CHARACTERISTICS OF KCC DRAINAGE WATER OF EXISTING OUTLETS OVER MAYUR RIVER AND ITS TREATMENT FOR SAFE DISPOSAL

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ABSTRACT

Water quality focuses on the various aspects of the physico-chemical parameters of raw water which plays the key role in detecting the status of pollution and suitability of a particular water body for various aquatic organisms. Urban residents in Khulna city use Mayur river, which is situated at the back swamp of Rupsha and Bhairab rivers, as a dumping site for discharging waste. The present study was conducted to measure the various water quality parameters of the drainage outlets existing over Mayur river and to develop a simple low-cost treatment unit for safe disposal of the drainage water into the river. To fulfill the purpose of the research, a simple treatment unit consisting of mainly roughing filter and sand filter was developed. The raw and treated water quality parameters were monitored to determine the performance of the proposed unit. From the initial testing of raw water, it can be seen that pH, hardness, chloride, nitrate and sulphate values were within the standard limit. However, the collected samples were heavily polluted by organic matter and microorganisms. The BOD ranges from 124.8 mg/l to 205.8 mg/l and total coliform ranges from 12000 N/100ml to 22600 N/100ml of sample. Color and turbidity values were of high range. For reducing the quality parameters, the simple drainage treatment process were used and the removal efficiency of color, turbidity, total suspended solid, BOD and total coliform were found to be around 91%, 88%, 79%, 91% and 98% respectively.

Keywords: *Drainage water, Mayur river, Low-cost treatment unit*

1. INTRODUCTION

Clean water is essential for all living things. To protect the surface water from pollution the effective treatment and management of wastewater is a must. In many developing countries wastewater is the only source of water for irrigation during drought periods. Besides, wastewater is high in nutrient content and requires less chemical fertilizers for crop cultivation. The characteristics of the wastewater discharges vary from location to location depending upon the population density and industrial sector working in the area, land use pattern, groundwater levels, and degree of separation between storm water and sanitary wastes.

As urban population in developing countries increase and residents seek better living standards, larger amounts of freshwater are diverted to domestic, commercial, and industrial sectors, which generate greater volumes of wastewater (Lazarova and Bahri, 2005; Qadir *et al*., 2007a). Consequently, as UNESCO (2003) reported, over 80% of the wastewater generated in developing countries is discharged untreated into the environment, and approximately 50% of the population depends on polluted water sources for various uses. However, using urban wastewater in agriculture can conserve water, recycle nutrients, ensure reliable water supply to farmers, and prevent pollution of surface water that would otherwise be used for the disposal of wastewater (Van der Hoek *et al*., 2002; Jimenez, 2005). Some studies suggest that at least 3.5 Mha are irrigated globally with untreated, partially treated, diluted or treated wastewater (Jimenez and Asano, 2004; IWMI, 2006). Cultivators in urban and peri-urban areas of nearly all developing countries who are in need of water for irrigation divert this wastewater in a partially treated, diluted or untreated form and use it to grow a range of crops (Ensink *et al*., 2002). Despite farmers good reasoning, this practice can severely harm human health and the environment (Qadir *et al*., 2007b) mainly due to not only the associated pathogens, but also heavy metals and other undesirable constituents depending on the source.

The Economic and Social Commission for Asia and the Pacific (ESCAP, 2000) reported an annual production of 725 Mm^3 of wastewater from the urban areas of Bangladesh. So, it is plausible and convincing that the use of this water for irrigation can be integrated in a holistic approach for the management of water quantity and quality (Mojid *et al*., 2010). In Bangladesh, urban and peri-urban communities in different cities, i.e. Bogra,Chittagong, Comilla, Dhaka, Gazipur, Jamalpur, Khulna, Khustia, Mymensingh, Rajshahi, Pabna, Natore, Sherpur and Sylhet, have already been using wastewater for irrigation (Jayakody *et al*., 2007; Mojid *et al*., 2010). They are using mostly untreated wastewater which may aggravate the negative attributes of wastewater irrigation. However, the productive use of wastewater or wastewater polluted water sources should be ensured in agriculture that will increase food production by more irrigation coverage and improve the livelihood of farmers at urban and peri-urban areas of Bangladesh (Mojid *et al*., 2010). The evaluation of wastewater quality is one of the important primary steps in well-planned utilization of wastewater for use in irrigation.

1.1 Study Area

Khulna, the third largest city in Bangladesh and the second largest in the coastal zone, is located on the banks of the Rupsha and Bhairab Rivers in Khulna District. It is the capital of Khulna Division and a major industrial and commercial center. Geographically, the city along with its surrounding lies between 22˚54'37" to 22˚45'58" N latitudes and 89˚29'22" to 89˚34'52" E longitudes. The whole city area is only about 2.5 meters above the mean sea level. As a deltaic plain the land is flat and poorly drained. The land-use pattern of this coastal city has been substantially influenced by Bhairab-Rupsha River system in the east and by the Khudi Khal-Mayur River system in the west.

According to a land-use survey undertaken for the preparation of Khulna Master Plan (JICA, 2010), about 79% of the city area is classified as "built-up" and the remaining 21% is mostly covered by agricultural land. According to the land use survey undertaken for Khulna's Master plan (Aqua-Sheltech), about 46% of the built-up area is occupied by residential housing. Near about 15% land is under industrial use, small percentage (about 5%) of land is under commercial use. The remaining land use in the built-up area consists of transport infrastructure, official buildings, community and defense, facility parks and water bodies.

1.1.1 Population

Population of the Khulna City Corporation (KCC) area is about 1.7 million and the growth rate is 5% which is mainly due to rural-urban migration. Economic activities in Khulna are mainly centered on its rich natural resources – fisheries and forestry. Around 1.9 % of the population of Bangladesh lives in Khulna, however, it contributes a slightly higher percent in terms of Gross Domestic Product (GDP) (2.5% of national GDP) (ADB, 2009). The service sector dominates the economic activities of the area (54%) following agriculture (26%) and industries (20%). Dwellers of the KCC area, usually, consume water for domestic purpose, commercial and industrial purposes, and public sector.

1.1.2 Waste Generation

Expansion of urban populations and heterogeneous land-use pattern, improved standard of livings, and increased coverage of water supply and sewerage give rise to greater quantities of municipal wastewater (MWW) in Khulna. MWW means domestic wastewater or the mixture of domestic wastewater from commercial establishments and institutions including hospitals with industrial wastewater and storm water run-off, which flow into the sewerage system. It contains a broad spectrum of contaminants resulting from the mixing of wastewaters from aforesaid sources like households, restaurants, educational institutions, offices and hospitals. Due to limited industrial development, domestic effluent and urban run-off now contribute the bulk of wastewater generated in KCC area. Domestic wastewater usually contains grey water (sullage) which is generated from washrooms, laundries, kitchens etc. and can also contain black water, which is generated in toilets.

Assuming a return flow of 80% from total water supply requirement, presently around 140 MLD of wastewater is generated in the city area that would increase to around 201, 262 and 388 MLD in 2020, 2030 and 2050, respectively. More than 80% of the total wastewater flows toward the Khudi Khal-Mayur River system that was once the only irrigation water source for crop production in the western fringe of the city. However, providing safe and sufficient drinking water and proper sewerage system remains as the challenging tasks in the city.

1.1.3 Waste Dumping System

Drainage system in Khulna City is not well-developed. The wastewater effluents, generated in KCC area, flow through the numerous concrete and earthen drains which finally dispose of to the nearby water bodies, i.e. the Mayur River, Rupsha River, etc. There are about 18 big and small canals and drains that drain out the effluents from KCC area to the Mayur River which is located at western fringe of the city. This triggered the reduction in fish population, increased the prevalence of disease, etc. The wastewater is now polluting the river water as the treatment facilities are not yet established in Khulna. As the quality of wastewater is not satisfactory, problems like pollution of surrounding rivers and the streams, deterioration of the environment, and health sanitation have become alarming.

1.1.4 Rainfall and Temperature

The average annual rainfall in Khulna during 2004-2010 was 1924 millimeters (mm), and more than 90% of this occurs between May and October (ADB, 2011). The highest average maximum temperature of 33˚C and above is usually recorded during March and May, and the lowest average minimum temperature of about 15˚C is usually recorded in December and January.

1.2 Uses of Mayur River Water

Mayur river is one of the imperative portion of Khulna city, in which most of the drainage water discharges. A large number of poor farmers residing particularly in western fringe of Khulna city apply untreated wastewater in irrigation crop fields and people living besides the Mayur river use the polluted water. Therefore, this study was carried out to assess the characteristics of this wastewater for use in irrigation and other purposes. This helps in planning effective wastewater management system for the city in Bangladesh.

The peri-urban residents of Khulna use the Mayur river for meeting the agricultural water demand, domestic water demand and water demand for pisciculture, an important livelihood. It also plays an important role in groundwater recharge. However, urban residents use this river as a dumping site for discharging waste waters, domestic sewerage, solid waste dumping and other related uses. A number of hospitals, clinics, and automobile workshops are located within the catchment area of Mayur which also add to the pollutant load of the river. A large slaughter house is located on the banks of the Mayur at Gollamari bus station from where wastewater is directly discharged into the river without any treatment. Thus anthropogenic activities have retarded the natural flow and degraded the water quality of Mayur. The river now completely looks like a wastewater channel at several points (Rayermahal, Gallamari, Shashanghat, etc).

2. METHODOLOGY

The methodologies adopted to satisfy the research are -

- Preliminary field investigation
- Site selection for wastewater collection
- Wastewater quality measurement of the collected sample
- Development of physical model of a low-cost treatment unit
- Find out the quality of treated wastewater
- Conclusion and recommendations

2.1 Preliminary Field Investigation

There are mainly ten outlets from which the wastewater releases into Mayur river. The outlets are shown in Figure 1.

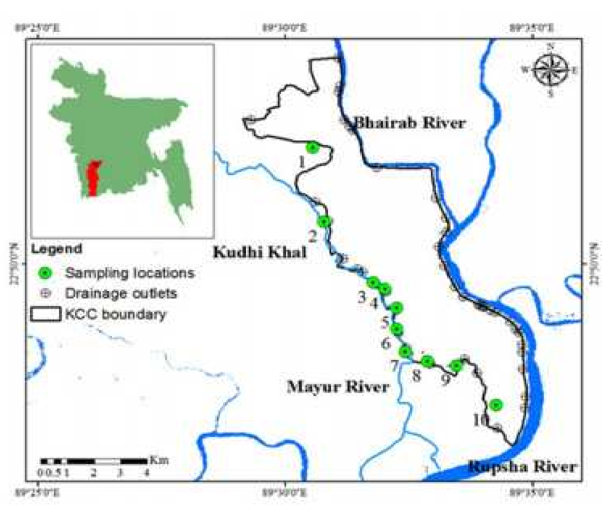

Figure 1: Sampling stations over Mayur River

The name of the outlets are the following:

1. Nirala area
2. Nobinogor khal
3. Taltola khal
4. Bastuhara khal
5. Prantik khal
6. Tamijuddin khal
7. Mandar khal
8. Gollamari khal
9. Sonadanga, Bus terminal
10. Sonadanga, Truck terminal

The existing area around the Mayur river was visited to observe the prevailing situation of Mayur river region and the drainage facilities of Khulna city as a high amount of wastewater of Khulna city discharges by the drainage outlets into Mayur river. By visiting the outlets, it can be stated that the condition of the drain were very poor and miserable. The color of the water was dark greyish and it was full of insects.

2.2 Site Selection and Waste Water Collection

Among the eight outlets four drainage water outlet were selected for the research. They were Nabinogor khal, Tamijuddin khal, Mandar khal and Gollamari north khal.

Fig 2: Condition of some outlets over Mayur river

At first, samples were collected from aforesaid sampling spots during the months of January-May and June-August, 2015. For the initial investigation of the sample water, they were collected in new plastic bottles with hard plastic screw caps. The bottles were properly cleaned before using and washed 2-3 times with the wastewater to be sampled before sampling. Wastewater samples were collected from the midpoint of the trunk drains by dipping each sample bottle approximately 5-10 cm below the water surface, opening the bottle and allowing it to fill in and closing with its cap under water. Wastewater samples were collected, placed in an ice box and transported to the laboratory on the same day.

After testing the initial parameters in the laboratory, a suitable treatment unit was selected and developed for treating the raw wastewater. Samples were collected in big, hard water drums for using the wastewater in the unit.

2.3 Development of Drainage Water Treatment Unit

For the purpose of treatment of drainage water, a simple low cost treatment unit was selected among all the management methods and developed it. The treatment unit consists of three main phases. First one is the sedimentation tank, next one is the roughing filter and at last the sand filter.

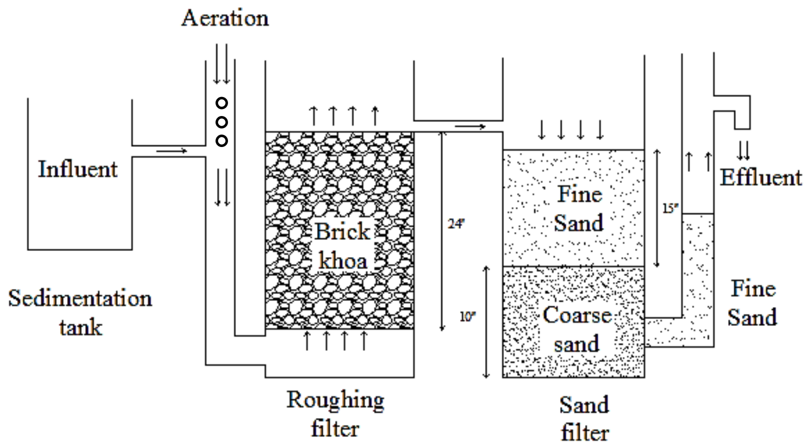

Figure 3: Schematic diagram of developed drainage water treatment unit

A normal tank was used for sedimentation and it was connected with the roughing filter by a hose pipe. The tank can contain about 30 liters of water where the large particles settle down to some extent and the operation becomes easy to handle. From the settling tank, water was conveyed to the roughing filter. The roughing filter was made by using a tank and it was filled with brick khoa of about size 0.75 in. to 1.0 in. The thickness of the roughing filter was about 24 inches.

The sand filter consists of two types of sands: fine sand and coarse sand and the FM value of them are 1.2 and 2.6 respectively. The two types of sand are arranged in three layers. Lower portion and upper portion of the tank is filled with coarse sand and fine sand respectively. The thickness of coarse sand is 10 inches and fine sand is 15 inches. And the pipe connected to the sand filter is also filled with fine sand of 15 inches. The storage tank, roughing filter and sand filter are connected by 1.0 inch diameter pipe. Aeration is provided in the treatment unit by using an air pump.

2.4 Operation and Maintenance

The collected raw water was poured into the sedimentation tank, which was passed through a connecting hose pipe into the roughing filter. Raw water passed through the roughing filter. Up flow water collection system was applied in the roughing filter. The water was aerated for a suitable time before pouring the water into the filter so that oxygen can be mixed with water properly. After that it was again decanted into the sand filter. No power was used for the flow generation. Gravity flow was used in the sand filter. The whole setup is presented in Figure 4.

Figure 4: Several portion of instrumental setup and operation of developed treatment unit

The performance of the developed treatment unit was strictly maintained by avoiding the falling of any type of additional waste. Before using the brick khoa and sand, they were cleaned properly by clear water. The filters need to be observed and maintained regularly because it can be clogged very fast and can hamper the whole system. After a certain time, the used brick khoa and sand must be changed for the continuity of the treatment system.

3. RESULTS AND DISCUSSION

Investigating the initial raw water quality, the contamination rate of the wastewater was studied in the laboratory. The pH, hardness, chloride, nitrate and sulphate values of raw water were within the standard limit. To treat the wastewater having large amount of organic matter and microorganisms, treatment of wastewater was done with the help of simple treatment unit and the tested water quality was observed and discussed by graphical interpretation. The water quality parameters of the raw water and the treated water were tested to study the performance of the treatment unit and to judge the suitability of the treated drainage water for further reuse. Laboratory experiments were carried out using the samples considering the requirements of resources and time related to the research. Physical, chemical and biological water quality parameters were obtained from the laboratory testing which is given below in Table 1.

Table 1: Initial water quality parameters studied for the collected wastewater (January, 2015)

Parameters	Nabinogor khal	Tamijuddin khal	Mandar khal	Gollamari north khal	Standard for water in irrigation
pH	7.43	7.42	7.59	7.40	6-9
Color (Pt.Co.)	123	185	284	325	-
Turbidity (NTU)	118	65.8	76.1	95.1	-
TDS (mg/l)	1310	830	960	1080	2100
TSS (mg/l)	300	100	500	240	100
Hardness as $CaCO_3$ (mg/l)	157.42	78.71	64.82	92.60	200
Chloride content (mg/l)	300	230	240	240	600
BOD(mg/l)	205.2	94.2	205.8	124.8	100
Total coliform (N/100ml)	22000	12000	22600	20000	1000
E. Coli (N/100 ml)	12500	7000	12600	9500	200
Nitrate(mg/l)	0.2	1.6	1.6	2.7	10
Sulphate(mg/l)	0	7	11	5	250

3.1 Preliminary Treatment

3.1.1 Screening

For the removal of large non-biodegradable and floating solids that frequently enters a wastewater works such as paper, plastic, tins, containers and wood, screening of the collected water was done by using fine screening of a size of 10mm.

3.2 Primary Treatment

3.2.1 Sedimentation

After the preliminary treatment, the collected water was reserved into a settling tank overnight so that solids that were heavier than water will accumulate at the bottom of the tank.

3.3 Secondary Treatment

3.3.1 Aeration

Aeration brings water and air in close contact by exposing drops or thin sheets of water to the air or by introducing small bubbles of air (the smaller the bubble, the better) and letting them rise through the water. The scrubbing process caused by the turbulence of aeration physically removes dissolved gases from solution and allows them to escape into the surrounding air. Aeration also helps remove dissolved metals through oxidation, the chemical combination of oxygen from the air with certain undesirable metals in the water. Once oxidized, these chemicals fall out of solution and become particles in the water and can be removed by filtration or flotation and biochemical oxygen demand also reduces.

Sewage discharges cause the water body to suffer from anoxic conditions. In this research, a mechanical device is used to increase the oxygen saturation in water. Microorganisms need both oxygen to live and food to grow. As the microorganisms grow due to increased supply of oxygen, they build up on the media and form micro clogs, which can be removed through the filtration. On the other hand, air is a powerful oxidizer of both iron and hydrogen sulphide. It quickly converts unfilterable ferrous iron to filterable ferric iron, and it reduces hydrogen sulphide to elemental sulphur, which is easily removed by a filter.

3.3.2 Filtration

Rouging filter is used for treatment of raw water as it can be made at a low cost and materials of roughing filter are easily available. This filter is suitable for the removal of color, turbidity, total solids, chloride, BOD, total coliform and E. coli.

Aerated water was passed through an up flow roughing filter, which consists of a number of layers of gravel of different gradation. There is a successful removal of bacterial pathogens by passing the water through the filter. Micro flocs formed due to aeration are clogged by the layers of gravel and removed. It was observed that this model of filter removed 98% of total coliform (TC) and E. Coli. It was also observed that the pH remain same as before filtration.

This model of roughing filter is very useful to remove the color and turbidity, which can be illustrated in Figure 5 & 6. Figure 5 shows that, there is approximately 89 to 93% removal of color, which is aesthetically acceptable.

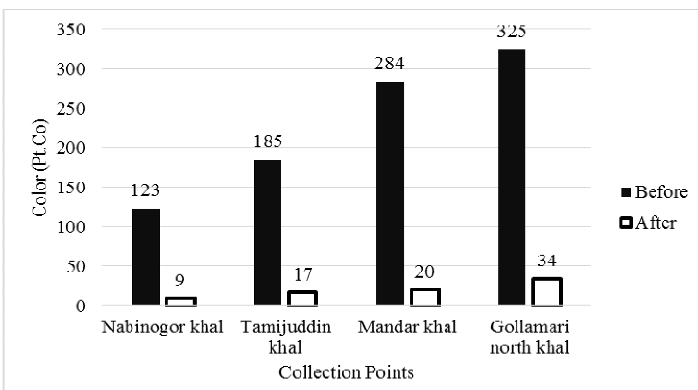

Figure 5: Effect of Treatment Unit on Color

Whereas, it is approximately 85 to 90% removal of turbidity by this filter. The fine particles causing turbidity, stucked and removed by the gravel layers. Particles, which are not removed by course aggregate layers, are removed through the fine aggregate layers. It is a need to periodically renewal of aggregates not to clogs the pore spaces between the aggregate particles.

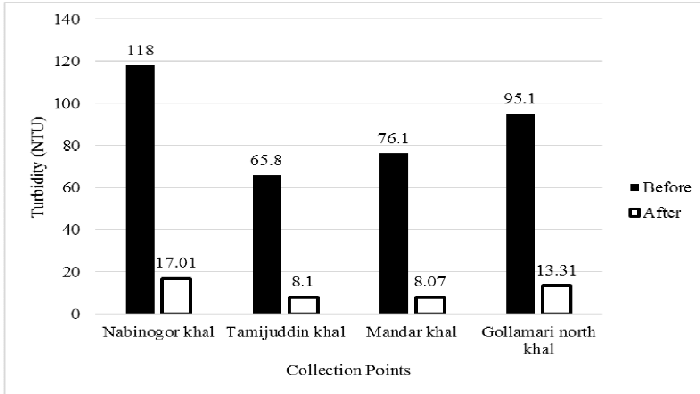

Figure 6: Effect of Treatment Unit on Turbidity

On the other hand, suspended solids are also clogged into the pore spaces between the aggregates. It is seen from the Figure 7 that, there is about 73 to 80% removal of TSS due to filtration.

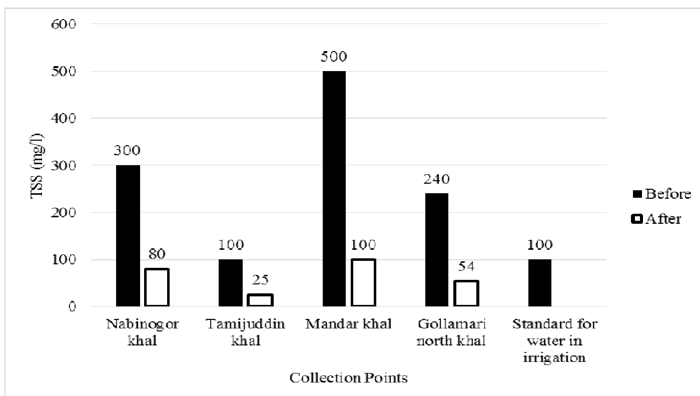

Figure 7: Effect of Treatment Unit on TSS

The estimation of BOD gives an indication of the amount of pollution in a body of water. The high amount of BOD indicates large bacterial and fungal population. Figure 8 shows that among the four outlets, three of them are highly polluted exceeding the limiting value of BOD which is 100 mg/l. After running the sample water through the roughing filter, there is about 90 to 92% removal of BOD.

By reducing the BOD value, it can be said that sample drain water becomes practically safe for disposal in the river and for supplementary uses.

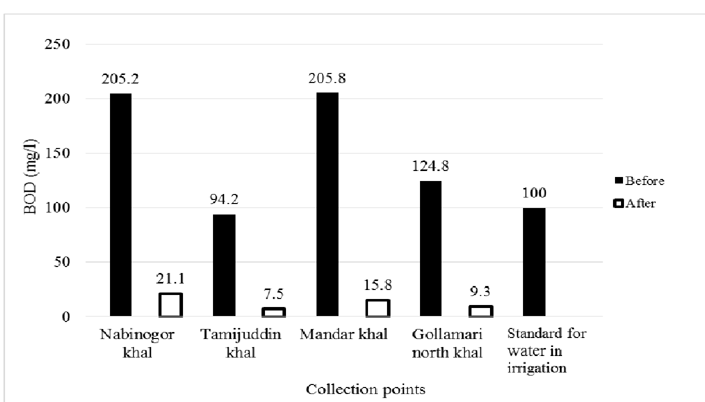

Figure 8: Effect of Treatment Unit on BOD

The TC removal efficiency was 97% to 98%. There are three general actions behind this phenomenon. These are sedimentation and adsorption, microbial action and electrostatic attraction. During the process of filtration, a coating of microorganisms is formed around the sand grains. This is primarily responsible for the removal of organic matters and bacteria present in the raw water. A part of the organic material present in raw water is oxidized for energy requirements and another part is transformed into cell materials for microbial growth. The layer of microbial film around the sand grains is called 'Schmutzdecke', and is very prominent in the top layer of the sand filter.

Electrostatic attraction is most effective between particles having opposite electrical charges. The sand particles having negative surface charges are not likely to attract negatively charged bacteria and colloids during the initial ripening period of the filter. However, with the adsorption positively charged particles and ions, the sand surfaces become over saturated and charged reversal occurs. The overall charge of the filter grain coating becomes positive and negatively charged particles are attached and retained. The filter bed, after the ripening period, will exhibit continuously varying negative and positive charged grain coatings that are able to absorb most impurities present in water. The value from the treated water were in the permissible limit.

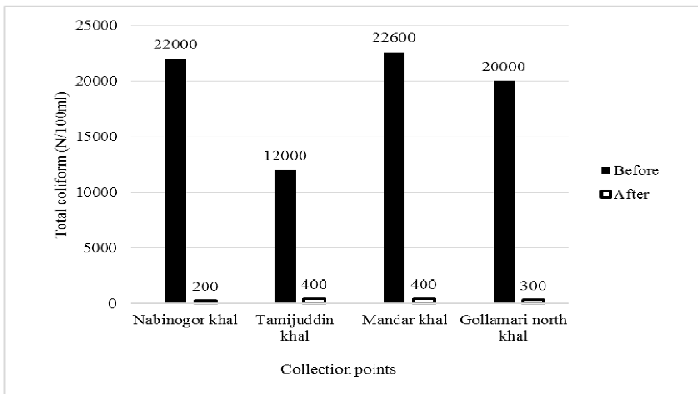

Figure 9: Effect of Treatment Unit on Total coliform

4. CONCLUSIONS

Based on the information of the study the following facts can be concluded:

Physical, chemical and biological water quality parameters of the drainage outlets of wastewater over Mayur river were investigated in the laboratory testing using standard methods. Different characteristics of the drainage water and also the water quality in terms of different parameters were studied. The pH, hardness, chloride, nitrate and sulphate values of raw water were within the standard limit.

Considering the values of different parameters of raw water, a suitable and simple treatment unit consisting of sedimentation tank, roughing filter and sand filter was developed for treating the water. The treated water quality was found to be satisfying the permissible limit.

The microbiological water quality in terms of total coliform (TC) and faecal coliform was improved satisfactorily. They were almost totally removed in the secondary treatment unit including sand filter. BOD_5 value was also reduced to satisfactory level by the filtration.

The quality parameters which exceeded the standard value, most of them were reduced to their permissible limit with the help of the developed unit. . Using the developed treatment unit, the removal efficiency of color, turbidity, total suspended solid, TC and BOD were found to be around 91%, 88%, 79%, 98% and 91%.

Thus, the treated water can be disposed safely into the river and can be used for washing of all kinds and also may be a potential source of laundry use. Based on the above findings, it can be concluded that the recycling and reuse of treated drainage water would have promising application in the household in Khulna city and agricultural uses after simple treatment without any hazard to human health and aquatic environment.

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