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ASSESSMENT OF WATER QUALITY USED FOR IRRIGATION ALONG ROMI RIVER OF CHIKUN LGA, KADUNA STATE, NIGERIA

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ABSTRACT

The discharge of the industrial effluents into water bodies causes not only a direct mutilation of water physicochemical features but also instigates detrimental effects on the ecosystem and consequently the human health. The quality of water used for irrigation on selected sites along Romi River in Chikun LGA, Kaduna State, Nigeria, was assessed. Water samples were collected from five different locations; Agyeita (ATW), Ungwan Tanko (UTW), Karatudu (KTW), Ungwan Markus (UMW), Ungwan Zarmai (UZW) and a control site (CTW). Physicochemical analysis for pH, DO, COD, BOD, turbidity, TH, TDS and EC were carried out using standard methods. Water samples were digested using concentrated nitric acid and the heavy metals were determined using Atomic Absorption Spectrometry (AAS).The water quality index (WQI) and heavy metal evaluation index (HEI) of the water were calculated. The results for the WQI indicated that water from UTW (48.51) and CTW (43.76) were of good quality, UMW (61.65) poor, ATW (79.92) very poor, KTW (155.67) and UZW (165.04) unfit. The HEI of the water indicated that water samples ATW (8.73) and CTW (3.09) were < 10 which implies the pollution at this site is low, water sample UZW (17.06) with index 10 – 20 which indicates the pollution is moderate, while KTW (26.22), UTW (28.70) and UMW (42.44) the pollution is high (> 20) hence not suitable for consumption or irrigation purposes. By extension, when the plants are consumed by livestock and humans, possible health hazards can be developed. The water along river Romi is unsafe for irrigation and drinking purposes hence could be harmful for plant and human health.

Keywords: Evaluation index, Heavy metals, Irrigation, Pollution, Water Quality Index.
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INTRODUCTION

Water is essential to life without it, the biosphere that exists on the surface of the earth would not be possible. When the quality of water is poor, it affects not only aquatic life but the surrounding ecosystems as well. Discharge of the industrial effluents into water bodies causes not only a direct mutilation of water physicochemical features (some of which are; color, pH, salinity, turbidity, suspended solids, total dissolved solids, biological oxygen demand, chemical oxygen demand), but also instigates detrimental effects on the ecosystem and consequently the human health. The occurrence of heavy metals in industrial and municipal sewage effluents constitute a major source of metals in the aquatic media. At higher concentrations, heavy metals may be toxic to the biota and could disturb the biochemical process and cause hazards [1].

Water pollution by wastewater discharged into rivers and other water bodies or by anthropogenic activities has increased due to population growth [2, 3]. Heavy metals are not biodegradable, thus when present in water, they persist and can lead to toxicity [4, 5]. Low concentration of non-essential heavy metals has a great impact on human health and aquatic life. They can cause respiratory problems, weakening of the immune system, damage to the kidneys or liver, genetic and neurological alterations and death [6].

Rivers serve as sinks for wastes from different sources, mainly from anthropogenic activities which include various toxic chemicals, acids, alkalis, detergents and agrochemicals which greatly affect the physicochemical properties of water used for irrigation [7]. River Kaduna serves as the only source of water to Kaduna refinery. It is located 14 kilometers away from the refinery. The refinery has three lift pumps charged with the responsibility of lifting water from the river to the surface for pretreatment [8]. After the water is treated and used, the waste water from the refinery is treated in waste water treatment plant and the effluent is conveniently discharged into Romi River [9]. Apart from improving water supply to the populace, Romi River provides suitable sites for irrigation farming resulting in the production of selected crops such as vegetables, rice, maize and sugar cane [10]. The river under study receives huge amount of untreated effluents from industries such as Kaduna refineries and petrol chemical company (KRPC) and others which are released directly or indirectly into the river. This may likely render the water unfit for drinking and agricultural purposes [11], hence there is the need to evaluate the quality of the water in river Romi. Therefore, the aim of this work is to assess the quality of water used for irrigation on selected sites along Romi River.

MATERIALS AND METHODS

Study area

Chikun local government area is located in the southern part of Kaduna State. Romi river which lies within Longitude: 10°25'35.3N and Latitude: 7°20'25.06E (Figure 1) is a major river in Chikun LGA. Romi River is a tributary of Kaduna River with the largest water body flowing through Chikun and traverses Romi Village and its environs (Rido, Juji, Karatudu, Goningora) which eventually discharges into Kaduna River at Garko [9].

Samples collection and pre-treatment

Water samples were collected using Grab method from five different locations; Ungwan Tanko (UTW), Agyeita (ATW), Karatudu (KTW), Ungwan Markus (UMW), and Ungwan Zarmai (UZW). The samples at each location were collected at different points to form a composite using two 2 liters plastic bottles that have been previously soaked in 10% nitric acid and rinsed with distilled water before sampling. During sampling, the sample bottles were rinsed three times with the water to be sampled and then the samples were collected by careful immersion of the sampling bottles into the water body. The samples were well-labeled and taken to the laboratory for analysis [9]. The control (CTW) was collected from a stream about 1 km away from the sampling points.

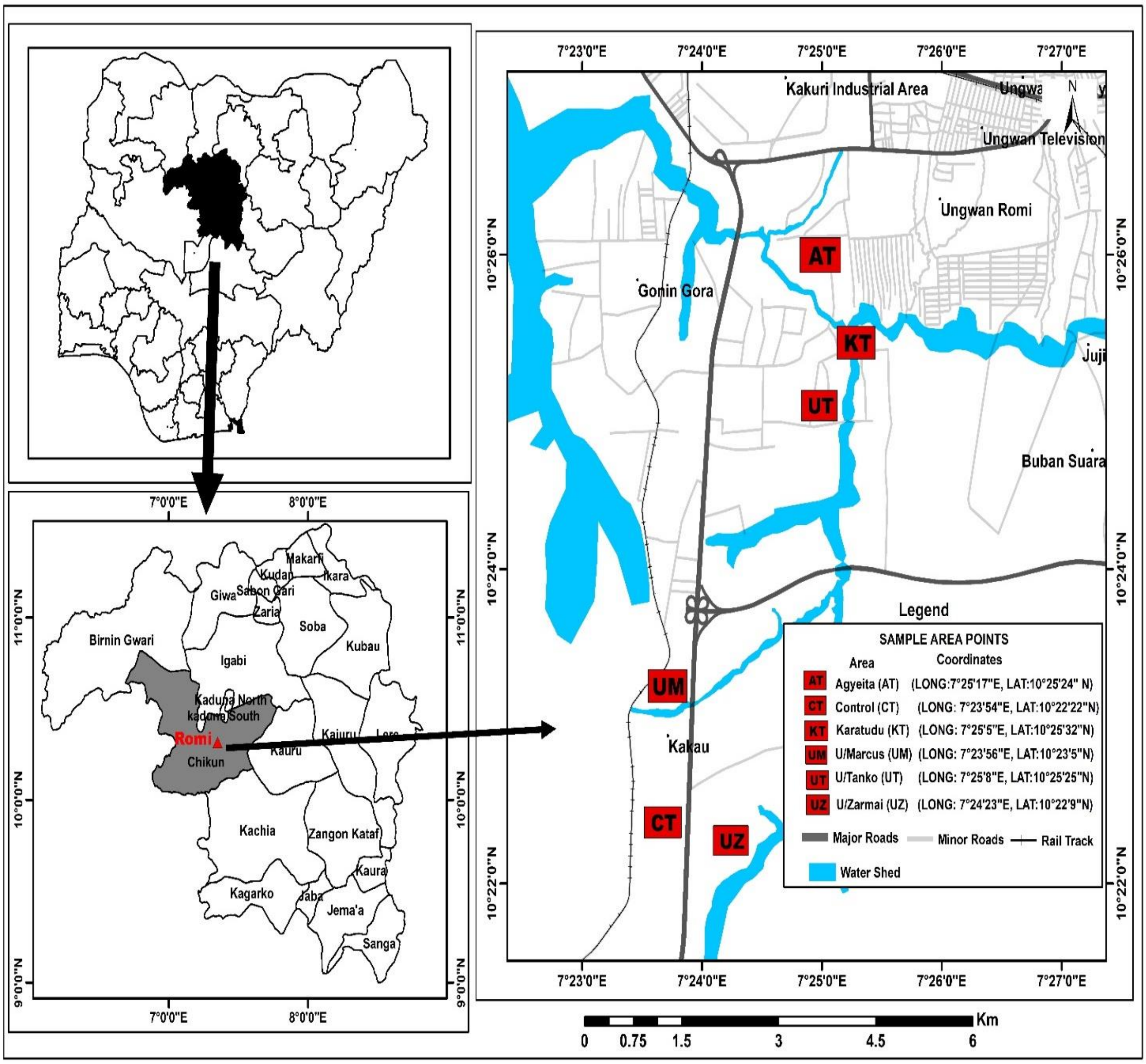

Figure 1: Map showing Study Area (Source: Department of Geography, ABU Zaria

One of the 2 liters of water samples collected at each location was treated immediately with 2ml of nitric acid and stored in a laboratory refrigerator prior to digestion for AAS analysis while the other 2 liters containing the water samples from each location was taken for physicochemical analysis [12].

Samples digestion and analysis

Physicochemical parameters such as pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD), turbidity, total hardness (TH), total dissolved solid (TDS) and electrical conductivity (EC) were determined using standard methods [13]. Exactly 100 cm^3 of the sample was transferred into a digestion flask and 5 cm^3 concentrated HNO_3 acid was added. The beaker with its content was placed on a hot plate in a fume cupboard and evaporated down to about 20 ml. The beaker was cooled and another 5 cm^3 concentrated HNO_3 acid was added. The beaker was covered with a watch glass and returned to the hot plate. The heating continued and then 2 cm^3 of HNO_3 acid was added until the solutions appeared colorless and clear. The beaker and watch glass were washed with distilled water and the samples were filtered into a 100 cm^3 standard volumetric flask using Whatman no. 42 filter paper to remove some insoluble substances that could clog the atomizer. The volume was adjusted to the mark with distilled water [14]. The digested samples were taken for analysis to determine the concentrations of Ni, Fe, Cu, Pb and Zn using AAS (Model AA FS280). The analysis was done in triplicate.

Water quality index (WQI)

This provides a single number that expresses the overall water quality at a certain location and time based on several water quality parameters. It is helpful for the selection of appropriate treatment technique to meet the concerned issues. The WQI based on Shannon entropy method [15] was calculated using the following equation:

$$WQI = \frac{\sum QiWi}{\sum iWi} \quad (1)$$

The quality rating scale (Qi) for each parameter is calculated using this expression:

$$Qi = 100\left[\left(\frac{Vi-Vo}{Si-Vo}\right)\right] \quad (2)$$

where; Wi = unit weight; Vi = estimated concentration of ith parameter in the analyzed water; Vo = the ideal value of this parameter in pure water; Vo = 0 (except pH = 7.0 and DO = 14.6 mg/L); Si = WHO recommended standard value of ith parameter.

The water quality index is classified into the categories [16];

0- 25= Excellent; 26 – 50= Good; 51 – 75= Poor; 76 – 100= Very poor; > 100= Unfit for consumption.

Heavy metal evaluation index (HEI)

HEI provides an overview of the water quality with respect to heavy metals. The HEI index is calculated based on maximum allowable concentration (MAC) for each target heavy metal using:

$$\text{HEI} = \sum \text{HEI}i \quad (3)$$

where HEIi is the pollution index corresponding to ith heavy metal calculated as:

$$HEI = \frac{Mi}{Hi\text{mac}} \quad (4)$$

where Hi_{mac} is the maximum permissible concentration of ith heavy metal. This method divides the water quality into three classes to demarcate the different level of contamination including: low (HEI < 10), moderate (HEI = 10–20), and high (HEI > 20) [15].

RESULTS AND DISCUSSION

Physicochemical parameters

Table 1 indicated that the pH values are within the permissible limit except for UZW which has a value of 4.57±0.03 and is below the permissible limit set by WHO [17], implying that it is slightly acidic. The low pH in UZW could be as a result of high quantity of effluents from the industry and also heavy metals leached from the environment. This might also be due to the presence of CO_2, nitrate and sulphate ions in water. DO, BOD, EC, TDS are all within the permissible limit. The result for turbidity for all the samples exceeded the permissible limit except UTW. The high values of turbidity may be as a result of the presence of clay, silt, finely divided organic and inorganic matter, colored organic compound, plankton and other microscopic organisms in the water body WHO [17]. COD and TH also exceeded the permissible limit for all the samples except KTW. Increase in COD is due to oxidized organic matter and can also be attributed to the inflow of sewage into the water bodies. The high values of TH may be as a result of formation of crust in pipes. Dissolved oxygen (DO) varied between 1.45 mg/L (UTW) and 2.05 mg/L (KTW) and they were below the permissible limit of 4- 6 mg/L[17] for all the water samples. The low level of DO could be due to leaching of phosphorus, potassium and nitrogen from the soil as a result of fertilizer application, which leads to eutrophication; the excessive growth of algae. The result obtained was lower than that of Yunana *et al*. [9] with values ranging from 3.9 to 8.3 mg/L.

The quality of water is important to the health of humans as well as the plants and animals that live in and around streams or rivers. The values of these physicochemical parameters are harmful for human, animal and plant health when they occur more than the permissible limits [18].

Concentrations of heavy metals

Table 2 shows the concentrations of the heavy metals determined in the water samples studied. The concentrations of Ni exceeded the permissible limit of 0.02 mg/Lfor all the samples except ATW (0.01 ± 0.30 mg/L) and the control (CTW) (0.01 ± 0.24 mg/L). The high levels of Ni could be attributed to natural sources like direct leaching from rocks and sediment and anthropogenic activities; this may result in cardiovascular and kidney disease. Nickel is an essential mineral element but is also categorized as a toxin if its level exceeds certain limits. It acts as an activator.

Table 1: Physicochemical parameters of the water samples

Parameter	UTW	ATW	KTW	UMW	UZW	CTW	WHO (2012)
pH	6.95±0.01	6.78±0.01	6.66±0.01	6.55±0.00	4.57±0.03	6.97±0.01	6.5-8.5
DO (mg/l)	1.45±0.07	1.95±0.07	2.05±0.07	1.65±0.07	1.80±0.00	1.40±0.00	4.0 -6.0
BOD(mg/l)	0.75±0.07	0.90±0.00	0.70±0.00	0.45±0.07	0.40±0.00	0.37±0.00	6
Turbidity (NTU)	7.40±0.00	5.10±0.14	18.60±0.14	42.90±0.14	6.10±0.14	0.40±0.00	5
EC(µs/cm)	146.00±0.00	65.40±0.14	57.20±0.14	59.00±0.28	304.50±0.71	36.01±0.01	400
TDS(mg/l)	74.90±0.43	32.65±0.07	28.40±0.14	29.45±0.21	151.95±0.07	11.10±0.02	500
COD(mg/l)	95.00±7.07	120.00±0.00	120.00±0.05	125.00±7.07	105.00±7.07	30.00±0.00	80
TH (mg/l)	222.20±0.00	176.76±7.14	101.01±0.00	161.61±0.00	126.26±7.14	99.20±0.00	150

Table 2: Concentrations (mg/L) of heavy metals in the water samples

Sample	Ni	Fe	Cu	Pb	Zn
ATW	0.01±0.30	2.41±0.05	0.34±0.03	BDL	0.10±0.08
UTW	0.04±0.01	3.14±0.04	0.39±0.08	0.`16±0.00	0.09±0.04
UZW	0.24±0.10	1.46±0.01	0.38±0.02	BDL	BDL
UMW	0.26±0.13	8.77±0.08	0.41±0.03	BDL	BDL
KTW	0.33±0.10	2.85±0.01	0.43±0.01	BDL	BDL
CTW	0.01±0.24	0.73±0.09	0.32±0.01	BDL	BDL
WHO (2012)	0.02	0.3	2	0.01	3

BDL = Below Detection Limit.

or cofactor for a number of enzymes as well as hormones, while excessive intake may lead to cell damage, alteration of enzyme and hormone activities [19]. The result obtained from this study, is higher than that reported by Yakubu *et al.* [20] with values ranging from 0.03- 0.05 mg/l. The concentrations of Fe obtained in this study were above the permissible limit of 0.3 mg/l for all the samples, including the control. Fe is one of the most abundant resources in the earth's crust; its high concentration may be as a result leaching from soils and rocks. Concentration of dissolved iron in Deep Ocean is normally 33.5×10^{-9} mg/ l or 0.6 nM. Its concentration is low in freshwater with a detection level of 5 µg/l – ICP, whereas in groundwater the dissolved iron concentration is very high with the level of 20 mg/l [21].

High concentration of iron in wastewater contributes to soil acidification and loss of availability of phosphorus and molybdenum when applied to the soil [22]. Increase in soil acidity increases the availability of metals for plant uptake. Consumption of large quantity of iron can lead to hemochromatosis, a severe disease that can damage the body organs [23]. Also, it has been reported that iron toxicosis occurs via four stages (i): iron toxicosis after 6 hrs of iron overdose is marked by gastrointestinal effects (gastro intestinal bleeding, vomiting and diarrhea). (ii): iron toxicosis within 6-24 hrs of iron dose is considered as period of apparent medical recovery (latent period). (iii): iron toxicosis between 12-96 hrs of iron dose is marked by shocks, lethargy, tachycardia, hypotension, hepatic necrosis, metabolic acidosis and sometimes death. (iv): iron toxicosis within 2-6 weeks of iron dose is marked by the formation of gastrointestinal ulcerations and development of strictures [24]. The values of Fe in this study was higher than the highest value of 5.30 mg/l reported by Adefemi and Awokunmi [12] and are similar to 1.68 to 5.45 mg/l obtained from Abui *et al.* [25].

The concentration of Cu was in the range of 0.32 – 0. 43 mg/l and were below the permissible limit of 2 mg/l [17]. Copper is an essential element for normal human growth, but becomes a toxin at high levels [19]. The estimated safe and adequate intake for copper is 1.5–3.0 mg/day. Excessive ingestion of Copper could lead to severe mucosal irritation and corrosion; capillary, hepatic and renal damages; and gastrointestinal and neural disturbances [26]. Copper toxicity seldom occurs but may occur and its consequences may be severe. Intakes of supplements exceeding 3 mg copper/day for a protracted period of time may be a cause for concern [27].

The results for this study showed that the concentrations of Zn were below the permissible limit for all the samples and those of UZW, UMW, KTW and CTW were below the method's detection limit for Zn. Zinc can be cytotoxic when it is in high concentration in human body [28]. Zinc is an important essential mineral that people need to stay healthy; its deficiency in humans is now known to be an important malnutrition problem world-wide. Zinc deficiency can lead to growth failure during growth periods, and epidermal, gastrointestinal, central nervous, immune, skeletal, and reproductive systems are the organs most affected clinically by zinc deficiency [29].

The Pb concentrations were all below detection limit for all the samples except for UTW which exceeded the permissible limit of 0.01 mg/L [17]. The concentration of Pb in UTW may be attributed to the discharge of untreated municipal, agricultural and urban effluent into the water body. The concentration of Pb was lower than the highest value of 0.55 mg/l reported by Owuna [30] and lower than 0.83 to 3.97 mg/l as reported by Abui *et al*. [25]. Lead consumption can result in adverse health effects such as the dysfunction of some vital organs such as kidneys, liver and heart. Also, multiple organs in the body are targeted by Lead due to systemic toxicity as emphasized by Mahurpawar [31]. It has been reported that Pb and Cd are toxic to forage crops even at low concentrations [32].

The trace elements and heavy/toxic metals, which are present in many rivers water or wastewater used for irrigation exhibit serious toxicities to plants although in most cases, the plants themselves accumulate these metals. When wastewater is used to irrigate crops, the quantity of heavy metals increases in the soil as well as in cultivated products [33]. By extension, when the plants are consumed by livestock possible health hazards can be developed.

Water Quality Index for analyzed water samples

Table 3 shows the water quality index (WQI) with respect to the physicochemical parameters for the analyzed water samples. The water from UTW (48.51) and CTW (43.76) were of good quality, UMW (61.65) poor, ATW (79.92) very poor, KTW (155.67) and UZW (165.04) unfit. When the quality of water is poor, it affects not only aquatic life but the surrounding ecosystems as well and consequently the human health [1].

The heavy metal evaluation index (HEI) of the water quality with respect to heavy metals (Table 4) indicated that water samples ATW (8.73) and CTW (3.09) were < 10 which implies the pollution at these sites is low, water sample UZW (17.06) with index 10 – 20 indicating pollution is moderate, while KTW (26.22), UTW (28.70) and UMW (42.44) the pollution is high (> 20) hence not suitable for consumption or irrigation purposes [15]. Wastewater irrigation is known to contribute significantly to the heavy metal contents of soil and plants [34].

Table 3: Water Quality Index for selected water sample sites

Parameter	UTW	ATW	KTW	UMW	UZW	CTW
pH	2.026716	8.106863	12.71304	16.58222	89.54399	1.105481
DO (mg/l)	37.80525	36.41754	36.12967	30.8534	36.84937	37.72455
BOD(mg/l)	2.878858	3.454629	2.686934	7.600184	1.535391	1.420237
Turbidity (NTU)	2.210963	28.18977	102.8098	2.072778	33.71718	2,210963
EC(µs/cm)	0.126094	0.056483	0.049401	2.964072	0.262984	0.0311
TDS(mg/l)	0.0414	0.018947	0.015698	0.040765	0.083989	0.006135
COD(mg/l)	2.051186	2.590972	0.647743	0.101739	2.2671	0.647743
TH (mg/l)	1.364778	1.085583	0.620359	1.439429	0.775434	0.609243
∑WQI	48.50525	79.91989	155.6726	61.65459	165.0354	43.75545
STATUS	Good	Very Poor	Unfit	Poor	unfit	Good

Table 4: Heavy Metal Evaluation Index (HEI) for the analyzed water samples

Sample			HEI$_i$			HEI	status
	Ni	Fe	Cu	Pb	Zn	{∑HEIi}	
ATW	0.50	8.03	0.17	-	0.03	8.73	Low
UTW	2.00	10.47	0.20	16.00	0.03	28.70	High
UZW	12.00	4.87	0.19	-	-	17.06	Medium
UMW	13.00	29.23	0.21	-	-	42.44	High
KTW	16.50	9.50	0.22	-	-	26.22	High
CTW	0.50	2.43	0.16	-	-	3.09	Low

CONCLUSION

The results for the water quality index (WQI) for the analyzed water samples indicated that water from UTW (48.51) and CTW (43.76) were of good quality. The heavy metal evaluation index (HEI) of the water indicated that only water samples from ATW (8.73) and CTW (3.09) had low pollution levels. Hence except for the sample from UZW (17.06) that is moderately polluted, all the other samples are not suitable for consumption or irrigation purposes. Thus, the water from river Romi is unsafe for irrigation and could be harmful for human and plant health.

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