Available online at www.elixirpublishers.com (Elixir International Journal)

Applied Chemistry

ISSN: 2229-712X

Elixir Appl. Chem. 87C (2015) 35812-35815

Performance Evaluation of Barekese Water Treatment Plant, Kumasi, Ghana

Raphael Kwaku Klake[1,*], Philip Dwamena-Boateng[2] and Cornelius Kwame Akpabli[1]

[1]School of Physical and Mathematical Sciences, Chemistry Department, University of Ghana, Legon, Ghana.

[2]GhanaWater Company, Ltd, P.O. Box 41, Ho, Ghana.

ARTICLE INFO

Article history:

Received: 27 August 2015;
Received in revised form:
13 October 2015;
Accepted: 17 October 2015;

Keywords

Water treatment plant,
Contaminants,
Faecal coliforms,
Performance evaluation.

ABSTRACT

The performance of the Barekese Water treatment plant situated near Kumasi in Ghana has been evaluated. The raw water that feeds the plant was found to be weakly acidic (pH 6.4), high in turbidity (14.8 NTU) and high in iron content (2.7 mg/L). The values however reduced tremendously in the final treated water. With the exception of acidity which decreased only marginally (pH 6.6), turbidity decreased to 0.8 NTU and the concentration of iron was below the detection limit. The results of the study suggest the water treatment plant performed well in terms of reducing the levels of some other contaminants to levels below the WHO guideline limits. The water treatment plant was also able to reduce the faecal coliform levels to zero which is within the WHO permissible limits.

Introduction

Water, apart from air, is the most important substance for the sustenance of life. The relevance of water as a resource needed to improve the social well-being of a people and for national development cannot be over-emphasized. It is for this reason that the quality and quantity of water supplied to a community are critical in determining its health status, standard of living and level of development [1, 2].

The purpose of water treatment is to purify the water and to make it suitable for human consumption through the removal of taste, smell and excess dissolved metals as well as killing of pathogens in the water [3]. A potable water supply system usually comprises of a water source, treatment, transmission or transportation of the potable water to a community, a network of pipes and appurtenances (valves, hydrants, meters, reservoirs) which is known as the distribution system that conveys potable water to the consumers in the required quantity and quality at a satisfactory pressure. The water transmission system is made up of large diameter pipes that transport water from the treatment plant to the community for distribution. The distribution network consists of small to medium sized pipes usually laid along the sides of the road to allow households tap water using their service lines [4]. It is also important that the treated water meant for distribution meets the WHO standards for potability.

During the transportation of water from the treatment plant to the customer, a variety of physical, chemical and biological transformations can occur as the water travels through the distribution system [5,6,7].The deterioration of water treatment facilities and distribution systems can allow microorganisms to attach themselves to pipe surfaces, producing a complex microbiological environment known as biofilm. Biofilms offer a favorable environment for microbial growth resulting in the proliferation of macro invertebrates. Some of these undesirable water quality changes result in taste and odor problems due to improper and unreliable treatment [8]. In this experiment, the emphasis is on the efficiency of the plant which is a major player as far as the quality of the water supplied to the customer is concerned.

Ghana Water Company Limited (GWCL) is responsible for the provision, installation of treatment plant, distribution and management of urban water supply in Ghana. The Kumasi Water Supply System (KWSS), managed by GWCL, is involved in the abstraction of water from the Ofin River to the Barekese and Owabi Head works in the Ashanti Region of Ghana. Here, the water is purified and subsequently distributed to the Kumasi metropolis.

Some inhabitants of the area served by the Plant belong to the low income group. The protection of the customer from high cost of water and public health threats which may result from undesirable water quality due to improper and unreliable treatment calls for a low cost but highly efficient treatment plant. High concentration of iron in River Ofin has led to high cost of treating the water resulting in high cost to consumers. The Barekese treatment plant was rehabilitated in 2010 with the aim of improving the treatment processes as well as increasing its production capacity. Yet, there were occasional complaints from consumers as a result of color and deposits in the treated water supplied from the plant. The regular monitoring of the quality of water being treated by a water purification system and the performance evaluation of its unit operations and processes is very essential to the health of the consumer [9]. The main objective of this study is to determine whether the new design is able to remove most contaminants especially iron, from the treated water

Materials and methods

Sampling

A total of twelve water samples were collected from the Barekese Headworks at four different points. Raw water samples (labelled A) were taken from the Ofin river; settled water from clarifier (labelled B); filtered water from the filter gallery as filtrate (labelled C) and final treated water from reservoir tank from where water is pumped for distribution (labelled D). In all four samples were taken monthly totalling twelve water samples for the sampling period. The sampling was carried out in the middle of the month for three months January, February and March, 2014.

Tele: +233207523076
E-mail addresses: rkklake@gmail.com

1.5 litre plastic sampling bottles were soaked in 10% HNO_3 for 24 hours and rinsed several times with de-ionized water prior to use. At the sampling locations, the bottles were thoroughly rinsed with aliquots of the water to be collected prior to collection. On-site analyses were carried out for parameters like pH, color, turbidity and conductivity. The samples were labelled as raw water (A), settled water (B), filtered water(C) and treated water (D). The collected samples were preserved in an ice chest and taken to the Suame laboratory in the Kumasi Township for the analysis of other parameters.

Analytical Procedure for Physico-Chemical Parameters

The raw water, settled water, filtered water and treated water were analyzed for pH, Turbidity, Color, Conductivity, Chloride, Iron and Faecal coliform. The data quality was checked by careful standardization, procedural blank measurements, using spiked and duplicate samples.

Analyses of Samples

Physico-chemical parameters

pH was measured with the Horiba Compact B-122 and Conductivity was measured using Inolab 7300 Conductivity/TDS portable meters respectively. Color, turbidity and iron were also measured by spectrophotometry using Hach DR/2500 following Standard Methods [11]. Alkalinity and chloride measurements were performed by Titration Methods [11].

Bacteriology

Faecal coliform (E-coli) was measured with the Traditional Multiple Tube Fermentation method proposed in Standard Methods [11]. All equipment used were first pre-sterilized using an autoclave and 95% ethanol.

Quality Assurance and Control

A quality control standard was run routinely during the sample analysis to monitor instrument drift and overall quality of the analysis.

Results and Discussion

pH

pH is an important indicator of water quality. The pH of water affects the solubility of many toxic and nutritive chemicals. Low pH levels are objectionable because of the corrosive effect it has on metal pipes and fixtures. Low pH can also cause leaching of lead from solder used at the joints of copper pipes in older homes and of lead from brass plumbing fixtures. Metallic taste is frequently associated with water of low pH. High pH levels decrease the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact times. pH values less than 6.5 is as a result of coagulant added to the raw water to aid the coagulation and flocculation processes. The pH values of the raw water samples ranged between 6.3 and 6.4 for the raw water and 6.5 and 6.7 for the treated water for distribution as shown in Table 2 and illustrated graphically in Figure 1 below. The pH of the treated water is within the WHO permissible limit shown in Table 1.

Table 1. Parameters analysed and their WHO guideline values [10]

Parameter	WHO Maximum permissible limit
pH	6.5-8.5
Color	15 Pt-Co (max)
Turbidity	5 NTU (max)
Conductivty	1000 (µS/cm) (max)
Chloride	250 mg/L (max)
Iron	0.3 mg/L (max)
Faecal Coliforms	0 MPN/100 ml (max)

Table 2. pH of water samples at various stages of the treatment process

SAMPLE TYPE	pH		
	JAN	FEB	MARCH
A	6.3	6.4	6.4
B	5.8	5.9	5.9
C	5.7	5.7	5.9
D	6.7	6.5	6.5

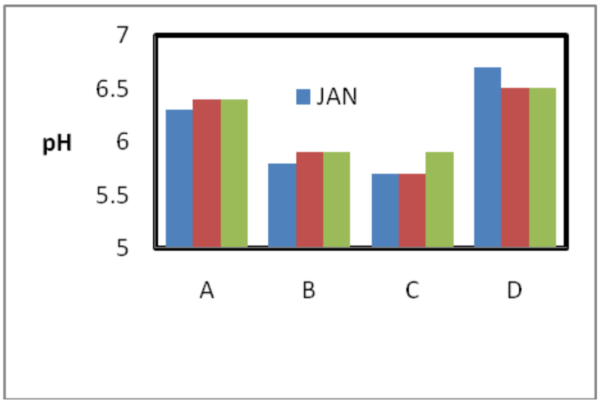

Figure 1. pH of water samples at various stages of the treatment process

Color

Drinking-water should ideally have no visible color. Color may be indicative of large quantities of organic chemicals, inadequate treatment and high disinfectant demand. While color itself is not usually objectionable in the case of health, its presence is aesthetically objectionable. The high color value recorded for the raw water samples might be due to iron and organic matter from decaying vegetation. The color recorded for the raw water ranged between 150 and 200 Pt-Co and between 5 Pt-Co for the treated water (Table 3 and Figure 2.). The color of the treated water is within WHO permissible limit for drinking water Table 1. The results indicate that the treatment plant was able to reduce the color to values below the WHO permissible limit. This represents about 97 % reduction in color.

Table 3. Color of water samples at various stages of the treatment process

SAMPLE TYPE	COLOR (Pt-Co)		
	JAN	FEB	MARCH
A	170	200	150
B	15	20	20
C	5	5	10
D	5	5	5

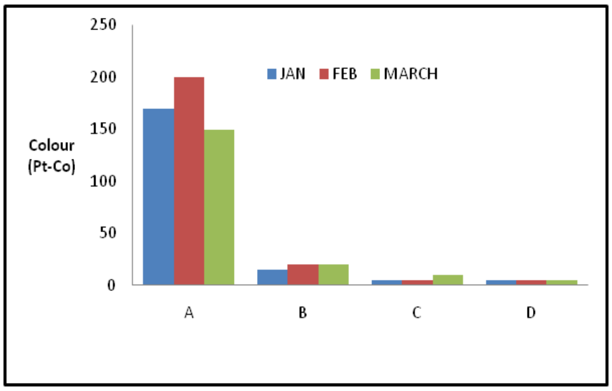

Figure 2. Color of water samples at various stages of the treatment process

Turbidity

Table 4. Turbidity of water samples at various stages of the treatment process

SAMPLE TYPE	TURBIDITY (NTU)		
	JAN	FEB	MARCH
A	13.2	19.2	12.1
B	4.0	3.2	3.2
C	0.7	0.9	1.0
D	0.9	0.4	1.2

The measured turbidity for the water samples are shown in Table 4 and illustrated graphically in Figure 3. The turbidity of the raw water is (between 12.1 and 19.2 NTU). High turbidity levels could be a strong indication of the existence of suspended or colloidal particles in the water. Through the treatment processes in the plant, turbidity drastically reduced to (between 0.4 and 1.2 NTU) for the final treated water samples. This is below the WHO maximum permissible limit shown inTable 1.

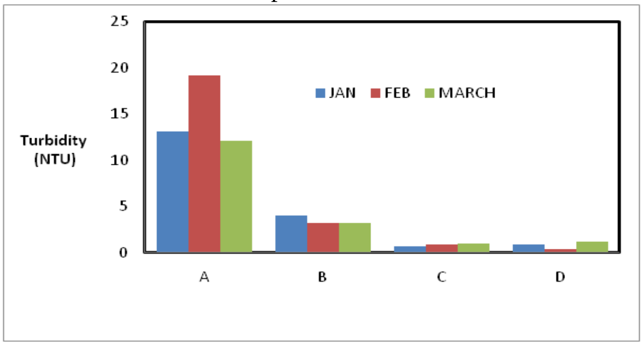

Figure 3. Turbidity of water samples at various stages of the treatment process

Electrical Conductivity (Ec)

Results of the measurement of Conductivity of the water samples are shown in Table 5 and illustrated graphically in Figure 4. Conductivity values of the samples ranged between 102.1 and 104.6 µS/cm for the raw water to between 150.1 and 161.1 µS/cm for the treated water. The increased conductivity observed in the settled water during the treatment can be attributed to the addition of Alum which in this case is Aluminum Sulphate $(Al_2(SO_4)_3$ at the coagulation and flocculation stage. The decrease in conductivity observed in the filtered water can be attributed to the reduction in the concentration of ions as a result of the filtration process which removes flocs. The increase in conductivity observed in the treated water can be as a result of the addition of calcium hydroxide to adjust the pH and addition of chlorine after the filtration stage to disinfect the water. Conductivity is directly related to the concentration of ions in water. Hence, a higher conductivity indicates a higher concentration of ions in the water [12]. In spite of the fact that there is little direct health risk associated with this parameter, high values can lead to poor taste of the water resulting in customer dissatisfaction and complaints. The conductivity of all the samples are low and within allowable WHO maximum permissible limits for drinking water.

Table 5. Conductivity of water samples at various stages of the treatment process

SAMPLE TYPE	CONDUCTIVITY (µS/cm)		
	JAN	FEB	MARCH
A	104.2	102.1	104.6
B	124.6	128.4	123.1
C	118.3	120.0	120.6
D	161.1	158.4	150.1

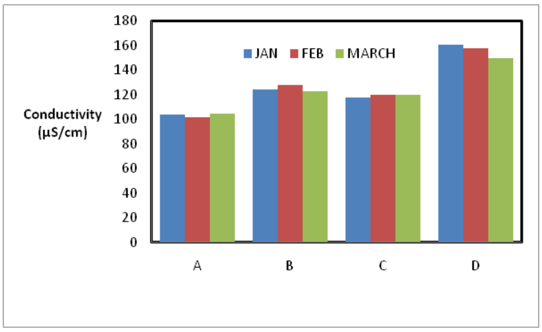

Figure 4. Conductivity of water samples at various stages of the treatment process

Chloride

Chloride concentrations determined for the various water samples are between 28.0 and 34.0 mg/L for raw water and 28.0 and 40.0 mg/L for the treated water as shown in Table 6 and illustrated graphically in Figure 5. The chloride levels in the treated water were higher than in the raw water due to the introduction of hypochlorite to disinfect the water. The levels in all the water samples were within WHO maximum permissible limit.

Table 6. Chloride concentrations of water samples at various stages of the treatment process

SAMPLE TYPE	CHLORIDE (mg/L)		
	JAN	FEB	MARCH
A	34.0	28.0	30.0
B	24.0	30.0	34.0
C	24.0	31.0	36.0
D	28.0	34.0	40.0

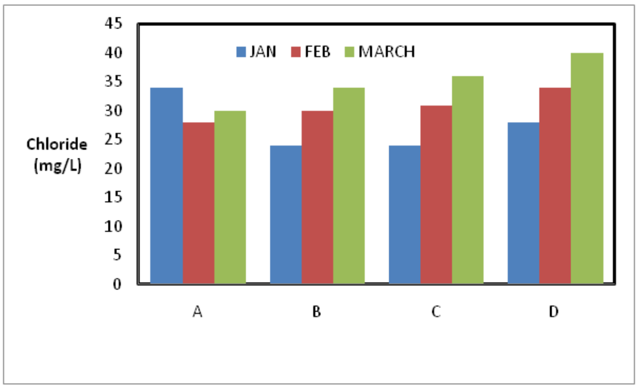

Figure 5. Chloride concentrations at various stages of the treatment process during the sampling period.

IRON

The concentration of iron determined in the water samples are shown in Table 7 and plotted in Figure 6. The mean iron concentration was between 2.8 and 3.2 mg/L for the raw water and between 0 to 0.02 mg/L for the treated water. While the raw water had iron concentration above the WHO permissible limit, iron concentration measured for the treated water was found to be below WHO maximum permissible limit for drinking water considering the limit of experimental error. High Iron concentrations if allowed to reach the consumer can cause staining to plumbing fixtures, dishware and clothes. High iron concentration by imparting color to water can also make it undesirable for domestic use [13]. High iron concentration in the settled water results in frequent backwashing of the filter since iron precipitate tends to clog the filter media during the filtration process. This will result in the reduction of the number of times a filter will be used before backwashing is done.

Table 7. Iron concentrations at various stages of the treatment process

SAMPLE TYPE	IRON (mg/L)		
	JAN	FEB	MARCH
A	2.8	3.2	2.0
B	0.7	0.9	0.8
C	0.1	0.05	0.1
D	0.02	0.01	0

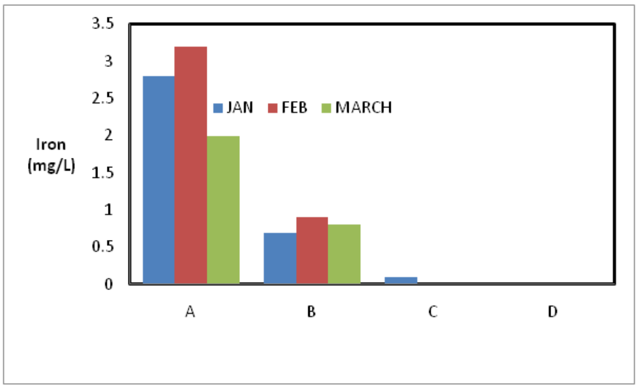

Figure 6. Iron concentrations of water samples at various stages of the treatment process

Faecal Colifoms

Results of faecal coliforms are presented in Table 8.The results indicate that there was a high level of faecal coliforms in the raw water. However, the final treated water for distribution contained no coliforms. This is indicative of the fact that the disinfection process was effective. The bacteriological quality of water was within the WHO maximum permissible limit of zero.

Table 8. Feacal Coliform Levels of water samples at various stages of the treatment process

SAMPLE TYPE	FAECAL COLIFORM BACTERIA (MPN/100ml)		
	JAN	FEB	MARCH
A	>16	>16	>16
B	5.1	2.2	0
C	0	0	0
D	0	0	0

Conclusion and Recommendations

From the results obtained in the analyses, parameters like pH, conductivity, and chloride were all below the WHO maximum permissible limits in the raw water and the treated water for distribution. The other parameters namely turbidity, iron and faecal coliforms were all above the WHO maximum permissible limits for the raw water but dropped to below the WHO maximum permissible limits in the treated water for distribution. It can therefore be concluded that the Barekese treatment plant is effective in reducing the concentration of iron in the raw water from between 2 mg/L to 3.2 mg/L to practically nil in the treated water. Faecal coliform were also completely eliminated from the raw water.

References

[1] UNCED (Protection of the Quality and Supply of Freshwater Resources: Application of Integrated Approaches to the Development, Management and Use of Water Resources. The United Nations Conference on Environment and Development Chapter 18, Agenda. 1992.

[2] Falkenmark, MGlobal Water Issues Facing Humanity, in Journal of Peace Research, 1990. 177-190.

[3] Mohammed, A. A., Shakir, A. A. International Journal of Advances in Applied Sciences (IJAAS) 2012;Vol.1, No.3, , 130~139.

[4] Umar Mohammed Water Quality Deterioration In Piped Water And Its Effect On Usage And Customers' Perception: Case Study Of Adum- Kumasi, Ghana. B.Sc Thesis KNUST Kumasi. 2012.

[5] Rodriguez. M. J. and Se•rodes. J. B. Spatial and temporal evolution of trihalomethanes in three water distribution systems. Water Res., 2001; 35: 1572¬1586.)

[6] Powell, J. C., Hallam, N. B., West, J. R., Forster, C. F., Simms, JFactors which control bulk chlorine decay rates. Water Res., .2000; 34:117–126.

[7] Lahlou, Z. M. Water quality in distribution systems. Tech Brief. A national drinking water clearinghouse fact sheet. West Virginia University Lerk 2002.

[8] USEPAhttp://water.epa.gov/drink/contaminants/secondarystandards.cfm Accessed 30/06/2015;2008.

[9] Ali, A, Hashmi, H. N, Baig, N., Shahid Iqbal1, Khurram S.I., Performance evaluation of the water treatment plants of Islamabad – Pakistan Arch. Environ. Sci., 2012;. 6, 111-117

[10] WHO Guidelines for drinking water quality. Health criteria and other supporting information. Geneva: World Health Organization. Vol. 2 1998..

[11] APHA and AWWA. Standard methods for the examination of water and wastewater. 20th edition. American Public Health Association, New York.1998..

[12] Hach Company. Water Analysis Handbook. 2nd. ed. Hach Company. Loveland, Colorado, USA 2000. P.829.

[13] Bertram, J., Balance, R.. A practical guide to the design and implementation of fresh water. quality studies and monitoring programmes. Published on behalf of UNEP and WHO, E & R' spoon publishers 1996 pp 172-177