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SUSTAINABLE DEVELOPMENT OF WATER RESOURCES, WATER SUPPLY AND ENVIRONMENTAL SANITATION

Performance Evaluation of Drinking Water Treatment Plants in Kampala – Case of Ggaba II

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Kampala water treatment plant (Ggaba II) was evaluated in terms of performance, design, operation and maintenance. The evaluation was done across the dry and wet seasons, measuring physical-chemical parameters. Receding water level of Lake Victoria combined with poor quality of water at the intakes affected the supply of water in Kampala and the neighbouring districts. There was considerable increase in the colour of about two fold at the intake works during the period 1997 to 2005 with increased chemical usage to achieve acceptable standards. The conditions of operation and maintenance were also found to be deficient with some design and construction problems as well. The annual mean colour of the finished water was found to be significantly above the National standard value of 15 Ptu with 53.4% of samples not compliant. 21.6% and 9.3% of the samples taken were not compliant with the WHO pH and turbidity values respectively.

Introduction

KAMPALA is the capital city of Uganda, a landlocked multilingual East African country lying within the latitude of 1° South and 4° North and longitude of 29.5° and 35° East of Greenwich. Kampala has a resident and daily transient population of about 1.2 million and 2.5 million respectively with a population growth rate at 3.9% (Population Census, 2002).

Drinking water supply in Kampala is the responsibility of the National Water and Sewerage Corporation (NWSC). Water supplied to Kampala City is treated at two water treatment plants, Ggaba I and Ggaba II, located about 11 Km South East of Kampala, at the shores of Lake Victoria. The Kampala water service area goes beyond the political boundaries of Kampala district to include parts of Wakiso District (Kira Sub-county, Kyengera, Nansana, Kajjansi and part of Makindye) and now Mukono resulting in a tremendous increase in the water demand. Due to this demand, another water treatment plant, Ggaba III is under construction with a design capacity of 80,000m^3/day and Ggaba IV will follow in the future. Raw water is abstracted from the Inner Murchison Bay (IMB) (Figure 1).

Variation in water level of Lake Victoria combined with poor quality of water at the intakes has affected the supply of water in Kampala and the neighbouring districts. The catchment of the IMB receives contaminated water from the city drainage system, which, because of low sanitation coverage, contains significant pollutant material. The original extensive wetlands that fed into the IMB and which provided some removal of contaminants are becoming rapidly degraded (Tibatemwa, 2002). The wastewater treatment works at Bugolobi discharges into the IMB through Nakivubo channel/ wetland and there is growing industrial and commercial development with associated untreated discharges. The catchment also includes agricultural and local fishing, with Ggaba fishing village being one of the major pollutant contributors to the Bay. The receding lake level has exposed the intakes thus affecting both extraction capacity and water quality. Similarly the deteriorating raw water quality has resulted into increased chemical usage for water treatment. To detect the main problems and to improve operations of the plants, evaluation was done of Ggaba II water treatment plant.

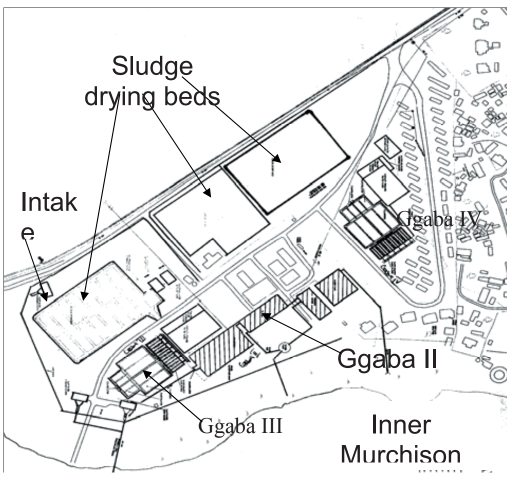

Figure 1. Kampala water treatment works

Materials and Methods

In the assessment of the Ggaba II plant, the different treatment stages were evaluated on the basis of design criteria, treatment effectiveness, operation and maintenance conditions. For the plant performance, one-year (2005) data was used. Samples were taken at points 1, 2, 3, and 4 for raw, clarified, filtered and final treated water respectively (Figure 2). The service water samples were taken from the backwash water tank. The water quality parameters measured for raw water were pH, free and total chlorine, colour and turbidity. Colour was used as a surrogate parameter for organic matter. All analyses were done following the Standard Methods for Analysis of Water and Wastewater (2000). Colour and turbidity were measured using DR 4000 spectrophometer. The results were compared with both the WHO and National guidelines. The media size distribution was obtained by sieve analysis in accordance with procedures laid down in BS 1377(1990).

Results and Discussion

Design and Operation of Ggaba II plant

The selection of the treatment process train is influenced among others by the ability to meet final water quality objectives, considering both seasonal and long-term changes in raw water, and hydraulic requirements. Conventional water treatment is used at the plant (Figure 2). The water undergoes settlement, clarification (coagulation, flocculation and sedimentation), rapid gravity sand filtration and disinfection. The design capacity of all treatment plants (Ggaba I and II) is 117,270 m^3/day while the average total production is 113,907 m^3/day, 97% of the design capacity. This indicates that the plants are all operating at almost their full design capacity. The design capacity of Ggaba II is 80,000 m^3/day with an average production of about 70,252 m^3/day. Ggaba 1 water works were refurbished resulting in the increase of water production from 30,000 to 65,000 cubic metres per day with modifications to the clarification process. However, with this production, only 67% of the target population of 1,302,138 is served. There is normally a sharp rise in demand during the peak hours of the day and to meet this demand, the clarification stage at both plants is always by-passed. The unaccounted for water lost within the distribution system is 37.2%. Although Ggaba III is under construction to help meet the demand and there are plans to shift the intake works away from the shore to deep in the lake, there are challenges of changes in the raw water quality that have not been given much attention.

The clarifiers with retention time and overflow rate of about 2 hours and 2.4 m/hr respectively are bypassed during cleaning or to increase the throughput at periods of high demand. The filters are single media rapid gravity sand filters with a design filtration velocity of 9.1 m/hr and are operated manually because the automatic system failed as soon as the plant was commissioned. The filter run ranges from 8 – 24 hours depending on the quality of the incoming water and state of the filter media. The backwash cycle lasts for 30 to 45 minutes compared to 8 to 15 minutes reported in the literature (Quasim, *et al.,* 2000). The elevation of the lip of the trough was raised by 200mm from the original design height of 100mm to avoid excessive loss of filter media. However, this resulted into ineffective backwashing, as the dirt cannot easily be removed during backwashing. The size and depth of sand were not correct when replacing the media and loss of media due to excessive backwashing has worsened the situation. The average effective size (ES), uniformity coefficient (UC) and depth were 0.76, 2.48 and less than 50 cm respectively. Recommended values for rapid gravity sand filters are 0.45 – 1.0 for ES, 1.2 – 1.7 for UC and 50 – 150 cm depth (Quasim, *et al.,* 2000). There is therefore need to re-sand the filters with proper media size and depth.

Performance of the Ggaba II treatment plant

Data analysed showed that there was a significant change in the raw water quality (at 5% significant level) during the period 1997 - 2005 (Figure 3) with an increase of about two fold at the intake works. Between 1997 and 2005, the annual mean colour increased from 64.2 Ptu to 146.6 Ptu probably due to pollutants from the catchment brought by runoff into the IMB. Between 2001 and 2005, the colour continued to increase despite a declining trend in rainfall. The rainfall steadily decreased from about 1730mm in 2001 to about 950mm in 2005. Therefore the rise in colour

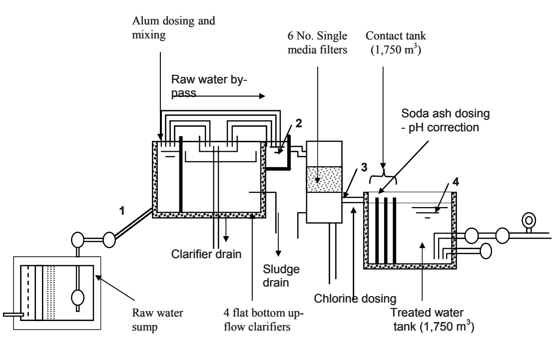

Figure 2. Ggaba II Plant process units

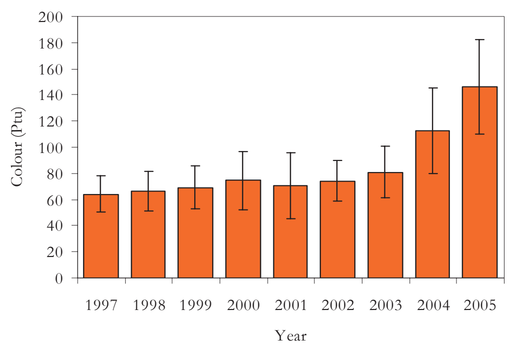

Figure 3. Mean annual daily colour

during this period was probably due to the concentration effect during the dry periods, increase in the algal bloom and organic matter.

Apart from water quality changes, other problems in the drinking water treatment plants are related to operational and maintenance procedures. Table 1 indicates the water quality of the treated water. The colour of treated water increased with increase of colour of raw water. Figure 4 indicates the water quality trend when the clarifiers were by-passed and Figure 5 when they were in operation. The clarification process is effective in reducing colour. However, in all cases, the colour of the water increases in the subsequent treatment stages. This indicates an operational or design problem of the subsequent units. The annual mean colour of the final water was found to be significantly above the National guideline value of 15 Ptu. High colour and turbidity could also indicate a high propensity to produce by-products from disinfection processes (WHO 2004) and inadequate protection of water in distribution against contamination.

The water quality continues to deteriorate after the filtration stage. This is probably due to overloading of the filters during by-pass with the aim of increasing the treatment plant output and inadequate media size and depth. Algal growth within the filters was also evident. High population of algae and plankton are difficult to coagulate and usually float (Quasim *et al.,* 2000). Carryover of flocs from the clarifiers probably also contributed to the poor performance of the filters. The bleeding of sludge was found to be inadequate because the bleeding system is located on one side of the clarifiers.

In addition, due to the high day temperatures, the sludge blanket is raised so high causing a lot of carryover to the filters. There are also shrimps in the clarifiers that disturb the sludge blanket thus giving rise to increased carryover of flocs or sludge particles into the filters. All these result in the reduction of filter runs necessitating more frequent backwashing.

The high colour and turbidity in the filtered water would result in the formation of trihalomethanes during the subsequent chlorination process and inadequate disinfection. Trihalomethanes have been reported to exhibit a potentially carcinogenic activity (Chang *et al.,* 2000; Letterman, 1999; Singer *et al.,* 1999). The colour/ organic matter is also known to give rise to growth of biofilms, which act as food to micro-organisms within the water distribution system. Therefore, although the final water leaves the plant free from disease causing organisms, the residual chlorine may react with the remaining colour in the final water within the distribution system leaving it less protected against re-contamination.

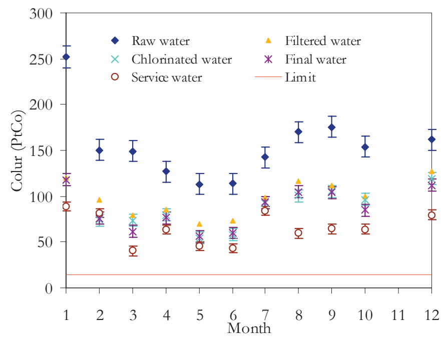

Figure 4. Performance of Ggaba II WTP without the clarification stage

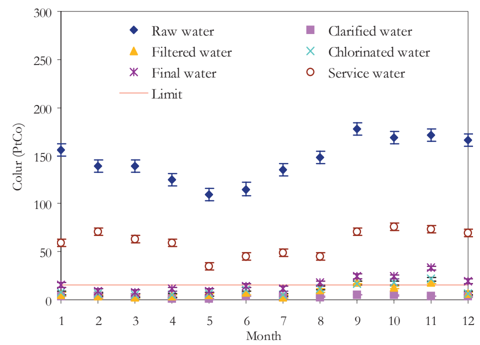

Figure 5. Performance of Ggaba II WTP with the clarifiers in operation

Table 1. Final water quality at Ggaba II water treatment plant

Parameter	Samples	Mean (Std)	% Not Compliant
pH	357	6.65 ±0.29	21.6
Colour (PtCo)	357	31.91±33.72	53.4
Turbidity (NTU)	357	2.36±2.08	9.3
EC (µS/cm)	357	144.73 ±19.87	0.0
Free Cl_2 (mg/l)	357	1.11±0.30	0.0*
Total Cl_2 mg/l)	357	1.29 ±0.33	-

* Based on required minimum residual chlorine of 0.2 mg/l

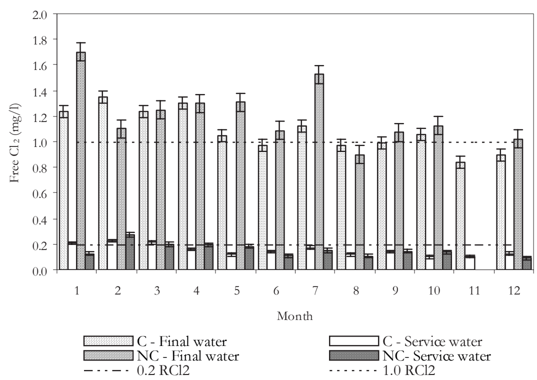

Figure 6. Free chlorine residual

The high consumption of the residual chlorine within the plant premises and distribution reservoirs is a good indication (Figure 6) that water might reach the furthest consumer point without enough residual chlorine. Free chlorine in the three distribution reservoirs at Muyenga, Naguru, Rubaga and Mutungo were 0.45, 0.15, 0.15 and 0.10mg/l while the corresponding total chlorine concentrations were 0.80, 0.55, 0.50 and 0.45 mg/l respectively.

Conclusion

There was a significant change in the raw water with an increase in the colour of raw water of about two fold at the intake works for the period under consideration. There is therefore need to control the water quality right from the catchment if water quality measures and planned plant modification are to be sustainable.

The operation and maintenance procedures of treatment plant were inadequate and are major factors affecting the performance of the plant although there is also need to modify the clarifiers and filter units to be able to handle the deteriorating water quality and increasing water demand.

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