DEVELOPMENT OF A PILOT-SCALE TREATMENT PLANT FOR MARKET WASTEWATER

Azrina Karima*[1] and Khondoker Mahbub Hassan[2]

[1] *Post Graduate Student, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: weina07@yahoo.com*

[2] *Professor, Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh, e-mail: khmhassan@yahoo.com*

ABSTRACT

An increasing amount of market wastewater is generated in the major cities of Bangladesh due to the rapid urban development and high population growth posing significant threat to the human health and environment. Market wastewater produced from the commercial areas referring butcher houses, chicken slaughtering and processing, etc. contains body fluid, which is highly contaminant of diseases. For this, effective management of market wastewater is required to reduce the environmental pollution considering all necessary parameters such as public awareness, environmental regulations, treatment methods and safe disposal. The aim of this study is to identify the level of pollution occurring due to the market wastewater in Sonadanga Thana and to develop a pilot-scale treatment plant to treat the market wastewater. This study reveals the degradation of water quality parameters due to direct disposal of market wastewater into watercourses. The Biochemical Oxygen Demand (BOD_5), Iron, Nitrate, Phosphate, Alkalinity, p^H, and Conductivity of the raw water were found to be 62.6 mg/L, 21 mg/L, 24 mg/L, 40 mg/L, 2000 mg/L, 7.50, and 3950 mg/L, respectively. For the treated water in the developed pilot-scale treatment plant using only activated sludge process the same water quality parameters were found to be 17.4 mg/L, 0.8 mg/L, 3.0 mg/L, 2.4 mg/L, 600 mg/L, 7.8, and 3730 mg/L, respectively. Thus, the studied treatment efficiency of the developed treatment unit was found remarkable and hence its implementation in real field at various market places would be a promising option in the context of pollution reduction and environmental sustainability.

Keywords: *Activated sludge process, environmental sustainability, market wastewater, pilot-scale treatment plant*

1. INTRODUCTION

Urbanization is one of the most important demographic trends now and growth is particularly rapid in developing countries. The majority of urban growth is associated with the rapid expansion of smaller urban centres and peri-urban developments, which mostly is unplanned and informal. The developed part of the developing country like Bangladesh is even built in a piecemeal fashion. Rapid industrial development is a crucial part of advancement as improper planning may lead to environmental damage. For high population density and careless construction of commercial areas, Bangladesh is now suffering from various problems. Market wastewater is one of these problems, which mainly is produced from the commercial areas referring butcher houses, chicken slaughtering and processing, etc. (Parkinson, 2003).

Due to huge population, unemployment problem, lack of public awareness and mostly ignorance of the administration of well-planned market places, the wastewater generated from that part is polluting the main watercourses of Bangladesh. In developed countries, the slaughterhouses consist of separate treatment plants but in our country, there are no separate slaughterhouses rather there are some extra spaces for slaughtering animals in the markets. Wastewater produced from those slaughterhouses and processing units combined with wastewater from other units is dumped together in the main watercourses through canals and open channels. This kind of markets wastewater contains highly contaminated body fluid, blood, worms, bacteria and viruses.
Children and others may come into contact with polluted water, especially as they often play in open areas where wastewater and refuses collect. Health risks are increased by the fact that surface water drainage systems are invariably combined with commercial disposal system (Khulna City Corporation, 2000).

The lack of infrastructure and services and effective systems for managing market wastewater has led to widespread pollution of surface water and groundwater and deterioration in environmental health conditions. Hence, market wastewater should be treated prior to disposal with a view to reducing the negative impacts on human health and environment (Wastewater treatment, 2014). The introduction of small-scale treatment plant for the market wastewater could be an admirable solution as the effluent quality will be within the water quality standard that can be discharged back to the environment safely (WHO, 2006). There are numerous processes for the treatment of market wastewater depending on the type and extent of contamination. A physical treatment process followed by chemical and biological purification methods can effectively remove suspended solids along with the organic substances and toxic pathogens from market wastewater.

Khulna city, one of the fast growing commercial cities in Bangladesh with a population of 1.9 million, has been generating enormous amount of market wastewater and thus causing a huge burden for its proper management by the local authorities (Ahsan, Islam & Shams, 2009). In Khulna city, there is no designated disposal site or any treatment facility for the market wastewater and in most cases; it is directly disposed to the nearby water bodies. The Gollamari bazar, Nirala bazar, Boyra bazar, Banaragti bazar and New market are the main markets with a vast area in Sonadanga thana under the Khulan city corporation. Among those, the Gollamari bazar is situated near the river Moyur. The market wastewater produced from the Gollamari bazar is directly disposed to the Moyur river without any treatment, causing serious health hazard and pollution of the river water by aggravating the quality of the river water (Banglapedia, 2014). The aim of this study is to identify the level of pollution by determining the physical, chemical and biological characteristics of market wastewater from Sonadanga area in Khulna city and to develop a pilot-scale treatment plant to treat the market wastewater.

2. METHODOLOGY

For developing a pilot-scale treatment plant and observing its performance, it needs some chronological systematic methods. The steps are gradually drawn here.

2.1 Baseline Survey in Various Markets of Sonadanga Thana in Khulna City Area

Detailed field survey was carried out in various markets of Sonadanga thana as it was identified the most vulnerable location with regards to environmental pollution due to market wastewater in Khulna metropolitan area. The Gollamari bazar, Nirala bazar, Boyra bazar, Banaragti bazar and New market are the main markets in Sonadanga thana. The market wastewater is often disposed directly to the nearby Moyur river and other surrounding water bodies. The Gollamari bazar is just near to Moyur river and huge amount of market wastewater is disposed every day to the river through the canals containing animal body fluid. Figure 1 is showing an illustration of Khulna Metropolitan Area focusing Sonadanga thana which is the study area.

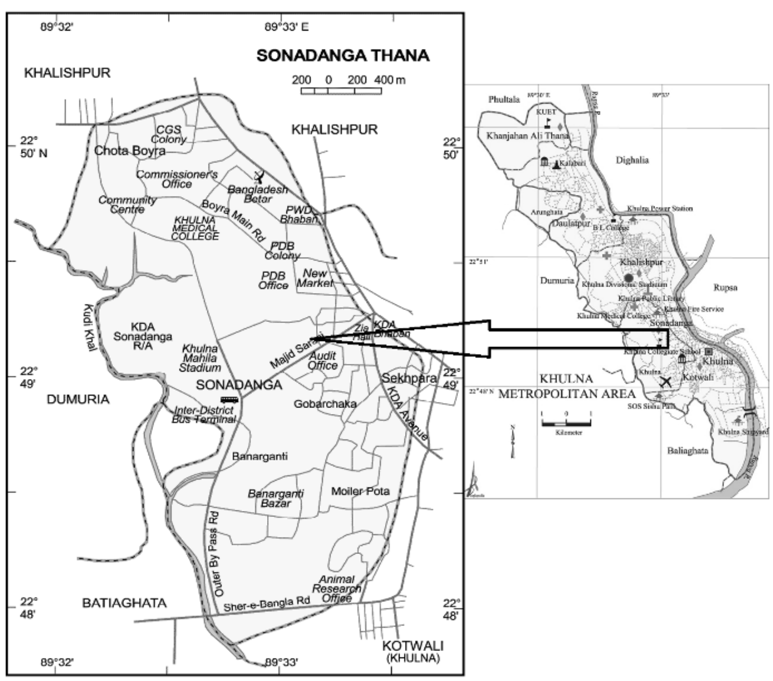

Figure 1: Location of the study area

2.2 Collection and Sampling of Wastewater from Gollamari Bazar

The wastewater generated from Gollamari bazar was collected from the nearby canal just after disposal to forbid any kind of adulteration. The sample was collected from three different places of the market where the wastewater production, concentration and contamination rate was higher. About thirty litres of wastewater was collected manually in a well cleaned and dried jerrycan. This sampling and collection process was done by following the sampling and analysis protocol to ensure wastewater quality control. After collection, the samples were transported carefully to the laboratory for testing different water quality parameters. Within stated time duration the test was done following the protocol of collection and sampling (Shannon, Lee, Trevors and Beaudette, 2007).

2.3 Characterization of Market Wastewater and Development of Pilot-Scale Treatment Plant

When untreated, market wastewater can have serious impacts on the quality of the environment and on the health of people. To check the impacts, the physical, chemical and biological characteristics were determined in the laboratory to identify the extent of pollution. The dominant physical, chemical and biological characteristics of the wastewater to be determined were selected according to the Environmental Conservation Rules (ECR, 1997). In this Rules, standards for effluent discharge are given for inland water bodies. The market wastewater was tested to check those parameters along with some other parameters to distinguish among the standard values and their variation with the obtained values for a clear conception about its safe or unsafe disposal. The test was done with three different samples individually. The first sample was taken from the slaughterhouse. The sample contained mostly animal blood and body fluid, which was directly dumped into open channels after generation. The second sample was taken from the fish market. The sample contained mostly body fluid of fishes but not blood. The fish was kept in that water to make sure of its survival. This water was also directly dumped into open channels after generation. The third sample was taken from the vegetables market but wastewater from fish market combined and flowed together in the open channels of the vegetables market. The sample contained mostly debris of vegetables and body fluid of fish.

After the primary test to measure wastewater quality with three raw samples, depending on the level of pollution, design criteria considering those characteristics were made for the treatment plant. Based on the developed criteria, a pilot-scale wastewater treatment plant was constructed in the laboratory. The activated sludge process mainly was adopted for this treatment method, as this method is comparatively cheap and easy (Davis & Cornwell, 1998). The pilot-scale wastewater treatment plant was made of high quality plastic container and consisted of a primary clarifier, the aeration tank with an aeration pump, the secondary clarifier with a pump for returning sludge and a final chamber for storing treated water (Figure 2, 3). All the containers are of same dimension.

The Influent was passed through the screen to strain off any solid waste into the primary clarifier, which was also worked as a grit chamber. Wastewater was allowed to stay there for few minutes to settle and then transferred to the next compartment, the aeration tank. In aeration tank, the wastewater was aerated for three hours and then sent to the secondary clarifier for biological treatment with a discharge of about 300 cc/min. From the secondary clarifier, a return sludge line was maintained through a pump which returned 4.17 cc/min of sludge to the aerator. A balance was made in the wastewater flow rate between the aerator and secondary clarifier. Another sludge line was also formed in secondary clarifier to deduct fixed amount of wastewater to maintain the activated sludge process properly. After the continuation of all these steps, finally the treated water was collected in a chamber called treated wastewater. In this whole process, the wastewater had a total run time of 101 hours or more than 4 days approximately with a mean cell residence time of 96 hours or 4 days. The following Figures (2, 3) demonstrate the experimental set up for the pilot-scale treatment plant of market wastewater as flow-diagram and photograph, respectively.

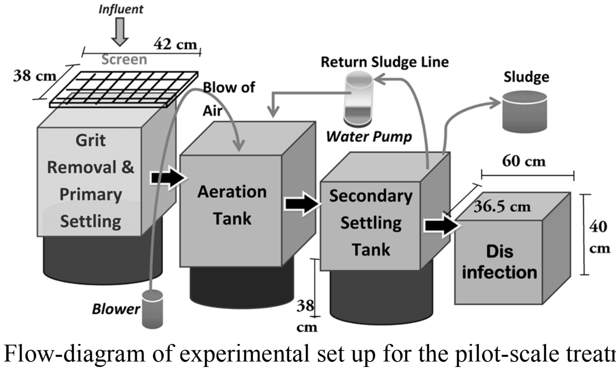

Figure 2: Flow-diagram of experimental set up for the pilot-scale treatment plant

Figure 3: Photograph of experimental set up for the pilot-scale treatment plant

2.4 Performance Study of the Pilot-Scale Treatment Plant

A detailed performance study was carried out for the developed pilot-scale treatment plant. The treatment efficiency in different unit processes was monitored. During the process, some slight difficulties were observed and identified, which required some modifications with the treatment plant. For this, the test needed to be done for several times with a view to achieving a user-friendly as well as environment friendly treatment plant for its long-term sustainability.

3. RESULTS AND DISCUSSION

The results reveal the present condition of the market wastewater and its level of pollution. The results also show the actual dimension of treatment in the pilot-scale treatment plant. The findings from the test of these raw samples are list below in Table 1:

Table 1: Water quality test results of raw market wastewater samples

Water Quality Parameters	Unit	Raw market wastewater			*ECR'97 Standard
		Sample 1 (Gollamari bazar)	Sample 2 (Banaragti bazar)	Sample 3 (Nirala bazar)	
Temperature	^oC	30.9	28.1	27.7	30
p^H	--	8.6	7.9	7.5	6.0- 9.0
Biological Oxygen Demand (BOD_5)	mg/L	619	141	62	40
Chemical Oxygen Demand (COD)	mg/L	9600	8640	4690	-
Total Coliform	N/100 mL	600000	6000	3840	1000
Escherichia Coli (*E. Coli*)	N/100 mL	280000	2000	1800	-
Total Solid	mg/L	5080	3560	3280	-
Total Suspended Solid	mg/L	3300	3040	1840	100
Total Volatile Solid	mg/L	3100	1640	1400	-
Volatile Suspended Solid	mg/L	960	1580	1280	-
Electronic Conductivity	µS/cm	66690	1627	3950	-
Iron (Fe)	mg/L	35	4.5	21	-
Nitrate (NO_3)	mg/L	1020	9	24	250
Phosphate (PO_4)	mg/L	4510	178	40	35
Alkalinity	mg/L	2500	1000	2000	-

*ECR'97: The Environmental Conservation Rules (1997) for Wastewater Disposal into Inland Surface Water Bodies

The results of different raw market wastewater samples are clearly showing that huge amount of polluting agents that are dumped every day in the water bodies without any treatment which is very concerning for the ecology of inland surface water. In the pilot-scale treatment plant these three samples were treated to reduce the level of pollution. After the treatment process, the same water quality parameters were measured again to check the performance of the developed treatment unit. The outcome of this test is listed below in Table 2.

Table 2: Water quality test results of treated market wastewater samples

Water Quality Parameters	**Unit**	**Treated market wastewater**			***ECR'97 Standard**
		Sample 1 (Gollamari bazar)	**Sample 2 (Banaragti bazar)**	**Sample 3 (Nirala bazar)**	
Temperature	^oC	24.7	27.7	28.2	30
p^H	--	8.9	8.3	7.8	6.0- 9.0
Biological Oxygen Demand (BOD_5)	mg/L	124	59	17	40
Chemical Oxygen Demand (COD)	mg/L	6400	5120	3290	-
Total Coliform	N/100 mL	700000	28500	2740	1000
Escherichia Coli (*E. Coli*)	N/100 mL	400000	18900	2570	-
Total Solid	mg/L	4600	1120	3240	-
Total Suspended Solid	mg/L	2800	900	760	100
Total Volatile Solid	mg/L	2600	880	680	-
Volatile Suspended Solid	mg/L	890	780	320	-
Electronic Conductivity	µS/cm	5650	1502	3730	-
Iron (Fe)	mg/L	22	2.7	0.8	-
Nitrate (NO_3)	mg/L	110	6	3	250
Phosphate (PO_4)	mg/L	626	46.8	2.4	35
Alkalinity	mg/L	2450	750	600	-

Results from the three samples before and after treatment are clearly denoting that water quality parameters have been improved significantly. One of the objectives of this study is to remove the harmful contaminants from wastewater before discharging it to nearby watercourses. To check this, the allowed standard value for disposal into inland surface water bodies of these water quality parameters are also listed in Table 1 and Table 2 for easier comparison (ECR, 1997). According to the standard, the temperature should not exceed 30^oC in case of wastewater disposing into the inland water bodies. From Table 1 and Table 2, it was observed that the treated water temperature lie within the standard limitation. The graphical representation of comparative plot of different temperature and p^H between raw and treated market wastewaters are shown below in Figure 4.

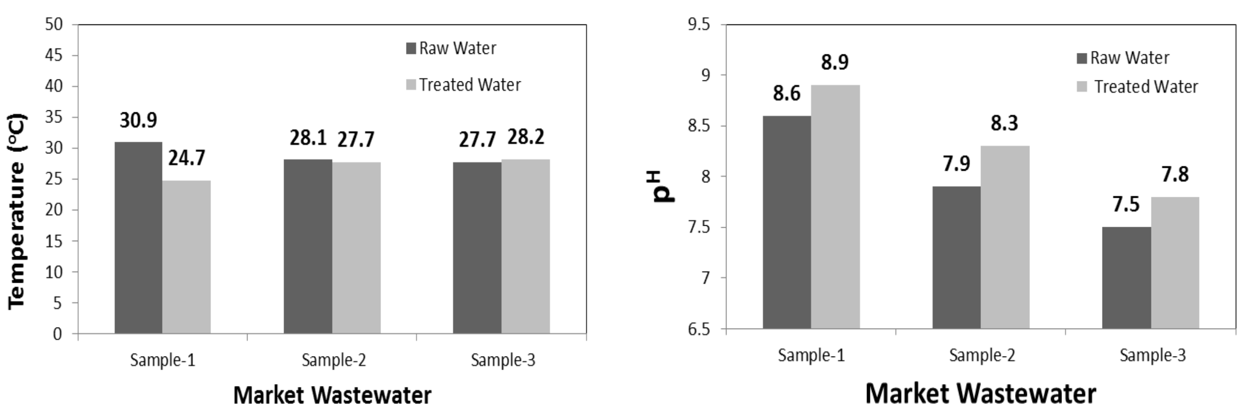

Figure 4: Variation of temperature and p^H in raw and treated market wastewater

The standard value of p^H for perfect ecological balance is within 6.0 to 9.0. In all cases, the value of p^H increases after treatment although the treated value remains within standard limit. The trend of increasing p^H in treated wastewater may be a result of a closed circulation operation with CO_2-freed air which has the potential to increase the p^H of wastewater to high levels (Cohen & Kirchmann, 2004). As there was no extra CO_2 supplied the value of p^H did not increase to that high level. The most important water quality parameter is the value of Biochemical Oxygen Demand (BOD_5) as it is employed to determine the aerobic destructibility of organic substances and it is an aerobic process of decomposition of organic materials, caused by microorganisms (Eriksson, Auffarth, Henze, & Ledin, 2002). From figure 5, it is clear that, after treatment of market wastewater the BOD_5, COD of all the samples has been reduced significantly.

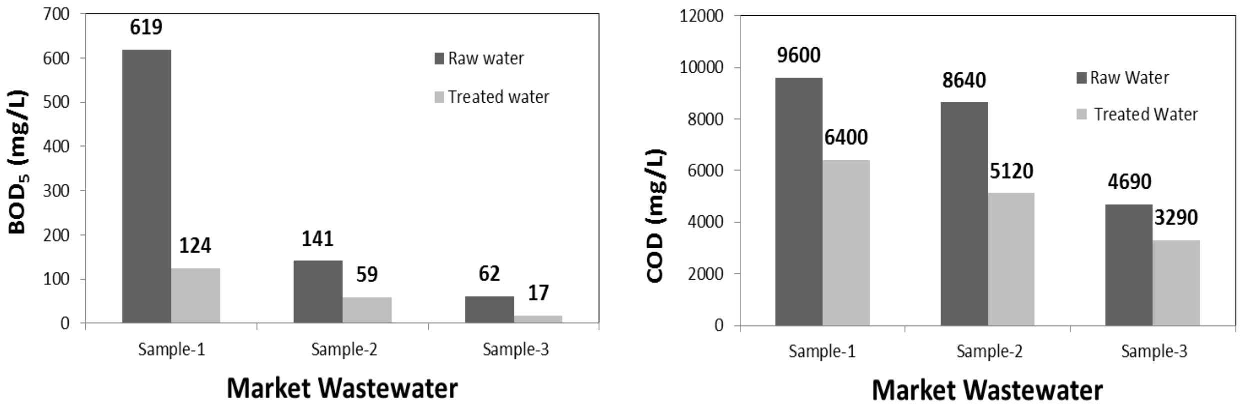

Figure 5: Variation of BOD_5 and COD values in raw and treated market wastewater

The standard value of BOD_5 for disposal to inland water bodies is 40 mg/L. In case of sample 1 and sample 2, the BOD_5 after treatment could not meet the requirement of disposal but in case of sample 3, the treated value of BOD_5 lied within the limit. The BOD removal efficiencies were found to be varied in the range of about 80%, 60% and 70%, respectively for the market wastewater samples 1, 2, 3. The BOD_5 removal efficiency was good but for high level of pollution it could not satisfy the allowable (ECR, 1997). Thus, the wastewater sample 1 with high organic loads might need to adopt some additional treatment for its effective treatment before disposal to inland water bodies. The Value of Chemical Oxygen Demand (COD) shows a positive result after treatment. For all three samples, the COD removal efficiency was found remarkable; however, there is no set standard value for COD in wastewater disposal.

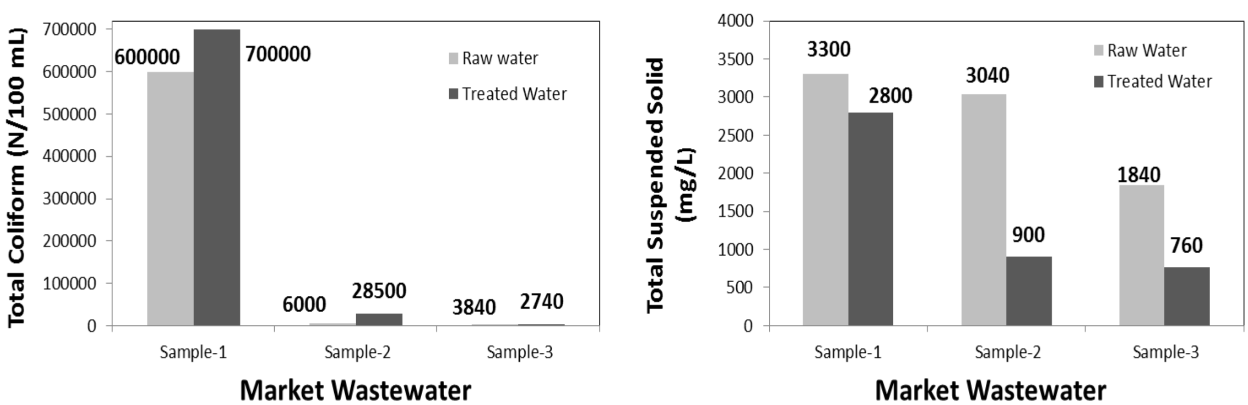

Figure 6: Number of coliform and amount of total suspended solid in raw and treated wastewater

One of the most important factors for wastewater is the number of coliform. After biological treatment using activated sludge process, the bacteriological contamination was not found to be reduced possibly for not using any disinfectant in the experimental procedure (Figure 6). There may be another reason for increament of coliform as the p^H of wastewater increased after treatment. Low p^H usually is used to kill off bacteria in wastewater. Most organic matter and bacteria we are familiar with and contact daily are best suited to a neutral or slightly basic environment. At an acidic p^H the excess hydrogen ions begin to form bonds with and break down the cell, slowing their growth or killing them outright. After a wastewater treatment cycle the p^H must be raised back to neutral (Alwan, 2008). According to Environmental Conservation Rules, 1997, the number of coliform count must be within 1000 per 100 mL of disposing water but none of the sample fulfils the standard. Thus, the treated wastewater must be disinfected before disposal to natural stream. The suspended solids in treated water had been decreased remarkably after treatment in each case. But according to National Standard, the suspended solids should not exceed 100 mg/L (ECR, 1997). These results indicate that additional treatment facility is required to maintain all the effluent water quality parameters within the acceptable limit.

The standard limit for nitrate to dispose in surface water is 250 mg/L (ECR, 1997). The treated water for three samples contains far less nitrate than the standard value (Figure 7). Nevertheless, the standard limiting value for phosphate for safe disposal into inland surface water bodies is 35 mg/L. The treatment of sample 3 is satisfactory in this case but in sample 1 and sample 2 the treated wastewater contains phosphate beyond acceptable limit which cannot be allowed for safe disposal to natural streams. As phosphates increase in open water bodies, the growth of aquatic plants is encouraged and algal blooms can occur. With the increase in algae growth and decomposition, the dissolved oxygen levels will decrease. But as the value of nitrate is far below the standard level, only increased value of phosphate alone cannot be liable for algal bloom. If these two parameters would have gone above standard level, the surface water would suffer algal growth. From this discussion, it is obvious that the developed treatment method alone is not capable to meet the standard requirements for safe disposal of effluents into inland surface water bodies. Thus, a proposal for modification on the developed pilot-scale treatment plant could be a solution of this problem.

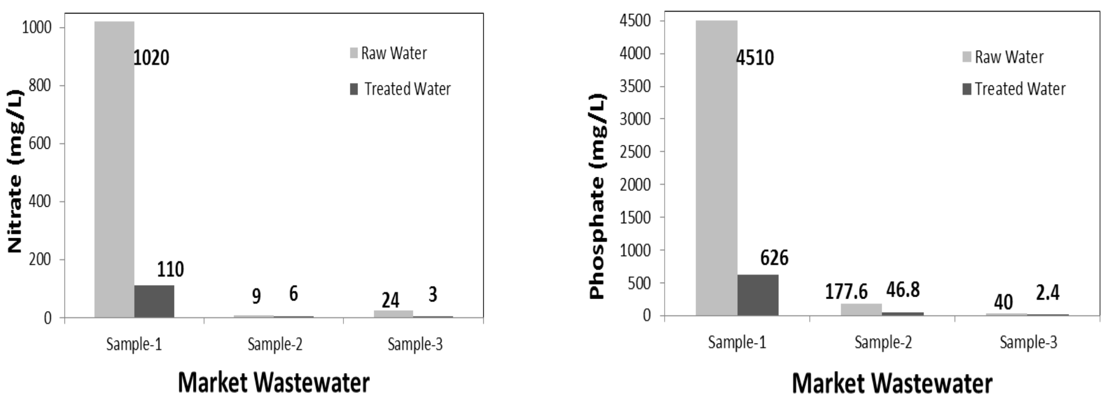

Figure 7: Nitrate content and Phosphate level of raw and treated market wastewater

3.1 Proposal for Modification

To improve the developed pilot-scale treatment plant, an additional biological filtration method can be adopted. Granular duel-media filtration method can be the best suited here as traditionally known worldwide and cheapest method of wastewater treatment (Huisman & Wood, 1974). After treatment with the developed treatment plant, the effluent is needed to pass slowly through the gravel media and sand filter to improve the water quality parameters. The modified pilot-scale treatment plant is drawn in figure 8. Instead of following the traditional down-flow method, the flow path could be up-ward through gravel layer first and then sand bed and finally the supernatant could be disposed off through an outlet arrangement. This approach is recommended for longer duration of filter run with less operation and maintenance requirements.

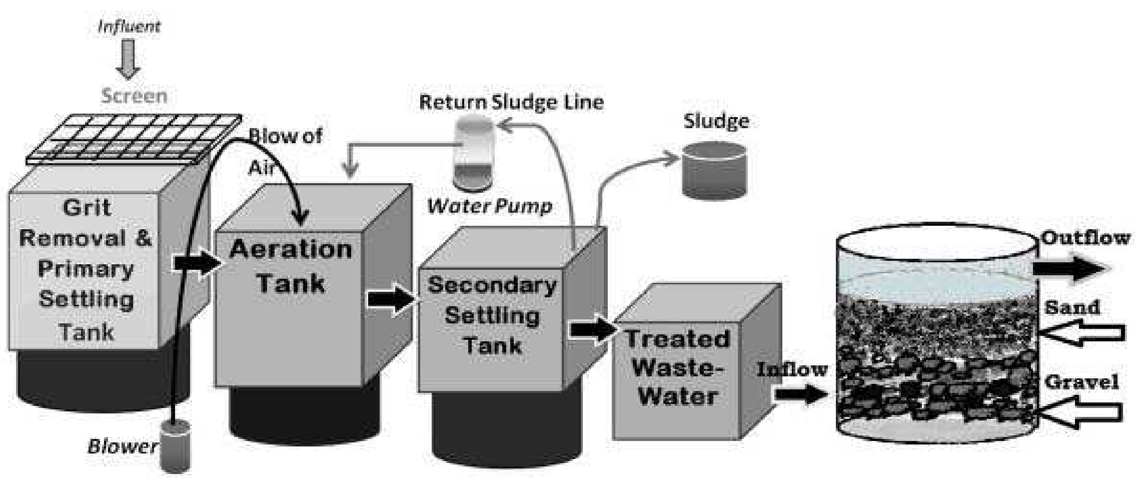

Figure 8: Illustration of Slow sand filter

4. CONCLUSIONS

According to the first objective of this study, the identification of physical, chemical and biological characteristics of market wastewater reveals the actual pollution potentials. The typical concentration of biodegradable organic matters in market wastewater of Sonadanga thana of Khulna City had been found to be 141 mg/L as biochemical oxygen demand (BOD_5) which appears to be highly threatening for the ecology of inland surface water bodies by reducing the dissolved oxygen levels significantly. Along with the BOD_5, the number of coliform, total suspended solid, nitrate and phosphate would also be liable for environmental aggravation. Direct disposal of such market wastewater without any treatment would cause catastrophic circumstances to fisheries as well as living organism in aquatic environment. Considering the second objective, a pilot-scale wastewater treatment plant has been developed and observed carefully to check its performance. The developed treatment plant for the market wastewater certainly served to reduce the level of pollution to some extent but not completely satisfying all the parameters within the standard limit. After treatment, the concentration of BOD_5 had been reduced to 59 mg/L whereas the standard limit was 40 mg/L which deems the necessity for further treatment. Thus, the raw wastewater with high concentrations of organic pollutants needs to run through the system more than once to meet the standards. The increment of mean cell residence time from 98 hours to more may lessen the pollutant level whereas implementation of some disinfectant may help to get rid of the coliforms. In our extended research work, the developed pilot scale treatment plant will be integrated with an up flow granular duel-media filtration arrangement with a view to achieving the effluent water quality within the standard bounds for safe disposal into inland surface water bodies and hence ensuring the environmental sustainability.

ACKNOWLEDGEMENTS

Our sincere gratitude to Khulna University of Engineering & Technology for the financial support of this research work under the CASR recommended funds for M.Sc. Engineering degree.

REFERENCES

Ahsan, R., Islam, A.K.M. K. and Shams, S. (2009). Municipal Waste Management Mechanism for Khulna City: A Practice for Better Environment. In: M. Alamgir, Q.S. Hossain, Q.H. Bari, I.M. rafizul, K.M.M. Hasan, G. Sarkar & M.K. Howlader (Eds.), Proceedings of the International Conference on Solid Waste Management, 1, (pp. 101-108). Khulna: WasteSafe.

Alwan, G.M. (2008). pH Control Problems of Wastewater Treatment Plant. Al-Kwarizmi Engineering Journal, 4(2), 37-45.

Cohen, Y., & Kirchmann, H. (2004). Increasing the pH of Wastewater to High Levels with Different Gases-CO2Stripping. Springer, 159 (1), 265-275.

Davis, M.L., & Cornwell, D.A. (1998). Introduction to Environmental Engineering (3rd ed.) McGraw-Hill International Editions, Chemical Engineering Series.

Eriksson, E., Auffarth, K., Henze, M., & Ledin, A. (2002). Characteristics of grey wastewater. Urban Water, 4, 85–104.

Huisman, L., & Wood, W. E. (1974). Slow Sand Filtration. World Health Organization, Geneva, Switzerland.

KCC (2000). Water and Sanitation Program-South Asia, Community Based Pilot Project on Solid Waste Management in Khulna City: General Project Description, Khulna City Corporation.

Municipal/Industrial Strategy for Abatement (1999). Protocol for the sampling and analysis of industrial/municipal wastewater. Retrieved from https://dr6j45jk9xcmk.cloudfront.net/documents/959/5-7-1-protocol-for-the-sampling-and-analysis-en.pdf

Parkinson, J., & Tayler, K. (2003). Decentralized wastewater management in peri-urban areas in low-income countries. Environment & Urbanization, 15(1), 75-90.

Shannon, K. E., Lee, D.Y., Trevors, J.T. & Beaudette, L. A. (2007). Application of real-time quantitative PCR for the detection of selected bacterial pathogens during municipal wastewater treatment. Science of the Total Environment, 382(1), 121-129.

The Environment Conservation Rules (1997). Government of the People's Republic of Bangladesh. Ministry of Environment and Forest.

Wastewater use in agriculture (2006), WHO guidelines for the safe use of wastewater excreta and greywater.