Water Quality Assessment of River Adema, Nasarawa, Nasarawa State, Nigeria

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ABSTRACT: The quality of water is of utmost importance because it determines the suitability of water for use domestically, industrially or otherwise. The quality of water from River Adema was determined by the analysis of thirty (30) samples for physicochemical parameters using standard AOAC methods and heavy metals using atomic absorption spectrophotometer, AAS. The WQI and MI of water were evaluated to ascertain its suitability for the desired purposes. The results obtained were; physicochemical parameters: temperature (24.21±1.55 ºC), turbidity (0.57±0.08 NTU), TDS (722.88±103.02 mg/dm^3), TSS (23.30±1.08 mg/dm^3), pH (6.84±0.31), EC (3111.54±30.51 µS/cm), total hardness (7.62±0.62 mg/dm^3), alkalinity (1.18±0.03 mg/dm^3), chloride (0.49±0.05 mg/dm^3), nitrate (0.02±0.01 mg/dm^3) and sulphate (2.03±0.08 mg/dm^3). Heavy metal concentrations (mg/dm^3) were Cd (0.06±0.01), Cr (0.62±0.13), Cu (0.58±0.08), Fe (0.54±0.12), Pb (ND), Mn (0.57±0.10), Ni (ND) and Zn (0.04±0.01). All physicochemical parameters were below WHO recommended standards and for the heavy metals Cd, Cr, Fe; and Mn concentrations were higher than the standard values. WQI for the water was 15.29, an indication that the water is of good quality however, MI for metals such as Cd (20), Cr (6.2), Fe (1.8), Mn (57) were higher than the recommended WHO limit, an indication of metal contamination. The results also showed that there was a strong positive correlation between turbidity and chloride and between copper and manganese. Therefore, there is an urgent need for the regulation of indiscriminate dumping of domestic wastes, runoffs from farmlands, mining locations into surface water bodies, since these are the likely sources. Regular monitoring of the water quality should be ensured and water from River Adema should be treated before use.

Cite this paper as: OPALUWA, O. D; MUHAMMAD, A. I; MADAKI, K. S; USMAN, A; MOHAMMAD, I. A. (2022). Water Quality Assessment of River Adema, Nasarawa, Nasarawa State, Nigeria. *J. Appl. Sci. Environ. Manage.* 26 (8) 1433-1442

The role of water in the lives of living organisms and humans cannot be over-emphasized (Nguyen and Huynh, 2022). The availability and reliability of portable water is a major factor in the establishment of very stable communities and human settlements; rural, semi-urban and urban. There has been increased demand for good quality water over the decades due to developments; increased population growth, industrialization, and urbanization (Opaluwa *et al.*, 2020). This demand for water has resulted in the use of any form of water; be it groundwater or surface water available particularly in developing countries.

Therefore, there is the need to determine the quality of water, and this mostly depends on the purpose for which the water is meant for. As water has positive effects, it could also have negative effects on life, particularly health hazards, when the various parameters that determine its quality are beyond the recommended maximum permissible limits set by regulatory bodies (Madhab *et al.*, 2011). Surface water (rivers, lakes, dams, ponds) are the main sources of water, and surface water reservoirs remain the most important freshwater resources on planet earth known for numerous benefits (Dirican, 2015). These surface

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water reservoirs in their natural form as aquatic ecosystem contains different physical and chemical parameters in very low concentrations, however, these are always on the high side due to developments and increased exploitation of natural resources (Mehedi *et al.*, 1999). Surface water could be contaminated in a number of ways; discharge of industrial effluents, agricultural practices, and domestic wastes, and these are the usual practice in densely populated areas in third world countries, Nigeria inclusive. This has been an issue of serious concern over the years because it affects the quality of water which is directly linked to the health of the water body and also directly linked to human health (Tirthesh and Ramendra, 2016).Water quality is an indication of relationships between the hydrological properties; physical, chemical, biological, and microbiological properties of water. As a result, the analysis carried out to determine the quality of water depends on the physical, chemical, biological, and microbiological properties of water as they indicate the abiotic and biotic status of a give aquatic ecosystem (Smitha and Shivashankar, 2013). Taking the aggregate of the products of parameter qualities and the unit weights divided by the aggregate of the unit weight gives the evaluation of the water quality index (WQI). It gives a nominal number that represents the overall water quality in a given location and time based on the water quality parameters (Opaluwa *et al.*, 2020).Also of serious concern over the years on the quality of surface water reservoir sources is contamination by heavy metals. Heavy metals which include lead, cadmium, arsenic, chromium, copper iron, and a few others refer to heavy, dense, metallic elements or metalloids that occur in matrices at trace levels, and have the potential for toxicity (Opaluwa *et al.*, 2020). Heavy metal pollution of surface water bodies arises from direct dumping of domestic wastes, discharge of industrial effluents, exploration and exploitation of natural resources as well as irrigation extension and modern practices in agriculture which are marked by heavy use of heavy metal blended fertilizers and agrochemicals and lack of enforcement of environmental regulations (Biney *et al.*, 1991). The presence of heavy metals in water beyond the natural load could be of serious hazard to the health of humans that have such water source as the main water supply reservoir. It could also be deleterious to the aquatic ecosystem that is the source of water in question. This could, however, be supported by the case of "Mina Mata Disease" that occurred in Japan as a result of mercury poisoning of the consumers of fish from Mina Mata Bay that had been polluted by surrounding industries (Abubakar, 2015, FEPA, 1991).Several works have been done on water quality assessment of surface water locally and internationally and these included the assessment of water quality parameters of Rivers Doma, Farinruwa, and Mada in Nasarawa State, Nigeria (Gav *et al.*, 2015), water quality status and heavy metal contents of selected rivers at Tasik Chini due to increasing land use (Adilah and Nadia, 2020). Included are concentrations and human health risk of heavy metals in rivers in southwest, Nigeria (Adesiyan *et al.*, 2018), assessment of surface water quality, and monitoring in southern Vietnam using multicriteria statistical approaches (Nguyen and Huynh, 2022) and a host of others. River Adema flows through the town of Nasarawa, Nasarawa State, Nigeria. Nasarawa is known for the mining of tantalite (ore of tantalum pentoxide) and columbite (ore of niobium pentoxide) and these have associated heavy metals that are released into the soils during mining. Run-offs from mining sites and farms on which heavy metal blended fertilizers and agrochemicals have been used transfer heavy metals to the river. Also common is the direct discharge of domestic wastes and effluents from cottage industries into the water body leads to the elevated metal load in the river water. In Nasarawa town, the supply of pipe-borne water is epileptic and therefore, many inhabitants that cannot afford to get water supply from groundwater sources resort to the water from River Adema for their daily water needs. Much has not been done on the quality of water from this river thus; objective of this research is to evaluate the water quality of River Adema, Nasarawa, Nasarawa State, Nigeria.

MATERIALS AND METHODS

Study Area: The study area is Nasarawa town in Nasarawa Local Government Area, Nasarawa State, North-central Nigeria. It is located on latitude 8° 32' 20.22" N longitude 7° 42' 29.56" E with an area of 4,872 km2 and a population 187,220 to the census, 2006. Generally, the topography of the study area is that of hills/ dissected terrain, undulating plains, and lowlands with forest savannah vegetation. The study area has tropical rainy climate; dry season (November – March) and rainy season (April – October) with an annual rainfall 1200 – 2000 mm and average temperature 29.39 ℃. The inhabitants of the study area are Afo, Hausa/Fulani, Gbagi and other tribes that settlers. The occupations in the study area include farming, mining, business, livestock production and a few others.

Sample Collection and Preparation: Water samples were collected from River Adema at an interval of 30 days. A total number of 30 water samples were collected; from ten points (three times) at a distance of about 1.0 km and the samples were taken 5.0 cm below the water surface (to minimize the contamination of the water sample by surface films). The samples were

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taken into 1.0 dm^3 plastic bottles that had been washed and rinsed with concentrated HNO$_3$ to prevent the adsorption of metal ions in water samples on the walls of the containers (acid rinsing of bottles is particularly meant for samples to be used for metal analysis).

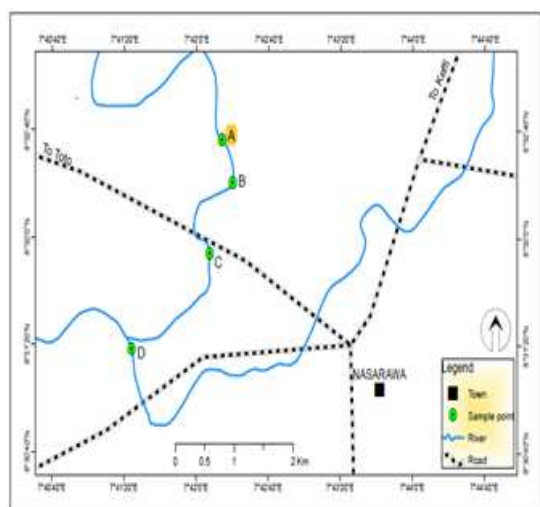**Fig 1:** Map of Nasarawa State showing Nasarawa Local Government Area

Fig 2: Map of Nasarawa town with A – D showing the course of River Adema

Samples were thoroughly mixed by shaking after which 100.00cm^3 of each sample was measured into a glass beaker and 5.00cm^3 of concentrated HNO$_3$ was added. The beaker was placed on a hot plate and was allowed to evaporate down to 20 cm^3. The beaker was allowed to cool and another 5.00cm^3 of concentrated HNO$_3$ was added. The beaker was covered with a watch glass and returned to the hot plate. Heating

continued until the digest appeared light-coloured and clear. It was then brought down and allowed to cool, the sample was then filtered through Whatman No. 1.0 filter paper and the filtrate was made up to mark in 50.00cm^3 volumetric flask using deionized water and kept awaiting metal analysis (Aloke *et al.*, 2019, Singh *et al.*, 2012).

Analyses of Water Samples
Physicochemical Analysis of Water Samples: The physicochemical parameters for water samples were determined using standard methods of analysis. Electrical conductivity (EC), pH, temperature, turbidity, and total dissolved solids (TDS) were determined in situ using electrical conductivity meter JENWAY – 430, pH meter JENWAY – 430, mercury bulb thermometer, SGZ 200BS turbidity meter, and TDS meter JENWAY – 430 respectively (Opaluwa *et al.*, 2020). Parameters such as total suspended solids (TSS) was determined by gravimetric method, total hardness (TH) by EDTA titrimetric method, alkalinity, and chloride by titrimetric method, nitrate and sulphate were determined by methods prescribed by AOAC, 1990 and adopted by Ademoroti (1996).

Water Quality Index (WQI): The water quality index for River Adema was evaluated from eleven parameters; turbidity, TDS, TSS, pH, EC, total hardness, alkalinity, chloride, nitrate and sulphate using the mean values of the parameter from the ten sampling locations along the stretch of the river to assess the suitability of the water for drinking. WQI was evaluated using the weighted arithmetic water quality index method proposed by Horton (1965), and adopted by Ewaid and Abed (2017). Water parameters were multiplied by a weighting factor and are then aggregated using simple arithmetic mean by the following equations:

$$Qi = \frac{(Mi-Ii)}{(Si-Ii)} \times 100 \qquad (1)$$

$$Wi = \frac{K}{Si} \qquad (2)$$

$$WQI = \sum_{i=1}^{n} \frac{WiQi}{\sum_{i=1}^{n} Wi} \qquad (3)$$

Where Qi is the sub-index of the ith parameter, Wi is the unit weight of the parameter, n is the number used, Mi is the monitored value of the parameter, Ii is the ideal value and Si is the standard value of the ith parameter. Ideal value for pH = 7, dissolved oxygen = 14.6 mg/dm^3, and for all other parameters is zero (Chowdhury *et al.*, 2012). Wi the weight unit of each parameter was evaluated as an inverse proportion of

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the standards (Si) of the World Health Organisation (WHO, 2011).

Determination of Heavy Metals in Water Samples: Heavy metals; Cd, Cr, Cu, Fe, Pb, Mn, Ni, and Zn were determined in the digested water samples using atomic absorption spectrophotometer, AAS (AA280FS, Agilent Technologies, USA).

Metal index: The metal index of water from River Adema was evaluated by using the method described by Akpoveta *et al*. (2011) and adopted by Aloke *et al.* (2019) which is as given below;

$$MI = \frac{M_c}{MAC} (4)$$

Mc is for the observed metal concentration of ith metal in the water sample, MAC is the minimum permissible concentration of metal in drinking water prescribed by WHO (2011). MI value >1 is an indication of the significant degree of metal contamination and MI < 1 shows no metal contamination. The metal indices for each metal give information about their relative contaminations contributed to the samples of water from the Adema River (Aloke *et al*., 2019).

Statistical Analysis: The data obtained from the research work were subjected to statistical evaluation. Statistical tools evaluated were mean, standard deviation, and correlation matrix.

Quality Control/Quality Assurance: There was strict adherence to quality control/quality assurance procedures to ensure that the results obtained are correct and had high precision. The chemicals used were all of the analytical grades obtained from Sigma Aldrich and BDH (British Drug House).All the glass wares used for the research work were washed thoroughly with 9% nitric acid and rinsed severally with deionized water. Deionized water was used for dilution throughout the duration of the work.

Blank solutions and standard solutions were analyzed along with replicate samples to ensure accuracy and precision of results obtained. Samples were also repeated, for example, after every five samples the fifth one will be repeated as the sixth. This was to ensure the precision of the instrument.

RESULTS AND DISCUSSION
Physicochemical Parameters: The results of the determination of physicochemical parameters of water samples from River Adema are presented in Table 1. The mean temperature of water samples from River Adema was 24.21±1.55 (21.98 – 27.00) ℃. The fluctuations in the temperatures of water are

insignificant because it has the function of regulating temperatures (Nguyen and Huynh, 2020). The temperature of surface water sources is influenced by the season and intensity of sunlight at any given time. High temperatures have a negative effect on the aquatic ecosystem because it reduces dissolved oxygen that could cause the mortality of fish and other aquatic organisms (Usman, 2016). The temperature of 24.21±1.55℃ is in the same range as a temperature range of 24.08 – 24.50 ℃ recorded for water from River Iko (Usoro *et al*., 2013). It is however; lower than 26.3 – 29.5 ℃ recorded for water from River Mkomon, Benue State, Nigeria (Ioryue *et al*., 2018). The mean temperature from the current research is very close to the ambient (25 ℃) recommended by WHO and therefore, is suitable for aquatic organisms. Turbidity of water from River Adema had mean value of 0.57±0.08 (0.48 – 0.78) NTU. Turbidity of surface water could be found to be high due to indiscriminate dumping of wastes into the water body, run-offs, or as a result of turbulent flow which could stir up non-living matters, silt, and sand at the bottom of the river (Gupta *et al*., 2017). The turbidity from the research work is far low probably due to the period of the sampling, when there is no runoff. It is far less than 5.0 NTU recommended by WHO and therefore, constitutes no danger to water quality. The turbidity mean value from the current research is within the range 0.01 – 178.25 NTU recorded for river water of Narmada, Madhya Pradesh, India (Gupta *et al*., 2017) and it is lower compared to 1.20 – 16.40 NTU observed for pond and river water in Lumding town of Assam, India (Madhab *et al*., 2011).The mean value of TDS for water samples from River Adema was 722.88±103 (560.85 – 940.00) mg/dm^3. This value is on the high side and could be attributed to sewage discharge and other anthropogenic activities along the river bank. TDS are composed of mainly inorganic compounds, organic matter, salt, and other particles (Ioryue *et al.*, 2018). TDS of surface water tends to be diluted when the flow is turbulent. TDS in the current research is higher compared to 5.80 – 350 mg/dm^3 recorded for pond and river water in Lumding town of Assam, India (Madhab *et al*., 2011) as well as 18.8 – 60.8 mg/dm^3 observed TDS for water from River Mkomon Kwande, Benue State, Nigeria (Ioryue *et al.*, 2018). The value is also far higher than 500 mg/dm^3, the recommended permissible limit by WHO, and portends potential danger to the health of the consumer of the water.

TSS had a mean value of 23.30±1.08 mg/dm^3 for water from River Adema. This is slightly lower than the recommended tolerable limit by WHO and it is relatively high due to runoff and the direct discharge of wastes and effluents into the river. This mean value

of TSS is with the range values of TSS 17.03±0.48 – 31.85±1.74 mg/dm^3 for water from Ajiwa Reservoir, Katsina State, Nigeria (Usman, 2016) and 17.00 – 36.00 mg/dm^3 observed for water from selected rivers in TasikChini, Malaysia (Adilah and Nadia, 2020).

Table 1: Physicochemical parameters of water from River Adema, Nasarawa

Parameters	Sample Locations										Mean	SD	WHO (2011)
	1	2	3	4	5	6	7	8	9	10			
Temperature (°C)	23.76	23.05	24.05	22.98	26.65	27.00	21.98	23.76	25.4	23.5	24.21	1.55	Ambient
Turbidity (NTU)	0.53	0.51	0.65	0.56	0.48	0.78	0.50	0.52	0.60	0.55	0.57	0.08	5.00
TDS (mg/dm^3)	738.67	716.51	700.5	690	585.55	805.67	560.85	790.9	700.15	940	722.88	103.02	500.00
TSS (mg/dm^3)	23.06	22.37	23.10	24.90	23.95	20.95	23.80	24.65	23.10	23.15	23.30	1.08	25.00
pH	6.67	6.47	6.65	6.90	6.90	7.10	6.60	7.15	6.50	7.50	6.84	0.31	6.50
EC (µS/cm)	300.65	291.63	310.15	400.15	295.35	300.67	320.25	298.15	300.1	298.25	311.54	30.51	1000.00
T.Hard (mg/dm^3)	7.56	7.33	7.50	7.80	7.56	6.90	8.95	6.50	8.20	7.85	7.62	0.64	150.00
Alkalinity (mg/dm^3)	1.18	1.14	1.15	1.2	1.25	1.15	1.19	1.17	1.19	1.20	1.18	0.03	200.00
Cl$^-$ (mg/dm^3)	0.44	0.43	0.56	0.45	0.50	0.61	0.48	0.49	0.52	0.45	0.49	0.05	250.00
NO$_3^-$ (mg/dm^3)	0.02	0.02	0.01	0.02	0.03	0.04	0.01	0.02	0.01	0.02	0.02	0.01	50.00
SO$_4^{2-}$ (mg/dm^3)	2.05	1.99	2.01	1.99	1.98	1.95	1.98	2.25	2.10	1.99	2.03	0.08	100.00

SD = Standard Deviation

Table 2: Quality index of water from River Adema

Parameters	Standard Value (Si)	Ideal Value (Ii)	Monitored Value (Mi)	Sub-index (Qi)	Weight Unit (Wi)	Wi*Qi
Turbidity (NTU)	5	0	0.57	11.40	0.20	2.28
TDS (mg/dm^3)	500	0	722.88	144.58	0.002	0.2892
TSS (mg/dm^3)	25	0	23.30	93.20	0.04	3.728
pH	6.50	7	6.84	2.46	0.154	0.3785
EC	1000	0	311.54	31.15	0.001	0.0312
T. Hardness (mg/dm^3)	150	0	7.62	5.08	0.0067	0.0339
Alkalinity (mg/dm^3)	200	0	1.18	0.59	0.005	0.0030
Cl$^-$ (mg/dm^3)	250	0	0.49	0.20	0.004	0.0008
NO$_2^-$ (mg/dm^3)	50	0	0.02	0.04	0.02	0.0008
SO$_4^{2-}$ (mg/dm^3)	100	0	2.03	2.03	0.01	0.0203
					$\sum Wi$ = 0.4425	$\sum WiQi$ = 6.7655

$$WQI = \sum_{i=1}^{n} \frac{WiQi}{\sum_{i=1}^{n} Wi} = 15.29$$

The mean pH of water from River Adema was 6.84±0.31. This is within the range of 6.50 – 8.50 recommended by WHO. pH is very important to the aquatic ecosystem because the metabolic activities of organisms in the aquatic ecosystem are dependent on the pH. It is an index for water quality determination and is indicative of the extent of pollution. High pH affects the solubility of many nutritive and toxic chemicals; and therefore, reduces the availability of these chemicals to the aquatic organisms. Increased acidity makes many metals present in water more soluble and more toxic. It also leads to increased toxicity of cyanide and sulphide (Akpan, 2004). The pH value is higher compared to the range values 6.62±0.50 – 6.69±0.1 recorded for water from Iko River, Nigeria (Usoro *et al*., 2013) and lower compared to 8.05 – 8.48 recorded for water from River Narmada, Madhya Pradesh, India (Gupta *et al*., 2017). The electrical conductivity of water from River Adema was 311.54±30.51µS/cm. This value is moderately high and could be attributed to discharge from feeder streams and runoff from domestic and other anthropogenic activities along the river bank. This EC is higher compared to the value 21.2 – 53.4 µS/cm recorded for Rivers Lukemi and Luini in the Democratic Republic of Congo (Nienie *et al*., 201) but lower in comparison to 923.72±36.98 – 1335.74±46.86 µS/cm as EC for water from Turag River, Bangladesh (Arafat *et al*., 2021). However, the EC from the current work is far below the recommended limits by WHO and therefore, does not affect the water quality and eventually poses no form of danger to the use of the water domestically.The total hardness of water from River Adema had a mean value 7.62±0.64 mg/dm^3. The hardness of the water is low based on the classification of water in terms of softness and hardness; 0 – 50 soft, 50 – 100 moderately hard, and 100 – 150 mg/dm^3 above hard (Efe*et al.*, 2005). This implies that the discharge into the river does not really have constituents that could cause hardness. The hardness of water from River Adema is lower compared to 21.60 – 40.9 mg/dm^3 recorded for water in Benue, Nigeria (Okenyi *et al*., 2016) as well as 28.00 – 200.00 mg/dm^3 observed for Pond and River in Lumding town of Assam, India (Madhab *et al*., 2011). The value of 7.62±0.64 mg/dm^3 for hardness is far way less than the recommended limits by WHO.

Table 3: WQI Categories

Range	Quality
0 – 25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very Poor
>100	Unsuitable for drinking

The mean value of alkalinity for River water was 1.18 ± 0.03 mg/dm^3. From all the sampling points, the total alkalinities for the samples were low. This could be that contaminant that would have caused increased alkalinity was not much in the different discharges and runoffs received by the river. The value is far lower than the recommended limit by WHO. The result is less than the range values 210.05 ± 20.34 – 281.16 ± 23.70 mg/dm^3 reported for water from Urban River, Bangladesh (Arafat *et al.*, 2021) as well as 23 – 800 mg/dm^3 reported by Madhab *et al.* (2011).

Table 4: Correlation matrix of physicochemical parameters of water from River Adema, Nasarawa

	Temp	Turb	TDS	TSS	pH	EC	T. Hard	Alkalinity	Cl⁻	NO₃⁻	SO₄²⁻
Temp	1										
Turb	*0.52	1									
TDS	0.06	0.35	1								
TSS	-0.45	*-0.68	-0.31	1							
pH	0.18	0.15	**0.70	0.06	1						
EC	-0.36	-0.01	-0.21	*0.51	0.00	1					
T. Hard	-0.40	-0.30	-0.47	0.18	-0.38	0.25	1				
Alkalinity	0.20	*-0.50	-0.32	*0.54	0.23	0.18	0.36	1			
Cl⁻	*0.68	**0.83	0.00	*-0.50	0.07	-0.20	-0.25	-0.24	1		
NO₃⁻	*0.67	0.38	0.26	-0.43	0.48	-0.12	*-0.58	0.07	0.33	1	
SO₄²⁻	-0.10	-0.23	0.18	0.43	0.07	-0.19	-0.40	-0.10	-0.09	0.28	1

*Moderate correlation; **Strong correlation*

Table 5: Concentrations (mg/dm^3) of heavy metals in water from River Adema

Metals	Sample Locations										Mean	SD	WHO (2011)
	1	2	3	4	5	6	7	8	9	10			
Cd	0.06	0.09	0.05	0.06	0.07	0.08	0.06	0.04	0.05	0.07	0.06	0.01	0.003
Cr	0.48	0.55	0.45	0.65	0.75	0.56	0.49	0.85	0.75	0.69	0.62	0.13	0.100
Cu	0.53	0.52	0.68	0.65	0.75	0.53	0.55	0.45	0.56	0.56	0.58	0.08	1.000
Fe	0.52	0.54	0.56	0.45	0.65	0.43	0.42	0.41	0.65	0.78	0.54	0.12	0.300
Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.050
Mn	0.57	0.62	0.56	0.67	0.75	0.43	0.43	0.45	0.56	0.63	0.57	0.10	0.010
Ni	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND		0.05
Zn	0.03	0.04	0.05	0.06	0.02	0.04	0.03	0.02	0.02	0.04	0.04	0.01	5.000

SD = Standard Deviation, ND = Not Detectable

Chloride in water samples from River Adema had a mean concentration 0.49 ± 0.05 mg/dm^3. The chloride concentration is very low and could be attributed to runoffs from sources; domestic sewage and other effluents which do not contain a good amount of chloride to contribute to its level in the water from the river. It is far less than the WHO recommended permissible limits for chloride in water and therefore, does not affect the water quality. The value from the present study is lower than the range values 45.2 ± 0.48 – 55.2 ± 1.35 mg/dm^3 reported by Ioryue *et al.* (2018) as well as 19.7 – 32.1 mg/dm^3 for River Benue reported by Okenyi *et al.* (2016).Nitrate concentration above 50 mg/dm^3, the limit set by WHO causes a disease known as methemoglobinemia (blue baby syndrome) (Ibrahim *et al.*, 2019). The mean nitrate from the water of River Adema was 0.02 ± 0.01 mg/dm^3 and therefore, below the recommended permissible limit. There is, therefore, no effect on the quality of water and also no health danger posed by using the water for domestic purposes. High nitrate level is caused by an inflow of nutrients most especially, from runoffs from agricultural farmland, effluents from the abattoir, septic tanks that have failed and municipal effluents (Ibrahim *et al.*, 2019). The chloride level of River Adema is below 47.37 ± 2.12 – 68.15 ± 2.21 mg/dm^3 reported by Usman (2016) as well as 1.1 ± 0.2 – 7.7 ± 1.3 mg/dm^3 reported by Nienie *et al.* (2017).The sulphate mean concentration of water samples from

Adema River was 2.03 ± 0.08 mg/dm^3. This value is very low and could be attributed to the river receiving domestic discharge containing low sulphur contaminants in runoffs and other sources. This concentration of sulpahte is far below the WHO recommended permissible limits and therefore, constitutes no negative effect on the water quality and eventually poses no health challenges. However, high concentrations of sulphate could cause high acidity in water.

Table 6: Metal index of the heavy metals in water from River Adema

Metals	Mc	MAC	MI
Cd	0.06	0.003	20
Cr	0.62	0.1	6.2
Cu	0.58	1	0.58
Fe	0.54	0.3	1.8
Pb	ND	0.05	ND
Mn	0.57	0.01	57
Ni	ND	0.05	ND
Zn	0.04	5	0.008

Table 7: Correlation matrix of heavy metals in water from River Adema

	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Zn
Cd	1.00							
Cr	-0.30	1.00						
Cu	0.05	-0.08	1.00					
Fe	0.16	0.23	0.35	1.00				
Pb	0.00	0.00	0.00	0.00	1.00			
Mn	0.26	0.20	**0.70	*0.61	0.00	1.00		
Ni	0.00	0.00	0.00	0.00	0.00	0.00	1.00	
Zn	0.25	-0.49	0.25	-0.13	0.00	0.17	0.00	1.00

*Moderate correlation; **Strong correlation*

The present level of sulphate in Adema River is higher compared to $0.12\pm0.07 – 0.35\pm0.36$ mg/dm^3 in water from Kainji Lake, National Park, Nigeria (Omonona *et al.*, 2019) but lower than $20.0 – 260.5$ mg/dm^3 for sulphate in the water reported by Madhab *et al.* (2011).

Water Quality Index: Table 2 shows the evaluation of the water quality index of water from River Adema and Table 3 shows the WOI categories. The water quality index gives a nominal number that represents the overall quality of water from a given location and time and it is based on parameters that determine water quality. The water quality index converts complex water quality data into information more detailed and useful to the public. WQI present water quality in terms of index number and provides very useful information to the public on the water for any use or to help reduce pollution where it is eminent as well as water quality management (Qureshimatva *et al.*, 2015). The WQI for water from River Adema was evaluated to be 15.29 and from Table 3 it could be categorised to be of excellent quality. This value is in the same category for water from Owo River in Lagos with WQI 19.62 (Akoteyon *et al.*, 2011) but it is, however, lower compared to the WQI $110.12 – 821.5$ for water from surface water sources from Warri Metropolis, Nigeria (Asibor and Ofuya, 2019) and the water falls under the category of water that is unsuitable for use domestically.

Correlation of Physicochemical Parameters: The results of the correlation study of the physicochemical parameters are shown in Table 4. From the results obtained, strong positive correlation exists between turbidity/chloride and TDS/pH which signifies that the contaminant contributing to the level of these parameters in River Adema could be coming from the same source, anthropogenic activities. However, a moderate positive correlation exists between temperature/turbidity, temperature/chloride, temperature/nitrate, TSS/EC and TSS/alkalinity whereas a moderate negative correlation exists between turbidity/TSS, turbidity/alkalinity, TSS/chloride and TSS/alkalinity.

Heavy Metals: Cadmium mean concentration in water from River Adema was 0.06 ± 0.01 mg/dm^3. This is relatively high and could be attributed to runoffs from farmlands, mining sites and anthropogenic inputs. The possible source of cadmium in surface water includes atmospheric fall-outs, fossil fuel combustions and the release of sediment-bound metals (Dan *et al.*, 2014). Cadmium concentration in the study area is higher compared to the range concentrations $0.0004\pm0.01 – 0.002\pm0.01$ mg/dm^3 for water from Nzehelele River, South Africa (Edokpayi *et al.*, 2017). The value is also higher compared to $0.003\pm0.002 – 0.005\pm0.001$ mg/dm^3 obtained for cadmium in water from Sanguling Reservoir, West Java Province, Indonesia (Eka *et al.*, 2018). The value of cadmium in water from the present study is higher than the WHO recommended permissible limits 0.003 mg/dm^3 and therefore, the water is said to be polluted with cadmium.The mean concentration of chromium in water from River Adema was 0.62 ± 0.13 mg/dm^3. This value is high and could be attributed to waste dumps in the river and agricultural lands. Some part of it might also be from runoffs from mining locations. The value is within the range concentration $0.047 – 0.87$ mg/dm^3 for chromium in water from River Mkomon in Benue State, Nigeria (Ioryue *et al.*, 2018). But the value from the present study is far higher compared to $0.002 – 0.10$ mg/dm^3 for chromium in water sources from Tejgaon industrial area, Bangladesh (Mondol *et al.*, 2011). However, the mean concentration of chromium in water from Adema River is far more than the WHO recommended permissible limit 0.10 mg/dm^3 which signifies the water source is polluted with chromium.Copper had a mean concentration of 0.58 ± 0.08 mg/dm^3 in water from River Adema. The recommended permissible concentration of copper for drinking water is 1.00 mg/dm^3 therefore; it implies that the observed mean value is below the permissible level for drinking water and does not portend any potential health risks. The range concentrations of copper $0.00 – 0.01$, $0.03 – 0.07$, and $0.00 – 0.05$ mg/dm^3 in Rivers Buriganga, Turag, and Shitalakhya respectively (Chowdhry *et al.*, 2007) when compared to the mean value from the present study indicate that the latter showed increased concentration.The mean concentration of iron in the water from River Adema was observed to be 0.54 ± 0.12 mg/dm^3. This value is relatively high compared to the WHO recommended permissible limit 0.30 mg/dm^3 which invariably implies iron contamination of the River Adema water source. The high value could be attributed to runoffs from mining locations and farmlands as well as indiscriminate dumping of wastes into the water body. However, the value is lower compared to $3.79\pm0.94 – 6.49\pm0.69$ mg/dm^3 for iron in the water from Mada River, Nigeria (Tukura, 2015) as well as $7.36\pm1.94 – 10.68\pm1.91$ mg/dm^3 for iron in the water from Qua-Iboe River, South-South, Nigeria ((Dan *et al.*, 2014). Lead is a highly toxic metal in water particularly, when present in concentrations that are beyond the recommended permissible limits set by regulatory bodies. Lead was observed to be below the detectable limit in water samples from River Adema. This observation is similar to the level of lead recorded for water from River Sokoto in both dry and wet seasons (Raji *et al.*, 2016). This poses no potential health danger to the water from this source with respect to

lead.Manganese had a mean concentration 0.57 ± 0.10 mg/dm^3 in water samples from River Adema. Manganese is present in the environment naturally due to rock and soil weathering as well as from anthropogenic sources such as domestic waste dumps, landfill leaching, mining, and industrial discharge. Manganese from the present study is higher compared to $0.07\pm0.02 - 0.20\pm0.12$ mg/dm^3 in water from Mada River, Nigeria (Tukura, 2015) and falls within $0.07 - 0.65$ mg/dm^3 in water from Calabar River, Cross River State Nigeria (Ewa, *et al.*, 2013). The mean manganese concentration in water from River Adema is far more than 0.01 mg/dm^3 the WHO recommended permissible limit for drinking water. This is indicative of manganese contamination of the water source.Nickel in water samples from River Adema was below the detectable limit as reported. The primary source of nickel in the surface water is leaching from metals that are in contact with metals. It could also be from sea beds that might have nickel ore-bearing rocks. The result observed for nickel in water from River Adema is similar to that obtained for nickel in water from Calabar River, Cross River State Nigeria (Ewa, *et al.*, 2013).Zinc had a mean concentration 0.04 ± 0.01 mg/dm^3 in water from River Adema. This low level of zinc is an indication of low waste streams from zinc and other metal manufacturing and zinc chemical industries, domestic wastewater, and run-off from soil containing zinc that is discharged into the water body. The value of zinc from this research work is lower compared to the range values of zinc $0.34\pm0.06 - 0.36\pm0.06$ mg/dm^3 in water from Mada River (Tukura, 2015) but falls within the range concentrations of zinc $0.03\pm0.01 - 0.08\pm0.03$ mg/dm^3 in water from Qua Iboe River estuary and adjoining creek, South-South Nigeria (Dan et al., 2014). Zinc mean concentration in the present work falls far below the WHO recommended permissible limit in drinking water and therefore, poses no potential health risks with respect to zinc.

Metal Index: Table 5 shows the metal indices for Cd, Cr, Cu, Fe, Pb, Mn, Ni, and Zn ($P>0.05$). The metal indices for Cd (20), Cr (6.2), Fe (1.8), and Mn (57) in water from Adema River indicate significantly that they are above the WHO permissible limit while the metal indices for Cu and Zn are within WHO permissible limit. Pb and Ni were below detectable limits.

Correlation of Heavy Metals in Water from River Adema: Table 7 shows the correlation matrix for heavy metals in water from River Adema. All the metals have a weak correlation with one another except for Cu/Mn and Fe/Mn where a strong positive correlation exists

signifying the same source for contaminants, from anthropogenic sources.

Conclusion: The physicochemical parameters of water from River Adema analysed were within the threshold of WHO recommended limit except for TDS. WQI calculated revealed that the water from River Adema is of good quality. For the heavy metals determined Pb and Ni were below the detectable limit. Cd, Cr, Fe, and Mn had concentrations that were higher than the WHO recommended permissible limit whereas Cu and Zn were within the WHO threshold. The metal index revealed heavy contamination of the water from River Adema with Cd, Cr, Fe, and Mn.

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