list of risk factors related to faecal sludge management along all the components of the faecal management service chain was developed in the form of questioners/ observation checklists based on literature review and expert consultations.

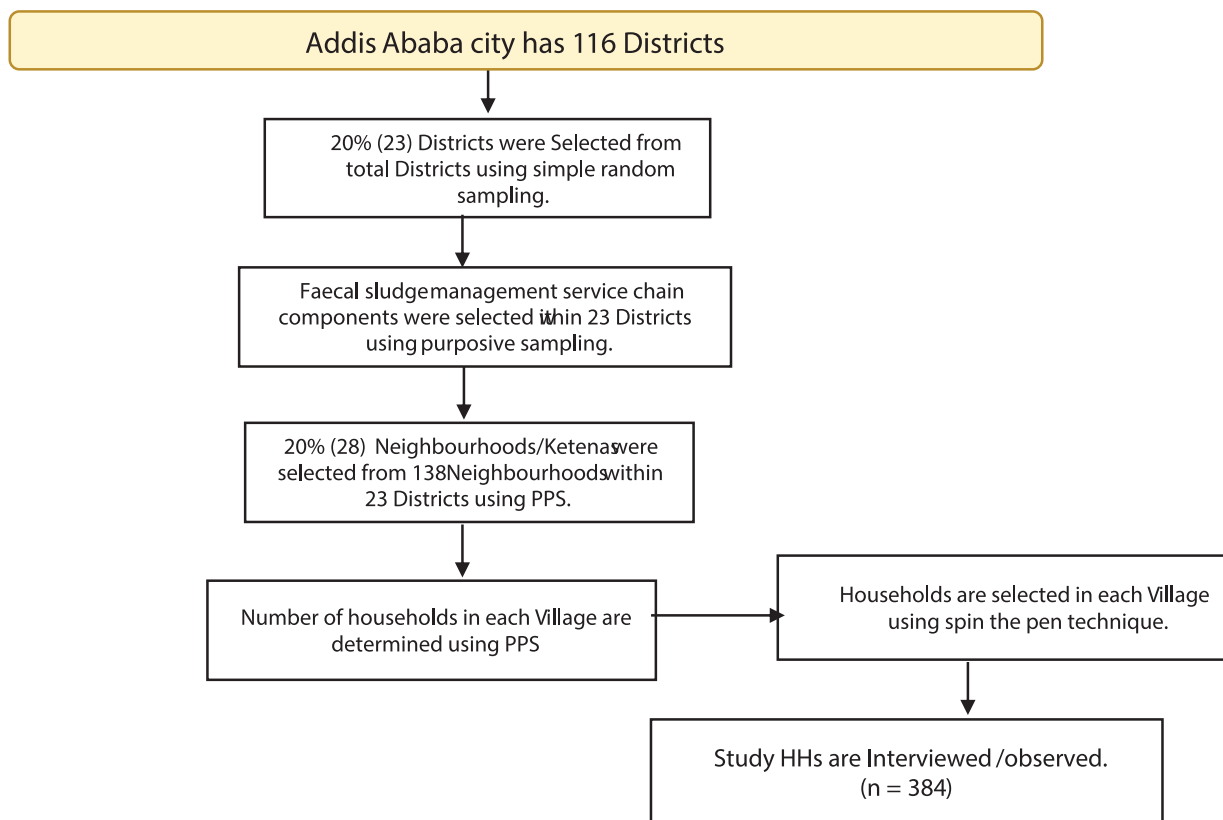


Figure 1. Sampling procedure.
Abbreviation: Key PPS, proportional to size.

These sanitation safety standards and associated risk factors encompassed different stages of the faecal sludge management process, including containment, collection, transportation, treatment, and disposal of faecal sludge.

Risk Scoring: to assess the level of risk associated with each identified risk factor, a scoring system was devised and included in the data collection tools. The scoring system assigned numerical values to different parameters or indicators associated with each sanitation safety practices identifying the risk factor. These parameters were selected based on their relevance and potential impact on sanitation safety. The scoring system ranged from <6 as low risk, 6–12 medium risk, 13–32 high risk and >32 very high risk.

Data Collection and Evaluation: data collection involved a combination of quantitative and qualitative methods. Quantitative data were collected through structured surveys, observations, and measurements, while qualitative data were gathered through interviews, focus group discussions, and document analysis. Data collectors assessed the presence or absence of safe sanitation safety practices and identify the risk factors/scores based on the assigned scores which is the predefined parameters.

Risk Categorization: based on the collected data and scores, the risk levels for each sanitation safety practice were determined. A cumulative risk score was calculated by summing the scores assigned to individual parameters or indicators. The cumulative risk score was then compared against predefined threshold values to categorize the risk level as low, medium, high, or very high.

Data processing and analysis

The collected data underwent a series of steps, including data entry, cleaning, editing, and analysis, conducted by the principal investigators using SPSS version 26 (Statistical Package for the Social Sciences). These processes aimed to ensure the accuracy, consistency, and completeness of the data, enhancing the reliability of the analyzed results.

To categorize sanitation safety risk and practices, the study followed the risk scoring system outlined in the WHO Sanitation Safety Planning Manual, Second Edition.²⁰ Risk levels were classified as low risk, medium risk, high risk, and very high risk. Table 1 shows semi-quantitative risk assessment

Table 1. Semi-quantitative risk assessment matrix for sanitation safety practices in fecal sludge management.

RISK LEVEL	RISK SCORE RANGE	DESCRIPTION
Low risk	<6	Sanitation safety practices are well-implemented, with minimal risk factors identified
Medium risk	16-12	Some sanitation safety practices have moderate risk factors that may require attention and improvement
High risk	13-32	Significant sanitation safety risks are present, indicating a need for immediate action and remediation measures
Very high risk	>32	Severe sanitation safety risks exist, posing a serious threat to public health and requiring urgent intervention to prevent potential outbreaks or hazards

matrix we have used to analyse the sanitation safety practices along the fecal sludge management service chain:

Diagnostic sanitary inspection questions were utilized to assign standard scores to each component of the fecal sludge management system, enabling the evaluation of risk levels associated with sanitation safety practices.

Descriptive statistics, such as percentages, means, and standard deviations, were employed to analyze most variables. These statistics provided a comprehensive overview of the data, allowing for a better understanding of the distribution and characteristics of the variables.

Additionally, factor analysis was conducted to assess the variability and identify common themes among observed, correlated variables related to sanitation safety practices. The factor analysis utilized a principal component analysis extraction method and a varimax rotation with Kaiser normalization. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy value, albeit mediocre at .664, supported the application of factor analysis to the empirical data. The eigenvalue-greater-than-one retention criteria were used to retain significant factors. To enable multivariate logistic regression analysis, transformations were applied to the originally categorical data, creating continuous data. multivariate logistic regression analysis was then conducted to estimate the relationship between sanitation safety practices and socio-demographic variables. The data cleaning process ensured accuracy, consistency, and completeness of the data and variables, enhancing the reliability of the analyzed results.

Results

Overview of institutional framework for FSM

The institutional framework for fecal sludge management (FSM) in Addis Ababa involves a collaborative effort among various stakeholders, including governmental agencies, non-governmental organizations (NGOs), private sector entities, and community-based organizations. The Addis Ababa Water and Sewerage Authority (AAWSA) is the primary agency responsible for water supply and sewerage services in the city, overseeing the collection, transport, treatment, and safe disposal of fecal sludge.

The Addis Ababa City Administration plays a critical role in urban planning, policy formulation, and enforcement of sanitation regulations. It works closely with AAWSA to ensure that proper FSM practices are implemented, having been involved in several projects aimed at enhancing sanitation infrastructure. The Ministry of Health (MoH) is involved in public health initiatives related to sanitation and hygiene, providing guidelines and standards for FSM practices to prevent health risks associated with improper sludge management.

NGOs play a pivotal role in promoting improved sanitation practices in Addis Ababa. They often collaborate with government agencies to implement FSM projects, provide training, and raise awareness about the importance of safe sanitation. Organizations such as WaterAid and SNV Netherlands Development Organisation have been instrumental in capacity building and community engagement in FSM. Private companies are increasingly involved in FSM services, particularly in the emptying and transport of fecal sludge. These companies operate under licenses from AAWSA and adhere to regulations set by the city administration. The involvement of the private sector helps to increase the capacity and efficiency of FSM services in the city. Community-based organizations (CBOs) are vital in educating communities about sanitation practices and mobilizing local resources for FSM initiatives. They often act as intermediaries between residents and service providers, facilitating communication and ensuring that community needs are addressed.

Socio-demographic characteristics

A total of 384 participants took part in the study, providing data on their gender, religion, education, marital status, and income. The study revealed that approximately 62% were male indicating a higher male participation rate in the service chain. Among the respondents, 64% identified as Orthodox, 21% as Muslim, 11% as Protestant, and the remaining 4% followed other religions.

The education levels of the participants varied, with 28.9% having completed secondary education (Grade 9-12), followed by 24% higher education graduates (diploma to Masters). Furthermore, 23% of participants had completed

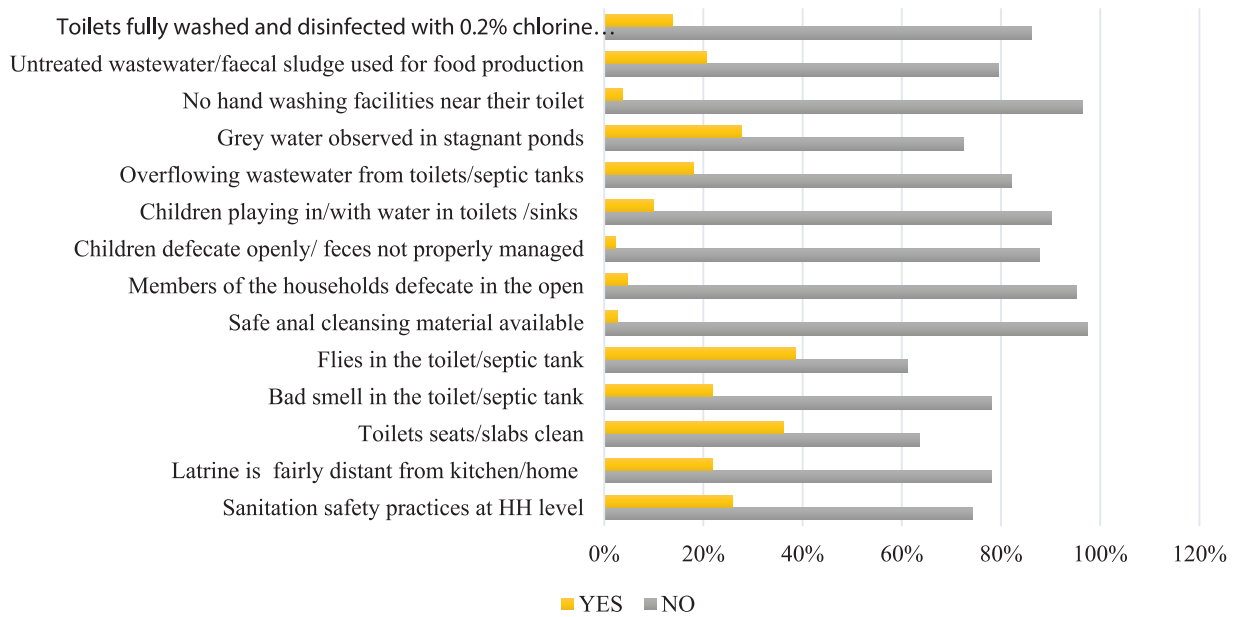


Figure 2. The level of sanitation safety practices and risks during households' fecal sludge management.

primary education (Grade 1-8). Additionally, 15% possessed basic literacy skills, capable of reading and writing, while 9.4% lacked even basic literacy skills. In terms of marital status, 58% of the respondents were married, 31% were single, 6% were widowed, and the remaining 5% were separated. Regarding income, 52% fell into the intermediate income category, 43% were classified as low income, and the remaining 5% belonged to the higher income category.

Households access to sanitation facilities

Based on the household survey conducted in the study sites, the majority of the family members use a flush/pour flush in to swear toilet (47.4%), followed by 32.0% who use a pit latrine with slab (Concrete, ceramic, plastic) and 15.9% who use a communal toilet (Figure 2). Only a small percentage of the study participants' family members use a VIP latrine (3.6%), composting/biogas toilet (0.3%), or public toilet (0.8%).

The majority of latrines (58.3%) are situated in the backyard of homes, within a distance of 6-15 m. A smaller percentage of latrines (29.7%) are located inside the buildings, while 12.0% are positioned at a distance of 15-50m. Nearly all household members (97.7%) have constant access to and use of toilets without any issues. Significant portions of households (37.2%) have children under the age of 5 indicating the need to have other means to dispose children's feces. A noteworthy percentage of surveyed households (31.8%) reported that they dispose of young children's feces in the latrine, while a smaller number dispose in the backyard (3.1%) or anywhere outside the compound (2.3%). However, a large proportion of respondents (62.8%) chose not to provide an answer to this question.

Regarding the proximity of onsite latrines to the kitchen or home, the majority of households (70.8%) stated that the

latrines are relatively close. As for the availability of well water or underground tanks located 15 m below the water level, a significant percentage of households (87.8%) do not possess such facilities. Instead, they rely on the utility water supply system for their water needs.

The level of sanitation safety practices and risks during households' fecal sludge management

The study assessed the level of sanitation safety practices and risks encountered due to the operation of fecal sludge management along the fecal sludge management service chain using standard diagnostic assessment tools adapted from the WHO water safety and sanitation safety guidelines (citation required). Accordingly, the sanitation safety risks and practices were categorized into four: low, intermediate, high and very high risks. The majority of the households (67%) were at low risk and significant number of households (33%) are falling under intermediate risk level (Figure.2).

The analysis shows that, on average, there is some level of wastewater overflow in sanitation systems, with a mean value of .259. The relatively high standard deviation of .225 indicates considerable variation in the severity of this issue among different observations. This implies that certain households face more severe cases of wastewater overflow than others. Regarding the presence of flies, dirt, and odor in the household sanitation facilities environment, the mean value of 0.4384 indicates a moderate level of occurrence. This suggests that, on average, households face a noticeable presence of flies, dirt, and unpleasant odor.

The study indicates a relatively low prevalence of open defecation and unsafe use of wastewater, with a mean value of .0321. This suggests that, on average, households have adopted safe practices and refrain from open defecation or using wastewater

Table 2. Descriptive statistics on sanitation safety practices.

SANITATION SAFETY PRACTICES	N	MEAN	SD	VARIANCE
Unsanitary wastewater management and hygiene practices	384	0	.8	.2589
Toilet cleanliness and maintenance	384	0	1	.4384
Open defecation and fecal waste management	384	0	1	.0321
Unsafe toilet management practices and insufficient disinfection	384	0	1	.1732
Unsafe wastewater practices and the lack of safe toilet habits	384	0	.67	.0486
Valid N (list wise)	384			

in an unsafe manner. However, the standard deviation of .12215 suggests some variability in the occurrence of this issue, indicating that certain households still engage in unsafe wastewater and open defecation practices. Unsafe practices during toilet emptying and cleansing are moderately prevalent, as indicated by a mean value of .1732. The standard deviation of .30969 highlights considerable variation in the severity of this problem across households.

This suggests that some households exhibit more unsafe practices during toilet emptying and cleansing than others. Lastly, the analysis reveals that, on average, a relatively small proportion of wastewater from toilets remains untreated, with a mean value of .0486.

The standard deviation of .12497 indicates some variability in the levels of untreated wastewater, suggesting that certain households may have higher amounts of untreated wastewater. The findings indicate the presence of issues such as wastewater overflow, flies, dirt, and odor, unsafe toilet emptying and cleansing, and untreated wastewater. While some households exhibit satisfactory practices, there is still room for improvement, especially in addressing the variability and severity of these issues (Table 2).

This study employed factor analysis to examine sanitation safety practices and risks at the household level. Utilizing a principal component analysis extraction method and a varimax rotation with Kaiser normalization.

The factor analysis yielded 5 significant factors that represented different dimensions of sanitation safety practices and risks. These factors explained approximately 66.4% of the total variance, while the remaining 8 factors accounted for approximately 33.6% of the unexplained total variance. The insignificant factors were discarded based on their eigenvalues, which were less than one (Table 3).

Factor 1: Unsanitary wastewater management and hygiene practices. This factor was characterized by high loadings on variables related to overflowing wastewater, flies, and odor. It indicated the presence of unsanitary conditions associated with wastewater management. Households scoring higher in this factor were likely to encounter issues such as wastewater

overflow, the presence of flies in the toilet or septic tank, unclean toilet seats or slabs, and unpleasant odors. Inadequate access to proper handwashing facilities near toilets and a lack of toilet paper or safe anal cleansing materials were also common.

Factor 2: Toilet cleanliness and maintenance. This factor exhibited high loadings on variables related to toilet cleanliness and maintenance. Variables such as the presence of flies in the toilet or septic tank, unclean toilet seats or slabs, and bad smells indicated sanitation issues linked to the cleanliness and maintenance of toilets. The presence of flies suggested inadequate sanitation practices and poor waste management, while unclean toilet seats or slabs indicated a lack of proper cleaning and disinfection. Bad smells pointed to poor ventilation or inadequate waste management practices.

Factor 3: Risks related to open defecation and fecal waste management. This factor was characterized by high loadings on variables related to open defecation and fecal waste management practices. Variables included children defecating in the open or not disposing of feces in the toilet, evidence of feces in the premises due to open defecation, and the usage of wastewater or fecal sludge for food production without proper treatment. Households with higher scores on this component were more likely to engage in unsafe sanitation practices, highlighting the need for improved sanitation facilities and education. Inadequate fecal waste management and the use of untreated wastewater or fecal sludge for food production posed significant health hazards.

Factor 4: Unsafe toilet management practices and insufficient disinfection. This factor represented variables related to unsafe toilet management practices and insufficient disinfection. It included unsafe toilet pit emptying and inadequate disinfection practices. Improper handling and disposal of waste during toilet pit emptying could lead to environmental contamination and health risks. Inadequate disinfection practices, such as failure to wash down toilets and disinfect them with a 0.2% chlorine solution, increased the persistence of harmful bacteria and pathogens, compromising overall sanitation and hygiene.

Table 3. Factor analysis—total variance explained.

COMPONENT	INITIAL EIGENVALUES			ESSL			RSSL		
	TOTAL	% OF VARIANCE	CUMULATIVE %	TOTAL	% OF VARIANCE	CUMULATIVE %	TOTAL	% OF VARIANCE	CUMULATIVE %
1	2.979	22.914	22.914	2.979	22.914	22.914	2.192	16.864	16.864
2	1.606	12.357	35.271	1.606	12.357	35.271	1.889	14.528	31.392
3	1.234	9.494	44.765	1.234	9.494	44.765	1.522	11.704	43.096
4	1.210	9.310	54.075	1.210	9.310	54.075	1.373	10.564	53.659
5	1.084	8.336	62.411	1.084	8.336	62.411	1.138	8.752	62.411

Extraction method: Principal component analysis.

Abbreviation: ESSL, extraction sums of squared loadings; RSSL, rotation sums of squared loadings. The varimax Rotation with Kaiser Normalization revealed the following 5 variables.

Factor 5: Unsafe wastewater management practices and lack of safe toilet management habits. This factor was characterized by variables related to unsafe wastewater management practices and the lack of safe toilet management habits. It included observations of wastewater overflowing and creating stagnant ponds, the use of untreated wastewater or fecal sludge for food production, and children playing in or with water in toilets or sinks. High scores on this component indicated practices that posed health risks related to wastewater management.

Multivariate logistic regression analysis was processed to identify the association between sociodemographic factors and sanitation safety practices during fecal sludge management at household level.

The multivariate logistic regression analysis revealed significant associations between certain sociodemographic factors and specific sanitation safety practices.

There was significant association between education level of the head of the household and the presence of a bad smell in the toilet or septic tank ($F=1.5778E+25$, $P<.001$, partial eta squared=1). Higher levels of education were associated with a lower likelihood of encountering a bad smell in the toilet or septic tank. Additionally, education was significantly associated with the use of wastewater/faecal sludge for food production without treatment ($F=3.9987E+24$, $P<.001$, partial eta squared=1). Higher levels of education were associated with a reduced likelihood of engaging in this unsafe practice.

Occupation was also significantly associated with multiple sanitation safety practices. Firstly, there was a significant association between occupation and the presence of a bad smell in the toilet or septic tank ($F=1.32156E+25$, $P<0.001$, partial eta squared=1). Certain occupations were more likely to be associated with a bad smell in the toilet or septic tank. Secondly, occupation was associated with open defecation by children ($F=1.33721E+23$, $P=.00$, partial eta squared=1). Occupations of household members influenced the occurrence of open defecation by children. Lastly, occupation was significantly associated with the use of wastewater/faecal sludge for food

production without treatment ($F=4.38385E+24$, $P<.001$, partial eta squared=1). Different occupations were associated with varying levels of engagement in this unsafe practice.

The analysis revealed significant association between the religion of the respondent and multiple sanitation safety practices. Firstly, religion was associated with the presence of a bad smell in the toilet or septic tank ($F=5.86619E+24$, $P<.001$, partial eta squared=1). Different religious affiliations were linked to different levels of encountering a bad smell in the toilet or septic tank. Secondly, religion was associated with open defecation by children ($F=2.31494E+22$, $P<.00$, partial eta squared=1). Religious beliefs influenced the occurrence of open defecation by children. Lastly, religion was significantly associated with the use of wastewater/faecal sludge for food production without treatment ($F=3.13028E+25$, $P=0$, partial eta squared=1). Different religions were associated with varying levels of engagement in this unsafe practice.

There was an extremely significant association between income and the use of wastewater/faecal sludge for food production without treatment ($F=3.46809E+22$, $P<.00$, Partial eta squared=1). Higher income levels were associated with a lower likelihood of engaging in this unsafe practice.

The level of sanitation safety practices and risks of wastewater management during fecal sludge emptying and transport. A health risk assessment matrix was used to assess the sanitation safety practices and the assessment identified an average of 11 (85%) unsafe sanitation safety risks/practices out of 13 safety standards observed in the four Sub-cities (Akaki kality, Bole, Yeka, and Nifas Silk-Lafto sites) purposively selected toilet emptying operational sites associated with fecal sludge emptying and transport. The findings of the inspection revealed that the sanitation safety practices during fecal sludge emptying and transport generally do not adhere to the recommended sanitation safety protocols. Multiple non-compliance issues were identified, notably the lack of properly functioning and mandatory use of personal protective equipment (PPE) by workers.

Workers were observed handling contaminated surfaces and containers without utilizing the necessary PPE. Additionally, spillages during waste transport were observed, posing a significant risk of community exposure. Furthermore, the collection vehicles were found to be inadequately washed and disinfected, and workers did not consistently wear PPE during their tasks. The condition of toilet emptying, and liquid waste discharge nozzles was also found to be poor. Maintenance workers were exposed to raw sewage during the maintenance of collection vehicles. Another concern was the absence of cleaning solutions such as lime or sodium hypochlorite, as well as ethanol-based solutions for disinfection, which heightened the potential risks associated with accidental contamination.

According to the information we have collected from the emptying operators and utility staffs, the presence of solid or hazardous wastes in toilets exposes the pit emptying workers to different public health and environmental risks because they have to remove them manually from the pit using their hands and a local litter fork made from nails. During this activity, it is common for the workers to suffer injuries from these sharp materials and to be exposed to infectious agents from the fecal sludge.

Moreover, these workers lack the awareness and training on safe wastewater management practices and do not use the personal protective equipment (PPE) that is provided to them. As a result, the emptying service providers are at high risk of contracting diseases and causing environmental pollution.

The level of sanitation safety practices and risks during the process of fecal sludge management at the transfer stations

A sanitary inspection was conducted at two transfer station to assess its compliance with sanitation safety standards. The findings revealed a combination of safe and unsafe operations at the fecal sludge transfer station. Safe operations were observed in several areas. The transfer station has adequate facilities for washing boots and tools, ensuring proper sanitation practices. Additionally, facilities for washing clothes with sodium hypochlorite or hot water above 60°C are in place, promoting effective disinfection. The transfer station also provides separate storage for workers' street clothing, personal protective equipment (PPE), and team tools, contributing to hygiene and organization. Facilities for cleaning vehicles, including a paved area with a drain, are available, ensuring cleanliness and maintenance. The transfer station adheres to "first-in, first-out" waste handling practices, promoting efficient waste management. Furthermore, a fence is installed, effectively preventing unauthorized access and enhancing site security.

However, several areas of non-compliance were identified during the inspection. The transfer station lacks a dedicated shower facility for workers, which is essential for maintaining proper hygiene standards. Workers are exposed to raw sewage during the maintenance of collection vehicles, indicating a breach of safety standards. Odor neutralizing systems are not in

place, potentially leading to unpleasant working conditions. Physical fly barriers are lacking in waste water and sludge transfer zones/stations, posing a potential risk of contamination. Instances of leakage and overflow were observed, highlighting the need for prompt attention to prevent environmental contamination risks and ensure worker safety.

Sanitation safety practices and risks in wastewater and sludge management at the sewer line

A sanitary inspection was conducted to assess the compliance of the sewer line related operations with sanitation safety standards during the management of wastewater and sludge. The inspection revealed a combination of compliant and non-compliant operations within the sewer line.

Certain areas within the sewer line demonstrated compliance with sanitation safety standards. Workers were found to be well informed about the risks associated with handling wastewater and sludge. They were observed wearing personal protective equipment (PPE) while managing liquid wastes in the sewer line. Additionally, the sewer line had lime or sodium hypochlorite solutions available for cleaning surfaces where accidental spills occurred. Workers were also observed practicing personal hygiene by taking showers at the treatment facility after work, effectively preventing potential contamination.

However, non-compliance was identified in 64% of sanitation safety standards during the inspection. Workers were not consistently wearing PPE while managing liquid wastes, exposing themselves to potential health hazards. The proper functioning and compulsory usage of PPE were not adequately ensured, compromising the safety of the workers. Furthermore, workers were observed handling contaminated surfaces and containers of feces and wastewater without the required PPE, posing a significant risk of contamination and pathogen transmission.

Spillages were occurring outside the sewer line during cleaning and fault fixing, especially in areas where community exposure is most likely to occur. This indicated a lack of effective containment measures. The area where sewer line cleaning takes place was not regularly disinfected with a 0.2% chlorine solution, which could lead to the survival and spread of harmful microorganisms. Workers were also observed being exposed to raw sewage during the cleaning and maintenance of sewer lines indicating a breach of safety standards. Furthermore, sewer line workers lacked sufficient information about the risks associated with handling wastewater and sludge.

The level of sanitation safety practices and risks during wastewater management during disposal and treatment

An assessment was conducted at the wastewater treatment and disposal facility to assess compliance with sanitation safety standards during the management of wastewater and sludge.

The facility demonstrated compliance in several areas, including the use of proper protective clothing and equipment by workers. They also followed appropriate procedures for the safe removal of contaminated clothing after job completion. Personal hygiene practices were observed, with workers taking showers at work and changing into clean clothes and shoes. Handwashing with soap and water before eating or smoking, as well as after contact with wastewater, was consistently practiced. Additionally, there were no significant bad odors detected, indicating effective odor control measures. The facility also showed no evidence of vermin nuisance, suggesting successful pest control efforts.

However, there were areas 45% of non-compliance identified at a wastewater treatment and disposal facility. The facility did not adequately address the control of bio-aerosols (such as ventilation, filtration, disinfection etc., facilities), which could potentially pose health risks to workers and the environment.

Proper handling and disposal procedures for hazardous substances in the waste were not in place, potentially endangering worker safety and environmental health. The facility lacked a comprehensive quality assurance process before disposal, raising concerns about proper treatment and potential environmental contamination. Weed infestation after the application of faecal sludge was not effectively controlled, indicating a need for improved weed management practices. Furthermore, the use of untreated sludge for agricultural purposes in some areas specially at the bank of the main Addis Ababa city rivers was observed, posing significant risks to public health and the environment.

Discussion

The findings of this study shed light on the level of sanitation safety practices and risks during households' fecal sludge management. The categorization of sanitation safety risks into 4 levels, namely low risk, intermediate risk, high risk, and very high risk, provides a comprehensive understanding of the overall situation.

In terms of the prevalence of sanitation safety practices, the majority of households (67%) were categorized as low risk, indicating satisfactory adherence to safe practices. This is consistent with the findings of similar studies conducted^{22,23} which reported a significant proportion of households demonstrating good sanitation practices. However, it is important to note that a substantial number of households (33%) fell under the intermediate risk category. The analysis revealed that wastewater overflow is a prevalent issue in households' sanitation systems, with an average mean value of .259. This finding is in line with previous research which reported similar challenges in managing wastewater overflow.²⁴ The relatively high standard deviation of .225 indicates significant variation in the severity of this issue across different observations. The presence of flies, dirt, and odor in the household sanitation facilities environment was reported at a moderate level, with a mean value of .438.

This indicates that, on average, households face a noticeable presence of flies, dirt, and unpleasant odor. These findings resonate with the study which emphasized the adverse effects of inadequate sanitation facilities on the overall cleanliness and hygiene of households.²⁴

The study revealed a relatively low prevalence of open defecation and unsafe use of wastewater, with a mean value of .0321. This suggests that, on average, households have adopted safe practices and refrain from engaging in these risky behaviors. These findings are align with the research which emphasized the positive impact of awareness campaigns and educational programs on promoting safe sanitation practices.²³ However, the standard deviation of .1222 indicates some variability in the occurrence of this issue, indicating that certain households still engage in unsafe wastewater and open defecation practices.

The study identifies 5 significant factors associated with sanitation safety practices, risks in households through factor analysis, and represent different aspects of sanitation practices and risks. Accordingly, Factor 1, labeled "Unsanitary Wastewater Management and Hygiene Practices," which indicates the presence of unsanitary conditions associated with wastewater management. Similar studies have also emphasized the importance of proper wastewater management and hygiene practices in ensuring sanitation safety.^{25,26}

Toilet cleanliness and maintenance is associated with variables related to toilet cleanliness and maintenance, including the presence of flies, unclean toilet seats, and bad smells. Similar studies have shown that inadequate toilet cleanliness and maintenance can contribute to the transmission of fecal-oral diseases.²⁷⁻²⁹

Risks related to open defecation and fecal waste management is characterized by variables such as open defecation, evidence of feces in the premises, and the use of untreated fecal waste in food production. Similar studies have demonstrated the adverse health impacts of open defecation, including the contamination of water sources and the spread of diseases.³⁰⁻³²

Unsafe toilet management practices and insufficient disinfection is associated with variables related to unsafe toilet pit emptying and insufficient disinfection. Similar studies have highlighted the risks associated with improper waste handling during pit emptying and the need for adequate disinfection to prevent the transmission of pathogens.³³ Unsafe wastewater practices and lack of safe toilet habits is characterized by variables related to unsafe wastewater practices and lack of safe toilet habits. This factor highlights the risks associated with inadequate wastewater management and unsafe behaviors. Other similar studies have shown that the improper discharge of wastewater, usage of untreated wastewater or fecal sludge in agriculture, and unhygienic practices in toilets can lead to environmental contamination and disease transmission.³⁴ Promoting safe wastewater practices and fostering hygienic toilet habits are crucial for reducing these risks.

This study also examined the relationship between sociodemographic factors and sanitation safety practices during household-level fecal sludge management by employing multivariate logistic regression analysis, the findings revealed significant associations between certain sociodemographic factors and specific sanitation practices. Multiple factors were found to be significantly associated with sanitation safety practices, highlighting the importance of considering sociodemographic characteristics in promoting safe sanitation behaviors. Education was found to be significantly associated with the presence of a bad smell in the toilet or septic tank and the use of wastewater/faecal sludge for food production without treatment. Higher levels of education were associated with a lower likelihood of encountering a bad smell and engaging in unsafe practices. These findings align with previous studies that have shown a positive correlation between education and improved sanitation practices.³⁵⁻³⁷ Education can play a crucial role in increasing awareness and knowledge about proper sanitation practices, leading to better hygiene behaviors.

Occupation was also significantly associated with multiple sanitation safety practices. Certain occupations were more likely to be associated with a bad smell in the toilet or septic tank, open defecation by children, and the use of wastewater/faecal sludge for food production without treatment. This suggests that the type of occupation held by household members can influence sanitation practices. Similar findings have been reported in other studies, highlighting the influence of occupation on sanitation behaviors.^{23,38} Occupational differences may be linked to variations in knowledge, access to resources, and cultural norms, which can impact sanitation practices.

Religion showed a significant association with multiple sanitation safety practices. Different religious affiliations were linked to different levels of encountering a bad smell in the toilet or septic tank, open defecation by children, and the use of wastewater/faecal sludge for food production without treatment. These findings are consistent with a study that have examined the influence of religion on sanitation behaviors.³⁹ Religious beliefs and cultural norms can shape individuals' attitudes toward sanitation, affecting their practices and behaviors.

Income was found to be extremely associated with the use of wastewater/faecal sludge for food production without treatment. Higher income levels were associated with a lower likelihood of engaging in this unsafe practice. This finding is supported by previous research highlighting the positive impact of higher income on sanitation practices.⁴⁰ Increased income can provide households with better access to improved sanitation facilities, resources for safe disposal, and hygiene products, reducing the need to resort to unsafe practices.⁴¹

A study conducted in a similar context like Khulna city, Bangladesh and other cities in Sub Saharan Africa observed similar non-compliance issues related to sanitation safety practices during fecal sludge emptying and transport.^{42,43} Both studies identified the lack of properly functioning and mandatory use of personal protective equipment (PPE) by workers as

a major concern. Workers in these studies were observed handling contaminated surfaces and containers without utilizing the necessary PPE, increasing the risk of exposure to harmful pathogens.

Furthermore, spillages during waste transport were observed in other studies,^{44,45} posing a significant risk of community exposure. The inadequate washing and disinfection of collection vehicles, as well as the lack of fly barriers in waste transfer zones, were common findings in both studies, indicating a lack of attention to basic sanitation safety measures.

Similar non-compliance issues have also been reported in studies conducted in other countries^{46,47} highlighted the inadequate usage of PPE by workers during fecal sludge management. The study revealed that workers frequently handled contaminated materials without the necessary protective measures, increasing the risk of infections and diseases.

In addition, studies conducted in various regions have consistently reported concerns regarding the lack of awareness and training among workers involved in fecal sludge management.⁴⁸ This is consistent with the finding of other similar study, where workers lacked awareness and training on safe wastewater management practices.⁴⁹ This knowledge gap contributes to the high risk of disease transmission among workers and the potential for environmental pollution.

While some studies have reported improvements in sanitation safety practices, particularly in wastewater treatment and disposal facilities, challenges still persist. This study identified non-compliance issues in areas such as bio-aerosol control, hazardous waste handling, and quality assurance processes, mirroring findings from other recent studies.⁵⁰

Conclusion and Recommendation

This research conducted a community-based cross-sectional study in Addis Ababa, Ethiopia, to assess current sanitation safety practices along the fecal sludge management service chain. The study found that while a majority of households demonstrated satisfactory adherence to safe sanitation practices, a significant proportion fell under the intermediate risk category, highlighting the need for improvement. Key factors associated with sanitation safety practices and risks included wastewater management, toilet cleanliness and maintenance, risks related to open defecation and fecal waste management, unsafe toilet practices, insufficient disinfection, and unsafe wastewater practices. Additionally, sociodemographic factors such as education, occupation, religion, and income were found to influence specific sanitation safety practices. The findings of this study resonate with global challenges related to non-compliance with sanitation protocols, such as lack of personal protective equipment, improper waste handling, inadequate vehicle disinfection, and insufficient worker awareness and training.

Table 4 consolidates key recommendations for improving sanitation and fecal sludge management (FSM) practices, addressing both community education and worker safety, as well as systematic interventions and infrastructure enhancements.

Table 4. Recommendations.

NO.	RECOMMENDATIONS
1	Implement tailored interventions targeting high-risk areas, such as promoting proper wastewater management and enhancing toilet cleanliness
2	Educate households about unsafe sanitation safety risks and promote safe toilet practices and disinfection methods
3	Promote safe wastewater practices and hygienic habits among the community to reduce sanitation-related diseases
4	Develop and implement training and awareness programs for workers involved in fecal sludge management. Ensure they are equipped with necessary skills and knowledge
5	Enforce the use of personal protective equipment and proper sanitation protocols among workers to mitigate health risks associated with fecal sludge management
6	Implement targeted interventions based on socio-demographic insights to improve sanitation practices
7	Enhance access to and maintenance of sanitation facilities, particularly focusing on safe feces disposal for young children
8	Strengthen sanitation safety practices by addressing identified risks such as wastewater overflow and inadequate disinfection

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Availability of data and materials

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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