PERFORMANCE EVALUATION OF DRINKING WATER TREATMENT PLANT IN GOPALGANJ TOWN OF BANGLADESH

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ABSTRACT

Water is one of the most important components for all forms of life. It is obligatory in the maintenance of life on earth. Since 2002, a water treatment plant (WTP) has been established at Gopalganjsadar with a view to supplying potable water. The main goal of this study is to evaluate the treatment efficiency and overall performance of the Gopalganj Water Treatment Plant based on Percentage Removal efficiency and Log Removal Value (LRV). This study revealed that the Madhumati River is considered as the promising option of raw water source due to the high arsenic and iron content in groundwater of Gopalganj town area. However, the quantity of river water fluctuates seasonally and in dry season generally mid-April to mid-June, the river water was found to be contaminated with salinity due to insufficient downstream flow across the river and at the same time, upstream flow of sea water. The source water is contaminated with high turbidity, color, TDS and Bacteria. The overall LRV and Efficiency of the treatment Plant were found to be varied in the range of: Physical parameters (2.09 to 2.31) and (99.19 to 99.51%), Chemical parameters (0.16 to 0.96) and (31.15 to 89.13%), Bacteriological parameters (0.83 to 1.08) and (85.22 to 91.67%) respectively. Furthermore, the overall qualitative efficiency of the WTP was found to be 82.66%. The quantitative efficiency of the WTP was found to be 64% and the rate of wastage possibilities is 2440000litre/day that is around 24% of total demand in this area.

Keywords:*Bacterial contamination, efficiency, Gopalganj town, log removal value, water treatment plant*

1. INTRODUCTION

Water is one of the vital components of the physical environment. Safe, adequate and accessible supplies of water are the basic needs and essential components of primary health care. Inadequate provision of safe drinking water is one of the main origins of communicable diseases and allied health risk. Therefore, providing safe drinking water is one of important public health priorities in the recent age. The World Health organization (WHO) estimated that up 80% of all sickness in the world is caused by inadequate sanitation, polluted water or unavailability of safe water (Ibrahim *et al*., 2014). The World Health Organization says that every year more than 3.4 million people die as a result of water related diseases, making it the leading cause of disease and death around the world. Most of the victims are young children, the vast majority of whom die of illnesses caused by organisms that thrive in water sources contaminated by raw sewage (Hossain& Hassan, 2015). Poor access to safe water sources in both urban and rural areas have been implicated for the prevalence of water diseases in our country.Gopalganj, a leading district headquarter of Bangladesh, is one of the densely populated urban areas which has been suffering from inadequate supply of drinking water often associated with water quality problems too. Over the last half-century, there has been an increasing tendency of population settlement in developing countries like Bangladesh. Increase in human population pose a great pressure on provision of safe drinking water especially in developing countries (Okonko*et al*., 2009). The present population of Gopalganj district is 1,172,415 and this population is increasing day by day. Therefore, this increase in population will certainly create severe problems due to rising water demands. Furthermore, potable water is a prime requirement for daily life of human beings. Most of the ground water sources in Gopalganj district are contaminated with high arsenic and Iron content and therefore, surface water sources are the only option for supplying potable water in Gopalganj town. In view of that, supply of adequate safe water is a challenging task in this area considering limited resources available in this area. Since 2002, a water treatment plant has been established at Gopalganjtown with a view to supplying potable water to residents of this town area of 13km^2. Therefore, this study has been motivated to explore the present status of supplied water as well as the efficiency of existing water treatment plant of this town. The main objective of this study is to evaluate the treatment efficiency and overall performance of the Gopalganj Water TreatmentPlant based on Percentage Removal efficiency and Log Removal Value (LRV).

2. MATERIALS AND METHODS

2.1 Gopalganj Water Treatment Plant (WTP)

2.1.1 General

The Gopalganj Water Treatment Plant (GWTP) is located within the city area of Gopalganj, Bangladesh. The plant was constructed in 2002 with a view to supplying potable water to the resident of Gopalganj town and since then it has been considered as the main source of drinking water in this area. The groundwater of this area is highly contaminated with Iron and Arsenic (up to 1.8 ppm) and therefore, groundwater may not consider as a potential source of water supply.Gopalganj town is located at 23.20°N and 89.80°E on the bank of the Madhumati River with an average rainfall is 490.2 mm.

Figure 1: Gopalganj Water Treatment Plant

2.1.2 Treatment Method

The water treatment technology involves pre-settling, flocculation, sedimentation, roughing filter, slow sand filter (SSF) and post-chlorination as shown in figure 2. Presently, surface water from Madhumati River have been using as the raw water sources in the WTP. The groundwater sources in this area are contaminated with high Iron and Arsenic (up to 1.8 ppm) content. The treatment operation is done for a period of 10 hours in a day but sometimes the operation have to be performed for 18 hours in a day in dry season according to the demand of beneficiaries.

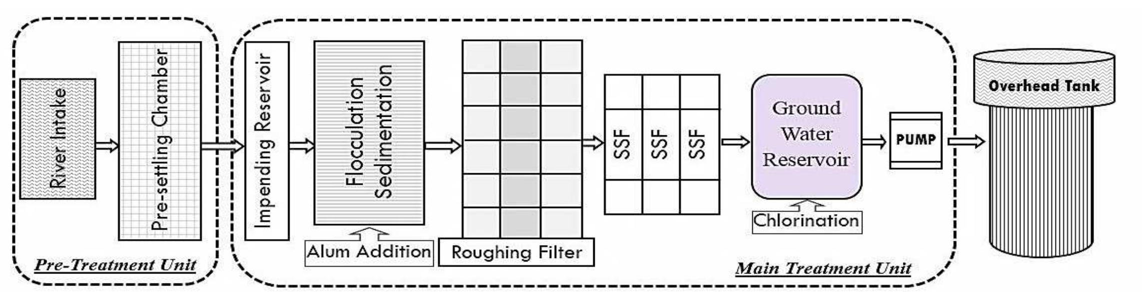

Figure 2: Treatment process flow diagram

2.2 Study Methodology

This study has been intended to field observation of the entre water treatment plant, comparison of water demand and capacity of WTP, water quality analysis, efficiency assessment and finally proposals of someinitiatives for the future development.

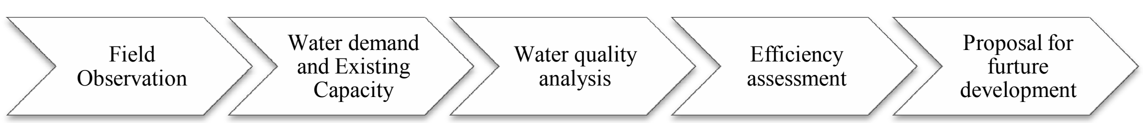

Figure 3: Study methodology

2.2.1 Sampling, laboratory testing and analysis:

Base on the existing unit operation of WTP a total number of five sampling points have been selected for sampling. Sample waterfrom the selected pointswas collected and all the samples were transported immediately to the environmental engineering laboratory of department of Civil Engineering, KUET for the analysis of qualitative efficiency of the water treatment plant. All the sampling and tasting were implemented according to the standard methods and procedures. Then quality of water has been analyzed based on drinking water standard recommended by ECR'97, Bangladesh. The removal efficiency and Log Removal value were calculated based on the formula as described in section 2.2.2.

2.2.2 Efficiency and Log Removal Value (LRV)

Plant efficiency is measured as the ratio of the concentration removal to the initial concentration of any parameter (Equation 1). The present trend to monitor the treatment plants is on the basis of Log Removal Efficiency of the parametric values of input and output of the treatment system (Ibrahim*et al.*, 2014). A log removal value (LRV) is a measure of the ability of a treatment processes to remove pathogenic microorganisms. Here, LRVs are determined by taking the logarithm of the ratio of concentration of any parameter in the influent and effluent water of a treatment process as shown in equation 2 (Amber *et al.*, 2004).

$$Efficiency = \frac{Initial\ concentration \sim Final\ concentration}{Initial\ concentration} \times 100\% \quad (1)$$

$$LRV = log_{10}\left[\frac{Influent\ concentration}{Effluent\ concentration}\right] \quad (2)$$

The value of LRV can be negative in case of increase in effluent concentration of any parameters. The cumulative Log Removal Value (CLRV) has been computed based on the cumulative value of LRV of various unit operations.

3. RESULTS AND DISCUSSION

3.1 Treatment Capacity, Demand and Wastage

This study illustrated that the present water treatment plant of Gopalganj town is supplying potable water throughout an area of 13 $km^2$of main town covering a total number of 7000 house connections during the study period. The initial house connection was around 1100 in the year of establishment (2002). The present demand of the supplied area is therefore, approximately 6 times of the demand of the year 2002.However, no initiatives were found to be taken by the respective authority till the period of the study to increase the capacity of the treatment plant.

Table 1: Water demand estimation in the service area

House Connection	Average Family Size	Total Consumer	Consumption rate (lcpd)	Net water Requirements (Litre/day)	Allowable percentage of System losses	Total Requirements with losses (Litre/day)
7000	4.67*	32690	180	5884200	15%	6766830
	6.00**	42000		7560000		8694000

*Population census 2011: District statistics, ** Standard Average Family Size.

Our study evaluated that the present treatment rate of WTP is around 540m^3/hour and the treatment operation was found to be performed for 10 hours. Therefore, the maximum treatment capacity of the WTP is 5400000litre/day for 10 hour of operation. The water supply authority use a number of 3 overhead tank having storage capacity of 1.5 lack gallon of each. Therefore the total storage capacity of 3 overhead tanks is around 4.5 lack gallons or 17 lackLitre. Again the estimated demand for present house connection is around 6766830 Litre/day considering 15% system losses. Moreover, the present water demand reported by the WTP authority is around 1Core Litre/day while the treatment capacity is around 54 lacks. Therefore, the quantitative efficiency is around 54% based on the estimation of treatment plant authority. Furthermore, according to our observation the maximum water requirement of 7000 households are about 6766830litre/day for average family size of 4.67 and 8694000 Litre/day for average standard family size of 6.00. Therefore, the quantitative efficiency was found to be around 62% based on our estimation. The estimated net water demand in the study area is 7560000 while the consumer'sdemands were found to be around 1 core Litre in a day. Therefore, the rate of wastage possibilities is around 2440000litre/day that is approximately 24% of total demand in this area.

3.2 Raw water quality

3.2.1 pH, Color and Turbidity

This study shows that the value of pH in the raw water source was within acceptable limit BDS value (6.5-8.5) during the period of the study. The values of pH were found to be in range of 6.6 to 8.38 as shown in figure 4(a). The maximum and minimum values of color were found to be 371 Pt.Co and 58 Pt.Co in the month of June and May, respectively. Therefore, the color content exceeded the acceptable limit of BDS value (15 Pt.Co). An increasing trend was found from November'14 to February'15 then the color content was decreased to 58 Pt.Co in the month of May'15.

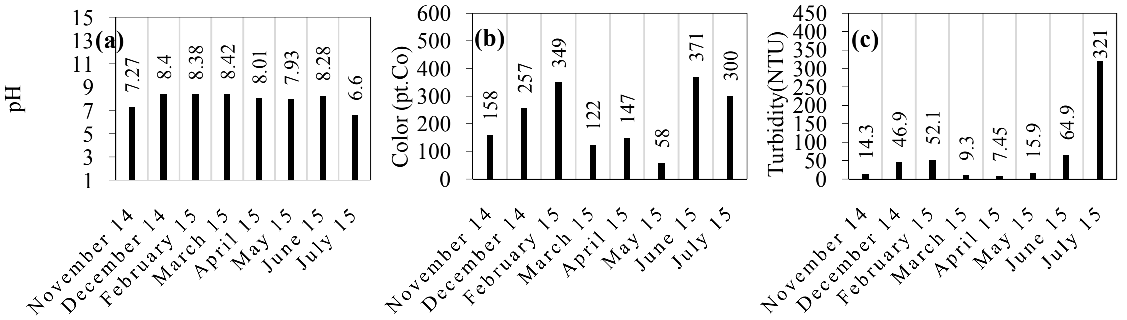

Figure 4: Seasonal variation of (a) pH value, (b) Color and Turbidity value in raw water source

The seasonal variation of turbidity values are shown in figure 4(c).The maximum and minimum values of turbidity were found to be 321 NTU and 9.3 NTU in the month of July'15 and March'15, respectively. The turbidity content exceeded the acceptable limit of BDS value (15 Pt.Co) in most of the period of the study.

3.2.2 Chlorides and Total Dissolved Solids (TDS)

This study displays that the chloride content in the used surface water source was found to havea chloride content exceeding the WHO standard limit (250mg/L). However, the chloride content ranges within the BDS allowable limit (600mg/L) as shown in figure 5(a). The maximum and minimum value of chloride content were found to be 655 mg/L and 60 mg/L in the month of April'15 and December'14, respectively. Chlorides in reasonable concentrations are not harmful to human, but beyond the WHO limits of 250 mg/L, it may cause objectionable salty taste in water(Jiwa, et. al., 1991). Values of TDS were found to be in the range of 30-790mg/L that is within the BDS standard value (1000 mg/L). The maximum and minimum value of TDS content were found to be 966 mg/L and 30 mg/L in the month of April'15 and December'14, respectively.

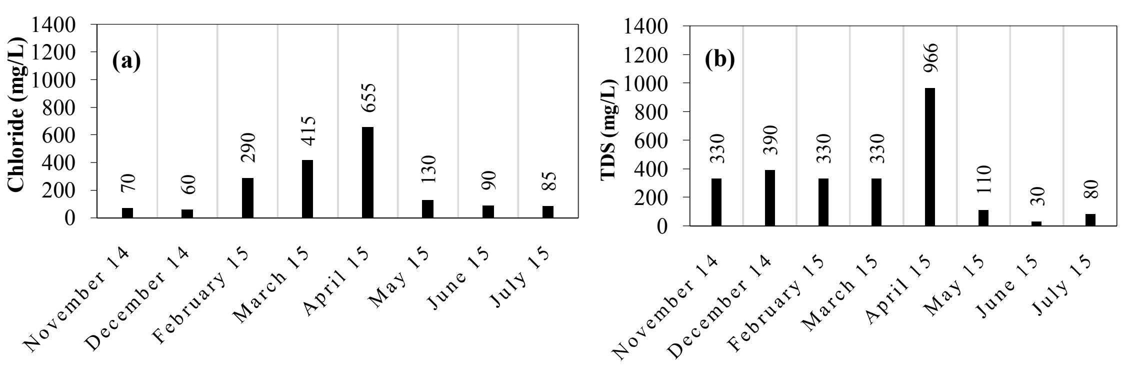

Figure 5: Seasonal variation of (a) Chloride content, (b) TDS content in raw water source

3.2.3 Total Coliform (TC) and E. coli (EC)

Faecal pollution of water may introduce a variety of intestinal pathogens as bacterial, viral or parasitic. Faecal coliform bacteria are not pathogenic but they can be used as an indicator of recent faecal contamination from either animal or human origin (Muller, 1977). Figure 6 shows the microbial characteristics of raw water source. The raw water source was highly contaminated with Total coliform and Faecal coliform throughout the year.

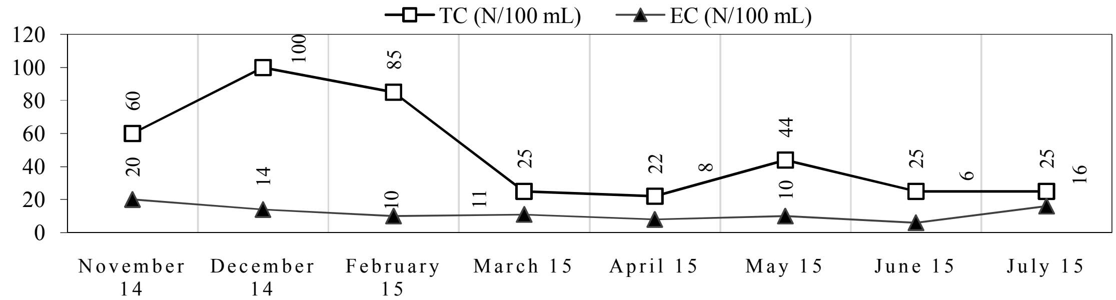

Figure 6: Seasonal variation of Total coliform and E. coli concentration in raw water source

3.3 Water quality in various Unit Operations

In this study a total number of five sampling points have been selected to evaluate the treatment performance of the various unit operation of the Water Treatment Plant. The test results show that the qualities of water were not within the acceptable limit for color, turbidity and microbial concentration at impending reservoir, exit of roughing filter as well. Yet, the color and turbidity were found to be removed after slow sand filtration (SSF). But the WTP was still unable to transfigure the bacterial contamination into its BDS standard value as shown in figure7. The TDS and Chloride content range within the acceptable limit in every unit operation.

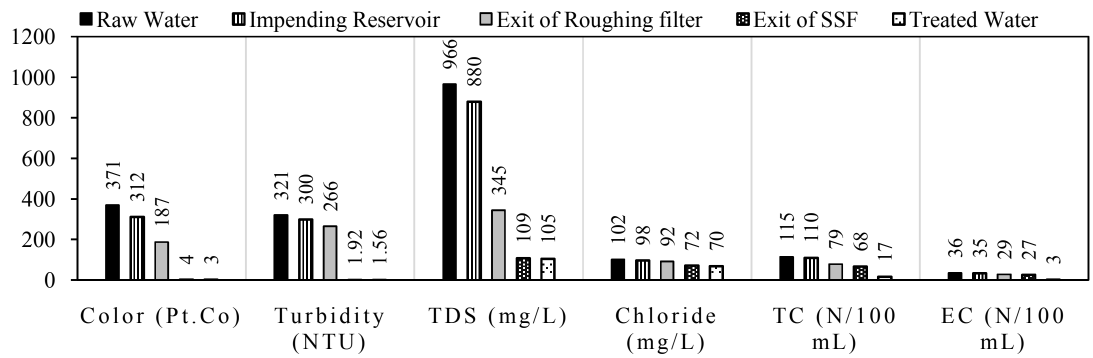

Figure 7: Water quality in various unit operation points of Water Treatment Plant

3.4 Removal Efficiency (RE)and Cumulative Removal Efficiency (CRE)

3.4.1 Removal Efficiency for Physical parameters

It is evident that the removal efficiency has been increased with the increasing of LRV of any parameters and vice versa. The color and turbidity removal efficiency of WTP at impending chamber were found to be 15.9% and 6.54%, respectively. Also, those at the exit of roughing filter are33.69% and 10.59%, respectively. Furthermore, the maximum color and turbidity removal efficiency were found to be 49.33% and 82.27%, respectively at the exit of Slow Sand Filter (SSF) as shown in figure 8.

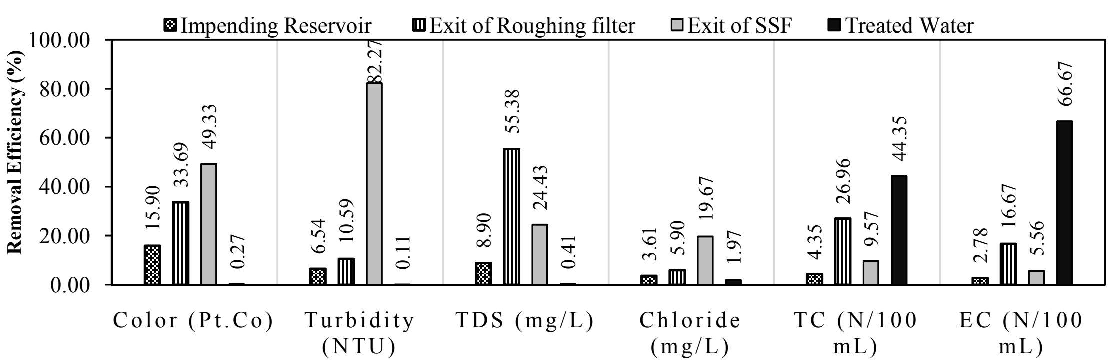

Figure 8: Removal Efficiency in various unit operation points of Water Treatment Plant

3.4.2 Removal Efficiency for Chemical parameters

This investigation displays that thechloride and TDS removal efficiency of WTP at impending chamber were found to be 3.61% and 8.90%, respectively. Also, those at the exit of roughing filter are 5.90% and 55.38%, respectively. Furthermore, the chloride and TDS removal efficiency were found to be 19.67% and 24.43%, respectively at the exit of Slow Sand Filter (SSF). So, the chloride and TDS removal efficiency were so much substandard to any other parameters.

3.4.3 Removal EfficiencyforMicrobial parameters

The results indicated that theTotal Coliform and E. coli bacteria removal efficiency of WTP at impending chamber were found to be 4.38% and 2.78%, respectively. Also, those at the exit of roughing filter are 31.30% and 19.44%, respectively. Furthermore, the maximum TC and EC removal efficiency were found to be 44.35% and 66.67%, respectively after post-chlorination process as shown in figure 8. The TC and EC removal efficiency were not up to the mark.

3.4.4 Cumulative Removal Efficiency (CRE)

The overall removal efficiency was determined based on the Cumulative Removal Efficiency (CRE) value. The overall color and turbidity removal efficiency were found to be 99.19% and 99.51%, respectively. Also, the overall TDS and chloride removal efficiency were found as 89.13% and 31.15%, respectively. Furthermore, the overall TC and EC removal efficiency were 85.22% and 91.67%, respectively as shown in figure 9 below. The acceptable removal efficiency for TC and EC removal is 100%, therefore, the treated water can't be considered as safe drinking water.

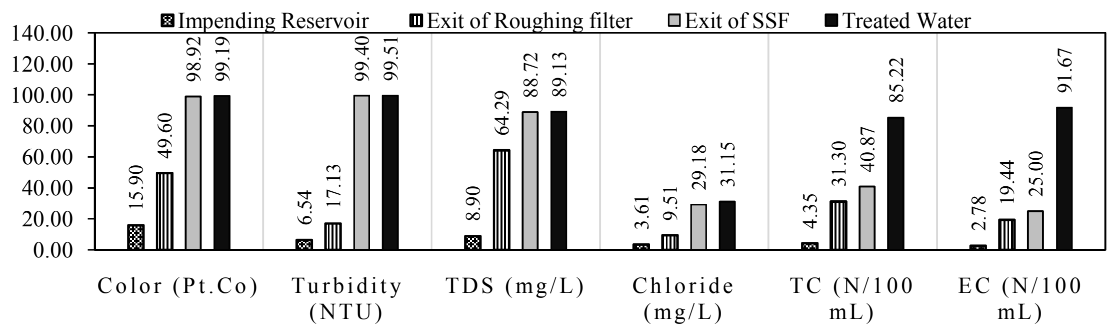

Figure 9: Cumulative Removal Efficiency (CRE) in various unit operation points of Water Treatment Plant

3.5 Log Removal Value (LRV) and Cumulative Log Removal Value (CLRV)

3.5.1 Log Removal Value for Physical parameters

From this study the Log Removal Value (LRV)forColor and Turbidity at impending chamber were found to be 0.08 and 0.03, respectively. Also, those at the exit of roughing filter are0.22 and 0.05, respectively. Furthermore, the maximum LRV for color and turbidity were found to be 1.67 and 2.14, respectively at the exit of Slow Sand Filter (SSF) as shown in figure 10 below.

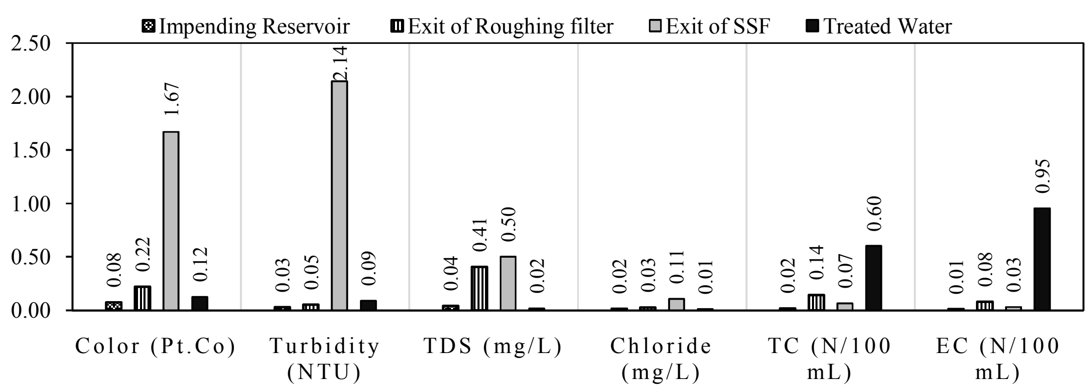

Figure 10: Log Removal Value in various unit operation points of Water Treatment Plant

3.5.2 Log Removal Value forChemical parameters

This investigation displays that theLRV for chloride and TDS at impending chamber were found to be 0.02 and 0.04 respectively. Also, those at the exit of roughing filter are 0.03 and 0.41, respectively. Furthermore, the maximum LRV forchloride and TDS were found to be 0.11 and 0.50, respectively at the exit of Slow Sand Filter (SSF) operation.

3.5.3 Log Removal Value forMicrobial parameters

The results indicated that theLRV for Total Coliform and E. coli bacteria removal at impending chamber as well as the exit of roughing filter and slow sand filter were found to be negligible. The maximum Log removal value for TC and EC removal were found around 0.60 and 0.90, respectively after post-chlorination process as shown in figure 10.

3.5.4 Cumulative Log Removal Value (CLRV)

The overall LRV was determined based on the Cumulative Log Removal Value (CLRV) value. The overall LRV for color and turbidity were found to be 2.09 and 2.31, respectively. Also, the overall LRV for TDS and chloride were found as 0.96 and 0.16, respectively. Furthermore, the overall LRV for TC and EC were found 0.83 and 1.08, respectively as shown in figure 11 below.

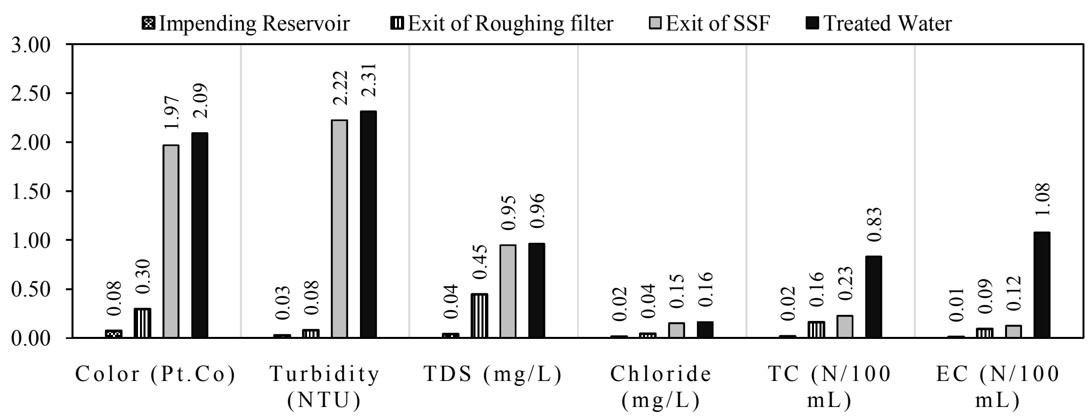

Figure 11: Cumulative Log Removal Value (CLRV) in various unit operation points of Water Treatment Plant

3.6 Operation and Maintenance Practice

This study mentioned that regular water quality monitoring is reasonably absent in the treatment plant and the respective authorities were also unconcerned about the proper maintenance of the water treatment plant.The present house connection is around the six times of the house connection of the period of establishment. However, no further additional unit has been addedto the treatment plant till now, while a part of operation unit has been consideredas obsolete and inoperable during the study. The chlorine addition rate was found to be uncontrolled and may not operate according to the requirement of the quantity of water. Therefore, the existing post-chlorination process is not fully capable to remove the bacterial contamination of treated water. The process used for cleaning the filter bed is backwashing and this operation was found to be performed once in a day.

4. CONCLUSIONS

This study revealed that the Madhumati River is considered as the promising option of raw water source due to the high arsenic and iron content in groundwater of Gopalganj town area. However, the quantity of river water fluctuates seasonally and in dry season generally mid-April to mid-June the river water is found to be contaminated with salinity due to insufficient downstream flow across the river and at the same time, upstream flow of sea water. The source water is contaminated with high turbidity, color, TDS and Bacteria. The overall LRV and Efficiency of the treatment Plant were found to be varied in the range of: Physical parameters (2.09 to 2.31) and (99.19 to 99.51%), Chemical parameters (0.16 to 0.96) and (31.15 to 89.13%), Bacteriological parameters (0.83 to 1.08) and (85.22 to 91.67%) respectively. Furthermore, the overall qualitative efficiency of the WTP was found to be 82.66%. The acceptable removal efficiencies for TC and EC should be 100% and consequently, the obtained efficiency is not up to the mark and the treated water can’t be considered as safe drinking water.The quantitative efficiency of the WTP was found to be 62% and the rate of wastage possibilities was found to be around 2440000litre/day that is around 24% of total demand in this area.This study recommended that the WTP unit operation might be scaled up to satisfy future water demand as well as awareness rising of the beneficiaries is also required to reduce the wastage possibilities. Yet again, Pre-chlorination process can be arranged and the existing post chlorination process should be scrutinized to ensure the removal of bacterial contamination in the treated water to the desired limit.Regular water quality monitoring is mandatory to ensure the provision of safe drinking water as well.

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