INVESTIGATING THE COMPATIBILITY OF EXISTING SANITATION SERVICES WITH SUSTAINABLE DEVELOPMENT GOAL USING GIS AND SFD GRAPHIC: A CASE STUDY ON SYLHET CITY CORPORATION

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ABSTRACT

The government of Bangladesh has developed a National Action Plan for the implementation of the Institutional and Regulatory Framework for Fecal Sludge Management (FSM), with an emphasis on meeting the requirements of Sustainable Development Goal (SDG) 6.2 by 2030. However, establishing safely managed sanitation for the urban region remains a significant challenge. Sylhet City Corporation is one of the fastest-growing metropolitan areas in Bangladesh. While a conventional sanitation management system with limited facilities exists in this metropolitan area, it is essential to verify whether the existing system is sustainable enough to meet SDG requirements.This study aims to investigate the current status of sanitation services and facilities in the city area and present the results by generating Shit Flow Diagram (SFD) graphics and GIS maps. In this research, household-based data have been collected through questionnaire surveys. Additionally, focus group discussions, key informant interviews, and physical observations have been conducted during the study. The study reveals that 92% of the population is connected to septic tank services. From the GIS map, the presence of open defecation in wards 8, 14, and 26 of the city corporation area has been identified. It has been found from the SFD graphic that about 91% of the total population lacks access to safely managed sanitation services, which is alarming. The city authority has only one vacuum truck to provide emptying services. The majority of city dwellers under the coverage of emptying services depend on private sweepers and dispose of fecal sludge in open drains, open fields, or water bodies, as there is no dedicated fecal sludge treatment plant in this city. This study helps identify the major shortcomings of the existing sanitation services in this city and underscores the necessity of urgent intervention, not only to secure a safe environment but also to meet the SDG 6.2 protocol.

Keywords: *Fecal sludge, safely managed sanitation, SDG 6.2, shit flow diagram*

1. INTRODUCTION

Sanitation is described as the ability to maintain hygenic condition in daily life and having access to facilities for the safe disposal of human waste. It is not only the issues about human health but also directly related to the economic development of the country. Sanitation is one of the most important indicators of the development of a country. Sanitation basically refers to toilet or latrine management (Mosler, Mosch & Harter, 2018). Environmental sanitation refers to human excreta control, safely management of human excreta, and confirming that contaminated sludge does not return to the environment. The United Nations (UN) has established a number of goals and targets to guarantee a sustainable future for humankind. One of the key goals that must be met by 2030 is sanitation (United Nation, 2015). In order to achieve Sustainable Development Goal 6 by the year 2030, it is crucial to assess the existing sanitation management practices and determine the appropriate actions to be taken.
Sylhet City Corporation (SCC) has been chosen for this study since any fecal sludge treatment plant is absent here. Sylhet City Corporation covers an area of 27.36 square kilometers, comprising a total of 27 wards and a population of 594096 (Collected from SCC in 2023). The specific objective of this study is to investigate sanitation conditions and represent the situation with SFD graphics and GIS map.
The assessment of the sanitation condition in the Sylhet City Corporation area using GIS and SFD graphics tools will reveal inadequate sanitation practices and infrastructure, indicating a need for urgent intervention. The people of this region will be beneficial, and Bangladesh can step forward to achieve SDG 6.
Sustainable Development Goal-6 also known as 'Water Goal' defines the importance of sanitation the headline of SDG 6 is to ensure availability and sustainable management of water and sanitation for all (Guppy, Mehta, & Qadir, 2019). The core message of SDG 6 is to guarantee accessibility and enduring management of water and sanitation for all (United Nations, 2015). WHO and UNICEF, through the JMP, are custodian agencies for the SDG targets on drinking water, sanitation and hygiene. Two separate ladders have been used as tools to indicate the improvement in sanitation and hygiene called JMP ladder (WHO/UNICEF JMP, 2015).

1.1 Safely Managed Sanitation

In order to establish a sustainable sanitation management system, 'safely managed sanitation' has been introduced in SDG 6 (Sustainable Development Goal 6), where it has been made clear that 'sanitation' is more than 'latrinization'. Safely managed sanitation is a service chain that consists of five basic components such as user interface/containment, emptying, conveyance/transport, treatment and disposal/reuse.

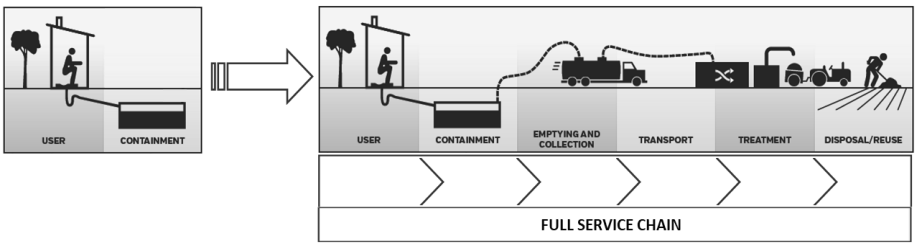

Figure 1: Transformation of conventional sanitation to full sanitation service chain

In many cases the reality is that there is a containment/toilet installed as a part of the sanitation system, but rest parts of the sanitation service chain are absent. Moreover, the number of unimproved toilet user is significant resulting higher risk of water borne diseases in regional areas in Bangladesh (Reza, 2019; Muhit, 2015).

1.2 SFD Concept

Shit flow diagram (SFD), which is also known as excreta flow diagram, is a decision-support tool that gives an insight about the physical flows of excreta in a study area. The concept has been developed by the collective effort of the Sustainable Sanitation Alliance (SuSanA) along with the financial support of the Bill and Melinda Gates Foundation. In general, it is very hard to understand the fate of excreta, however SFD has the capacity to identify whether the excreta produced from a locality is well

managed or not. In addition, it gives the information about the functionality of individual service component and represents full sanitation service chain within a single diagram. Safely managed flows are depicted in the SFD graphic transferring along the service chain moving from left to right. The arrows, turning towards the bottom of the graphic, represent the parts of unsafely managed excreta discharging to the surrounding environment. The breadth of each arrow is proportional to the percent of the population whose excreta contribute to that stream. SFD is a communication tool that shows where the main sanitation hazards are. It has a wide range of application flexibility and can represent the sanitation condition for a low-lying area, low-income settlements, or even for the entire city.

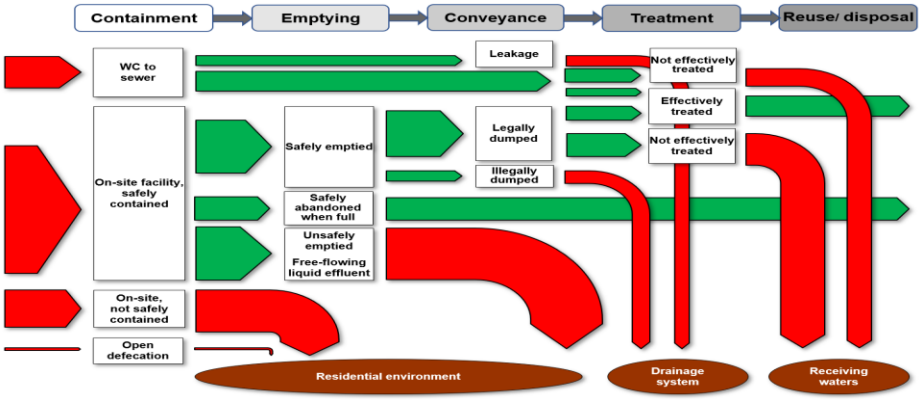

Figure 2: Shit flow diagram (SFD) demonstrating the fate of excreta (Eawag/ConCaD, 2019)

1.3 Application of GIS Tools

Geographic information systems are a special class of information systems that keep track of not only events, activities and things, but also of where these events, activities, and things happen or exist. (Longley, Goodchild, Maguire, & Rhind, 2006). A geographical information system integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms (ESRI, 2010). The world surroundings can be seen from a different perspective by the maps that are the foundation of GIS. They make the environment seem less complicated. Almost any piece of information that can be displayed on maps, and several types of information can be exhibited on the same map. Human would then be able to evaluate how different types of data interact with one another and come to better conclusions. Due to the complexity of surroundings, human cannot make decisions with little knowledge. But, GIS makes it possible to create a model of the complicated world in a easy method so that people can comprehend the environment and make judgments about it (Stan, 1995). Obtaining relevant data is one of the main difficulties in GIS work. The data used in GIS represents a particular aspect of the real world at a specific time. Accuracy, precision, timing, currency, and completeness are the five most essential characteristics of good data. Therefore, the amount of the topic of interest for which data are available is referred to as the area's completeness (Stan, 1995).

2. METHODOLOGY

The geographic location of SCC is between 24°51´ and 24°55´ north latitude and between 91°50´ and 91°54´ east longitude. There are more than half a million people in Sylhet City Corporation, with an average of 18,867 people per km^2 (Collected from SCC in 2023). Presently, SCC accommodates 1.2 per cent of the country's urban population (BIGD, 2017). Nearly 80% of the annual average rainfall of 4,200 millimeters (170 in) occurs between May and September (Archived, 2019). There are roughly 970 km of drain in the city, consisting of 231 km of CC drain, 11 km of clay drain, and 728 km of RCC drain (CWIS-FSM Support Cell, 2022).

2.1 Data Sampling

There are several formulas to calculate the sample size. Slovin's formula is widely used and expected when the population size is known. The formula was formulated by Slovin in 1960. It cannot calculate characteristics of the sample (Ryan, 2013). In this study "Slovene's" equation was used to calculate representative sample. The formula is as follows-

$$n = \frac{N}{1 + Ne^2}$$

Here, n is the targeted sample size, N is the number of total population and e is the significance number. To calculate the significance number it needs to assume the confidence level (95% for this study). In this study, the total sample size calculated from 54136 holdings is 397, where the significance (e) was calculated at 5%. The sample size from each ward was calculated as the weight of the holding number. All educational institutions, social institutions, public toilets, hospitals, hotels, restaurants, and religious institutions are included in this data sampling. These data were sampled by the convenience method.

2.2 Tools and Techniques of Data Collection

This research has been conducted through a social survey. In this study, the results are determined using both descriptive and analytical methods. The inhabitants provided the primary data through a questionnaire survey. Secondary data were collected from SCC and related reports and research papers. Data from respondents in the study area were collected using a semi-structured questionnaire, key information interviews (KII), field observations, and focus group discussions (FGD). Individual households were chosen at random from the wards to gather the primary data. Respondents were chosen from the study area purposively and randomly, as stated in the overall research design. Throughout the survey process, age and gender considerations were taken seriously.

2.3 KIIs and FGDs

Two FGDs and seven KIIs were performed with 397 field data points. FGD were conducted with the following groups:

1. Female stakeholders
2. Sweepers

KII were performed with the following individuals:

1. Head of conservancy department, SCC
2. Head of water supply department, SCC
3. Supernatant Engineer (CE), SCC
4. Executive Engineer, DPHE, Sylhet
5. Sanitation expert (Academician)
6. Sanitation expert (Field)

2.4 Creation of SFD Graphic

The application tool - 'SFD Graphic Generator (offline version)' were used for SFD matrix preparation and graphic creation. The tool is developed by the collective effort of the Sustainable Sanitation Alliance (SFD, 2018).

2.5 Creating GIS Map

GIS connects data to a map, integrating location data with all types of descriptive information. The present conditions of sanitation of the study were been illustrated trough spatial distribution map through ArcGIS software. While the safely managed sanitation represent a service check that consists of five components such as (i) User interface/containment, (ii) Emptying, (iii) Conveyance/Transport, (iv) Treatment and (v) Disposal/Reuse, component wise status, as well as the present conditions of the full service chain in the study area, were demonstrated through spatial distribution maps (GIS maps) where ArcGIS software were used.

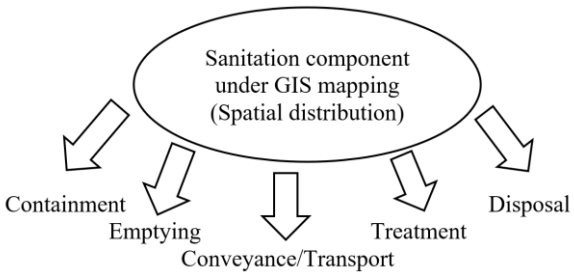

Figure 3: Sanitation component that were illustrated using the GIS tool

3. RESULT AND DISCUSSION

3.1 JMP Ladder Status for Sanitation

Basic sanitation facilities are found mostly in this study area. Very few are in safely managed. Only 0.5% of open defecation was found in this study. Figure 4 shows the ward-wise sanitation ladder for Sylhet City Corporation. Ward no. 8, ward no. 14, and ward no. 26 show open defecation. Some slum areas were found in these areas in this study. Ward no. 6 shows the maximum limited sanitation practice.

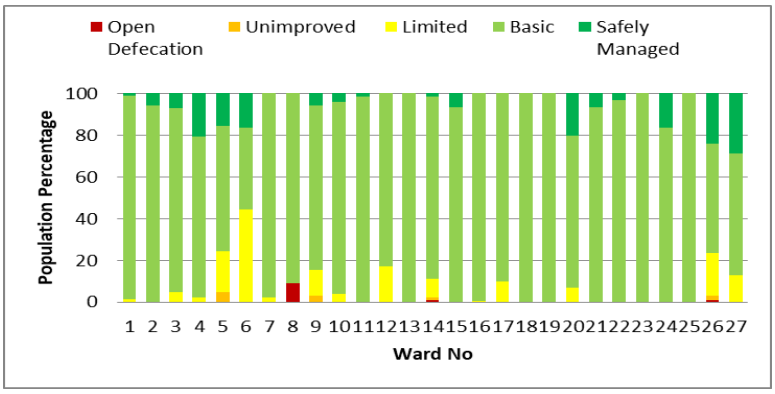

Figure 4: JMP ladder for Sanitation

This figure shows that the three wards have open defecation. These wards have low-income people and have slum areas as well.

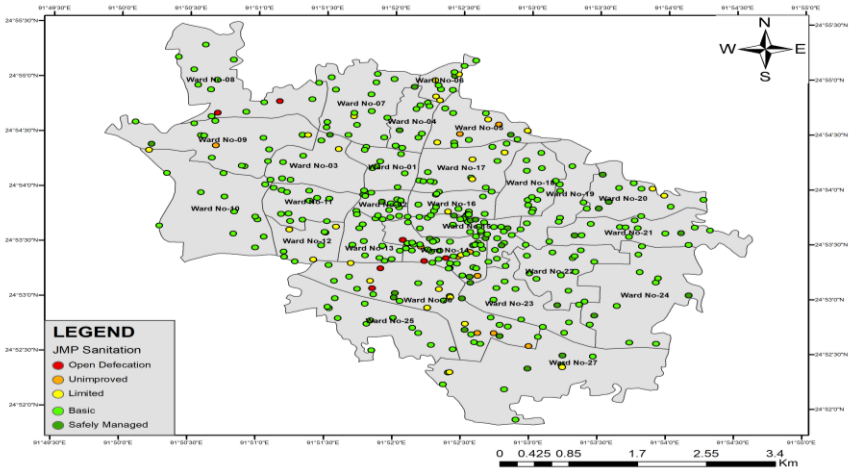

Figure 5: Map Showing JMP Sanitation Ladder for SCC

Most of the people in Sylhet City Corporation use basic sanitation. They used an improved toilet but were not concerned about the safe disposal of the waste. Some wards have safely managed sanitation as well. A few septic tanks are never empty, and some portions of the waste are managed onsite.

3.2 JMP Ladder Status for Hygiene

The hygiene condition of the study area was found to be comparatively better in this area. Hand washing with soap facilities is available mostly. Figure 6 shows the hygiene ladder for Sylhet City Corporation. This study found no hygiene facilities in ward no. 8, ward no. 14, and ward no. 26.

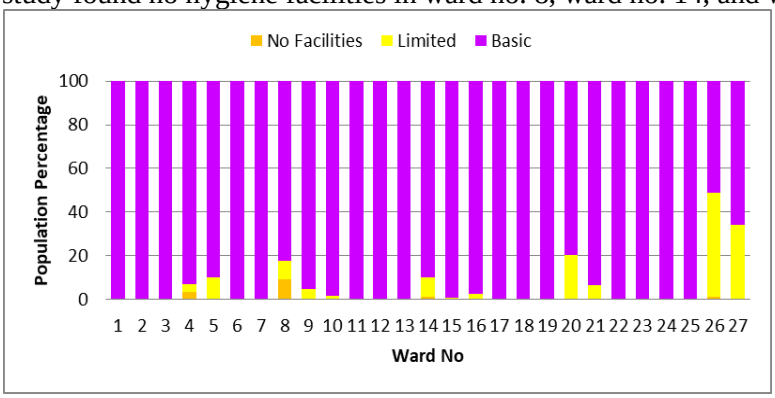

Figure 6: JMP ladder for Hygiene

The maximum population practices basic hygiene in this study area. Hygiene practice is directly related to the behavior of people. The people of Sylhet City Corporation are conscious of personal hygiene, but they are not fully concerned about safely managed sanitation. Because safely managed sanitation is not on their priority list.

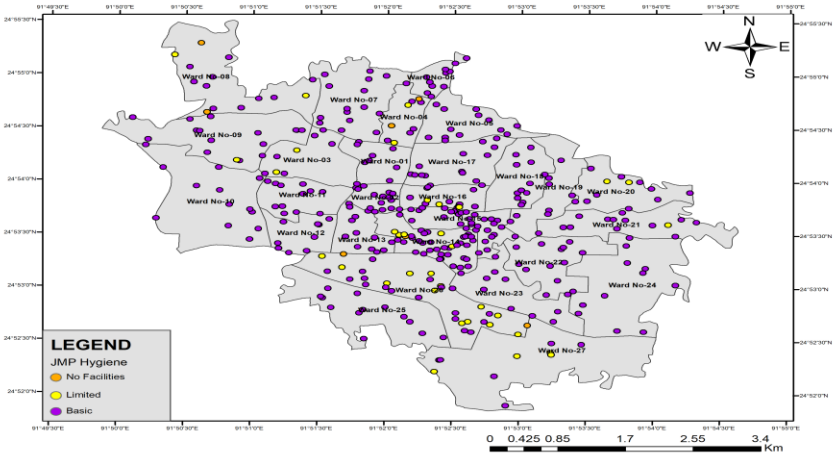

Figure 7: Map Showing the JMP Hygiene Ladder for SCC

In this area, most people practice handwashing with soap, indicating a relatively high level of hygiene awareness and access to sanitation facilities. This promotes better public health and disease prevention. However, this ladder does not indicate the management of the whole sanitation system. In Sylhet City Corporation, people are concerned about their health but careless about the safely managed sanitation.

3.3 Different Service Component under Safely Managed Sanitation

In this study, the presence of a "safely managed sanitation service chain" has been examined. Unfortunately, the findings reveal a significant deficiency in the existing sanitation system, as it does not meet the criteria for a safely managed sanitation service chain. This indicates that there are shortcomings in ensuring the safe and proper handling of sanitation services, potentially posing risks

to public health and environmental safety. All of the stages are so important to know about the whole system of sanitation management. Every stage of the service chain is explained below.

3.3.1 User Interface

The most common user interface used in this study area is the cistern flush toilet, along with the pour flush toilet. Cistern flush is mostly used in this study area. Figure 8 shows the ward-wise user interface at Sylhet City Corporation.

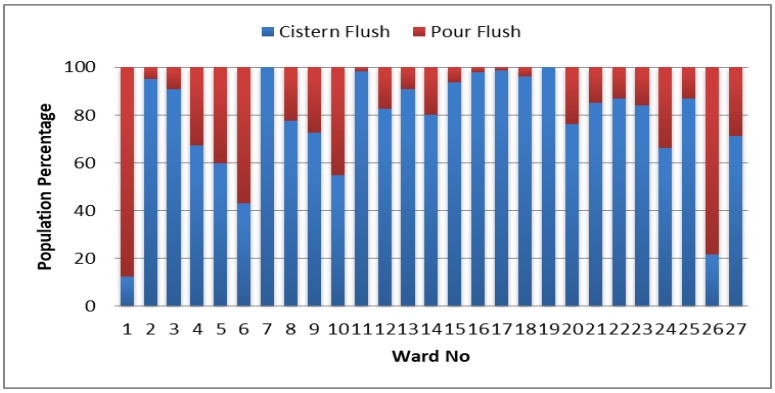

Figure 8: User interface

The availability of water is the main reason behind the use of cistern flushes. As Sylhet City Corporation is a city area, most residences have either supply water or private electrical water pumps. People get water easily in the toilet, and they are comfortable in the cistern flush.

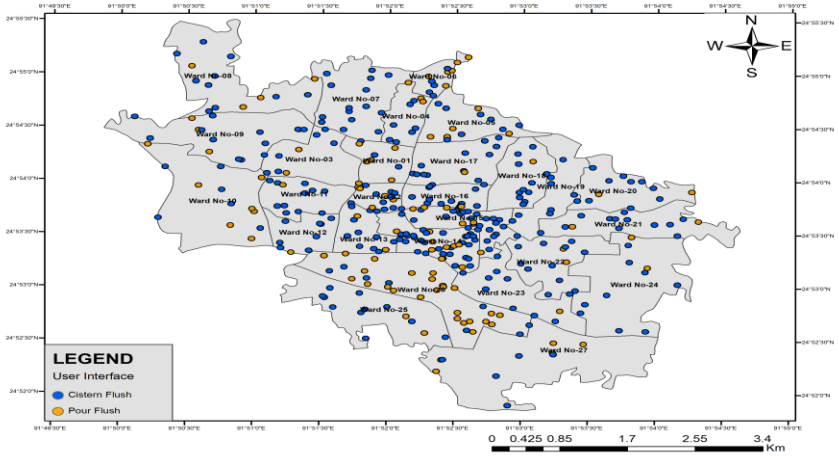

Figure 9: Map Showing the User Interface for SCC

3.3.2 Containment

About 97% of the total population uses toilet facilities, and the rest of them use community latrines, shared sanitation, or neighbor's toilets (CWIS-FSM Support Cell, 2022).

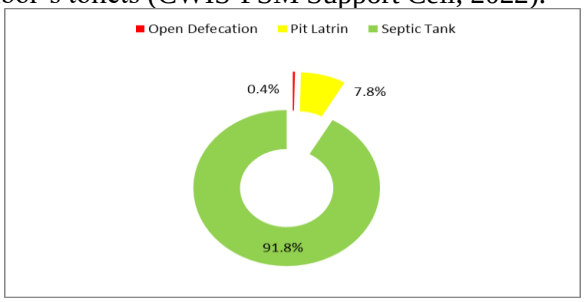

Figure 10: Status of the existing containment system in SCC

Among the users, about 91.82% use septic tanks as containment systems. 7.81% use pit latrines with semipermeable walls and open bottoms. Less than 1% of people in the area practice open defecation.

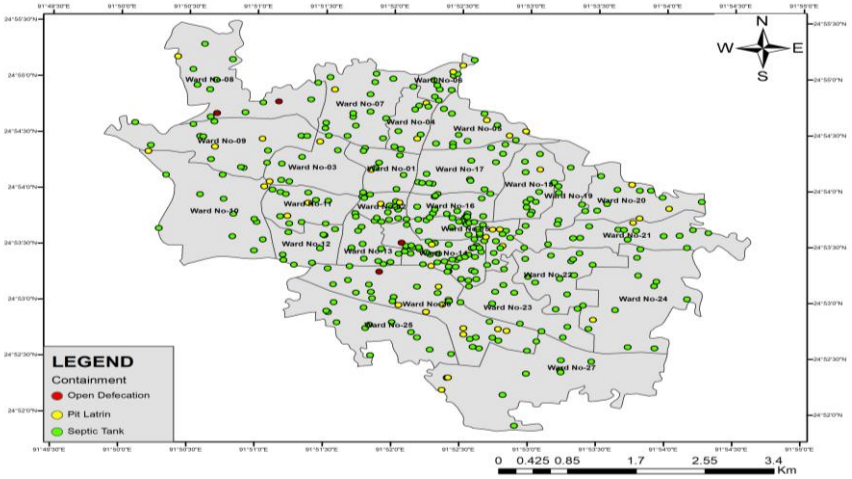

Figure 11: Map showing the containment system in SCC

The septic tank used in Sylhet City Corporation is considered a full-service septic tank with a proper design. Some of them have two or three chambers containing a supernatant outflow system. A septic tank connected to some other outlet is very common in this study area. A septic tank connected to an open drain is mostly found in this area. Septic tanks with no outlet were found at 29%, and septic tanks connected to soak pits were found at 26%. Figure 12 describes the status of septic tank connections in the SCC.

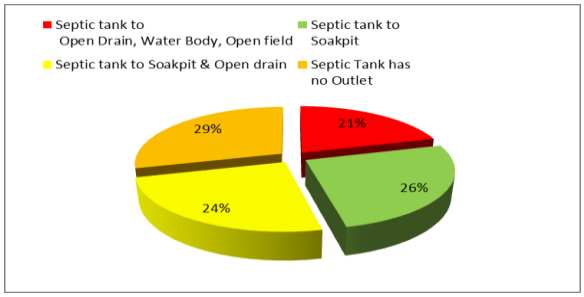

Figure 12: Status of the existing septic tank connecting in SCC.

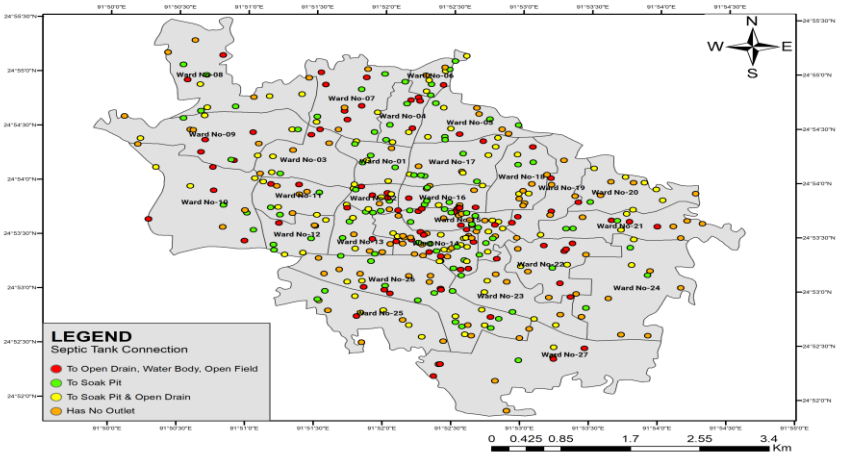

Figure 13: Map showing the connection of septic tank

Though around 91.8% of people use septic tanks in this study area, it is very important to know where the outlet of the septic tank is connected. The sanitation service chain mostly depends on the outlet of the septic tank. Here only one-fourth of the total septic tank connects to the soak pit. There is a

significant risk of groundwater contamination in this area. Otherwise, this is very harmful for the environment. When waste is connected to an open drain or an open water body, it is returned to the environment directly. It is the main obstacle to safely managed sanitation. A septic tank has no outlet, which is good for the environment, but it needs to be empty in a few years.

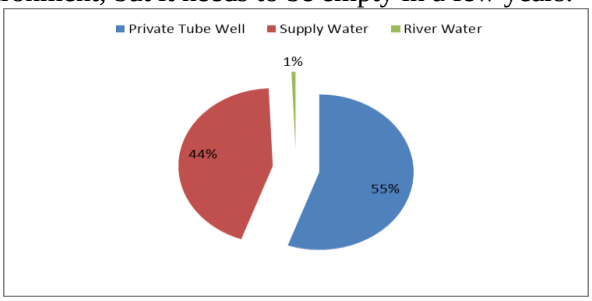

Figure 14: Water Source of SCC

These statistics give insight into the distribution of water sources used by residents in the city, with the majority relying on their private pumps or the central water supply for their water needs, while a small fraction relies on river water, which may have implications for water quality and sanitation55% of the people use their own hand pump or motorized pump for drinking water. 44% of people depend on centrally supplied water for drinking and daily use. 1% of people use river water for their daily needs and drinking purposes. Figure 14 shows the water source percentages for Sylhet City Corporation.

The source of groundwater must be 10 feet away from the source of contamination horizontally and 2 feet away from the source of contamination vertically (Ahmed & Rahman, 2005). In Sylhet City, the horizontal distance from the source of contamination is okay, but the vertical distance is below the minimum distance as the groundwater table is high in this region. As per the KII of city corporation officials, it has been known that the ground water table is 1 foot from the ground surface. So it has a huge chance of contaminating the groundwater in this area.

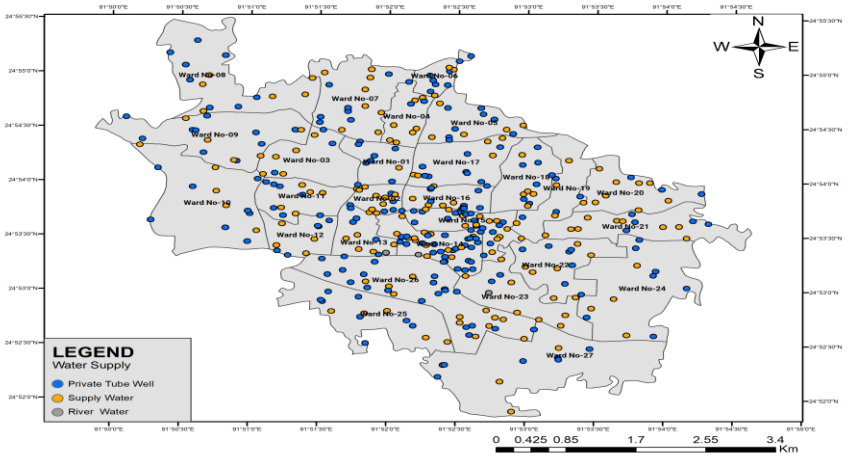

Figure 15: Map Showing Central Water Supply by SCC

3.3.3 Emptying

This study found only one vacuum truck to empty the containment in SCC, which is not working regularly (KII with SCC officials). Besides these, the septic tank or other containment is situated on the back side of the house, where no wide road is available. So the only vacuum truck (5000 liters) is not fully functional for this area. People depend mostly on manual emptying by private sweepers. This study found that, among septic tank users, around 41% have not emptied a septic tank once. Of the rest (59%), about 72% depend on private sweepers to empty the septic tank.

Only one vacuum track is not sufficient for the whole city. As per KII, it takes a long time to schedule this only vacuum truck. Besides this, this large truck is not accessible on narrow roads. Some three-wheeled small vehicles can overcome this problem. The cost of this vacuum truck provided by the

SCC is relatively high. It should be minimum cost or free of charge, so the low-income public should pay attention to the emptying of the septic tank at regular intervals.

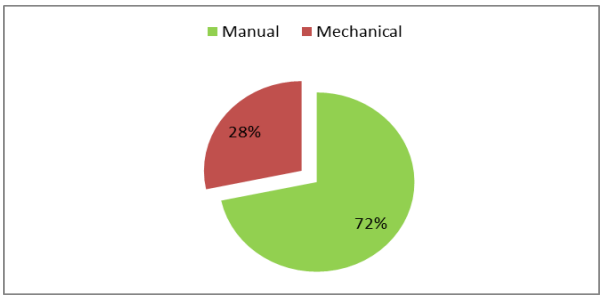

Figure 16: Methods used for emptying the containment in SCC

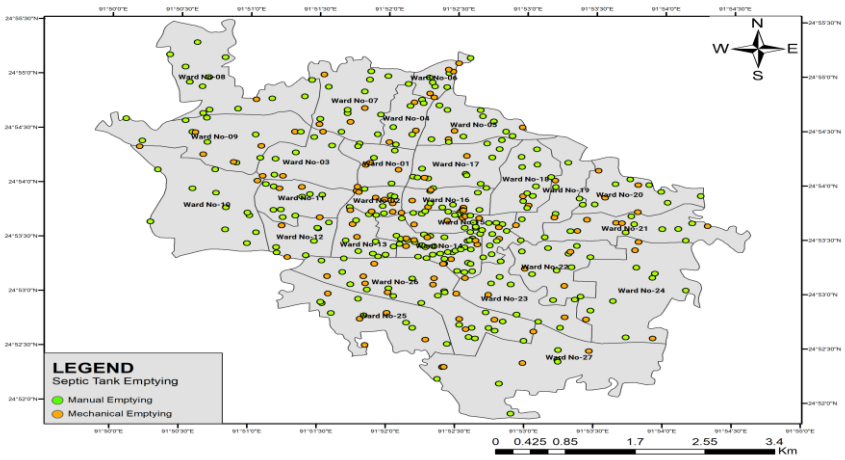

Figure 17: Map showing emptying methods of SCC

3.3.4 Sludge Destination

The cleaners remove the sludge from the latrine pits and septic tanks and dispose of it in various places. 64% of sludge is disposed of in open drains. Around 28% of the sludge is carried to the dumping site and disposed of in a trench. Another 8% of waste is disposed of in an open field or small soil trench. Since there are no treatment facilities in the town, vacuum trucks also discharge contained sludge into a trench situated in “Lalmatia, Sylhet” in SCC.

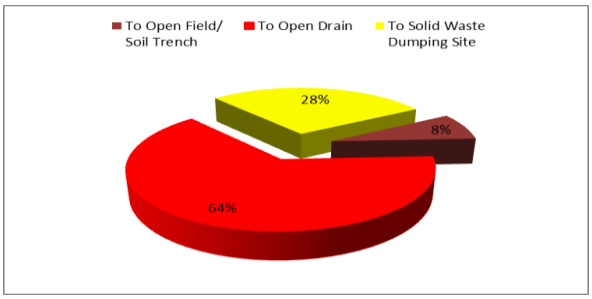

Figure 18: Transport Service Destination in SCC

No special sludge disposal site is present at Sylhet City Corporation. 36% are transported to solid waste dumping sites and through without care, which means all waste returns to the environment. Very little waste is dumped in an open field or on some low land, and sometimes into a small trench, but the trench remains open, ultimately returning waste to the environment. This practice is highly detrimental to the environment and poses risks to human health. Proper fecal sludge treatment facilities and disposal methods are urgently needed to address this pressing environmental and public health concern.

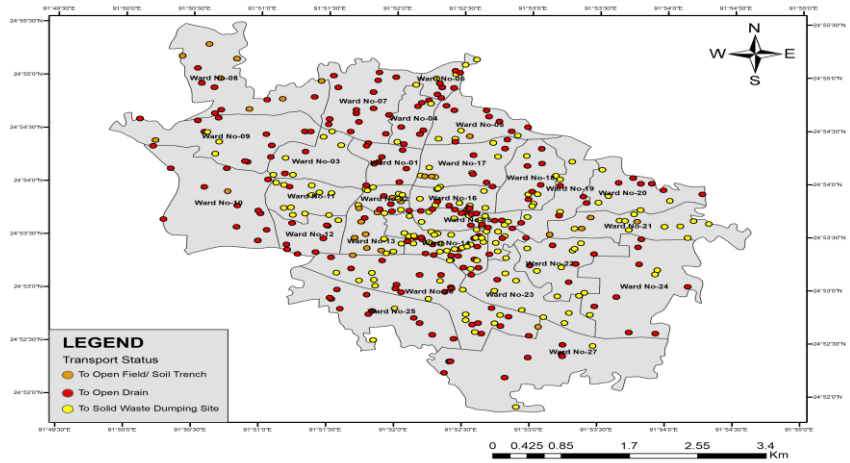

Figure 19: Map Showing the Destination of Conveyed Fecal Sludge in SCC

3.3.5 Treatment

There are no fecal sludge treatment facilities in this city, and as a result, cleaners from the city authority or private sector are dumping the sludge in inappropriate places, posing a serious threat to the environment. Manually emptied fecal sludge is dumped in the surrounding environment, and some sludge is carried to the dumping site and disposed of. As there is no treatment plan, there is no possibility of reusing the waste. All sludge is disposed of at dumping sites without any treatment, which is very harmful for the environment as well as humans.

3.4 Outcome from SFD Graphic

The essential data to trace the fecal waste flow is collected through a questionnaire survey and physical inspection. According to the collected data on the existing condition of the sanitation service chain, shit flow diagrams were developed using an SFD graphic generator. Shit flow diagrams provide valuable information about the whole sanitation service chain.

3.4.1 SFD Graphics

Figure 20 reveals that 9% of those who are sludge-contained in the population as a whole are not emptied. That is, we can say that a total of 9% sanitation service chain is present in the whole city. 14% of the rest are transferred but are not treated. A total of 1% is open defecation.

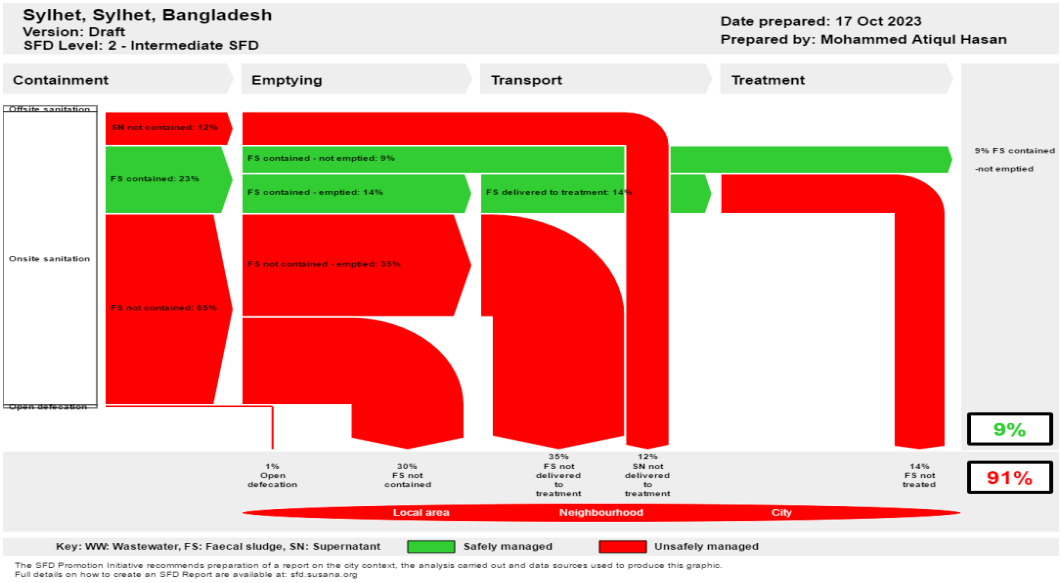

Figure 20: SFD Graphics

The result found from SFD graphics is too alarming for us. SDG 6 is too important for the nations that are committed to achieving economic development, especially developing countries like Bangladesh. SFD reveals the plight of the sanitation condition of Sylhet City Corporation. The authority must take the necessary steps to stop the red color dropdown. Only 14% of waste dropped during the treatment stage. 77% of waste never reaches treatment. Almost two-thirds of the total waste is dropped in the emptying and transport stages. So it is very important to take care of the specific stage where the red color dropdown occurs. Otherwise, SDG 6 will be a dream for us and never come true.

4. CONCLUSIONS

The evaluation of the sanitation situation in the Sylhet City Corporation (SCC) region using GIS and SFD graphics technologies offers important insights on the state of sanitation at the moment and its compatibility with the Sustainable Development Goals (SDGs). Numerous noteworthy conclusions from the study are revealed, with implications for SDG 6 fulfillment, environmental sustainability, and public health. By emphasizing the spatial distribution of pit latrines, septic tanks, and sewer networks, the GIS analysis enables us to pinpoint regions inside the SCC area that lack suitable sanitation infrastructure. In order to improve sanitary facilities, this information assists in identifying regions that require immediate attention and resource allocation.

Based on the SFD graphic depicting the current situation in the study area, it is evident that all components of the sanitation service chain are non-functional. To address this issue, it is crucial to ensure that all components of the sanitation service chain are functioning properly. This can be achieved through the implementation of improvement activities.

To ensure the safe and ecologically friendly handling and disposal of fecal waste, it needs to establish a specialized fecal sludge treatment plant (FSTP). Septic tank to open drain or open field should be banned. Collection track should be increased in number. Tourist should be counted in excreta calculation as Sylhet is a tourist city. It is necessary to promote alternatives to mechanical emptying, such as decentralized sanitation systems or the provision of subsidies to low-income homes.

Residents of the study area show reluctance to provide information concerning sanitation management. The relevant authorities are hesitant to disclose any information that may highlight their shortcomings. In this study, data collected for a single season yields less reliable results than data collected for both the summer and the winter.

SFD might be produce for every ward separately because SFD for every ward shows better result on sanitation condition. Separate SFD graphics may be produced for non-residential institutions. Similar type of study can be conducted for all cities and others areas in Bangladesh.

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