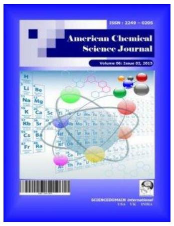

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Comparative Determination of Chromium, Iron and Lead in Tamburawa Treated and Raw Water Samples

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Authors' contributions

This work was carried out in collaboration between all authors. Author KJI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors IAV and IMO managed the analyses of the study. Author UFA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Chemical analysis of raw and treated water from the Tamburawa water treatment plant was conducted twice a week for six consecutive weeks using Spectrophotometric measurement, to determine the level of Cr, Fe, and Pb in the water. The result of the study showed that the concentration of Pb in the raw water (0.023±0.008 mg/L) and treated water sample (0.027±0.011 mg/L) exceeded the WHO permissible limit of 0.01 mg/L for Pb in drinking water. The concentrations of Fe (0.065±0.026 mg/L raw and 0.049±0.024 mg/L treated) and that of Cr (0.017±0.007 mg/L raw and 0.026±0.014 mg/L treated) were found to be within their respective threshold limit of (0.3 mg/L for Fe) and (0.05 mg/L for Cr) respectively set by the World Health Organization (WHO) for drinking water standard. It is concluded that treated Tamburawa water is not potable for drinking with regards to Lead (Pb) because its level exceeded its WHO permissible

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limit for drinking water standard. Furthermore, the treatment plant needs appraisal and upgrading regulations in order to improve the quality of water being supplied to the Kano metropolis.

Keywords: Raw water; treated water; WHO; Tamburawa; Kano metropolis.

1. INTRODUCTION

All life forms on earth depend upon water [1]. It is in fact the second important resources to human life after air. Man can survive longer without food than without water. Water is also needed for agriculture, manufacturing processes and domestic needs [1]. Water plays an important role in the world economy, as it functions as a solvent for a wide variety of chemicals and facilitates industrial cooling and transportation [2].

In the recent years, ground water contamination has attracted a lot of attention and has become an important environmental issue [3] and between the wide diversity of contaminants affecting water resources, heavy metals receive particular concern considering their strong toxicity even at low concentrations [4].

The problems of the ecosystem are increasing with developing technology; Heavy metals pollution is one of the main problems [5]. Toxic metal compounds coming to the earth's surface not only reach the earth's Waters (seas, lakes, ponds and reservoirs), but can also contaminate underground water in trace amounts by leaking from the soil after rain and snow. Therefore, the earth's waters may contain various toxic metals [6]. Heavy metals are often discharged by a number of industries, such as metal plating facilities, mining operations and tanneries; this can lead into the contamination of freshwater and marine environment [7]. There are demonstrated instances of chromium being released to the environment by leakage, poor storage or inadequate industrial waste disposal practices [8].

Heavy metals are non-biodegradable and can lead to accumulation in living organisms, causing various diseases and disorders [9]. It is a common knowledge that some metals are harmful to life, such as antimony, chromium, copper, lead, manganese, mercury, cadmium, etc., and are significantly toxic to human beings and the ecological environments [9]. High concentrations of heavy metals may accumulate in human body once they interrupt in human food chain and possibly cause severe health problems if the metals exceed the permitted concentrations [10]. Water contaminated with metallic effluent can cause several health problems. Lead for instance, can interfere with enzyme activities and formation of red blood cells. It can affect nerves and brain at low concentration. The greatest risk is to young children and pregnant women. Lead has been shown to slow down normal mental and physical development of infants and children. Heavy metals such as mercury, cadmium and chromium can accumulate through the food chain to toxic levels in man [11]. Chromium in excess concentration causes adverse dermatological effects over many years, such as allergic dermatitis (skin reactions) [8]. The Environmental Protection Agency cautions that although iron in drinking water is safe to ingest, the iron sediments may contain trace impurities or harbor bacteria that can be harmful [12]. Iron bacteria are naturally occurring organisms that can dissolve iron and some other minerals. These bacteria also form a brown slime that can build up in water pipes (which is the main source of iron in drinking water). Iron bacteria are most commonly problematic in wells, where water has not been chlorinated [12]. Iron is an essential element required for the circulatory system of the body and human nutrition, and the health effects of iron in drinking water may include warding off fatigue and anemia [13].

The quality of water and its effect are characterized by its physical and physico-chemical properties [1]. WHO has a drinking water standard of 50 micrograms per liter (μg/L) or parts per billion (ppb) for total chromium, which includes all forms of chromium including chromium (VI) [8]. The maximum concentrations of Iron and Lead permitted by Standard Organization of Nigeria for drinking water are 0.3 mg/L and 0.015 mg/L respectively [14].

Atomic Absorption Spectrometry (AAS), a widely used technique for quantification of metal species, has proved to be a powerful tool for trace element determination in a variety of materials in terms of the enhanced sensitivity, efficient matrix removal, high sampling frequency and low cost of equipment [1].

This research work is aimed at determining the level of Iron, Chromium, and Lead in the raw and treated water samples from the Tamburawa water works, with the objectives of making comparison between the concentrations of these heavy metals in both water samples in order to establish the efficiency of the treatment process and lastly, to compare the quality of the treated water with the recommended water quality by World Health Organization (WHO). The detection limits of the three metals are shown in Table 1.

Table 1. Detection limits of heavy metals for Buckmann model 4

Metals	Detection limit (mg/L)
Cr	0.0001
Pb	0.0004
Fe	0.0003

2. MATERIALS AND METHODS

2.1 Materials

In the preparation of the reagents, chemicals of analytical grade purity and de-ionized water were used. All glass wares were cleaned by immersion in 10% nitric acid overnight and then washed with a solution of non-ionic detergent, thereafter rinsed with water and then later rinsed with de-ionized water. The water samples (raw water and treated water) were collected twice in a week at an interval of three days and at a specific period from Tamburawa water treatment plant. The collection was done using a one Litre plastic container for each of the sample (raw water and treated water). During the sampling, sample bottles were rinsed three times with sample water to be contained in them and then filled to the brim. Sampling was done for some weeks and each sample labeled with a date of sampling inscribed on the plastic container.

2.2 Methods

2.2.1 Sample pre-treatment

Each one Litre water samples collected, were evaporated on a hot plate to 100 mL and cooled for further analysis.

2.2.2 Sample treatment for Metals determination

For Lead, Iron and Chromium determination, the water samples were digested as follows: 100 mL of each sample was transferred separately into different beakers and labeled accordingly (one for each sample). 5 mL concentrated HNO_3 was then added to the content of each beaker. Each beaker with the content is placed on a hot plate and evaporated to about 20 mL. Each beaker was cooled and another 5 mL concentrated HNO_3 added. Each beaker was covered with a watch glass and returned to the hot plate. The heating was continued and small portion of HNO_3 added until the solution appeared light coloured and clear. The beaker wall and watch glass were washed with distilled water and the sample was filtered to remove some insoluble materials that could clog the atomizer. The volume was then adjusted to 100 mL with distilled water, after which the samples were taken for metals determination using the Atomic Absorption Spectrometry (Buckmann model 4). This analysis was in triplicate [15].

2.3 Description of Study Area

Tamburawa water works is one of the major sources of pipe-borne water available to the entire populace of Kano city. Kano city (latitude 12°02'N, longitude 08°30'E), in northern Nigeria is one of the largest and most populous city in Nigeria. The population of the city is estimated at over ten million during the 2006 national population census. It is the commercial nerve centre of northern Nigeria. The high population is brought about by the much economic and industrial activities occurring in the city [14].

Therefore, it has become a necessity to determine the concentration of these toxic metals in water, as a way of guiding against associated health problems.

3. RESULTS AND DISCUSSION

The analysis of digested raw water and treated water samples from Tamburawa water treatment plant using Atomic Absorption Spectrometer (AAS) was carried out to determine the absorbance of Iron, Chromium and Lead in both the raw and treated water samples. The various absorbances determined, were used to establish various concentrations (mg/L) of the metals ions present in the raw and treated water samples (Table 2). From these concentrations, their standard deviation, mean and mean concentrations were also obtained (Table 3).

3.1 Analyses of the concentrations of Cr, Fe, and Pb in the Raw and Treated Water Samples

3.1.1 Chromium (Cr)

The bar graph in Fig. 1 shows a disparity in concentration of chromium in both raw and treated water samples taken for a given number of weeks. The concentration of all samples analyzed are far below the World Health Organization (WHO) threshold limits for drinking water, except the treated sample taken in week 2 having a concentration of 0.0591 mg/L as against the World Health Organization (WHO) threshold limit, 0.05 mg/L permitted for drinking water. This slight increase in concentration could be due to erosion of a natural deposit of chromium on that particular day since the abrupt increase was not continuously observed.

3.1.2 Iron (Fe)

The bar graph in Fig. 2 shows the various concentrations of Iron in the raw and treated water samples from Tamburawa water treatment plant. This metal is present in all the water samples analyzed in concentration that is within the World Health Organization (WHO) threshold limit, 0.3 mg/L.

Table 2. The various absorbance and concentrations of Cr, Fe, and Pb

Week number	Day	Sample	Absorbance			Concentration (mg/L)		
			Cr	Fe	Pb	Cr	Fe	Pb
	Monday	Raw	0.004	0.014	0.003	0.0296	0.1037	0.0261
		Treated	0.004	0.008	0.005	0.0296	0.0593	0.0435
1	Thursday	Raw	0.003	0.013	0.002	0.0222	0.0963	0.0174
		Treated	0.005	0.006	0.005	0.0370	0.0444	0.0435
	Monday	Raw	0.002	0.011	0.001	0.0148	0.0815	0.0087
2		Treated	0.005	0.006	0.003	0.0370	0.0444	0.0261
	Thursday	Raw	0.001	0.009	0.002	0.0074	0.0667	0.0174
		Treated	0.007	0.004	0.002	0.0591	0.0296	0.0174
	Monday	Raw	0.001	0.010	0.004	0.0074	0.0741	0.0348
3		Treated	0.003	0.005	0.002	0.0222	0.0370	0.0174
	Thursday	Raw	0.002	0.008	0.003	0.0148	0.0593	0.0261
		Treated	0.002	0.006	0.003	0.0148	0.0444	0.0174
	Monday	Raw	0.003	0.012	0.002	0.0222	0.0889	0.0348
4		Treated	0.004	0.016	0.003	0.0296	0.1185	0.0261
	Thursday	Raw	0.003	0.010	0.002	0.0222	0.0741	0.0174
		Treated	0.002	0.005	0.004	0.0148	0.0370	0.0348
	Monday	Raw	0.002	0.004	0.003	0.0148	0.0296	0.0261
5		Treated	0.003	0.006	0.002	0.0222	0.0519	0.0174
	Thursday	Raw	0.003	0.006	0.004	0.0222	0.0444	0.0348
		Treated	0.002	0.006	0.001	0.0148	0.0444	0.0087
	Monday	Raw	0.003	0.004	0.003	0.0222	0.0296	0.0260
6		Treated	0.002	0.006	0.004	0.0148	0.0444	0.0348
	Thursday	Raw	0.002	0.005	0.003	0.0148	0.0370	0.0260
		Treated	0.002	0.004	0.003	0.0148	0.0296	0.0260

Table 3. Standard deviation, mean and mean concentration of Chromium, Iron, and Lead

Water sample	Standard deviation	Mean	Mean concentration (mg/L)
Chromium			
Raw	±0.007	0.017	0.017±0.007
Treated	±0.014	0.026	0.026±0.014
Iron			
Raw	±0.026	0.065	0.065±0.026
Treated	±0.029	0.049	0.049±0.029
Lead			
Raw	±0.008	0.023	0.023±0.008
Treated	±0.011	0.027	0.027±0.011

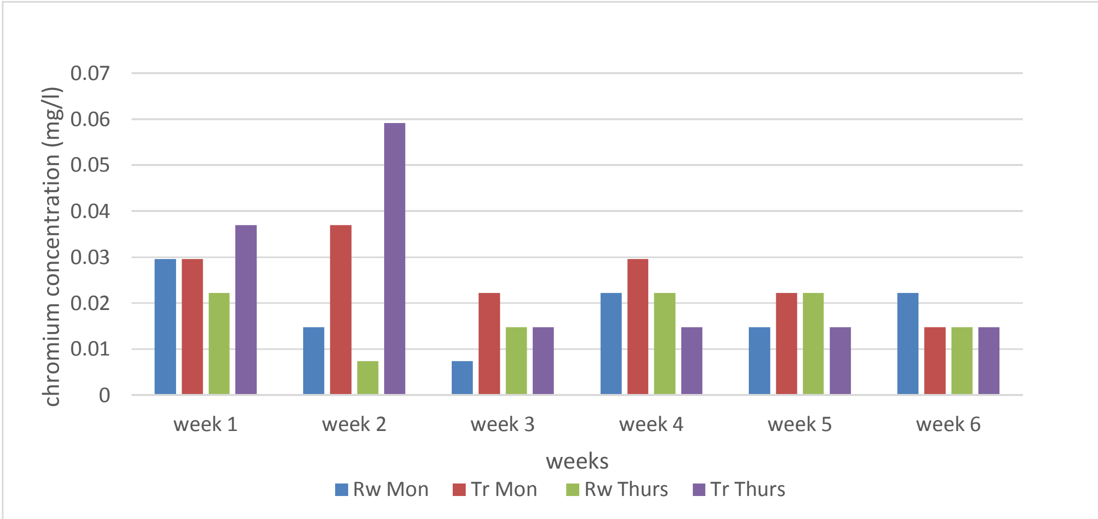

Fig. 1. Variation of concentration of chromium in raw and treated water sample from Tamburawa water treatment plant

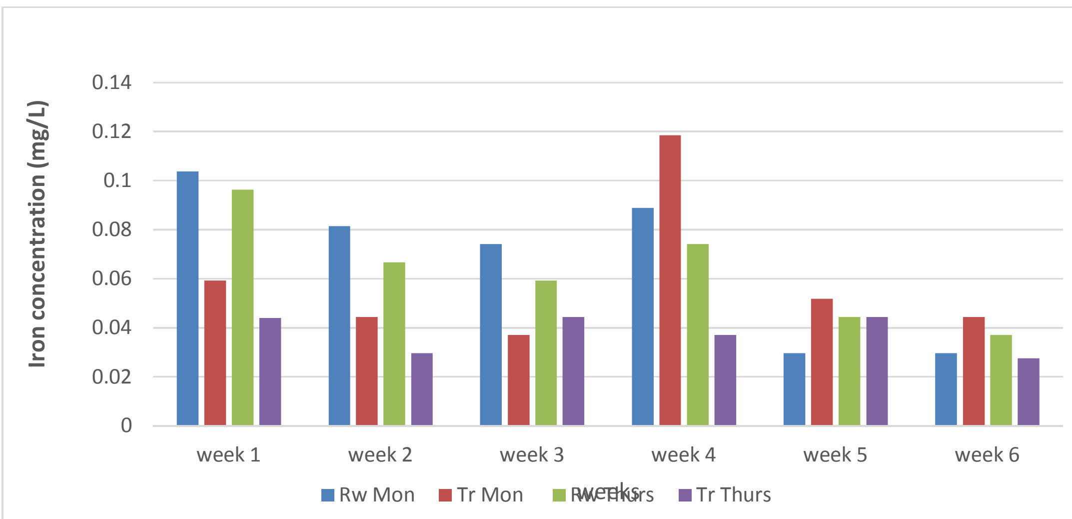

Fig. 2. Variation of Iron concentration in raw and treated water samples from Tamburawa water treatment plant

3.1.3 Lead (Pb)

The bar graph in Fig. 3 shows the various concentrations of Lead in the raw and treated water samples. Of all samples analyzed, only the raw water sample with concentration of 0.0087 mg/L taken on Monday in week 2 and treated water sample taken on Thursday in week 5 with concentration of 0.0087 mg/L are within the World Health Organization (WHO) threshold limits (0.01 mg/L) for Lead in drinking water samples. All other samples analyzed have concentrations above the World Health Organization (WHO) threshold limits. This large increase in concentrations of Lead in both raw and treated water samples suggests that the purification process does not include removal of metal ions, and also the use of leaded equipments in the purification and distribution units of the processing plant, which resulted to Pb ions dissolution in the water.

Lead is a very toxic metal and must be treated to meet the limits set by World Health Organization (WHO) in order to avert any danger it could impose on humans upon consumption.

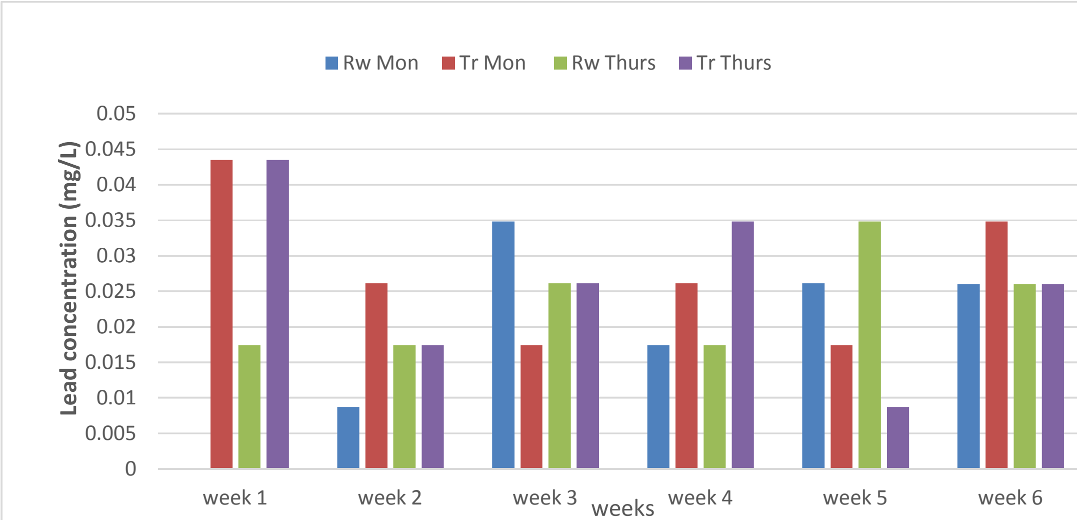

Fig. 3. Varying concentration of Lead in raw and treated water samples from Tamburawa water treatment plant

3.2 Comparative Analysis of the Mean Concentrations of Cr, Fe, and Pb in Both Water Samples

The results obtained indicated that the various metals analyzed were present in Tamburawa raw water and treated water samples at diverse concentrations. The mean concentrations of these metals in both water samples are shown in Table 4.

Analysis on Chromium showed that the mean concentration (0.0173±0074 mg/L) of the raw water samples satisfies the threshold limit established for Chromium in drinking water by World Health Organization, 0.05 mg/L. On the other end, the mean concentration (0.0259±0.0135 mg/L) of the treated water samples is also within the World Health Organization (WHO) threshold limit. Furthermore, the mean concentration of the treated water samples (0.0259±0.0135 mg/L) was found to be higher than that of raw water sample with a mean concentration of (0.0173±0.0074 mg/L), this suggests that the purification process does not include the removal of chromium ion and/or uses worn out equipments made of Chromium which dissolves in the treated water during purification.

The investigation on Iron indicated that the raw water samples analyzed had a mean concentration of (0.0654±0.0256 mg/L) which is within the permissible limit (0.3 mg/L) set for Iron in drinking water by World Health Organization (WHO) and Standard Organization of Nigeria (SON). This is also true for the treated water samples with mean concentration of (0.0487±0.0235 mg/L). Comparison between the mean concentrations of the raw water sample (0.0654±0.0256 mg/L) and treated water (0.0487±0.0235) showed that the purification process for Iron in the treatment process was efficiently done by the treatment plant.

Lead had a deviated result from the last two metals (Cr and Pb) analyzed. This analysis indicated that the raw water samples had a mean concentration of (0.0231±0.0087 mg/L) which is far above the permissible limit (0.01 mg/L) established by World Health Organization for Lead in drinking water. That of the treated water samples (0.0268±0.0108 mg/L) was equally above this permissible limit. The higher value in the treated water as compared to the raw water suggests that old and worn out pipes, machines and other equipment which must have been used during purification exercise in the treatment plant, dissolve during the process, and/or the treatment process does not involve the removal of Lead ions from the raw water.

The overview of all analyses carried out on Chromium, Iron, and Lead, illustrated that treated Tamburawa water is safe for drinking with regards to the concentration of Chromium and Iron as they are within the respective permissible limits by World Health Organization (WHO) and Standard Organization of Nigeria (SON). Conversely, Tamburawa water cannot be said to be safe for drinking with respect to the concentration of Lead as it exceeds the threshold limit set by World Health Organization (WHO).

Table 4. The mean concentration of Chromium, Iron and Lead

Metal ion	Raw water sample (mg/L)	Treated water sample (mg/L)	WHO threshold limit (mg/L)
Cr	0.017±0.007	0.026±0.013	0.05
Fe	0.065±0.026	0.049±0.029	0.3
Pb	0.023±0.008	0.027±0.011	0.01

4. CONCLUSION

The following were drawn in conclusion to this research work;

1. The concentrations of all the metals (except Pb) analyzed in the water samples were found to be within the limit set by World Health Organization (WHO) and Standard Organization of Nigeria (SON).
2. The efficiency of Tamburawa water treatment plant is said to be good with respect to the purification of the metals (Iron and Chromium) which were found to be adequately treated whereas the treatment of Lead was not effective.

5. RECOMMENDATION

It is recommended that pipe-borne water supplied to Kano metropolis from Tamburawa water treatment plant should be treated adequately to meet the limit permitted by WHO and/or SON in order to ensure safety of drinking water. Furthermore, the treatment plant needs appraisal and upgrading regulations in order to improve the quality of water being supplied to the metropolis.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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