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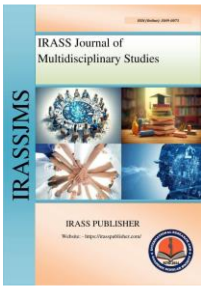

Comparative Assessment of Heavy Metals Concentration and Water Quality in Treated Water and Raw Water around Malali Water Works, Kaduna State, Nigeria

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Abstract: The water we drink is essential as it plays vital role in our welfare and healthy life. Heavy metals make our water unsafe. This study seeks to evaluate Heavy Metals Concentration and Water Quality in Malali Water work, Kaduna. Using standard procedures, heavy metals concentrations were determined. Significant difference in monthly concentrations was observed of nickel in the raw water samples. The values obtained ranged between 0.053 and 0.742 mg/L. Data obtained for Ni in raw water samples were seen to be higher than permissible limits set by the WHO (0.02 mg/L) and NSDWQ (0.07 mg/L). Chromium concentrations in raw water samples were between 0.0098mg/L (January) and 0.073 mg/L (July), with the monthly mean values presents significant differences. Significant differences were also observed in concentrations of copper in raw water samples with the values ranging between 0.57±0.54 mg/L (January) and 1.658±0.05 mg/L (September) and the values were within the NSDWQ permissible limit of 2 mg/L. although lead and other heavy metals are poisonous at certain level, their presence in water may be that contaminants may have been washed into the water body. Common sources of pollution in water include household paint, Lead batteries, fertilizers, and metal based-pesticides. In conclusion, Heavy metal content in treated water were generally within permissible range presented by WHO and NSDWQ, except iron concentration that was beyond permissible limits presented by WHO.

Keywords: Heavy-metals, Water quality, soil pollutants, Water Pollution

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1.0 Introduction

Water plays a vital role in human endeavors, hence determining the levels of heavy metals in aquatic environment is capable of supporting the health of living organisms, especially man and other animals. ''heavy metal'' refers to any metal and metalloid with relatively high density that is within the range between 3.5 and 7 g cm and is poisonous or toxic at concentrations that are low. Heavy metals include thallium (Tl), cadmium (Cd) zinc (Zn), nickel (Ni), copper (Cu), mercury (Hg), arsenic (As), chromium (Cr) and lead (Pb). These metals are documented widely and frequently applied to pollutants of soils and water bodies that are widespread. [1]

The evolvement of industries that produces or utilizes chemicals aid the discharge of pollutants into the environment over the past decades and are responsible for surface water and that which is below the ground resources contamination and the emergence of quantifiable environmental challenges. River can provide and are sources of portable water resources in both rural and urban localities, it also aids human and environmental health. However, in recent time due to the activities of man, the quality of water has changed leading to harmful effects of water contamination [2]. Decomposition of these solid pollutants within the environment depends on a long time as a result of their persistence, toxicity and non-degradability in the environment. More so, one of the most important environmental hazards is bioaccumulation potential in many aquatic species [3].

Concentrations of heavy metals in aquatic environment depends largely on a number of physicochemical factors such as dissolved oxygen, redox potential, salinity, pH, conductivity, temperature and ionic strength [4]. Some metals become toxic when they form complexes with organic compounds [5, 6]. These heavy metals have the capacity to exist in diverse forms of chemical existence like oxides, metal carbonates, sulfides, with the inclusion of ions that are in mineral crystal lattices [7] that have the capability to influence their properties which are therapeutic especially in mud.

The aim of this research was to determine heavy metals concentrations in Malali water work, Kaduna.

2.0 Materials and Method

2.1 Study Area

Malali water works, Kaduna with coordinates (10^o 33' 35" N, 7^o 28' 50" E) is where the study was conducted. Malali water works was founded in 1960 and commissioned in 1972. The water works have a total capacity of 270 ML/D.

The water works serves Kaduna town, Malali, Kawo, Anguwan Rimi, Anguwan Dosa, Tudun Wada, Unguwan Sarki, part of Sabo and part of Barnawa.

2.2 Water Samples Collection

Water samples were collected twice a month for a period of six months (July-September 2018 and January-March 2019) using plastic bottles (1000ml). Water samples were collected from River Kaduna at the point of raw water intake into the water works, and treated water at the point of distribution from the water works.

During the study, eight samples were collected monthly from river at the intake of raw water intake point and the treated water at distribution point in the water works, four samples at raw water intake point and four samples at distribution point from treated water in the water works. Forty-eight samples were from the points were collected during the period of the study.

Samples collected at the River (point of intake) were carried out by submerging sample container underneath the river surface, about 10–15 cm with the open end faced against current flow direction [8].

Before collecting water samples, deionized water was used to rinse each sample bottle used. Considering the nature of parameters to be analyzed, collected samples were kept in a dry and cool container to ensure that temperature and other necessary conditions needed to keep the physical and chemical properties intact are maintained. [9].

2.3 Digestion of Samples for the Analysis of Heavy Metals

The digestion of samples was carried out in accordance with the procedure of [10].

In the laboratory, 100ml of the sample was taken in a volumetric flask and then filtered using whatman 0.45µm membrane filter paper. After filtration, 3ml of hydrochloric acid (HCL) and 1ml of nitric acid (HNO_3) was added. The mixture was heated using hot plate (SH 1 STUART SCIENTIFIC) at a temperature of 90ºC - 95ºC until the volume was reduced to 15ml – 20ml. The mixture was filtered again using whatman 0.45µm membrane filter paper to remove any suspended particles. The final volume was adjusted to 100ml by adding deionized water using 100ml volumetric flask.

2.4 Determination of Heavy Metals

Samples digested were determined using Atomic Absorption Spectrophotometer (AAS) machine (thermos scientific i C E 3000 series).

Analysis were carried out following procedures and methods as described in Standard guidelines for examination of water and waste water 17th edition, published jointly by American Public Health Association [9]. Following the method used, sample was atomized after being aspirated into flame, a light beam through flame was directed into a mono-chrometor and the amount of light absorbed by atomized elements in the flame was measured using a detector.

Following the knowledge that metal has characteristic absorption wavelength that is specific, source Lamp which is composed of the element was used to make the method free relatively as a result of spectral or interferences of radiation.

2.5 Data Analysis

Data presented are in the form of mean ± standard error of mean (SEM) for each parameter. In order to compare mean values, One-way Analysis of Variance (ANOVA) was employed, $p \leq 0.05$ was considered statistically significant. Duncan multiple range test was used for multiple comparison of significantly differing mean values.

3.0 Results and Discussion

3.1 Concentrations of Heavy Metals in the Water Samples

There was significant difference in monthly concentrations of nickel in the raw water samples. The values were between 0.053 and 0.742 mg/L. The least concentrations of Nickel in raw samples of water were observed and recorded in the months of February and March while peak values occurred in September (Table 4.4a). All recorded values of Ni in raw water samples were higher than the permissible limits set by the WHO (0.02 mg/L) and NSDWQ (0.07 mg/L) (Table 1). The nickel concentration in treated water samples varied significantly from month to month with values ranging between 0.007 mg/L (March) and 0.024 mg/L (September). All the values were below the NSDWQ permissible limits of 0.07 mg/L (Table 2).

An amount of lead, 0.0014 mg/L was detected in treated water in the month of September; none was detected in the other sampling intervals (Table 2). In raw water, however, Lead was detected in water samples across all the sampling intervals with values detected ranging from 0.0017 mg/L (January) and 0.0131 mg/L (September); all the values were below the WHO and NSDWQ permissible limit of 0.01 mg/L except in September where higher value was recorded (0.0131mg/L) (Table 1).

Chromium concentrations in raw water samples were between 0.0098mg/L (January) and 0.073 mg/L (July), with the monthly mean values showing significant differences ($p < 0.05$) (Table 4.4a). In treated water, Cr was detected only in four of the sampling months (February, March, July and September) with values graduating from 0.0019 mg/L (March) and 0.025 mg/L

(September). The values were all lower than NSDWQ and WHO acceptable limit of 0.05 mg/L (Table 2).

Cadmium was detected in treated water at concentration 0.0002 mg/L in September and 0.003 mg/L in July with the monthly values showing significant differences ($p < 0.05$); the concentrations of Cd in treated water samples were in the permissible limit of 0.003 mg/L set by NSDWQ and WHO (Table 4.4b). The concentrations of Cd in raw water were above acceptable limit presented with values 0.03 mg/L (February) and 0.115 mg/L (July) (Table 1).

Significant difference in the mean concentrations of copper was observed in water samples (raw) with the values ranging between 0.57±0.54 mg/L (January) and 1.658±0.05 mg/L (September) and the values were within the NSDWQ permissible limit of 2 mg/L (Table 1). In treated water, the mean concentrations of Cu did not differ ($p > 0.05$) significantly from month to month; values were within acceptable limits of the WHO and NSDWQ (1mg/L), and ranged between 0.0214 and 0.084 mg/L (Table 2).

Iron concentration in treated water differed significantly from month to month with lower values recorded during dry season mononsths and higher values in the rainy season months. The mean monthly concentrati of Fe were within the limits set by the WHO (0.3 mg/L) except in September where the concentration was higher (1.145±0.031mg/L) (Table 2). There was significant monthly variation in Fe concentration in raw water with values ranging between 0.107 mg/L (March) and 1.444 mg/L (September). Generally, lower values of Fe were recorded in the dry season months while higher values were associated with the rainy season months (Table 1).

The concentrations of Zn in raw water samples were between 0.145±0.017 mg/L (January) and 3.206±0.144 mg/L (September); the values were within the permissible limit of the WHO and NSDWQ (3 mg/L) except in September where it was higher (Table 1). In treated water, the concentration of Zn were all within the permissible limit and ranged between 0.067±0.005 mg/L (January) and 1.115±0.05 mg/L (September) (Table 2).

Table 1: Heavy metals concentration in raw water samples at the Malali water works Kaduna

Raw	Ni (mg/L)	Pb (mg/L)	Cr (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)
July 2018	0.379±0.036^{c}	0.0028±0.0004^{bc}	0.073±0.0069^{a}	0.115±0.008^{a}	1.53±0.007^{ab}	1.124±0.02^{b}	1.43±0.011^{d}
Aug 2018	0.437±0.026^{b}	0.0029±0.0002^{bc}	0.017±0.0046^{c}	0.057±0.0015^{b}	1.65±0.103^{a}	1.075±0.047^{b}	2.56±0.078^{b}
Sept 2018	0.742±0.007^{a}	0.0131±0.0002^{a}	0.039±0.0023^{b}	0.054±0.0006^{b}	1.658±0.05^{a}	1.444±0.4987^{a}	3.206±0.144^{a}
Jan. 2019	0.058±0.004^{d}	0.0017±0.001^{c}	0.0098±0.0054^{d}	0.045±0.0024^{c}	0.574±0.545^{c}	0.136±0.0055^{c}	0.145±0.0176^{e}
Feb. 2019	0.053±0.001^{d}	0.0029±0.0003^{bc}	0.0123±0.0003^{d}	0.0383±0.0033^{d}	1.236±0.0046^{b}	0.120±0.022^{c}	2.039±0.0328^{c}
Mar. 2019	0.053±0.001^{d}	0.0033±0.002^{b}	0.012±0.0004^{d}	0.04±0.0018^{cd}	1.245±0.016^{b}	0.107±0.011^{c}	2.057±0.037^{d}
Mean	0.287±0.264	0.447±0.408	0.0272±0.23	0.0562±0.0271	1.33±1.49	0.67±0.59	1.91±0.90
NSDWQ	0.02	0.01	0.05	0.003	1	0.3	3
WHO	0.07	0.01	0.05	0.003	2	0.1	3
p value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Mean values with different superscripts are significantly difference ($p \leq 0.05$) down each column;

NSDWQ: Nigerian Standard for Drinking Water Quality

WHO: World Health Organization Drinking Water Quality

Table 2: Heavy metal concentration in treated water samples at the Malali water works Kaduna

Treated	Ni (mg/L)	Pb (mg/L)	Cr (mg/L)	Cd (mg/L)	Cu (mg/L)	Fe (mg/L)
July 2018	0.0023±0.002^{a}	ND	0.012±0.017^{bc}	0.003±0.0001^{a}	0.035±0.004^{a}	56±0.0178^{ab}
Aug 2018	0.011±0.0006^{b}	ND	ND	0.0007±0.0001^{cd}	0.033±0.004^{a}	.113±0.001^{b}
Sept 2018	0.024±0.0001^{a}	0.0014±0.0001	0.025±0.0033^{a}	0.0002±0.0001^{c}	0.046±0.005^{a}	.145±0.031^{a}
Jan. 2019	0.0117±0.0024^{e}	ND	ND	0.00185±0.0004^{abd}	0.0845±0.0035^{a}	263±0.0057^{c}
Feb. 2019	0.0049±0.004^{d}	ND	0.0029±0.0052^{c}	0.0026±0.0024^{ab}	0.0623±0.041^{a}	.0345±0.034^{c}
Mar. 2019	0.0078±0.0028^{c}	ND	0.0019±0.00056^{bc}	0.0013±0.0002^{bcd}	0.214±0.063^{a}	.012±0.001^{c}
Mean	0.0118±0.009	0.0225±0.052	0.0069±0.011	0.0016±0.0013	0.06±0.03	.08±0.06
NSDWQ	0.02	0.01	0.05	0.003	1	0.3
WHO	0.07	0.01	0.05	0.003	2	0.1
p value	< 0.0001	< 0.0001	0.0008	0.0052	0.4455	< 0.0001

Values with different superscripts are significantly difference ($p \leq 0.05$) down each column;

NSDWQ: Nigerian Standard for Drinking Water Quality

WHO: World Health Organization Drinking Water Quality

WHO: World Health Organization Drinking Water Quality

ND: Not Detect

The mean concentration of nickel in raw water was (0.287 mg/L) which was higher than the permissible limits of 0.02mg/L for nickel in drinking water. Thus, the untreated water is unsafe for consumption. At such high concentrations, nickel may cause gastrointestinal irritation. Some sources of nickel in natural water source include sewage sludge, waste water from sewage treatment plants, and ground water from dumpsites [10]. In treated water, the concentration of nickel (0.0118 mg/L) which was significantly lower than that of untreated water sample is also within the WHO/NSDWQ permissible limits for nickel in drinking water. Thus, the treated water was safe for human consumption [11]. The seasonal variation of nickel concentrations in treated water may result from inadequate removal of nickel during the water treatment process, since the concentration of the metal remained invariable in raw water across both seasons.

Lead is a poisonous trace element that is commonly observed in polluted waters that occurs naturally. It is responsible for anemia, cancer, kidney diseases, interference with the metabolism of vitamin D, mental development in infants and central and peripheral nervous systems impairment [12]. Common sources of Lead pollution in water include household paint Lead batteries, fertilizers, and metal based-pesticides [13]. Different authors have given varying concentrations of Lead in untreated water sources. [14] observed and reported Lead amount in concentration of 0.57 mg/L in raw water samples. [15] recorded concentration of 0.25 mg/L for Lead in raw water samples at Ajaokuta, Nigeria, while [10] recorded 0.157 mg/L of Lead concentration. In this study, concentration of Lead in raw water was 0.00447mg/L which is lower than those of the aforementioned reports, and within the WHO/NSDWQ permissible limits for Lead in drinking water. After treatment, Lead concentration was 0.225x 10^{-3} mg/L which was indicative of efficient removal of Lead from the raw water. Seasonal variation in Lead content of raw water was observed in the study, [16] made similar observation. This may suggest that Lead contaminants may have been washed into the water bodies. Contrariwise, Lead concentration in treated water did not differ significantly between the two seasons. This may be indicative of a stricter control of Lead content in the water over a narrow range because of its inherent toxicity.

Chromium is a trace heavy-metal which is usually found in ground and surface water. Sources of chromium include effluents from pulp and steel mills and erosion of natural deposits. The mean concentration of this heavy-metal was 0.00697 mg/L which is lower than WHO/NSDWQ permissible limits for chromium in drinking water (0.05 mg/L). Chromium plays a role in energy metabolism as it potentiates the actions of insulin. At higher concentrations, however, chromium contaminated water can cause anemia, stomach cancer, and weight loss in humans [16].

Cadmium levels in raw water were observed to be above the permissible limits of the WHO and NSDWQ. Increased cadmium concentration may be due to battery waste water deposited directly or indirectly into the water. More sources of this element include operations in mining and smelting industries, electroplating, plastic stabilizers and fertilizers [18]. The results in Table 1 further indicated that the concentrations obtained for these metals were significantly lower in water samples treated than untreated (raw) water, and were generally below the acceptable limits given by WHO and NSDWQ, that was indicative of effective water treatment process. Due to their persistence and cumulative tendency in the environment as well as their associated toxicity, it is a serious threat to environment and human health alike [18]. At-risk population due to cadmium toxicity includes the elderly, infants and women in their reproductive age. These set of individuals have very low body iron stores, and cadmium absorption and retention have been reported to be inversely related to body iron status [11].

Copper is an essential element for human nutrition due to its need in a lot of enzymatic reactions [17]. However, contamination of drinking water with high level of copper may lead to chronic toxicity. In raw water, the copper concentration was 1.3155mg/L which is higher than that of [18] who reported 0.07mg/L of Copper in spring water collected at Umuariaga Community in Ikwuano Local Government Area of Abia State, Southeast Nigeria. [14] also reported slightly lower value for copper (0.075mg/L) in stream water samples. Copper may enter water bodies via mineral dissolution, industrial and agricultural effluents and through copper alloy water distribution pipes corrosion. The high copper concentration recorded in the raw water samples may be indicative of increased pollution of water with these copper sources [19]. In treated water, the concentration of copper was 0.0572mg/L. This closely agrees with those reported by [20]. The copper concentration in treated water was within the WHO/NSDWQ permissible limits for copper in drinking water. Thus, on account of copper, the water in this area is safe for human consumption [21].

Iron concentration in raw water was 0.668mg/L. This value closely agrees with that of [22] who reported an Iron concentration of 0.75mg/L in water samples collected from Jibiya dam, Katsina state, Nigeria. In treated water, the mean Iron concentration was 0.076mg/L, a value lower than of [15] who reported 0.33mg/L concentration of Iron in drinking water in a study conducted in Niger state, Nigeria. Although iron has no serious health consequences, ingestion of large amount of iron results in haemochromatosis, a condition characterized by iron-related tissue damage, increased respiration, blood coagulation and hypertension [10]. contrariwise, iron concentration at low level can lead to gastrointestinal infection, nose bleeding and myocardial infarction [17].

Zinc, although recognized as a heavy metal, is a trace element required towards proper body functioning. Zinc plays critical role in metabolism and gene expression [13, 17]. For the present study, the mean concentration of Zinc in both raw was 1.906mg/L which is within the permissible limits for Zn in drinking water. The result also closely agrees with that of [14] and [10] who reported 1.055 mg/L and 1.555mg/L, respectively, for concentrations of Zn in untreated water samples. Zinc is reported to exist in very low concentrations in nature due to its restricted mobility from site of weathering of other natural deposits. However, zinc may accumulate in the environment through human and industrial activities such as exhaust fumes, waste incineration, engine wear and the utilization of sewage sludge as fertilizers [17]. Because of its tendency to accumulate in the body and the resultant toxicity, the amount of zinc in treated water is usually low. Therefore, mean concentration of zinc in treated water was 0.5669 mg/L. This value, though within NSDWQ and WHO permissible range for zinc of 3.0mg/L, is in consonance with the result of [14] who reported zinc concentration, 0.52mg/L present in drinking water sources in Enyigba, Ebonyi state, Nigeria. However, zinc concentration in the present study was slightly higher than that of

[23] who reported a mean zinc concentration of 0.277mg/L for Lagos drinking water. On the basis of comparison with permissible zinc concentration, the treated water at the Malali water works is safe for consumption as at the period of the study. High amounts of zinc in the body may induce vomiting, dehydration, abdominal pain, lethargy and dizziness. Other physiological dysfunctions associated with zinc intoxication include impaired copper utilization, sense of smell and taste, brain function and growth [15, 13].

4.1 Conclusion

Heavy metal content in raw water (such as nickel, lead, cadmium, copper, iron and zinc) were beyond the recommended levels as set by the WHO and NSDWQ. Heavy metal content in treated water were generally within acceptable limits set by WHO and NSDWQ, except iron concentration which was above the permissible limits set by the WHO.

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Conflict of interest

All authors declare that there is no area of conflict.

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