PHYSICOCHEMICALAND HEAVY METAL ANALYSIS OF RAW, TREATED WATER AND SLUDGE SAMPLES FROM A TREATMENT PLANT IN SOKOTO, NIGERIA

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Abstract: Access to safe drinking water is still a major challenge globally, especially in developing countries. The assessment of water quality is largely determined by the physicochemical parameters as well as organic and inorganic compounds that are either dissolved or suspended in it. The physicochemical and heavy metal concentrations of rawtreated and sludge water samples from a treatment plant in Sokoto, North West Nigeria were analyzed. The raw water was collected at the raw water intake along Kware road in Sokoto (10 km North-West of the treatment plant) latitude 13^o 13$^{'}$ 10.347" N and longitude 5^o 15' 52.293" E while the sludge and treated water was collected at the sampling points within the treatment plant. The physicochemical parameters were determined using standard analytical procedures for water analysis while the heavy metal contents were analyzed using atomic absorption spectroscopy (AAS). The samples showed a slightly acidic pH ranging from 5.30 – 6.43 while the levels of dissolved oxygen (DO) and biochemical oxygen demand (BOD) ranged from (3.13 – 4.10 mg/L) and (15.50- 17.97 mg/L), respectively, with raw water having the highest. The total content of HCO^{3-} ,Cl^-, Na, K, Ca, Mg, PO_4^{3-} and SO_4^{2-} in all the samples were within the specified limit set by the World Health Organization. Carbonates and copper were not detected in all the samples. Manganese and Iron concentration in the three samples as well as lead concentration in the raw water sample was above the permissible limits. These findings infer that the treatment procedures adopted by the water treatment plant is efficient as most of the parameters considered were within the permissible limits.

Keywords: Physicochemical parameters, heavy metals, sludge, raw and treated water

Introduction

Water is the most essential element of all natural resources (Adeyemi *et al.,* 2015). The acceptability of water for any purpose is defined by the type and level of impurities it contains. For instance, drinking water is considered safe if it contains impurities at concentrations within permissible limits of a given standards such as WHO standards and the Nigerian Standard for Quality Drinking Water (NSQDW). The suitability of water for other purposes such as agricultural and industrial purposes also depends on the type and level of impurities (Sharma and Sharma, 2000). Unfortunately, clean water sources are at great risk as contamination threatens existing supplies while emerging hazards are being recognized each year. Access to safe drinking water is still a major challenge worldwide especially in developing countries (Adeyemi *et al.,* 2015). According to the World Health Organization (WHO) report on access to drinking water and sanitation, it is estimated that about 663 million people are living without access to adequate and improved water supplies out of which 319 million live in Sub-Saharan Africa (WHO, 2015; UNICEF, 2015). Water pollution continues to be one of the major environmental problems globally. Indiscriminate dumping and discharge of solid and liquid wastes such as refuse industrial and agricultural runoffs, sewage and crude oil spills into water bodies have been identified as main sources of water contamination (Adejo *et al.,* 2013).

Heavy metals area group of metals with density usually greater than 5 g/cm^3. They are found mostly in group III-V of the periodic table. They cannot be degraded and could enter the human body via inhalation, ingestion and skin absorption. Most heavy metals have no beneficial function in the body and can be highly toxic (Expo *et al.,* 2008). They accumulate in soils and sediments of water bodies if released into the environment (Singh *et al.,* 2011). Heavy metals linked mostly to human poisoning include lead, iron, cadmium, copper, zinc, chromium. Some of the harmful effects of heavy metal toxicity in drinking water include; brain damage, irregularities in blood composition, affects vital organs such as the kidney and liver (Mohod and Dhote, 2013).

Literature search revealed that no study has been conducted to assess the quality of water samples from the New Extension treatment plant. This research is aimed at carrying out physicochemical, biochemical and heavy metal analysis onraw, treated and sludge water samples from the treatment plant in Sokoto State.

Materials and Methods

Chemicals and reagents

All chemicals and reagents used for the study were of analytical grades and purity (98 – 99 %) while sulphuric acid (H_2SO_4), nitric acid (HNO_3) and perchloric acid ($HClO_4$) were obtained from Sigma-Aldrich. Atomic absorption spectrophotometer (AAS) AA240FS Varian (GBC scientific England) was the major equipment used.

Sample collection

The sampling was carried out in the month of July, 2016. The samples were collected from appropriate units of the Sokoto water extension treatment plant.The raw water was collected at the raw water intake along Kware road in Sokoto(10 km North-West of the treatment plant) latitude 13^{o}13$^{'}$ 10.347" N and longitude 5^o 15' 52.293" E while the sludge andtreated water was collected at the sampling points within the treatment plant. Each of the three sampleswas collected in a 1 liter plastic container. The sample bottles were initiallywashed and rinsed thoroughly with detergent and distilled water after which they were soaked in 10% HNO_3 for 24 h. The bottles were finallyrinsed with distilled water prior to usage. Before sampling, the bottles were rinsed with the water samples before being filled with the sample.

Physicochemical and biochemical analysis

The physicochemical and biochemical properties of the water samples were analyzed using the methods described in the standard methods for the examination of water and waste water (APHA, 2005) and standard methods for water and effluent analysis (Ademoroti, 1996b).

Heavy metal analysis

Digestion of the Samples

The water samples were digested by transferring 100 cm^3 into a Kjeldahl flask and 5 cm^3 of freshly prepared HNO_3, 15 $cm^3$of conc. H_2SO_4 and 0.3 cm^3 of $HClO_4$ was added. The solution was stirred and heated on a hot plate for 2 h. The mixture was digested in a fume cupboard, heating continued until a dense white fume appeared which was then ingested for 15 min, allowed to cool and filtered into a 100 cm^3 volumetric flask. The filtrate was diluted to the mark with distilled water (Ademoroti, 1996b; Yusuf *et al*., 2015).

Determination of Pb, Cu, Mn and Fe using atomic absorption spectroscopy

Atomic absorption spectrophotometer (AA240FS Varian) was set up according to the instructions in the manual. The digested sample solution was placed in a 100 cm^3 volumetric flask and made up to 100 cm^3. Three concentrations of standard solution of a particular metal to be analyzed were selected; blank solution was aspirated and adjusted to zero. Each standard solution was aspirated into flame, calibration curve for absorbance versus concentration of each standard solution was prepared and the reading of the prepared samples solutionwas obtained using the hollow cathode lamp for the respective elements at the proper wavelength and slit width (0.5 nm) (AOAC, 2005). The flame type used for all the metals was air-acetylene.

Results and Discussion

The physicochemical and biochemical parameters of the water samples are presented in Table 1 while the heavy metal concentrations in the samples are presented in Table 2.

pH is one of the most important operational water quality parameter. Extreme pH is said to affect the palatability of water and cause corrosive effect on pipes used in household water systems (Adetoyinbo *et al.,* 2015). Failure to minimize corrosion can result in the contamination of drinking water and have adverse effects on its taste and appearance (WHO, 2011). The result of the pH determination implies that all the water samples were slightly acidic. The pH values range from 5.30-6.43 as against 6.5-9.5 permissible limit set by the WHO. The pH value of water sample is said to determine the solubility of trace and heavy metal, at low pH trace metals have the tendency to dissolve more (Mohammad *et al.,* 2007).

The level of dissolved oxygen (DO) in the three samples range from (3.13 – 4.10 mg/L). Raw water sample had the highest level of dissolved oxygen (4.10 mg/L). Low level of DO recorded indicates mild pollution of water sources due organic waste (Gupta *et al.*, 2011). DO levels decline if there is more consumption of oxygen than the production which could lead to the migration or death of sensitive aquatic life. DO playsan important role in the survival of aquatic life. A high DO level in a community water supply is desirable as it makes drinking water taste better (Adeyemi *et al.,* 2015). The dissolved oxygen content of water is influenced by the source, raw water temperature, treatment and chemical or biological processes taking place in the distribution system (WHO, 2011). The depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulphate to sulphide. It can also cause an increase in the concentration of ferrous iron in solution, with subsequent discoloration at the tap when the water is aerated (WHO, 2011).

Biochemical oxygen demand refers to the amount of oxygen that would be consumed if all the organic waste in one liter of water were oxidized by microorganisms such as bacteria and protozoa. It is a measure of the oxygen used by microorganisms to decompose waste.The biochemical oxygen demand (BOD) in the three samples range from 15.50-17.97 mg/L, this is above the 5.0 mg/L permissible limit set by the WHO. The high BOD levels explains why low levels of DO was recorded, this is because the available oxygen is being consumed by the decomposing bacteria (APHA, 2005).

Alkalinity is a measure of the acid neutralizing capacity of a water sample. It measures the presence of carbon dioxide, bicarbonates and carbonates naturally present in water. At normal drinking water pH levels, bicarbonates and carbonates are the main contributors to alkalinity (EPA, 2001). Carbonates are present in water only when the pH is greater than 8.5 which explain why carbonates were not detected in all the samples. The level of bicarbonate ranged from 0.63-1.27 mg/L. Calcium and magnesium carbonates are relatively insoluble therefore; high concentration of carbonates in water implies that the cations associated with them are likely sodium and possibly a small amount of potassium (CRI, 2006).

Chloride levels in all the samples range from (0.77-1.63 mg/L). These values are far below the permissible limit (250 mg/L) in drinking water. Chloride concentration in excess of 250 mg/L is likely to be detected by salty taste in water (WHO, 2011).

Hardness of water is usually associated with the level of calcium and magnesium which is indicated by precipitation of soap scum and the need for excess soap to achieve cleaning. The taste threshold for calcium ion was in the range of 100-300 mg/L depending on the associated anion while magnesium concentrations greater than 125mg/L may have a laxative effect on some people (WHO, 2011; Orewole *et al.*, 2007). Calcium (0.63-0.88 mg/L) and magnesium (0.37-1.18 0mg/L) concentration in the three samples were within the WHO acceptable limit.

The potassium (K) and sodium (Na) concentration in the samples varied from 1.97-4.43 and 2.93-3.43 mg/L, respectively whereas the permissible limit for K and Na as per WHO guideline is 50 and 200 mg/L, respectively. The concentration of these ions is within the permissible limit.

The concentration of sulphate in all the samples range from 1.51-49.38 mg/L with the treated water having the least while raw water had the highest concentration. This result conforms to the acceptable limit of 100 mg/L set by WHO which confirms the acceptability of these water samples in terms of their sulphate content. The presence of sulphate in drinking water can cause bitter taste, scale buildup in water pipes and very high levels of SO_4 can cause a laxative effect (WHO, 2011).

Phosphate levels in the samples was in the range of 0.17-0.13 mg/L. Treated water recorded the highest while raw water contained the least. The WHO permissible limit for phosphate in drinking water is 100 mg/L. Thus, all the samples were within the limit indicating that the samples are of good quality in terms of their phosphate content.

Lead was not detected in both sludge and treated water but was present in the raw water sample (0.076 mg/L). This value is above the permissible limit (0.01 mg/L) recommended by WHO and NSDQW. Adejo *et al.* (2013) reported similar elevated level of lead in borehole water. This implies that the raw water is contaminated with lead at an elevated level which is of health concern. This may be attributed to the geological composition of the area where the raw water intake is situated. Lead accumulates in aquatic biomass and is passed up the food chain to humans. It is known to interfere with Vitamin D metabolism. Pbaffects mental development in infants and it is toxic to the central and peripheral nervous system. It also damages the liver, kidneys and reproductive systems (Ademoroti, 1996a).

Table 1: Physicochemical analysis of the water samples

Parameter	Raw water	Sludge	Treated water
pH	5.30±0.00	6.67±0.06	6.43±0.06
DO (mg/L)	4.10±0.10	3.13±0.15	3.27±0.12
BOD (mg/L)	17.97±0.23	15.50±0.00	15.77±0.06
CO_3 (mg/L)	ND	ND	ND
HCO_3 (mg/L)	0.63±0.06	0.93±0.06	1.27±0.15
Chloride(mg/L)	1.63±0.15	1.23±0.15	0.77±0.06
Sodium (mg/L)	3.13±0.15	2.93±0.06	3.43±0.06
Potassium (mg/L)	4.43±0.12	3.03±0.06	1.97±0.06
Calcium (mg/L)	0.88±0.06	0.65±0.05	0.63±0.03
Magnesium (mg/L)	1.18±0.03	0.73±0.06	0.37±0.03
Phosphate (mg/L)	0.13±0.01	0.16±0.02	0.17±0.02
Sulphate (mg/L)	49.38±4.12	39.78±2.37	1.51±0.24

All values are mean values of triplicate determinations ±SD; ND=not detected

Table 2: Heavy metals analysis of the water samples

Parameter	Raw water	Sludge	Treated water
Lead	0.076±0.00	ND	ND
Copper	ND	ND	ND
Manganese	1.382±0.00	0.666±0.00	0.907±0.00
Iron	17.789±0.00	13.733±0.00	0.996±0.00

All values are mean values of triplicate determinations ±SD; ND=not detected

Manganese was present in all the samples analyzed. The range was between 0.666-1.382 mg/L with the raw water having the highest at 1.3818 mg/L. The concentration of Mn was higher than the 0.4 mg/L health based value for manganese. The presence of manganese in drinking water gives an undesirable taste and may lead to the accumulation of deposits in the distribution system (WHO, 2011).

The iron content ofthe samples is in the range of 0.996-17.789 mg/L, raw water sample had the highest concentration. These values are above the 0.3 mg/L limit by the WHO. There is usually no noticeable taste at iron concentrations below 0.3 mg/L, although turbidity and color may develop. Iron promotes the growth of "iron bacteria" which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on water pipes (WHO, 2011).

Conclusion

The physicochemical and heavy metal concentration of water samples from the treatment plant was analyzed. The parameters considered in this study were within permissible limits except for pH, Mn and Fe concentrations in all the samples and Pb concentration in the raw water sample which were above the WHO limits. The high levels of these metals could also be related to the acidity of the water samples which enhances their solubility. The high concentration of lead in the raw water could be attributed to thegeological composition of the area where the intake is situated. These findings infer that the treatment procedures adopted by the water treatment plant is efficient as most of the parameters considered were within the permissible limits. However, new trends in water treatment technology should be incorporated to enhance efficiency of the treatment methods. It is recommended that bacteriological analysis should be conducted on water samples from the treatment plant to further ascertain any possible contamination.

Conflict of Interest

None declared.

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