

THE EFFECTIVENESS OF FAECAL SLUDGE MANAGEMENT SYSTEMS IN CHITTAGONG

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ABSTRACT

This study investigates faecal sludge management (FSM) techniques in Chittagong, with an emphasis on urban, suburban, and rural settings. A total of 150 houses were picked using stratified random selection, with 50 from each region. The study uses survey data evaluated with Statistical Package for Social Sciences (SPSS) to look at housing types, water sources, septic tank cleaning techniques, service accessibility, and variables impacting customer satisfaction. The results show that 65% of households live in pucca housing, with the majority relying on natural surface water sources such as rivers and lakes. Septic tank cleaning is predominantly manual (56%), followed by pumping devices (23%) and vacuum cleaners (21%). Overall perceptions of FSM services are largely positive, yet significant spatial disparities exist across Chittagong. Urban households benefit from advanced FSM practices, with 100% vehicle access, longer septic tank emptying intervals, and 78% emptying tanks every two years or longer, reflecting more efficient service delivery and alignment with public health objectives. In suburban and rural areas, limited access constrains service efficiency: only 38% of suburban and 12% of rural households report adequate vehicle access, resulting in shorter emptying cycles and continued reliance on manual or low-cost methods. Service selection priorities highlight contextual differences: urban residents emphasize environmental considerations (76%), while suburban and rural households prioritize affordability and availability due to economic and logistical constraints. Satisfaction mirrors these disparities: urban areas report the highest satisfaction (74% very satisfied) linked to service quality and thorough cleaning, whereas rural households show higher dissatisfaction (16%), primarily due to access limitations and cost sensitivity. Cost emerges as a stronger determinant of satisfaction than service quality in non-urban areas. Overall, these findings reveal pronounced inequalities in FSM infrastructure, accessibility, and user priorities. While urban systems demonstrate effective management and higher compliance with health standards, targeted investments in infrastructure, affordable service models, and operational improvements are essential to enhance equity, service reliability, and sustainability in suburban and rural contexts.

Keywords: *Faecal Sludge Management (FSM), SPSS, Heat Map, Sankey Diagram, Chittagong*

1. INTRODUCTION

Bangladesh, situated between 20°34' and 26°38' North latitude and 88°01' and 92°41' East longitude, encompasses a land area of 147,570 square kilometers and supports a populace of 154.7 million, while the Chattogram district, an administrative segment of the Chittagong division in southeastern Bangladesh, exhibits unparalleled geographical diversity characterized by hills, sea, valleys, and forests, located between 20°35' and 22°59' North latitude and 91°27' and 92°22' East longitude with total population 79,13,365 (Population & Housing Census, 2011). The United Nations recognizes access to water and sanitation as human rights that are essential for everyone's dignity, health, and development. The United Nations recognizes access to water and sanitation as human rights that are essential for everyone's dignity, health, and development (Katukiza et al., 2012). FSM is a systematic technique to dealing with faecal sludge (FS) that generally involves five components of the sanitation service chain: (i) containment (ii) emptying (iii) transportation (iv) treatment (v) reuse and disposal (Hoque et al., 2020). In the FSM cleaning procedure, cleaning is done by pumping or the vacuum tanker method. The pumping uses mechanical pumps, such as centrifugal or diaphragm pumps, to transfer semi-liquid and liquid FS from septic tanks or pits to containers or vehicles. It is suitable for small-scale operations with limited access. In the country, in the vacuum tanker method, a vacuum pump creates a negative pressure that sucks FS directly into the tanker, enabling faster, more hygienic transport of large volumes of sludge (Strande & Brdjanovic, 2014).

The management of FS is of paramount importance in Chattogram, given its significant impact on public health, environmental sustainability, and the overall quality of life, particularly in densely populated urban areas (Kodom et al., 2021). Nevertheless, the considerable steps made in shortening open defecation in Bangladesh, with the proportion dropping from 34% in 1990 to 0% in 2017 (Ferdous et al., 2022). Urban regions in Chattogram continue to grapple with FSM-related challenges. 64.4% of population in nationally had access to sanitation facilities, in rural areas, this rate decreased to be 36.4%. The absence of appropriate FSM in these regions gives rise to environmental contamination and presents a considerable threat to public health, particularly in low-income areas where manual pit emptying and unsafe disposal are prevalent. The prevention of waterborne diseases such as diarrhea, cholera and dysentery, which are dominant in Bangladesh, hinges on the implementation of effective FSM (Azupogo et al., 2019). Furthermore, the effective implementation of FSM is crucial to achieving United Nations Sustainable Development Goal 6 (SDG 6) and ensuring the provision of safe sanitation for all (ESCAP, 2016). The lack of effective FSM systems in Chattogram's urban, suburban, and rural regions harms the environment while putting extra pressure on waste management systems. Therefore, FSM is a crucial element in the pursuit of sustainable urban development. Statistical studies and field observations found that Chittagong City has poor sanitation, hygiene, communal toilets, waste disposal, and drainage infrastructure. Poor sanitation and hygiene are major contributors to poor health and socioeconomic outcomes in underdeveloped countries, posing a significant development challenge (Tumwebaze et al., 2013).

Previous FSM research has primarily examined rural and urban settings separately. A study by Hoque demonstrated the significance of proper FSM and treatment systems in Khulsi Thana (Hoque et al., 2020). Research by Rahman examined the current status of WASH (Water, Sanitation, and Hygiene) practices in Bangladesh, including urban areas and slums (Hanchett et al., 2003; Uddin, 2018). Another study by Islam surveyed 72 families to assess access to sanitation and safe water in the rural area of Lohagara (Islam et al., 2015). These studies collectively reveal a research gap regarding comprehensive assessments of FSM systems across rural, suburban and urban zones of Chittagong. This study explores the current situation of FSM in urban, suburban, and rural regions of Chittagong, highlighting gaps, problems, and chances for development. The diversified geographical environment of Chittagong presents distinct difficulties and possibilities for FSM, making it critical to investigate and enhance the performance of existing procedures.

2. MATERIALS AND METHODS

The study was conducted in the Chattogram region of Bangladesh, encompassing urban, suburban, and rural areas to evaluate diverse sanitation management practices.

2.1 Study Area

The study collected data from urban, suburban, and rural areas, as depicted in Figure 1. The urban areas included Agrabad, GEC, Chawkbazar, Bayazid, and Bahaddarhut. Sitakunda, Boalkhali, Raozan, and Hathazari comprised the suburban areas, while Anowara, Fatikchori, Rangunia, and Patia represented the rural areas. Data collection involved a physical survey focusing on three categories: inside toilet, outside toilet, and FSM.

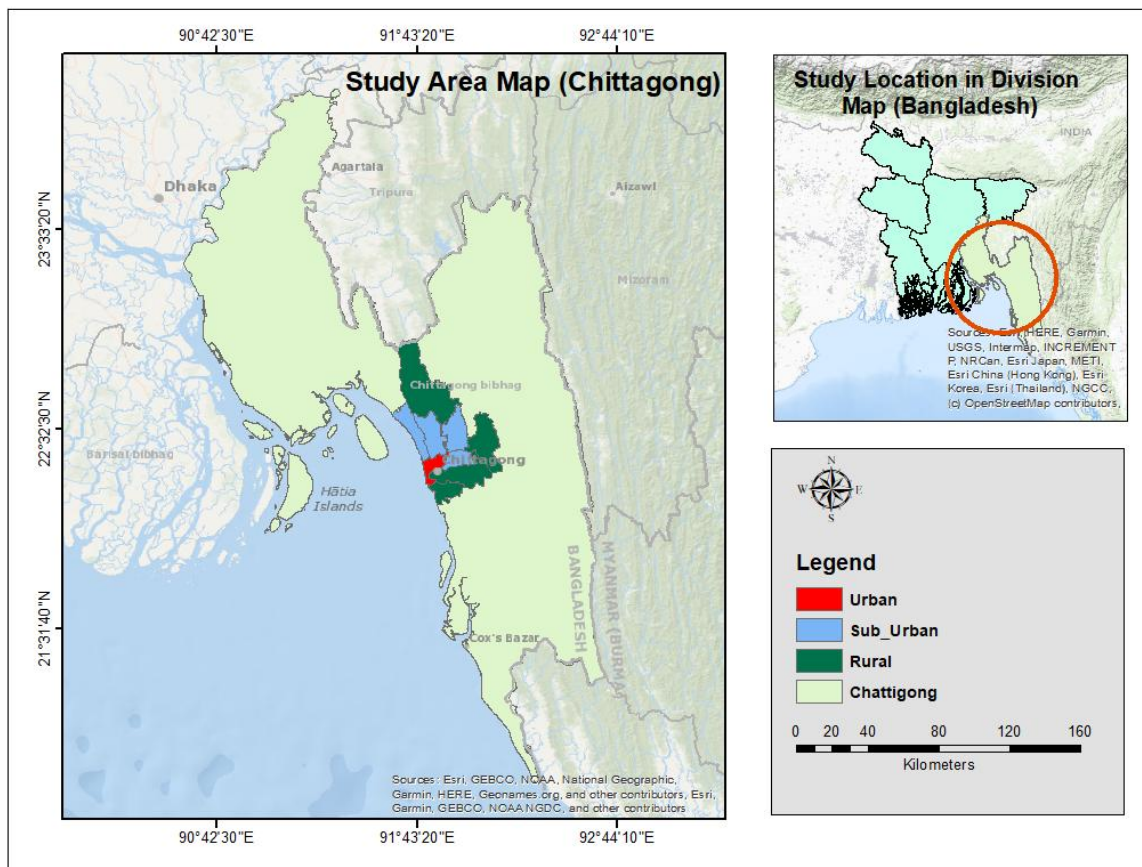


Figure 1: The study area location map, Chattogram.

2.2 Data Collection Method

A total of 150 households were selected through stratified random sampling, with 50 households from each area. Data were collected using structured interviews and surveys, focusing on the type of sanitation facilities, frequency of usage, waste disposal methods, water availability, duration of emptying of septic tank or pits, method of cleaning, household containment within the reach of FS collection pipes from parking space and type of containment connected to the toilets.

2.3 Analysis Method

The data were analyzed using various statistical and graphical methods, including pie charts, bar charts, heat maps, and sankey diagrams. The analysis was conducted using spread sheet tools, python and SPSS. This comprehensive approach shown in Figure 2 provided valuable insights into the sanitation practices across different areas of Chattogram.

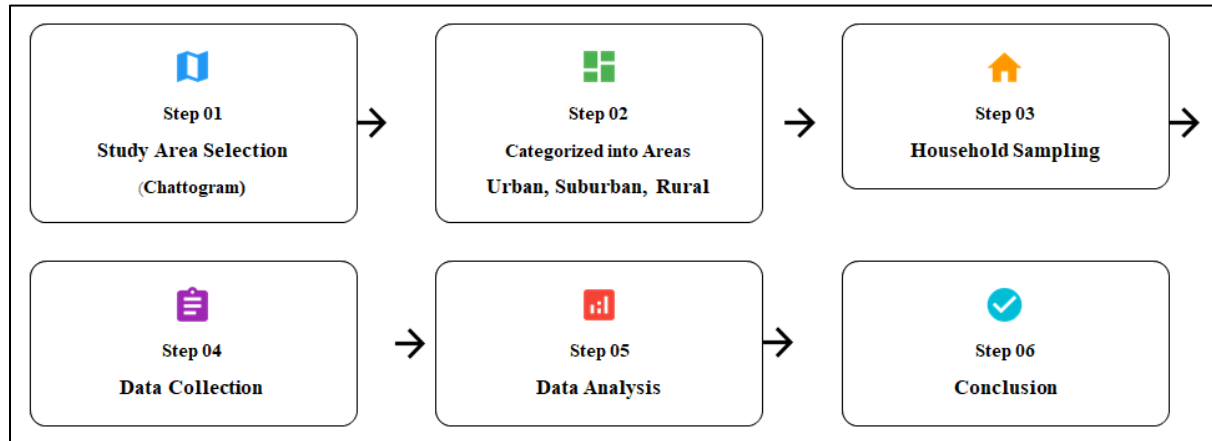
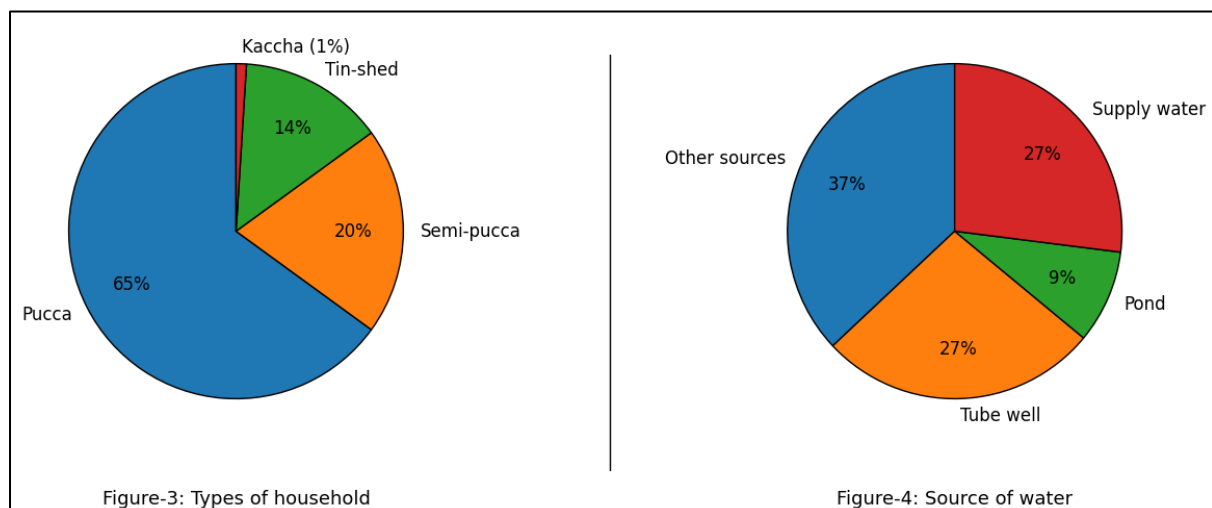


Figure 2: Methodology Flow Chart

3. RESULTS AND DISCUSSIONS

This section presents a comprehensive assessment of FSM practices across urban, suburban, and rural areas, focusing on housing types, water sources, sludge emptying methods, accessibility, service preferences, and user satisfaction. The findings highlight clear spatial variations in FSM service delivery, technology adoption, and decision-making priorities, revealing how infrastructure availability, cost, environmental awareness, and accessibility influence household behavior and service performance. This section integrates quantitative results from household surveys with comparative visual analyses to identify key challenges and opportunities for improving FSM systems in different land-use contexts.



The Figure 3 shows the majority of households (65%) live in pucca homes, with a few in semi-pucca (20%), tin-shed (14%), and kaccha houses (1%). The Figure 4 demonstrate water sources include 37% natural sources such as rivers or lakes, 27% tube wells, 27% supply water, and 9% ponds. Thus, pucca houses predominate, and natural water sources are the principal source, with pond water being the least utilized.

According to the Figure 5, 64% of respondents are satisfied, with 36% very satisfied with the manual/vacuum tanker/pumping service. Furthermore Figure 6 depicts 56% of cleaning is done manually, 23% using pumping devices, and 21% with vacuum cleaners, showing that manual cleaning is the most popular approach. However, relying on manual cleaning might increase labor intensity and pose health risks for workers.

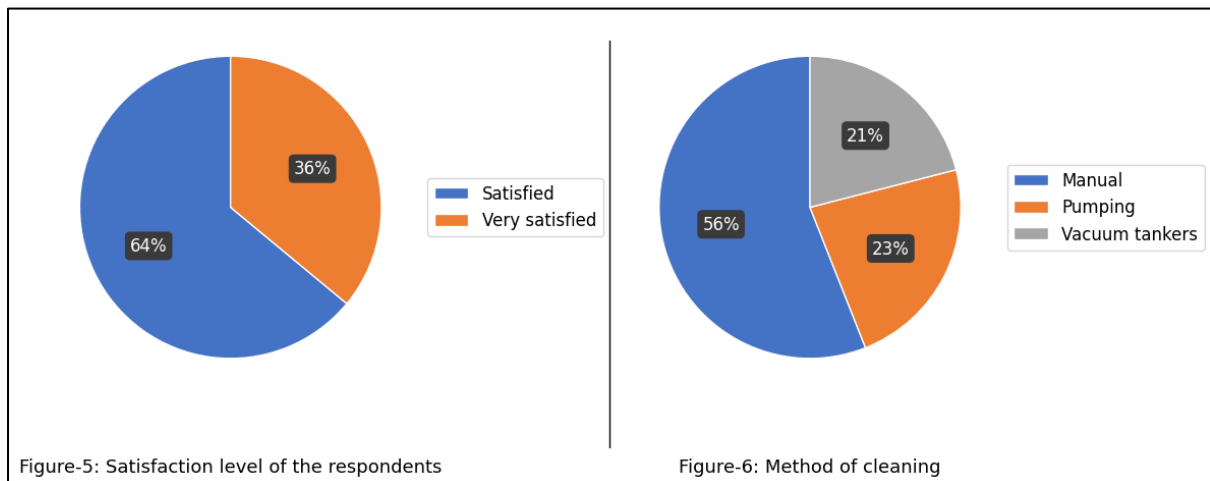


Figure 7 illustrates variations in the accessibility of household containment collection pipes across different settlement types. Here, accessibility refers to whether desludging vehicles can reach the collection pipes directly from nearby parking spaces for mechanical emptying. In urban areas, only 36% of the pipes are accessible from parking spaces, while the remaining 64% are inaccessible due to physical or spatial constraints. In contrast, sub-urban areas demonstrate very high accessibility, with 98% of collection pipes accessible and only 2% inaccessible. Rural areas exhibit the lowest accessibility, where just 20% of the pipes can be accessed from parking spaces, compared to 80% that remain inaccessible.

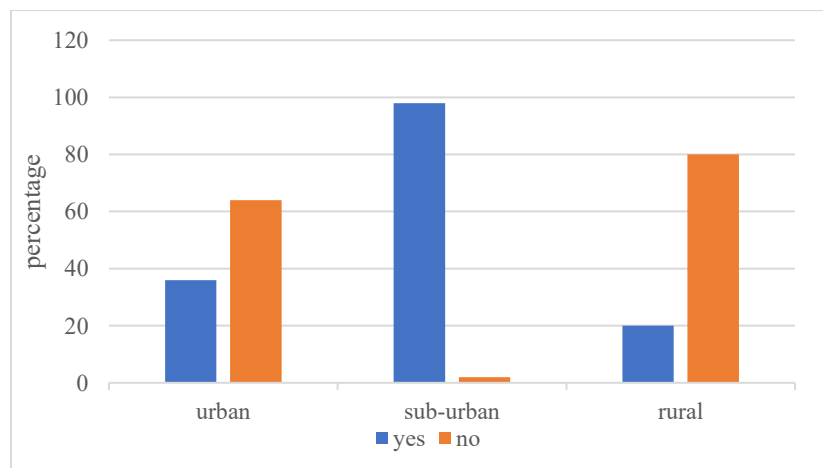


Figure 7: Household containment accessible to FS collection pipes from parking spaces.

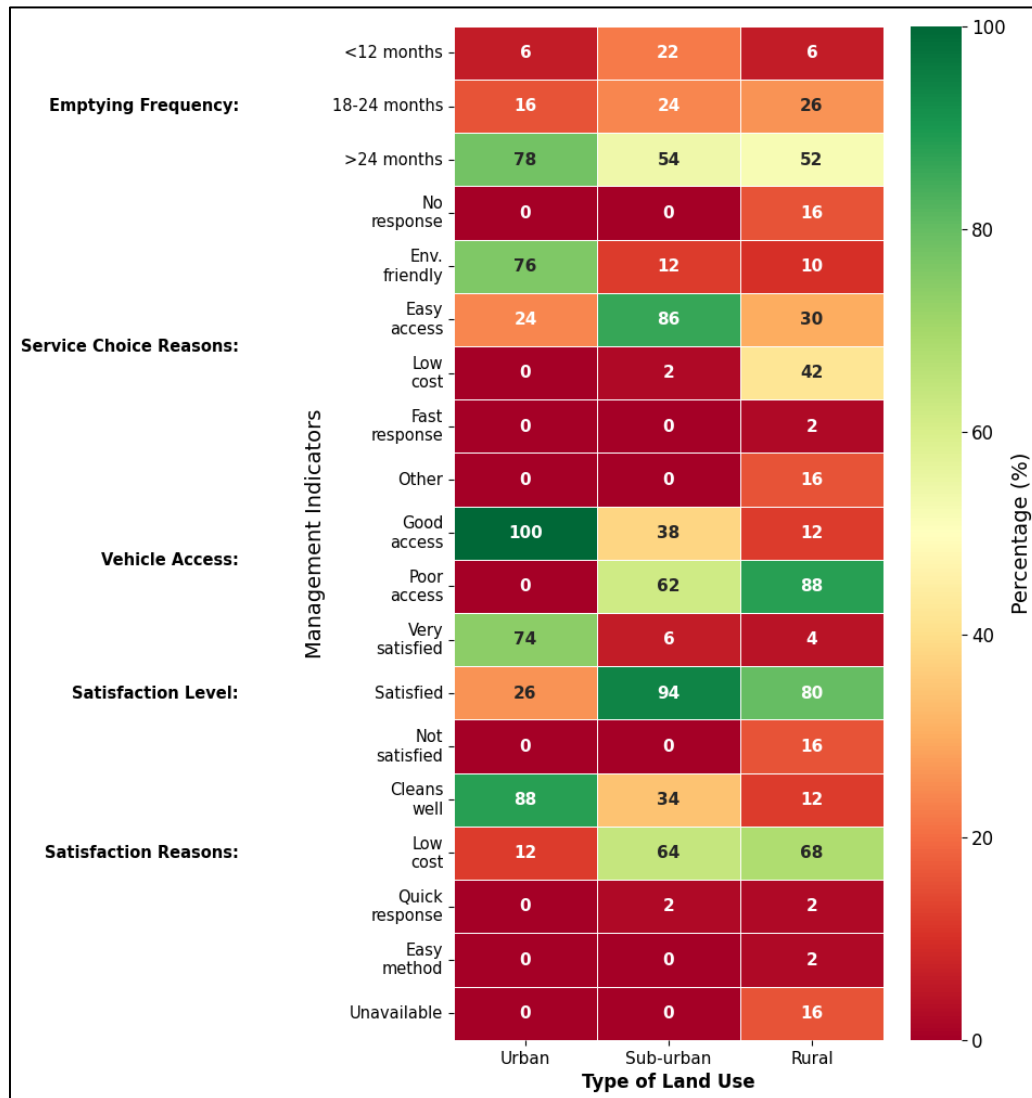


Figure-8: Heat Map on Regional Variations in FSM

Figures 8 utilize heat maps to compare FSM strategies in various locations and land use types. The heatmap employs a red-yellow-green color scale to represent percentage values from 0% to 100%. Red indicates low percentages, yellow signifies moderate values, and green corresponds to high percentages. This gradient effectively highlights variations across management indicators and land use types, allowing for clear and intuitive comparison of data intensity within the visualization. Urban residents demonstrate a tendency to prolong the duration between the emptying of their septic tanks. The majority (78%) prefer to empty their tanks every two years or longer, while a smaller percentage (16% and 6%) choose intervals of 18-24 months and less than 12 months, respectively. In suburban regions, a comparable trend is observed, with 54% opting for emptying every two years or more, and a higher frequency noted among the rest of the residents. Rural areas exhibit the most frequent tank emptying, as only 52% wait for two years or more. Here, a significant proportion (26%) carries out emptying every 18-24 months, and a few (22%) do so even more frequently. The rationale behind the selection of manual/vacuum tankers/pumping services revolves around environmental concerns as the foremost priority for urban dwellers.

Environmental concerns are the top priority for urban residents when choosing septic tank services. A substantial 76% place this aspect at the top, followed by the ease of availability (24%). Cost and response time are of lesser importance in their decision-making process. Suburban areas, conversely, prioritize ease of availability (86%), with environmental concerns still holding some significance

(12%). Cost plays a minor role (2%), while response time and other factors are deemed negligible. In rural settings, the cost emerges as the primary driver influencing service selection (42%), followed by ease of availability (30%). Environmental considerations rank the lowest (10%), with response time and other factors holding marginal importance (2% each). The emphasis on cost is prominent among suburban and rural inhabitants, whereas urban residents prioritize environmental factors.

The accessibility of vehicles for septic tank services poses varying challenges across different areas. Urban zones exhibit a 100% access rate, indicating minimal issues. However, suburban regions report a mere 38% with good accessibility, signifying hurdles for service providers to reach numerous locations. Rural areas encounter the most significant obstacle, with a scant 12% enjoying good access. Accessibility emerges as a major impediment in suburban and rural regions, impeding service delivery.

The satisfaction levels regarding septic tank services depict contentment among the majority of urban residents, with 74% being very satisfied and 26% satisfied. Notably, no instances of dissatisfaction were reported. Suburban areas echo a similar sentiment, with a high proportion (94%) expressing satisfaction and only 6% being very satisfied. Once more, no dissatisfaction is documented. Conversely, rural areas exhibit a higher number of dissatisfied individuals (16%). Nonetheless, the majority (80%) express satisfaction, with a minor percentage (4%) indicating very high satisfaction.

The reasons behind satisfaction with septic tank services vary across different areas. In urban regions, thorough cleaning stands out as the primary driver of satisfaction, with a significant 88% emphasizing this aspect. Cost emerges as a secondary factor (12%), while response time and ease of use hold minimal importance. Suburban and rural areas mirror a similar narrative, with cost being the primary determinant of satisfaction (64% and 68% respectively), followed by thorough cleaning (34% and 12% respectively). Other factors do not carry much weight in these locales. Thorough cleaning emerges as the principal satisfaction driver in urban settings, whereas cost plays a more significant role in suburban and rural areas.

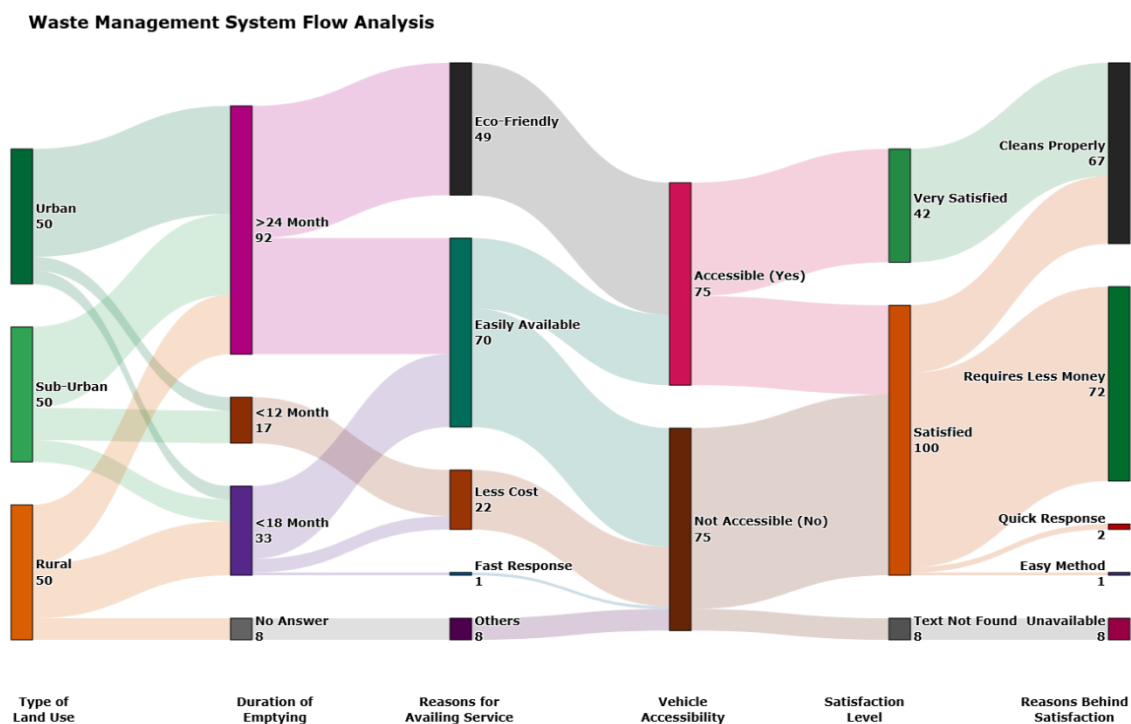


Figure-9: Sanky diagram on Comparison of FSM Practices Across Land Use Types

The Sankey map in Figure 9 summarizes responses from 150 respondents on septic tank emptying services. It shows that respondents are evenly distributed across urban, sub-urban, and rural areas. Most tanks are emptied after more than 24 months. The main reasons for using the service are environmental friendliness and easy availability. Accessibility of vehicles is split equally (75 yes / 75 no). Overall satisfaction is high, with most respondents being satisfied or very satisfied, mainly because the service requires less money and cleans properly, while a small number report issues like unavailability or no response.

Finally, this data illustrates a distinct difference in the management of fecal sludge in various parts of Chittagong City. Urban areas exhibit superior management practices and higher satisfaction levels, with robust infrastructure and a preference for environmentally friendly services, rendering them more suitable for environmental and public health standards. Suburban areas demonstrate moderate to high satisfaction levels, yet face accessibility challenges, with cost and availability being significant factors. Despite these obstacles, there is a notable uptake of services in these areas, indicating a potential for improvement in infrastructure. Rural areas face challenges in accessibility and satisfaction. Cost is a significant concern, and there are notable gaps in service availability, which makes them less suitable for environmental and public health standards.

4. CONCLUSIONS

The study on FSM in Chittagong found considerable differences across urban, suburban, and rural locations. Urban areas have better management practices, higher satisfaction levels, and a desire for environmentally friendly services, all underpinned by strong infrastructure. Suburban locations have average satisfaction but suffer accessibility issues, with cost and availability being important considerations. In rural areas, restricted access, high expenses, and service gaps impede effective management, creating health hazards. Infrastructure improvements, as well as an emphasis on accessibility and cost, are critical for improving FSM in all regions.

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DECLARATION

The authors utilized artificial intelligence tools, including ChatGPT (OpenAI, GPT-5.1) and DeepSeek (DeepSeek Inc., DeepSeek-V2), solely to improve the clarity and language of the manuscript.

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