Scientific Research Publishing

Journal of Water Resource and Protection, 2018, 10, 979-993
http://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

Characterization and Laboratory-Scale Treatment of Municipal Drainage Wastewater of Khulna, Bangladesh

Md Rasel Sheikh[1], Md Saiful Islam[2]

[1]Department of Disaster Resilience and Engineering, Patuakhali Science and Technology University, Patuakhali, Bangladesh
[2]Department of Civil Engineering, Khulna University of Engineering and Technology, Khulna, Bangladesh
Email: raselsheikh55@gmail.com, saifulkuet92@gmail.com

How to cite this paper: Sheikh, M.R. and Islam, M.S. (2018) Characterization and Laboratory-Scale Treatment of Municipal Drainage Wastewater of Khulna, Bangladesh. *Journal of Water Resource and Protection*, **10**, 979-993.
https://doi.org/10.4236/jwarp.2018.1010057

Received: August 14, 2018
Accepted: October 26, 2018
Published: October 29, 2018

Abstract

The study was conducted to characterize and perform laboratory-scale treatment of municipal drainage wastewater of Khulna, Bangladesh. Wastewater samples were collected from three different points of existing urban drain outlets into the Mayur River around Khulna. Laboratory testing shows the BOD_5 and COD concentration of wastewater samples varied from 57 - 226 mg/l and 320 - 435 mg/l, respectively, and the total dissolved solids ranged from 1800 - 2525 mg/l. Therefore, a laboratory-scale treatment technology was developed to treat this wastewater. Treatment technologies adopted were primary sedimentation, followed by aeration, chemical precipitation and filtration. In treated wastewater, BOD_5, COD and TDS were found to be in the range of 40 - 115 mg/l, 160 - 256 mg/l and 1356 - 1500 mg/l, respectively. These test results suggest that the performance of laboratory-scale treatment plant was not adequate to fulfil the acceptable limit (ECR'97) for safe disposal into surface water bodies. Due to poor quality of effluents, modification of laboratory-scale treatment plant was made by an activated sludge process followed by granular media filtration. The final BOD_5, COD TDS and TSS concentration of effluents was found to be 1.38 - 9.8 mg/l, 32 - 192 mg/l, 590 - 1667 mg/l, and 35 - 95 mg/l respectively, which satisfy ECR'97 standard limits for safe disposal into inland water bodies.

Keywords

Drainage Wastewater, Laboratory-Scale Treatment, Activated Sludge Process, Granular Filter Media, Effluents

1. Introduction

As city populations are growing in many developing countries and inhabitants look for better living standards, huge amounts of freshwater are converted to domestic, commercial, and industrial sectors, which creates larger volumes of wastewater [1] [2]. Consequently, as UNESCO reported in 2003, more than 80% of the wastewater generated in developing countries like Bangladesh is disposed untreated into the surface water bodies nearby, and around 50% of the population have no way to access fresh water other than polluted water sources [3]. 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 [4]. The use of wastewater for irrigation has now become a reality rather than a matter of choice. As Huibers and Van Lier reported [5], such a reality exists not only in arid and semi-arid regions, but also in humid areas where seasonal water storage occurs. Some researchers predicted that at least 3.5 Mega-hectors are irrigated globally without treatment, partly treated, diluted or treated wastewater [6]. For different crop production, farmers in Khulna area, are using this wastewater as their available water source, which diverts this wastewater in a partially treated, diluted or untreated form. This exercise can severely damage human health and the environment, not only with related pathogens, but also heavy metals and other unwanted wastewater components [7].

Khulna is the third largest city of Bangladesh and the city has population of around 663,342 in 2011 and total area is about 59.57 square kilometers [8]. According to a land use survey undertaken for the preparation of the Khulna Master Plan, about 79% of the city area is classified as "built-up" and the remaining 21% is mostly covered by agricultural land [9]. Due to the regular activity of city dwellers and rapid urbanization, a huge amount of grey water is being produced. It has been noticed that the drainage wastewater is mostly generated from the water used in households, restaurants, educational institutes, offices, hospitals and industries in the city. Moreover, the average annual rainfall of Khulna is 1800 millimeters (mm) and approximately 87% of the annual average rainfall occurs between May and October [10]. This water flows through numerous concrete and earthen open drains and finally drains to the peripheral rivers and canals without treatment. The drains are also somewhere directly connected with the septic tank system, which has severe negative impact on environment especially on surface water bodies. Because of broken and uncovered drains, sometimes different solid wastes such as food wastes, garden wastes, are disposed into the drain, which causes blockage of drains and increases mosquito breeding. Mayur River is one of the most important parts of Khulna where large amounts of drainage water are released. Many poor farmers living in the western peripheral of Khulna put polluted wastewater in their agricultural fields. However, the use of this unconventional water for irrigation by poor farmers and local people is not yet documented. Birks and Hills (2007) [11] reported that, microbiological characteristics of municipal drainage wastewater have received much attention in recent research. Khulna City Corporation (KCC) has its own drainage network system, which is not well-developed. Wastewater produced in the KCC area flows through numerous concrete and earthen drains, which finally lead to the nearby water bodies, *i.e.* the Mayur and Rupsha rivers. About 18 big and small canals and drains carry effluents from the KCC area to the Mayur River, which is placed at the western part of the city. This drainage wastewater is now polluting the river water, because treatment facilities are not yet established in KCC.

A study on wastewater treatment technologies is a very important aspect of water pollution studies. Although, many research works have been carried out on water pollution, but a few number of research can be found on development of wastewater treatment technology particularly for Khulna municipal drainage wastewater. Therefore, this study attempts to characterize and develop a laboratory-scale drainage wastewater treatment plant to understand issues of large-scale implementation to protect surface water bodies around Khulna municipal area.

2. Materials and Methods

2.1. Research Design

This study was based on a laboratory research design, because the study focused on investigating the drainage wastewater quality analysis and its treatment. At first, a field visit was carried out in various drainage outlets of KCC, mainly the Daulatpur to Gollamari bazar areas. Then the methods outlined in the Standard Methods for the Examination of water and wastewater [12] were followed for the analyses of collected wastewater samples for all the physical and chemical parameters. TDS and TSS were determined by using filter paper and oven. After filtering the sample by the filter paper, it was placed into oven at 105˚C for 24 hours. Conductivity meter was used for the determination of electrical conductivity and pH meter (HACH, sension 2) was used for determination of pH. Turbidity and color were measured with a Partech DRT 100B Turbidity meter and a color comparator respectively. For the determination of sulphate (SO_4) and Nitrate (NO_3), Sulfa-Ver 4 reagent and Nitra-Ver 5 reagent were used. EDTA was used in burette for titration in hardness test and Eri-chrom black T (EDT) was used as the reagent and titrated until the blue colour formed. DO bottle and DO meter (HACH, HQ 40d) were required for laboratory analysis of BOD_5 and 5 days were needed for the test. For determination of COD, $K_2Cr_2O_7$ was taken in the pipette and ferrion indicator was used as reagent and titrated until the radish color formed. Total coliform and faecal coliform were measured by the membrane filtration technique by using XMG Agar reagent into a petri-dish. Therefore, a laboratory-scale wastewater treatment plant was developed and treatment efficiency of the plant was monitored. Finally, paying attention to effluent quality of laboratory-scale treatment plant, modification has been made for better performance.

2.2. Sources of Drainage Wastewater Sample Collection

There are mainly ten outlets from which the wastewater releases into the Mayur River. The information regarding the drain outlets into the Mayur River and sampling locations are shown in Figure 1. Among 10 drain outlets, wastewater samples were collected from drain outlet 2 (Goalkhali, Bastuhara colony), 3 (Boyra Shahanghat bridge) and 7 (Gallamari, Gallamari bridge) for raw wastewater quality testing during December, January and April respectively. In addition, around Khulna city, during December to May farmers are facing freshwater scarcity for irrigation purpose [13]. However, the wastewater samples were collected from 50 to 100 feet ahead of drain outfall. The collected wastewater samples were analyzed individually. Drain outlet-2 and outlet-3 get water from almost domestic wastewater because this outlet passes through residential area including huge slaughter houses and there was no industrial and activity around outlet-2 and outlet-3. Moreover, this area has some clinics and hospitals and plastic recycling factories. Drain outlet-7 carries wastewater from residential areas, some factories and markets as well. This wastewater is also dumped directly into open channels after generation. Because of these highly contaminated domestic wastewaters, market wastewater and factory related wastewater of these three-drain outlets were considered as sampling points for this study. Table 1 illustrates details about sampling station including drain outlets, sample ID and location.

Table 1. Details of sampling station.

Sample ID	Drain outlet	Area, location	Latitude	Longitude	Elevation (m)
Sample I	2	Goalkhali, Bastuhara colony	22˚50'54.96"N	89˚30'47.37"E	3.0
Sample II	3	Boyra Shahanghat bridge	22˚49'35.48"N	89˚31'46.76"E	4.6
Sample III	7	Gallamari, Gallamari bridge	22˚48'3.75"N	89˚32'25.62"E	4.0

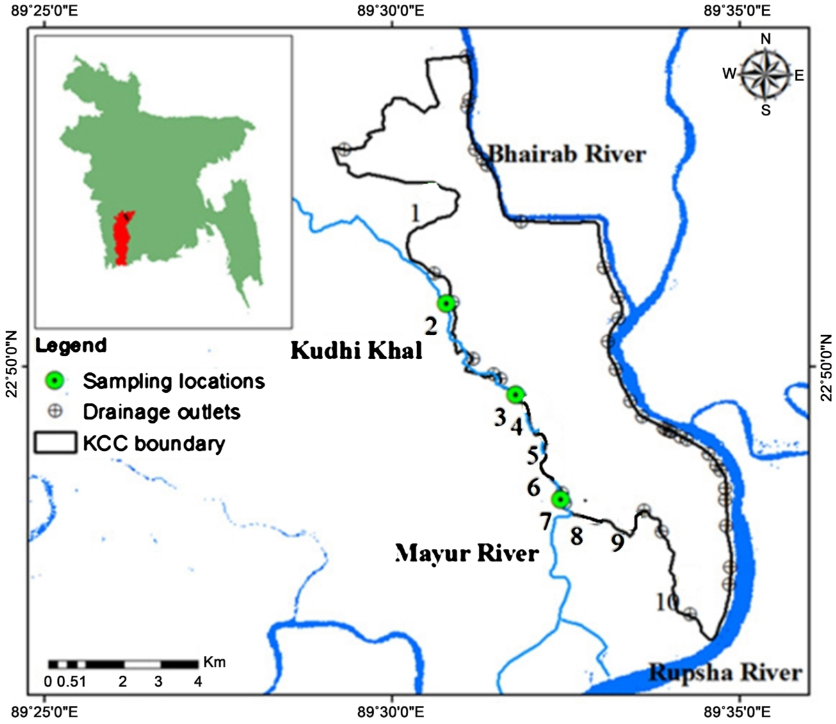

Figure 1. Sampling stations over Mayur River [13].

2.3. Sampling Size and Sampling Procedure

The KCC drain outlets were the potential sources of drainage wastewater sample collection of the study. Three drain outlets (No. 2, 3 and 7) were taken with random sampling from total ten drain outlets, mentioned in Table 1 and Figure 1, as raw wastewater sampling stations. From every sampling station, total three samples were collected with special care. In December 2015, one wastewater sample from each sampling station was collected for laboratory testing and same procedures were followed for month of January and April 2016. New plastic "Jerry Can" of 20 litter capacity with hard plastic screw cap was used for wastewater sample collection. The can was properly cleaned before using and washed 2 - 3 times before sampling. Wastewater samples were collected from the midpoint of the trunk drains by dipping each sample Jerry Can approximately 15 - 20 cm below the water surface, opening the Jerry Can, allowing it to fill in, then closing each Jerry Can with its cap under water. Wastewater samples were collected and transported to the laboratory on the same day. The samples were then preserved in a refrigerator at about 4˚C until analysis. In all analyses samples were measured at dry weather conditions.

2.4. Drainage Wastewater Treatment Techniques and Tools

Wastewater treatment consists of applying known technology to improve or upgrade the quality of wastewater. This study follows collecting the wastewater samples and subjecting the wastewater to various treatment processes, as discussed below:

1) To identify the treatment units needed for the development of laboratory-scale treatment plant, the physical, chemical and biological characteristics of wastewater were investigated in the laboratory. After the laboratory tests of DO, BOD_5, COD, TSS, TDS, NO_3, SO_4, pH, Conductivity, Color, Turbidity, and Coliforms of raw wastewater samples (three samples from each sites) and analyze secondary data, the design criteria were set for the treatment units. Based on the developed criteria, a laboratory-scale drainage wastewater treatment plant was constructed in the laboratory (Figure 2).

2) In this research work, a bar screen was used which consists of 5 mm × 5 mm steel wire mess to cover up the rectangular primary sedimentation tank. The incoming wastewater passed through the bars or screens and the accumulated material was removed manually before colloguing the screen.

3) For laboratory-scale study, a 45-litter capacity plastic rectangular container was used as primary clarifier. The size of the container was 20 inches in length, 15 inches in wide and 10 inches in height with 2-inch free board (Figure 2(a)). The detention time was fixed to 2 hours for the sedimentation of settle able materials. In every batch of treatment, 40 liters of wastewater sample entered the chamber for 2 hours, and a path was made from the bottom of the rectangular tank to remove sludge that accumulated in this stage of treatment.

4) A 20" × 15" × 10" size plastic tank (Figure 2(b)) was used as an aeration

chamber and a mechanical device (Air blower: SP-780 model Super Pump) was used to support a continuous source of oxygen. The chamber also made with a 2-inch freeboard for preventing overflow. Aeration to activate microorganism, was done for 24 hours with 2 hours detention time. After the completion of aeration, an optimum alum dose of 70 mg/L was added for chemical precipitation after being determined in the laboratory. Manual steering was done for complete mixing with 30 minutes intervals for 2 hours, and then sample was kept at rest for another 2 hours for settling down of sludge. Sludge was collected from the bottom of the chamber through gate valve that was incorporated for regulation of flow.

5) Chemical precipitation and granular filtration incorporated for phosphorous and nutrient removal purpose. Up-flow roughing filter retains the floc generated from chemical precipitation. After roughing filtration, the effluents passed through sand filter for nitrogen and pathogenic bacteria removal. Roughing filter and sand filter were made with a 10” × 15” × 10” sized (Figure 2(c) and Figure 2(d)) chamber full of brick khoa (crushed brick) and Sylhet sand. The brick khoa used for roughing filtration was 2 mm to 40 mm in size. Similarly, the effective size of sand for sand filtration was 0.45 mm to 1.5 mm. The chambers also consisted with a 2-inch freeboard for preventing overflow.

6) The collected raw wastewater sent into the sedimentation tank, which passed through a connecting hose pipe into the aeration tank. The wastewater

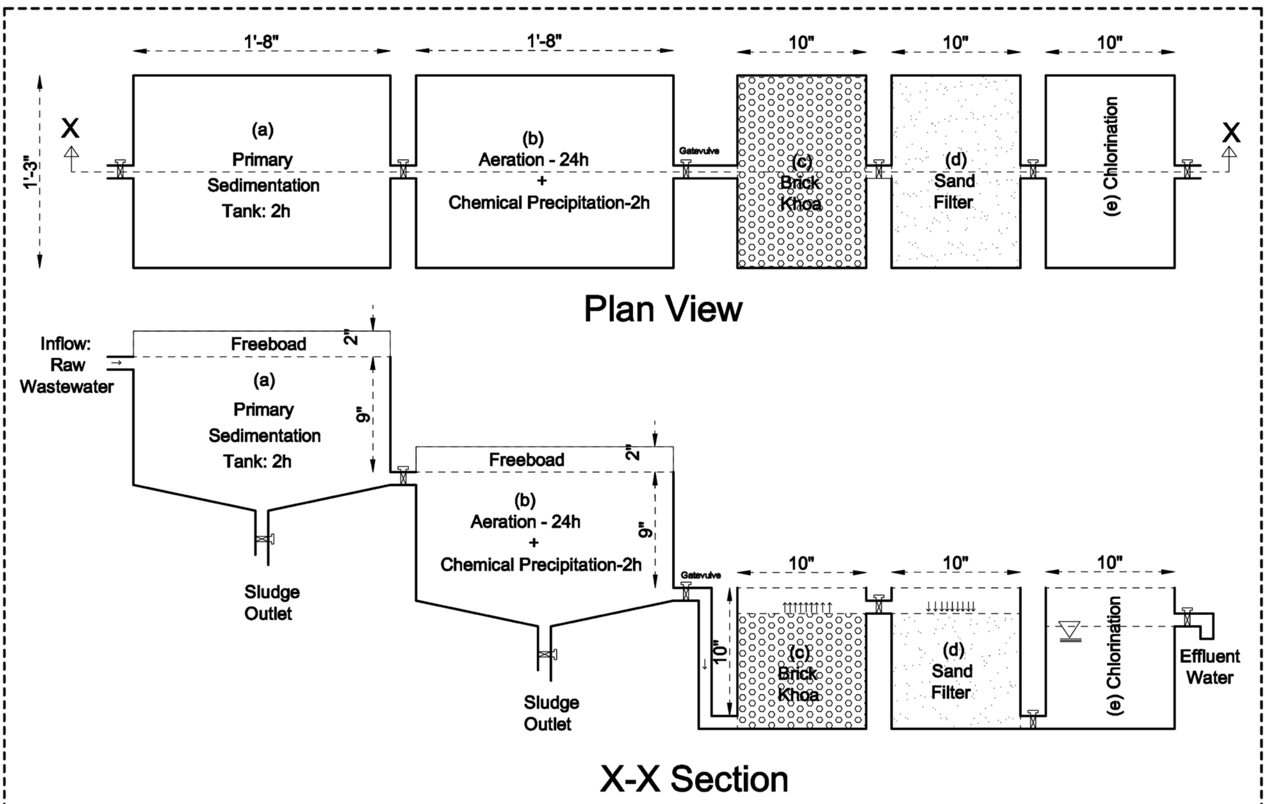

Figure 2. Instrumental setup and operation of developed treatment unit.

was aerated for 24 hours before pouring the effluent into filter media so that oxygen can be mixed with wastewater properly. After aeration, an optimum alum dose (70 mg/l) put into aeration chamber to remove phosphorous. Then water passed through the up-flow roughing filter to catch the floc generated in chemical precipitation. After this, water again transferred into the sand filtration unit for nitrogen and bacteriological removal. Finally, a storage tank used to store treated effluent for chlorination before discharging. No power was used for the flow generation. Gravitational force controlled whole flow system. The entire setup is presented in Figure 2.

3. Results and Discussion

3.1. Characterization of Raw Drainage Wastewater

The results of different drain outlet's raw wastewater samples revealed the large number of polluting agents that are dumped every day in bodies of water without any treatment, which is alarming for the ecology of inland surface water. The chloride is the most dominant anion in wastewater generated in Khulna city irrespective of sampling station. The least dominant element is iron in the study area. The test results of raw drainage wastewater are presented in Table 2, which

Table 2. Physico-chemical characteristics of raw drainage wastewater.

Water quality parameters	Unit	Sampling station (SS)			Max.	Min.	Avg.	Stand. Dev.
		SS-1	SS-2	SS-3				
pH	-	7.27	7.35	7.49	7.49	7.27	7.37	0.09
DO	mg/l	0.74	0.79	0.69	0.79	0.69	0.74	0.04
BOD_5	mg/l	59	126	226	226	59	137.00	68.62
COD	mg/l	320	420	435	435	320	391.67	51.04
TDS	mg/l	1800	1950	2525	2525	1800	2091.67	312.47
TSS	mg/l	120	150	190	190	120	153.33	28.67
Hardness as $CaCO_3$	mg/l	148	128	116	148	116	130.67	13.20
Alkalinity as $CaCO_3$	mg/l	357	370	310	370	310	345.67	25.77
Chloride	mg/l	1325	1250	1570	1570	1250	1381.67	136.65
Nitrate	mg/l	12	11	17	17	11	13.33	2.62
Phosphate	mg/l	8.74	9.89	16.75	16.75	8.74	11.79	3.54
Sulfate	mg/l	156	154	180	180	154	163.33	11.81
Iron	mg/l	0.98	1	1.2	1.2	0.98	1.06	0.10
Electrical Conductivity	μS/cm	1785	1965	2145	2145	1785	1965	146.97
Color	Pt.Co	478	503	615	615	478	532	59.57
Turbidity	NTU	42	65	93	93	42	66.67	20.85
E. Coli	Nos/100 ml	49,333	48,256	59,825	59,825	48,256	52,471	5218
Total Coliform	Nos/100 ml	70,000	65,800	98,050	98,050	65,800	77,950	14,315

shows a wide range of variation of drainage wastewater quality from different sampling stations of drain outlets of KCC. The values of raw wastewater parameter (SS-1, SS-2 and SS-3) presented are the average of three months (*i.e.* December, January and April) in each sampling station.

3.2. Performance of Developed Laboratory-Scale Treatment Plant

Performance of a developed laboratory-scale treatment plant (Table 3) varied depending on the parameters for which the plant was designed. Some parameters improved and satisfied the standard limit, whereas others did not. The removal of BOD_5, COD and TDS were not very good, because aeration alone is not sufficient for their reduction. Maximum 53% COD and 52% BOD_5 reduction were obtained for 24 hours aeration. Similarly, 24.7% and 60.0% reduction were attained for TDS and TSS respectively from 24 hours of aeration process. The application of alum and granular filter media accounted for a 90% and 96% reduction for fecal coliform and total coliform, respectively. Phosphate and nitrate reduction rate were 97% and 98.0%, respectively, after treatment with the developed laboratory-scale treatment plant. Table 3 clearly stated that BOD_5, COD, and coliforms do not meet ECR'97 standard. So, the developed laboratory-scale

Table 3. Effluents quality of laboratory-scale treatment plant.

Water quality parameters	Unit	Treated drainage wastewater			*ECR'97 discharge standard
		SS-1	SS-2	SS-3	
pH	-	7.37	7.32	7.99	4.5 - 8
DO	mg/l	8.79	5.03	6.90	-
BOD_5	mg/l	40	60	115	50
COD	mg/l	196	226	256	200
TDS	mg/l	1356	1450	1500	2100
TSS	mg/l	48	55	85	150
Hardness as $CaCO_3$	mg/l	134	121	76	-
Alkalinity as $CaCO_3$	mg/l	280	353	185	-
Chloride	mg/l	600	393	550	600
Nitrate	mg/l	1.1	0.20	0.9	10
Phosphate	mg/l	5.26	1.31	0.47	35
Sulfate	mg/l	11.3	9.3	11.8	-
Iron	mg/l	0.01	0.02	0.06	2
Electrical Conductivity	μS/cm	1785	1929	1874	1200
Color	Pt.Co.	136	132	18	-
Turbidity	NTU	13.9	8.04	2.18	-
E. Coli	Nos/100 ml	2400	2000	2100	-
Total Coliform	Nos/100 ml	2600	7600	9800	1000

*ECR'97: The Environmental Conservation Rules (1997) [14].

treatment plant needs to be modified for better BOD_5, COD, and Coliforms reduction efficiency. The values of effluent parameter (SS-1, SS-2 and SS-3) presented are the average of three months (*i.e.* December, January and April) in each sampling station.

3.3. Modification of Laboratory-Scale Treatment Plant

The laboratory-scale treatment plant could not remove all harmful contaminants from the wastewater as per standard requirement of ECR (1997). The modification of laboratory-scale treatment plant was made by activated sludge processing following filtration. The activated sludge process unit consisted of a high-quality plastic container as the primary clarifier, a reactor for the aeration chamber with an air blower, and a secondary clarifier with a pump for returning sludge. Three, five and seven days mean cell residence times were considered to activate the microorganisms in the activated sludge process unit. The effluents were passed through a granular filter media made from stone chips and sand (**Figure 3**). The filter media was constructed with locally available stone chips bed at the bottom of the container, along with a sand bed on its top. Both granular materials were well cleaned before use and each formed a uniform thick layer of 4-inch height. The bottoms of the filter chamber were kept empty for 2 inches for collection of sludge.

The effluent from the secondary clarifier traveled through the stone chips bed, followed by the sand bed, forming an up-flow of wastewater. The influent was

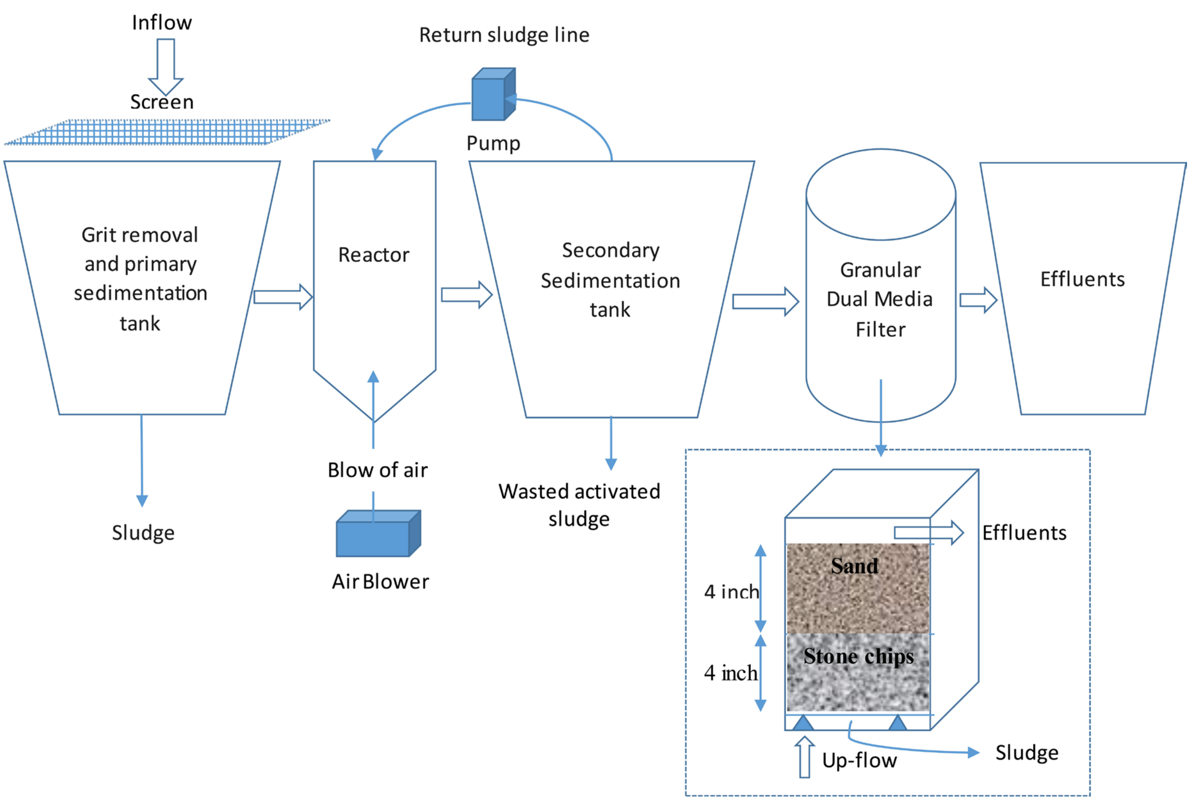

Figure 3. Flow diagram of modified treatment plant.

passed through the screen (5 mm × 5 mm) to strain off any coarse solids into the primary clarifier, which was also worked as a grit removal chamber. Then it was discharged to the reactor, an aeration chamber with a flow rate of 10 ml/min. The hydraulic retention time in the aeration tank for this developed treatment unit was calculated as 4 hours. The wastewater was then transferred to the secondary clarifier for bacterial floc formation and settlement as active sludge. A return sludge line from the secondary clarifier was linked through a pump, which returned 5 ml/min. of activated sludge to the reactor. A balance was made in the wastewater flow rate between the reactor and secondary clarifier. Another sludge line was formed in the secondary clarifier to discard a fixed amount of wastewater, with flow rate 0.05 ml/min. to maintain the activated sludge process properly.

After the continuation of all these steps, the treated wastewater passed through a final filter media. Following activated sludge processing in a slow sand filter, the operating filtration rate varied between 0.1 - 0.3 $m^3/m^2/hr$. The top layer of the sand becomes biologically active by the establishment of a microbial community on the top layer of the sand substrate. After treatment with an activated sludge process, the effluent needed to pass slowly through the coarse stone media and sand filter to improve the water quality. Instead of following the traditional down-flow method, the flow path was made upward through the stone chips bed layer and then sand bed. Finally, the effluents were disposed of through an outlet arrangement. This approach is recommended for longer filter runs with less operation and maintenance requirements [15].

3.4. Performance of Laboratory-Scale Treatment Plant after Modification

The performance of the laboratory-scale treatment plant after modification was monitored closely to determine the treatment efficiency of this system. The raw wastewater was collected from sampling station III. The test results from the raw wastewater and effluents from modified laboratory-scale treatment plant are illustrated in **Table 4**.

1) Biochemical Oxygen Demand (BOD_5)

BOD_5 is the most popular criteria parameter for organic pollution, useful to both wastewater and surface water. The raw wastewater sample has a BOD_5 value of 226 mg/l, which represents a lot of organic content present in the wastewater. After treatment of 3-days, 5-days and 7-days BOD_5 levels decreased to 9.8 mg/l, 1.78 mg/l and 1.38 mg/l, respectively. This shows that for 5 and 7 days, BOD_5 values fulfill the ECR (1997) standard limit of 50 mg/l, but 3 days does not in the range (**Table 4**). Based on test result, it can be concluded that moderate concentration of organic matter is decomposed when wastewater kept more than 5 days into secondary settling tank.

2) Chemical Oxygen Demand (COD)

The COD test measures the organic matter present in industrial and municipal wastewater while BOD_5 describes amount of oxygen required to decompose organic matter present in wastewater. The COD value of raw wastewater was 435 mg/l whereas after of 3-days, 5-days and 7-days, the values were measured at 192 mg/l, 96 mg/l and 32 mg/l, respectively. The standard value of COD for industrial wastewater for disposal into surface water bodies is 200 mg/l (ECR, 97), which was fulfilled in all three cases. Calculation shows about 56%, 78% and 93% removal efficiency measured from biological treatment of 3-days, 5-days and 7-days, respectively.

3) Total Dissolved Solids (TDS)

TDS is important to be considered in the calculation of irrigation water quality, because many of the toxic solid materials may be imbedded in the wastewater, which may cause harm to the plants [16]. Table 4 illustrates the final TDS values reported after treatment were 1667 mg/l, 705 mg/l and 590 mg/l for 3-days, 5-days and 7-days, respectively, which shows a positive trend of treatment of wastewater by the activated sludge system, whereas for raw wastewater the value was 2525 mg/l. Thus, the average effluent concentrations were below the ECR (1997) standard limit (2100 mg/l).

4) Total Suspended Solids (TSS)

Suspended solids refer to small solid particles which remain in suspension in water as a colloid or due to the motion of the water. It is used as one indicator of water quality. The raw wastewater sample had a TSS concentration 190 mg/l. After treatment, TSS levels in the final effluents decreased to 95 mg/l, 45 mg/l and 35 mg/l for 3-days, 5-days and 7-days, respectively. The standard limit of TSS concentration for disposal into inland water bodies is 150 mg/l (ECR, 1997). Thus, Table 4 shows that after treatment, the TSS concentration of effluents lie in the range of the standard limit.

3.5. Comparison between Developed and Modified Laboratory-Scale Treatment Plant

Table 5 illustrates that 49% BOD_5 reduction observed from laboratory-scale treatment plant, but after modification, the reduction efficiencies improved to 96%, 99% and 99% for 3-days, 5-days and 7-days, which also satisfies the ECR (1997) standard limit. COD and TDS reduction efficiencies are 41% and 41% for the primarily developed laboratory-scale treatment plant, while 56%, 78% and 93% COD and 34%, 72% and 77% TDS reduction efficiencies were achieved from the modified treatment plant for 3-days, 5-days and 7-days, respectively.

Table 4. Effluent quality of modified laboratory-scale treatment plant.

Water quality parameter	Unit	Raw wastewater	Effluent			ECR'97 discharge standard
			3-days	5-days	7-days	
BOD_5	mg/l	226	9.8	1.78	1.38	50
COD	mg/l	435	192	96	32	200
TDS	mg/l	2525	1667	705	590	2100
TSS	mg/l	190	95	45	35	150

The result shows a positive trend of treatment efficiency of the wastewater treatment by the modified laboratory-scale treatment plant.

A large change was also noticed with solids after treatment in the laboratory-scale treatment plant after modification, specifically in TSS removal. In the case of the primarily developed treatment plant, the TSS removal efficiency was 55%, whereas for the modified plant it rises to 82% for 7-days treatment. Based on the findings, it can be summarized that, the laboratory-scale treatment plant after modification is more efficient than primarily developed treatment plant.

3.6. Evaluation for Discharging into Surface Water Bodies and Agricultural Use

Effluents from wastewater treatment plants (WWTP) are widely used in different industries e.g. agriculture, cooling towers, etc., and can enter directly into the ecosystem through discharging to surface or groundwater [17]. The discharge of wastewater from municipal, industrial, and agricultural areas is an issue of serious concern as it affects a river's ecology [18]. These widespread usages of treated wastewater compel legislators to set stringent rules and regulations with respect to WWTP effluents.

This study reveals that the effluent quality stated in **Table 6** for discharging into surface water bodies mostly satisfies the standards. On the other hand, FAO standard for TDS (450 - 2000 mg/l) and TSS (50 - 100 mg/l) are also satisfy after

Table 5. Comparison of removal efficiency.

Water quality parameter	Primarily developed laboratory-scale treatment plant (% reduction) *	Modified laboratory-scale treatment plant (% reduction)		
		3-days	5-days	7-days
BOD_5	49	96	99	99
COD	41	56	78	93
TDS	41	34	72	77
TSS	55	50	76	82

*Data taken from effluent of sampling station III.

Table 6. Evaluation for discharging into surface water bodies and using irrigation purposes.

Water quality parameter	Unit	Raw wastewater	Effluent (7-days) *	FAO (1985) irrigation standard [19]	Bangladesh standard limits for disposal in surface water bodies (ECR'97)
BOD_5	mg/l	226	1.38	<100	50
COD	mg/l	435	32	-	200
TDS	mg/l	2525	590	450 - 2000	2100
TSS	mg/l	190	35	50 - 100	150

*Effluents form modified laboratory-scale treatment plant.

treatment by modified laboratory-scale treatment plant. The BOD_5 of raw wastewater is high because the organic content in the city wastewater is usually high. After biological treatment for 7 days in the activated sludge processing unit following filtration, the BOD_5 was reduced drastically to 1.38 mg/l, which satisfies FAO water quality standards that are highly suitable for irrigation.

4. Conclusions

Based on the experimental results the following conclusion can be drawn:

1) Laboratory testing shows that the BOD_5 and COD concentration of wastewater sample varied from 57 - 226 mg/l and 320 - 435 mg/l, respectively, and the total dissolved solids (TDS) ranged from 1800 - 2525 mg/l, which cross the standard range.

2) The laboratory-scale treatment units consisted of primary sedimentation followed by aeration, chemical precipitation and granular media filtration.

The mean removal efficiency for sampling station III is achieved 49%, 41%, 41%, 55%, 97%, 95% and 90% for BOD_5, COD, TDS, TSS, Phosphate, Nitrate and Coliform, respectively. But, for better BOD_5, COD, TDS and TSS reduction, laboratory-scale treatment plant needs to be modified so that all effluent quality parameters could meet the ECR'97 standards for safe disposal into surface water bodies.

3) To get better quality of effluents, modification of primarily developed laboratory-scale treatment plant was done by activated sludge processes, followed by granular media filtration. The effluent from the modified treatment plant contained BOD_5 1.38 - 9.8 mg/l, COD 32 - 192 mg/l, TDS 590 - 1667 mg/l and TSS 35 - 95 mg/l. Comparing with raw wastewater, about 96% - 99% BOD_5, 56% - 93% COD, 34% - 77% TDS and 50% - 82% TSS removal efficiency were recorded. After modification, the removal efficiency increases and satisfies the criteria for safe disposal into surface water bodies according to ECR'97 standards.

Finally, the effluent quality of modified laboratory-scale treatment plant is in the safe limit to use for irrigation purposes. The effluent can be used only in dry season, because this study was conducted during the months of December to April. Further studies need to understand the issues related to scaling up or commercial use of this laboratory-scale treatment plant.

Acknowledgements

The authors are deeply grateful to Technical Officer Mr. Sayed Ahsan Ali and Laboratory Technician Mr. Sardar Shahidul Alam who supported and motivated him throughout the whole study period.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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