Performance evaluation of the water treatment plants of Islamabad - Pakistan

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Abstract

This study was designed to evaluate the treatability performance of SG-WTP and SM-WTP for a period of 12 months. The entrance water samples collected were found to be highly turbid and microbial contaminated. The turbidity observed was 16NTU and 13.5NTU, with 1440/100mL and 1590/100mL microbial contamination at SG-WTP and SM-WTP, respectively. The effluent water qualities of both the purification plants were found to be within the limits of WHO guidelines. The overall turbidity removal was observed as 91% with log value of 1.051 and 81% with log value of 0.806 at SG-WTP and SM-WTP, respectively. And the microbial removal efficiency was noticed to be 100% at the exit of both the plants. It was observed that the overall treatability performance of the SG-WTP is comparatively better and economical. The results of the study suggest that the regular water quality monitoring and proper maintenance is required, to ensure the safe drinking water to the community.

Keywords: Monitoring, Water Treatment Plant, Turbidly, Coliform, Monitoring

1. Introduction

Water is the major necessity of life, but unfortunately even today in the 21th century most of the people, especially belonging to the third world do not have potable water for their household usage. More than one thousand million people of the world do not have access to clean drinking water [1]. Astonishingly, 50-80% of these deprived people are from the five countries only, i.e., India, China, Indonesia, Pakistan and Nigeria. In Pakistan, the water pollution dilemma is quickly propagating, presently 82% of the people do not have an access to safe water, 30-40% hospitalized patients are due to water borne diseases, and about 80% of the infant death is only because of the polluted water that causes diarrhea, cholera, dysentery, gastro-intestinal problems [2,3].

The disposal of untreated domestic and industrial effluent and the agricultural run-off are the main reason for the water pollution problems in Pakistan. Much of the existing water supply lines are damaged due to rusted pipes, leakages, unauthorized connections, poor administration, lack of resources etc. Therefore, it is very essential to monitor the quality of water at the outlet of the consumers to ensure healthy life [4]. According to the most recent report of Pakistan Council of Research in Water Resources [3], the water quality in most of the water supply schemes in Pakistan have crossed the limits of drinking water quality standard set by the WHO. The major water quality problem being faced currently is the microbial, arsenic, nitrate and fluoride contamination in most part of the country. Almost 64% of the drinking water supply is contaminated with total coliforms.

The Federal Area (Islamabad) of Pakistan is supplied with water from the two main water sources, i.e., the SG-WTP (Sangjani Water Treatment Plant) and SM-WTP (Simly Water Treatment Plant). The SG-WTP treats the water coming from Khanpur Dam, which is constructed on Horo River. Its designed capacity is 51 MGD (million gallons per day). The treatment components of SG-WTP consist of coagulation with alum dosage, flocculation, sedimentation, rapid gravity filtration and chlorination. The SM-WTP is designed to treats the water of Simly Dam that is constructed on Soan River. Its designed capacity is 42 MGD. It also consists of coagulation and flocculation systems, sedimentation, rapid gravity filtration and chlorination [5].

The regular monitoring of water quality being treated by water purification systems, and the performance evaluation of its unit operations and processes is very essential for the consumer health. Therefore, this study was designed to study the treatability performance of the SG-

WTP and SM-WTP. Since, the turbidity and coliforms have been considered as the most reliable and standard parameters for the performance evaluation of the treatment plants [6-8], therefore, attention was paid to these two water quality parameters while conducting this study.

2. Materials and Methods

Various water samples were collected continuously, for a period of more than twelve months at regular interval of fifteen days, from the water treatment plants as per the available standard of AWWA [9]. The samples were collected in sterile glass bottles containing few drops of 3% sodium thiosulfate to neutralize the residual chlorine. The typical layout of the sampling points is shown in the Fig. 1. The design capacity of both the treatment plants is more than fifteen thousand cubic meters per day, and the amount of coagulant dosage they use; vary from 10-13 mg/L, depending upon the raw water quality. The various water quality analysis techniques used in the study are in the Table 1.

Figure 1. Location of sampling points

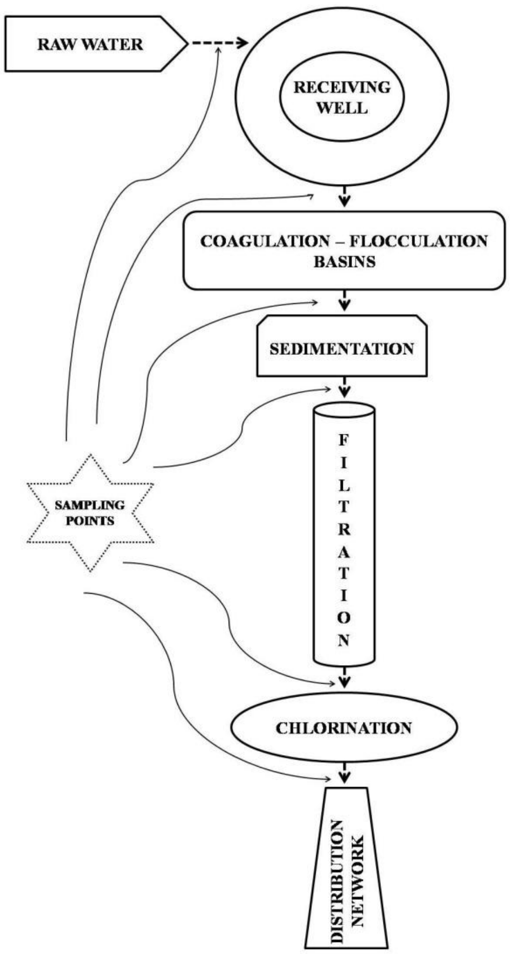


Table 1. Water quality analysis techniques

Parameter	Techniques
pH	pH meter
Turbidity	Nephelometric mMethod
EC	Conductivity meter
TDS	Gravimetric technique
Nitrates	UV spectrophotometric screening method
Sulfates	Spectrophotometer determination
Chlorides	Argentometric method
Total coliform	Membrane filter technique
Fecal coliform	Membrane filter technique

3. Results and Discussions

Prior to evaluating the performance of the SG-WTP and SM-WTP, the water quality being supplied to these plants was also analyzed. For this purpose samples were collected from the upstream side of the filtration plants. The results of the analysis are shown in the Table 2. The results indicate that most of the water quality parameters are within the limits of WHO drinking water quality guideline, except the turbidity and microbial contents. The turbidity noticed at SG-WTP and SM-WTP was 16 NTU and 13.5 NTU, respectively. And the total coliform contamination observed as 1440/100 mL at SG-WTP and 1590/100 mL at SM-WTP.

Table 2. Water quality analysis on the upstream side of filtration plants

Parameter	Upstream of		WHO limits
	SG-WTP	SM-WTP	
pH	8.12	8.63	6.5-8.5
Turbidity, NTU	16	13.5	5
EC, µS/cm	940	1024	--
TDS, mg/L	546	612	1000
Nitrates, mg/L	2.8	5.2	10
Sulfates, mg/L	38	54	400
Chlorides, mg/L	13	14	250
Total coliform, MPN/100 mL	1140	1590	Nil/100 mL
Fecal coliform, MPN/100 mL	925	1242	Nil/100 mL

The results indicate that the water samples collected on the upstream side of filters were highly contaminated with total coliform and fecal coliforms. The total coliform bacteria and the fecal coliform bacteria were within the range of 1400-1600 MPN and 920-1400 MPN, respectively. The fecal coliform bacteria are found naturally in the intestinal tract of warm-blooded animals. Average fecal coliform counts per gram of waste vary from 230,000 for cattle to 13 million for humans [10,11]. Fecal coliform bacteria are not pathogenic but they can be used as an indicator of recent fecal contamination from either animal or human origin [12]. The high level of microbial contamination in these water samples collected, were mainly due to the cattle grazing along the bank of the canal. During field survey a number of animals like cows, sheep, and cattle were seen either-grazing or drinking water directly from the canal. Cow dung was also seen at a number of places in the water body that could be washed out into the canal during rainfall or by the wind.

Performance Evaluation of the Treatment Plants

The Table 3 show the physiochemical characteristics of the water quality samples obtained at the exit of both the water treatment plants.

Table 3. Physicochemical characteristics of the drinking water

Parameter	SG-WTP	SM-WTP
pH	7.29 ± 0.2	7.47 ± 0.1
Temperature	25.4 ± 0.6	26.2 ± 0.24
EC, µS/cm	462 ± 3.9	391 ± 3.7
TDS, mg/L	352 ± 3.2	275 ± 2.24
Nitrates, mg/L	0.16 ± 0.8	0.48 ± 0.7
Chloride, mg/L	3.2 ± 0.1	3.7 ± 0.15
Sulfates, mg/L	11.86 ± 3.8	5.5 ± 1.28

pH

The role of pH is associated with the corrosion, hardness, acidity, chlorination, coagulation and alkalinity [13]. Since, due to water treatment, by removing the microbial contamination etc, the pH decrease, and the same phenomenon was observed whiling conducting this study, i.e., the pH of water samples collected from SG-WTP and SM-WTP were 7.29 ± 0.2 and 7.47 ± 0.1, respectively. Both of these values are within the WHO permissible limits of 6.5-8.5.

Temperature

Almost all water samples from both treatment plants had temperature values above WHO limits of 12°C. The temperature observed at the time of collection of water samples from SG-WTP and SM-WTP was recorded as 25.4 ± 0.6 and 26.2 ± 0.24, respectively. Temperature is associated with the atmospheric temperature, but it also increases with the depth of water. It is a critical parameter as far as the growth of microorganisms is concerned, i.e., the low temperatures are not optimum for the bacterial growth, and it often causes a rapid decrease in bacterial population due to inactivation of bacterial enzymes [14].

Electrical Conductivity

Electrical conductivity value of a water sample gives a general impression of quantity of dissolved ionic compounds in it. Electrical Conductivity will be higher for water that has dissolved more ionic species in it [15]. The electric conductivity was also recorded at the exit of these water treatment plants. The EC of the water samples of SG-WTP and SM-WTP were noticed to be 462 ± 3.9 µS/cm and 391 ± 3.7 µS/cm, respectively.

Total Dissolved Solids

TDS values are the measure of soluble salts in the water and have a linear relationship with electric conductivity. Values of TDS in the water samples collected from SG-WTP were observed as 352 ± 3.2 mg/L and that of the SM-WTP was 275 ± 2.2 mg/L. According to WHO, the highest limits, for TDS in drinking water is 1000 mg/L hence based on TDS criteria the water being supplied by these water treatment plants are fit for drinking purposes. Total dissolved solids in excess of standards as described by WHO are objectionable in drinking water because of the adverse effects of sodium (if present) on the patients with cardiac diseases and women with toxemia in pregnancy [16].

Nitrate-N

Nitrates are present in almost all water but some of them are produced microbiologically by the process of nitrification of NH_4^+ ions, nitrites being the intermediate species. These nitrites are soon converted to nitrates by the nitrosomonas bacteria. These species are present in sewage water and in the digestive tract of humans and animals [17]. The WHO permissible limit for nitrate in drinking water is 10 mg/L. Water containing excessive nitrates above the permissible limits can be regarded as heavily polluted microbiologically [16]. Nitrate concentration in the water samples obtained from SG-WTP and SM-WTP were observed to be 0.16 ± 0.8 mg/L and 0.48 ± 0.7 mg/L, respectively.

Chlorides

Water samples collected from SG-WTP and SM-WTP was observed to be 3.2 ± 0.1 mg/L and 3.7 ± 0.15 mg/L, 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 [18].

Sulfates

Sulfates concentration in water samples collected from SG-WTP and SM-WTP was observed as 11.86 ± 3.8 mg/L and 5.5 ± 1.28 mg/L, respectively during the study period. The results show that the sulfates concentrations in all water samples were well within the WHO permissible limits of 250 mg/L. Sulfates are important for public and industrial water supplies because of the tendency of water containing appreciable amount of sulfates to form hard scales in the boilers and heat exchangers, moreover, water containing high sulfate concentration may be undesirable because of their laxative effects [15].

Turbidity Removal Efficiency

Tables 4 and 5 show the individual units and the overall treatability performance of these water treatment plants in terms of turbidity removal. It is evident from the results that turbidity removal efficiency of SG-WTP through its primary sedimentation is 37.5% with log removal of 0.204, whereas, that at the SM-WTP is 33%, with log removal of 0.172. This better turbidity removal efficiency at SG-WTP is mainly attributed to the excessive hydraulic retention time of 2 days, at its raw water reservoir and due to the provision of eight horizontal flow-settling basins with a hydraulic retention time of 2.5 hrs. Also, the overall turbidity removal at SG-WTP is comparatively more than that of the SM-WTP. As the overall turbidity removal of 91% with log value of 1.051 and 81% with log value of 0.806 was observed during the study period at SG-WTP and SM-WTP, respectively.

Table 4. Overall turbidity removal efficiency

Filter plant	Efficiency	Log removal
SG-WTP WTP	91	1.051
SM-WTP WTP	81	0.806

Table 5. Comparison of turbidity removal efficiency

Filter plant	Unit operation	Removal efficiency	Log removal
SG-WTP WTP	Sedimentation	37.5%	0.204
SM-WTP WTP		33%	0.172
SG-WTP WTP	Filtration	91%	1.051
SM-WTP WTP		81%	0.806

Total Coliform Removal Efficiency

Figure 2 illustrates the individual efficiencies of different unit processes with regard to total coliform removal at both the water treatment plants. The results indicate that the total coliform removal efficiency of SG-WTP is 43% via coagulation, 52% via filtration and 100% via chlorination. And via coagulation, filtration, and chlorination for SM-WTP is 41%, 35%, and 100%, respectively. The initial total coliform concentration in the raw water of SG-WTP was observed as 925 MPN/100 mL that reduces to zero concentration at the end of the treatment process. Similarly, the initial total coliform concentration in the raw water of SM-WTP was recorded as 1242 MPN/100 mL, which also reduces to zero at the end. Hence, a maximum total coliform removal of 100% was noticed at the end of both the water treatment plants. The total coliform removal efficiency of SG-WTP is comparatively more than that of the SM-WTP via its primary treatment units, which is due to the natural sedimentation process in the long channels extending from Khanpur Dam to SG-WTP, whereas, in case of SM-WTP the water is drawn through conduction line from bottom of the dam that does not promote settling.

Figure 2. Comparison of Total Coliform Removal

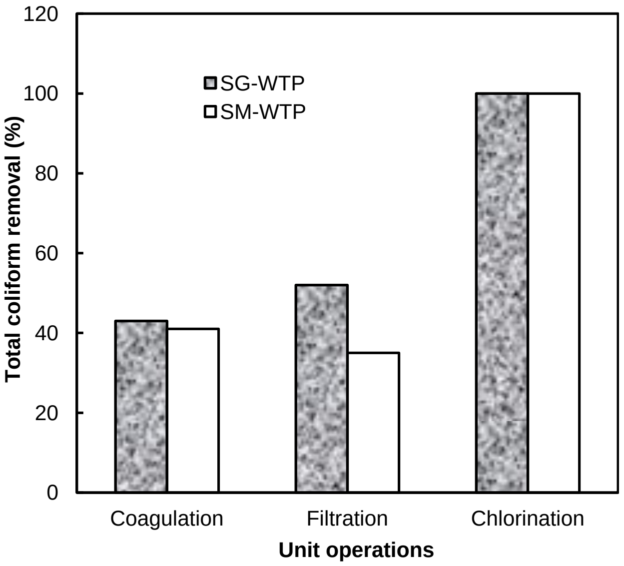
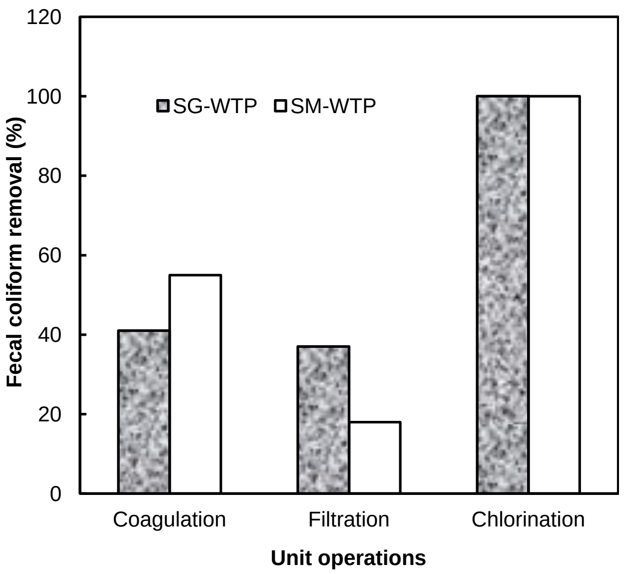


Figure 3. Comparison of fecal coliform removal



Fecal Coliform Removal Efficiency

Figure 3 indicates the total fecal coliform removal efficiencies through different unit operations in both the water treatment plants. At SG-WTP the total fecal coliform removal was observed as 41%, 37%, and 100% during its coagulation, filtration, and chlorination process, respectively. And at SM-WTP the fecal coliform removal efficiency of 55% during coagulation, 18% during filtration and 100% removal during chlorination process was noticed. However, the fecal coliform removal efficiency at the end of both the water treatment plants is 100%, but the amount of chlorine dosage being used at SM-WTP is comparatively greater than that of the SG-WTP.

Water Quality in the Distribution System

In order to evaluate the quality of water at the tail of distribution system, water samples were collected from four different localities at about 15-20 km downstream of SG-WTP. The distribution system of SG-WTP was selected as a case study because it is comparatively better quality of water, especially the in terms of turbidity which was 0.27 NTU, against the 6 NTU turbidity of water coming from SM-WTP. The results indicate that most of the water samples were within the permissible limits WHO limits. But at the extreme end of distribution system, about 18 km from the water treatment plant, a maximum of 9.5 NTU was recorded. This increase in the turbidity towards the tail of distribution system could be mainly because of the damaged sewage and water pipes, which run parallel to each other. However, no microbial contamination was observed even at the tail.

Table 6.Economic evaluation of the treatment plants

Plant name	SG-WTP	SM-WTP
Plant capacity	51 MGD	42 MGD
Operational capacity	24 MGD	30 MGD
Consumption of alum	10 mg/L	13 mg/L
Consumption of chlorine gas	2 mg/L	3 mg/L
Alum cost	0.32 $/kg	0.32 $/kg
Cost of chlorine gas	0.29 $/kg	0.29 $/kg
Total cost (US $ per 1000 m^3)	3.76 $	5.06 $
Total cost per day	410 $	685 $

Economic Evaluation

The cost comparison of the water treatment plants is based on their actual operational capacity during the study period. The required information for the economic evaluation was obtained from relevant finance department of these water treatment plants, functioning under the supervision of CDA (Capital Development Authority, Islamabad). Actual alum dosage was determined using Jar Test Apparatus [9]. The SG-WTP and SM-WTP were operating at a capacity of 24 MGD and 30 MGD, respectively, during the course of study period. Refer to Table 6 that shows the economic evaluation of these plants; indicate that the SG-WTP is more economical than the SM-WTP, i.e. the cost of water treatment in case of SG-WTP is 3.76 USD per day, whereas in the case of SM-WTP the amount is calculated as 685 USD per day.

4. Conclusion and recommendations

The following conclusions have been drawn from this study;

- The water samples from both the treatment plants are within the available water quality guidelines. However due to anthropogenic activities and grazing of animals near the banks of canal leading towards these plants, causes excessive turbidity and microbial contamination are being added.
- A significant amount of decrease in the microbial contamination and turbidity level can be achieved by providing maximum HRT during the sedimentation process.
- The overall turbidity removal efficiency of SG-WTP is comparatively better than that of SM-WTP.
- The decrease in the water quality at the tail of distribution system is mainly due to the existing cracks in the piping networks.
- The economic evaluation indicates that the cost of SM-WTP is almost 1.5 times more than that of the SG-WTP.

It is suggested that the canals leading towards the water treatment plants should be properly fenced to avoid the grazing of animals. Pre-chlorination should be done in order to discourage the growth of fungi and bacteria in the plants, and de-sludging pumps should operate round the clock in both the plants. Regular monitoring of the water quality is required to ensure the provision of safe drinking water to the community. It is further recommended that a study should be conducted on the efficiency of different coagulant dosage in terms of turbidity removal by both the plants and specifically, for the up-gradation of SM-WTP.

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