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Assessment of efficacy of drainage system in Rajshahi City Corporation, Bangladesh

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Abstract. A drainage system is one of the essential elements for a sustainable environment system in a locality. In this study, Rajshahi City Corporation (RCC) area is considered for proper investigation of drainage facility. This study aims to concentrate on the present scenario of the drainage system in RCC and the effect of human activity on solid waste management. A field survey was conducted to assess the drainage condition by measuring depth, width, amount of sludge, and wastewater with a measuring rod and scale. Polythene and food waste cover much of the sludge, which is about 80% of the overall waste. Among different categories of drains, the condition of secondary and tertiary drains is worse than primary drains. It was found that various human interventions disrupted the natural flow of drain. At the end of the study, several steps have been recommended to improve the existing condition of the drainage system in RCC.

Keywords: drainage system; environmental impact; human activity; Rajshahi; solid waste management

1. Introduction

Drainage system in a city plays a significant role in keeping the environment safe and living a healthy city life. Any failure of the drainage system is very sensitive as it relates directly to hygiene and public health. Due to inadequate planning, drainage system in a locality does not fulfil its purposes. Unfortunately, drainage planning is the most neglected aspect of urban planning and management activities among developing countries. Drainage engineering is often performed on an ad hoc basis, often overtaking drainage planning (Ashraf and Chowdhury 2009). In Bangladesh, as in most developing countries, solid waste management has so far been neglected and least studied environmental issues (Ahsan *et al*. 2014). Solid waste is disposed of in open dumpsites in many countries without giving it proper importance (Iorhemen *et al*. 2016).

Rajshahi is one of the prominent cities of the northern region of Bangladesh. It is the fourth largest city in Bangladesh, next to Dhaka, Chittagong, and Khulna. Rajshahi is one of the first municipalities in Bangladesh, established in 1876 and declared a city corporation in 1987 (Faridatul and Jahan 2014). It lies between 24°21´-24°25´ N and 88°32´-88°40´ E, with an area of

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96.72 square-km and accommodates about 0.85 million populations (Abdullah Al-Muyeed 2018). The drainage network of this area is connected by sixteen drains such as Chalna, Darush drain, Keshobpur, Srirampur (Boalia), Circuit House, Dargapur, Fudki para, Kumarpara, Kalpona, Kharbona, Kazla, Satbaria, Court, Bolonpur, Pathanpara and Masterpara. Among these, thirteen drains are connected with the BWDB regulators lying on the town protection embankment of BWDB along the bank of River Padma. The rest three are without regulators and north-going drains, discharging into the lowlands/beels on the north-east and northwest corners of the city. However, its drainage system is well recognized, especially in the periphery areas. Most of the areas of this city have no planned network, and most of the households dispose of their wastes haphazardly into the existing drains (Haldar and Chakraborty 2011). The unequal distribution of drainage patterns in this region produces unsafe conditions for the proper flow of solid and liquid waste and causes adverse environmental impacts (Ullah *et al*. 2013).

RCC had a population of 284,056 at the beginning of 1991, and according to 2011 census data, it had a population of 449,757 at that time (Statistics 2011). At present, the total population of RCC is about 0.85 million, with a Population Density of 4,318/Sq-Km (Abdullah Al-Muyeed 2018). With an increase in population, the rate of generation of waste is also increasing day by day. At present, the waste generation rate in this city is 0.3kg/capita/day. Approximately 350 tons of wastes are generated every day, while the amount of waste rises to 400 tons during the summer in RCC. Of collected wastes, only 20 tons are dumped into the dumping ground, and the remaining 140 tons are dumped directly into drains, water bodies, and open spaces. Wastes that remain uncollected are primarily dumped illegally in the streets of the neighbourhood, wastewater drains, ponds, lakes, etc. or managed informally (Matter *et al*. 2013). Dumping solid waste without treatment in open space poses environmental threats and also increases the cost of waste collection and disposal (Shahin *et al*. 2019).

According to the Drainage Master Plan of Rajshahi city, there are three types of drains in the city based on their structure and size. These include primary drain, secondary drain, and tertiary drain. Primary drains are the main drain in an area which have a width larger than 0.9m. Secondary drains are medium-type drains connected to the primary drain, which has a width of 0.6m to 0.9m. Tertiary drains are small and narrow in size, having a width smaller than 0.6m. According to RCC, 65% of tertiary drains, 14% of secondary drains, and 19% of primary drains are in good condition according to their structural condition. The management of the city is currently based on 30 wards with 132.27 km of various categories of drains. The existing drainage system of Rajshahi City was planned to take care of drainage of the core area only when the city was limited between the Railway line and town protection embankment on the River Padma, where the countryside along the embankment is at high levels varying from 16.75 to 18.25m.

Drainage systems involving open concrete drains on roads pose significant problems arising from blockage due to anthropogenic factors and sluggish water flow due to very low invert grade (Owuama *et al*. 2014). An area or drain is sufficiently sloped where the grade is greater than 2%. If the slope of the drain is less than this value and self-cleansing velocity is below 0.75 m/s, siltation and vegetal growth in the drains in conjunction with stagnant water will occur (Ozioma 2012). A longitudinal slope to be used in flat or slightly undulating terrain is between 2% and 5% in the drains. With gradients, less than 2%, silting occurs easily, while with gradients steeper than 5%, the drains will easily erode (Zumrawi 2014). A minimum width equivalent to $1/4^{th}$ of the road width is to be kept as drainage reserve on both sides of the road for providing primary and secondary drains. But whether the road width is 6m or 18m, the drain width mysteriously remains constant to 0.6m to 0.9m (Ashraf and Chowdhury 2009). As a result, flow capacity reduces, and siltation occurs. The use of low-quality construction material such as bricks, concrete, corrugated steel adversely affects the quality of the drain. Failure of built drains like the collapse of bed, sidewalls, and covers caused by improper design and construction settlement or heave may lead to the development of crack and subsequent failures (Zumrawi 2014). Increased urban developments without providing sufficient drainage facilities result in waterlogging. The logged water becomes polluted with solid waste, soil, and contaminants, leading to an unhealthy environment and spreading severe diseases (Zumrawi 2016). In urban areas, one sign of inefficiency of the drainage system is the continuous flooding of streets, sometimes even with low-intensity rainfall (Ochoa-Iturbe 2011). Poor drainage causes early pavement distress, leading to driving problems and structural failures of the road (Zumrawi 2014). Water on the road surface can cause one or more forms of pavement deterioration, such as reduction of subgrade and base or subbase strength, differential swelling in expansive subgrade soils, and stripping in flexible pavements. Rokade *et al*. (2012) found that pavement service life can be increased by 50% if water can be drained without delay. The causes of drainage problems are linked to poor design, construction, and maintenance of drainage structures as well as the negative attitude of residents. Signs of drainage problems requiring attention include puddles on the surface area, slope erosion, clogged drains, pavement edge raveling, preliminary cracking, pavement pumping, and surface settlements (Zumrawi 2016). In poorly drained areas, urban runoff mixes with sewage from overflowing latrines and sewers, causing pollution and a wide range of problems associated with waterborne diseases. Poor drainage of rainwater leads to the creation of breeding sites for disease vectors. Among the diseases associated with the mosquito, dengue is the main, and it spreads by special mosquitos named "Aedes" which breeds in stagnant water. Other social problems related to poor drainage systems are the disruption of traffic movement and interruption in normal life (Alom and Khan 2014). The drainage system can ensure the removal of waste from the city in due time. The habitable condition of a city depends very much on its drainage pattern (Clemett *et al*. 2006).

Specific objectives of this study are:

• To assess the present condition of the drainage network in RCC, analyzing the capability to meet its purposes.

• To determine the effect of human actions on the drainage system.

2. Material and methods

2.1 Data collection

Both primary and secondary data have been used for conducting the study. Primary data were collected from selected sites by performing a reconnaissance survey and field investigation. Primary data includes determination of sludge depth, water depth, freeboard, and also a collection of different drainage failure scenarios. The necessary information and secondary data were collected from Rajshahi City Corporation, ward offices, different project reports, and various online publications like research papers, online journals, etc. Data includes waste generation rate, gradient, number of different types of drain according to their size.

2.2 Field survey

A field survey was performed to investigate the field condition of the drainage system. To find out the composition, solid waste in drainage system was collected from selected drains, and also

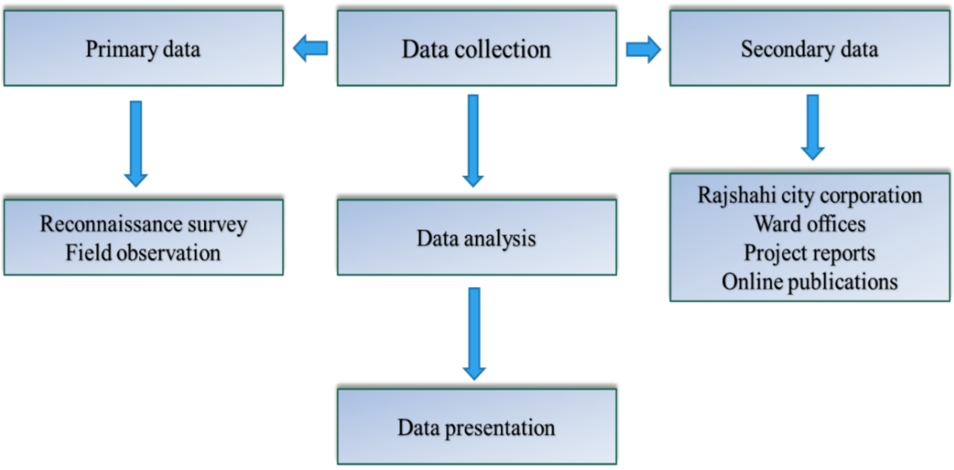

Fig. 1 Flow chart of research methodology

the people were interviewed who are responsible for cleaning operation, processing, and disposal. The waste was manually separated to quantify food waste, polythene, leaves, construction materials, egg skin, bottles, paper, and clothes. During this survey, the freeboard, width, and depth of different types of drain were measured by a scale. Sludge and water depth were measured by penetrating a steel rod of known length. Flow condition was observed for different types of drain, and also possible reasons were investigated behind this situation. Flow velocity was measured with the help of a floating body and stopwatch. The longitudinal slope was determined by taking the depth of the drain at a different distance. Drainage structures were surveyed to identify the drainage problem. In addition, photographs were taken to illustrate the existing condition and related obstacles in the drainage structures. The overall work done to perform this study is described schematically by the flow chart showing in Fig. 1.

3. Results and discussion

3.1 Composition of drainage waste

According to the RCC authority, the waste generation rate in Rajshahi City Corporation is 0.3 kg/capita/day, and 20% of total waste comes into the drain. The main aim of this study is to assess the existing drainage system considering solid waste in drains and evaluating the problems associated with it. In residential areas, the forms of solid waste were found polythene, food waste, leaves, construction materials, egg-skin, bottles, paper, clothing. The composition of the different types of drainage waste in the drain is shown in Fig. 2. A large quantity of polythene/plastic materials was found among the waste materials. There were 30% of polythene, 30% of food waste, 17% of leaves, 7% of construction materials, 5% of egg skin, 6% of bottles, 4% of paper, 3% of clothes. The nature of solid waste is changing over time and development. Of the solid wastes, polythene goods possess a large amount. Approximately 500 billion plastic bags are used worldwide every year that are harmful to a living organism because they are not readily biodegradable (Greener Ideal 2018). These goods are cheaply and easily available in the market

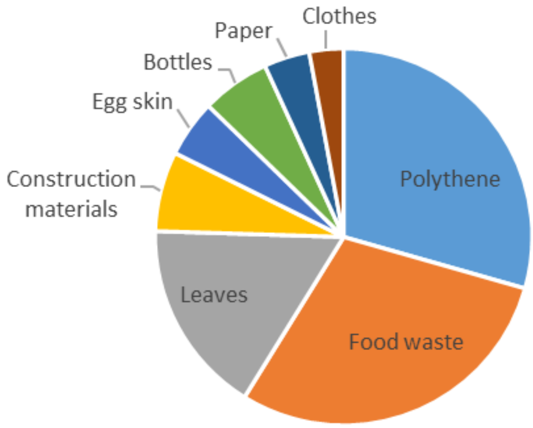

Fig. 2 Composition of drainage waste

and, when exposed to the environment, cause problems to the environment, human health, and drainage system (Tawhid 2004). Plastic bags and other plastic materials accumulate in the drain, hindering the flow of water resulting in clogging and flooding (Earth Science 2019). Though polythene bags were banned by the government of Bangladesh in 2002, these products are continuously being used due to a lack of monitoring. The second most solid waste that adversely affected the drainage system was food waste, including leftovers of vegetables, leaves, egg skin, fruit skin. Dumping food waste causes air pollution linked to respiratory diseases (Somashekar et al. 2013) and emission of greenhouse gas (Chang *et al*. 2014, Islam 2017, Shams *et al*. 2017).

3.2 Flow condition in different types of drain

Sludge is that part of a drainage system that disrupts the natural flow of drainage water. More than 25% sludge was found deposited in 33% of primary drains, 50% of secondary drains, 47% of tertiary drains. An increased amount of sludge in the drains was found due to illegal dumping of domestic waste by dwellers without having the proper knowledge of solid waste management. Deposition of sludge decreases total depth and capacity of drain. It also reduces the slope and, consequently, the flow velocity. For different categories of drain, the percentage of sludge deposition with respect to the total drain depth (including sludge depth, water, and freeboard depth) is shown in Table 1.

With the increase of sludge, the capacity of drain to carry sewage water decreases. Siltation can reduce the hydraulic capacity of drain by 40 to 60 percent (Gupta 2005). According to the RCC authority, a minimum freeboard of 0.10m below ground level is required for ensuring proper drainage flow. It was found that sludge and water took place in most of the part of drainage depth exceeding minimum freeboard. So, the overflow condition was seen in those drains. The Percentage usage of drain by sludge and water with respect to total drain depth are given below in Table 2 for different categories of drain. As secondary and tertiary drains are linked to primary drains, the effectiveness of primary drains depends on other types of drain. Results show that secondary and tertiary drains are subjected to more sludge deposition than primary drains. The depth of sludge and wastewater in these drains was also found higher than primary drains.

Table 1 Sludge deposition with respect to total drain depth in different categories of drain

Sludge deposition (%)	*Primary Drain (%)*	*Secondary Drain (%)*	*Tertiary Drain (%)*
Less than 10%	25	35	19
Between 10 to 25%	42	15	34
More than 25%	33	50	47

Table 2 Depth of sludge and water with respect to total depth in different categories of drain

Sludge & water (%)	*Primary Drain (%)*	*Secondary Drain (%)*	*Tertiary Drain (%)*
Less than 50%	42	41	30
Between 50 to 80%	41	38	28
More than 80%	17	21	42

Table 3 Flowing condition of different categories of drain

Sludge & water (%)	*Primary Drain (%)*	*Secondary Drain (%)*	*Tertiary Drain (%)*
Dry	No dry drain	10	12
Stagnant	`8	25	35
Flowing	92	65	53

The drainage system becomes ineffective if natural flows in drain are interrupted by the accumulation of sludge and water. Drains become dry if they don’t get discharge from the upstream side because of sludge deposition or any obstruction in the flow path. Again, drains become stagnant due to insufficient gradient and low self-cleansing velocity. During the field investigation, the longitudinal slope of drain was found less than 1.5%, and self-cleansing velocity was below 0.5 m/s. As these values are lower than the previously described value, siltation occurs. As a result, water in some of the drains was found stagnant, and some drains were completely dry. No primary drain was found dry, but 10% of secondary drains and 12% of tertiary drains were dry. On the other hand, 8% of the primary drain, 25% of the secondary drain, and 35% of the tertiary drain were stagnant. For different categories of drain, flow conditions are given below in Table 3.

3.3 Survey findings

Fig. 3 indicates a tertiary drain that was totally dry. Among 522 tertiary drains, 12% drain was found dry. Depth of these tertiary drains varies from 0.45m to 0.75m. Of which, 0.15m thick layer of soil with sludge was found at the bottom of drain. During field inspection, sufficient slope was not found to carry the sewage water at the outlet. The longitudinal gradient was less than 0.6%. Besides, sludge accumulation was found higher at the inlet. As a result, the drain didn’t get enough discharge from upstream, making the drain dry. Among 522 tertiary drains, 35% drain was found stagnant with water. During the field investigation, both deposited and suspended solids were found in sewage water, as shown in Fig. 4. More than 25% of sludge was found to be deposited in 47% tertiary drain. Self-cleansing velocity was less than 0.3m/s. Longitudinal slope varied from place to place due to suspended and deposited solids. But the slope was less than 1% in all conditions. As a result, drain became stagnant and flooded with water. When this water overflows the pavement, it deteriorates the road surface making potholes and removing the carpet of the

Fig. 3 Totally dry drain

Fig. 4 Water stagnant drain

bituminous layer of pavement. From field observation, it was found that the road experienced edge damage, raveling, and cracking at different portions of the road. As previously described, stagnant water is a breeding place of other disease vectors like mosquito can transmit diverse infectious pathogens and parasites that cause diseases such as dengue, Zika, Chikungunya, or malaria. So, passers-by who cross the road beside these drains have to suffer the bad smell causing different health issues.

Fig. 5 shows a primary drain of width 1.5m. This drain was seen in a flowing condition. But Constrictions and constructions over the drain were found to interrupt the normal flow of drainage water. People made a temporary platform with different local materials at several locations over the drain to pass the drain to go to their houses. Floating domestic waste was found accumulated around these temporary structures built in the flow path of drains. At these locations, the velocity of water was observed to decrease, and waste accumulated at the bottom resulting in thick sludge deposition. Fig. 6 shows a stagnant water drain over which a shop is constructed. During field inspection, a large amount of sludge was found at the bottom of the shop. Local people confirmed that cleaning work couldn't be performed properly due to these constructions made over the drain. These wastes clog the path of flowing water and create dry drains at the downstream location. Backwater condition was also observed in those drains, which made the entire drainage system ineffective connected to it.

Fig. 5 Obstruction inhibiting the natural flow of drain

Fig. 6 Construction over drain interrupting the cleaning work

Fig. 7 Domestic waste materials thrown near drain

During the field investigation, illegal sludge disposal was found at different locations in the city. Due to ignorance of solid waste management, People in the residential area and also pedestrians throw their waste after their use near the drain, which increases the amount of sludge in the drain when they are swept away and washed by stormwater. A typical scenario can be seen in Fig. 7. Due to the increase in population density, demand for constructing buildings and houses

Fig. 8 Accumulation of construction materials due to improper maintenance

is increasing day by day. But, knowledge of proper maintenance of building materials is necessary. Due to lack of appropriate maintenance, construction materials come into drains and add to the drain's sludge. Fig. 8 shows a drain with a thick slurry of cement, and water covered the maximum depth of drain. This slurry hardened with time after a permanent setting. As a result, the capacity of the drain decreased to carry sewage water.

4. Conclusions

A drainage system is the most important part of a modern urban area. Nowadays, without a good drainage facility, a city cannot be imagined. At present, there are 12 primary drains, 68 secondary drains and 522 tertiary drains existed in Rajshahi City Corporation. Though the number of drains in RCC is sufficient, the condition of the drainage system is not satisfactory. In this paper, the present state of different types of drain in RCC is evaluated by conducting a field survey. Based on the study results, the following conclusions are drawn:

• During the field survey, a variety of solid waste substances were found floating, submerged, and deposited in the drain. Among these wastes, plastic materials and food wastes were found at a high rate.

• To determine sludge deposition, the depth of the sludge and the water were measured using a steel rod and measuring tape in different categories of the drain. The result shows that secondary and tertiary drains have more sludge deposits than primary drains. More than 25% sludge deposition was found in 33% of primary drains, 50% of secondary drains, and 47% of tertiary drains. More than 80% depth of drain used by sludge and water was found in 12% secondary drains, 15% tertiary drains, and 17% primary drains.

• Findings also show that many of the tertiary and secondary drains are either dry or stagnant. 12% of tertiary drains and 10% of secondary drains were found dry, whereas 35% of tertiary drains and 25% of secondary drains were found water stagnant. Primary drains were found in comparatively better condition than secondary and tertiary drains, as the size of primary drains is greater than that of other drains. But, without getting proper discharge from other drains, the effectiveness of primary drains is in question.

• The reason for the increased amount of solid waste in the drain was investigated. It was found that people's ignorance of solid waste management played a key role in creating this unwanted situation. In urban and rural areas, methods of domestic waste disposal are mainly open burning and dumping (Alam and Qiao 2020). Most of the dry and stagnant drains had an insufficient slope, less than 2%, and self-cleansing velocity was below 0.75 m/s. In stagnant drains, sewage water overflowed pavement, causing stripping of bituminous layer, edge damage, cracking. Construction of temporary structures, shops, garages over drains, disposal of solid waste, and dumping of construction materials in drain were found responsible for the increased amount of sludge deposition causing both dry and stagnant drain.

5. Recommendations

Recommendations for alleviating the drainage problem in RCC are as follows:

• Proper drainage cross-section needs to be maintained to provide desired self-cleansing velocity and longitudinal slope. This will reduce the suspended particles to settle and wash load.

• To prevent blockage in the drainage system and to ensure proper flow, drains are to be cleaned regularly at a suitable interval of time.

• Flaws in the existing drainage system should be identified and fixed according to their priority as part of the routine maintenance work.

• City corporation authorities should adopt an annual budget for drainage maintenance work, drainage improvement works, and for establishing necessary drainage networks. They should recruit drainage inspectors to carry out monitoring of drainage maintenance work.

• Any encroachment on the drainage path has to be removed. Shops, garages over the drains are to be evicted.

• Finally, people need to be made aware of proper waste management by making documentaries, posters, short films, advertising.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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