Evaluation of Physical and Chemical Properties of Maikunkele Stream for Irrigation Purpose Using Water Quality Index

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Abstract- The study is aimed at using water quality index (WQI) as a standard for determining the suitability of the surface water for irrigation purpose within the Maikunkele Fadama area in Niger State, Nigeria by monitoring five sampling points for five months. The samples were analyzed for includes nitrate (NO_3), phosphate (PO_4), sodium (Na), potassium (K), magnesium (Mg), calcium (Ca), manganese (Mn), copper (Cu), zinc (Zn), and iron (Fe), besides other general parameters (pH, electrical conductivity (EC), total dissolved solids (TDS), alkalinity, total hardness, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity). The WQI for the parameters under investigation were determined and values compared international standards. The mean temperature value ranged between 29.5 and 30.4 ^oC, while pH values of 7.18 maximum and 5.95 minimum were observed for the study location. The electrical conductivity ranged between 174 and 274 µScm^{-1}. The mean concentration of calcium ion ranged between 3.68 and 4.44 mgL^{-1}. The concentration of Fe was 0.13 mgL^{-1} and 1.48 mgL^{-1}. The minimum and maximum values of Zn are 0.01 mgL^{-1} and 0.17 mgL^{-1} respectively. The Maikunkele Fadama stream had WQI value ranging from 43.469 to 47.120 which fall under good water category, these also conforms to the results obtained from the analysis carried out. It is therefore concluded that the stream water feeding the Maikunkele Fadama farm is fit to be used as irrigation water for the study area as Fadama stream had WQI value ranging from 43.469 to 47.120 thus falling under good water category as far as water quality for irrigation purpose is concerned. Hence, the stream water feeding the Maikunkele fadama farm is fit to be used as irrigation water.

Keywords- Agrochemicals, contamination, fadama farming, Irrigation water, water quality index

1 INTRODUCTION

Agrochemicals (pesticides and fertilizer) stand out as a major development in modern agriculture. They are widely used to save energy and labour, control pest and increase crop yields for food demand of the increasing population and control of vector-borne disease (Adeola, 2012). Despite the positive contribution of agrochemicals to agricultural production, it has been shown in the last few decades that they could also cause negative effects such as cancers, birth defect, reproduction and respiratory problem (Tadesse & Asferachew, 2008; Claeys *et al*., 2011). Some other problems related to agrochemical are destruction of the environment such as global warming, depletion of ozone layer, pest migration and bioaccumulation.

Sonika and Rashmi (2014) reported that only 0.1% of applied pesticides and agrochemicals get to the areas of interest, leaving 99.9% to impact on the environment. These pesticides can take part in different biological, physical, and chemical processes. Several of these pesticides are known with strong persistence which describes their wide existence in the different sections of environment. As a result of these physical and chemical characteristics and their wide use, many of the agrochemicals end up in subsurface and surface water (Sonika & Rashmi, 2014). Such agrochemicals constituents are often traced to most surface waters and in increasing number of aquifers (Postigo *et al*., 2021).

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Studies on groundwater usage for agricultural activities in Nigeria have shown a significant level of contamination (Egbueri, 2019) however certain agrochemicals when continuously used get to the groundwater with time (Anasco *et al*., 2010; Musa & Ahanonu, 2013). This is particularly true for herbicides, especially in developing countries such as Nigeria where Good Agricultural Management Practices (GAMP) are usually not taken into consideration (Ikpesu & Ariyo, 2013). The agrochemicals drain into surface water and groundwater from the points where they are applied. Researches have shown that agrochemicals get to surface water and groundwater either by runoff, run in and leaching thereby conveying the washed chemicals into either nearby surface water and groundwater. These actions result in serious contamination of water which poses great danger to living things that consume the water. The presence of agrochemicals in surface water in very small quantity negatively affects the life cycle of aquatic organisms within such environs (Rovedatti *et al*., 2001). Their existence in water body is considered as a potential risk not only to human being but also to the ecosystem (Ravi & Wantamutte, 2014).

Despite the fact that pesticides are also applied in other sectors, agriculture can undoubtedly be viewed as the most important source of some of these contaminants (Willian, 2008). Agrochemicals' residues found in agricultural produce, water and environmental samples has been a major issue for many years because of their potential risk on human health, persistence and tendency to bio-accumulate (Florin *et al*., 2009). According to a WHO (2009) report, worldwide there are more than 26 million human pesticide poisonings with about 220,000 deaths annually (Richer, 2002).

Water quality monitoring has one of the highest priorities in environmental protection policy (Pesce & Wunderlin, 2000; Simeonov *et al*., 2002; Sargaonkar and Deshpande 2003; Khan *et al*., 2003; Chauhan & Singh, 2010; Effendi & Romanto, 2015) to control and minimize the incidence of pollutant-oriented problems, and to provide water of appropriate quality to serve various purposes such as drinking water supply, irrigation, recreational and industrial; and to protect the valuable freshwater resources. Traditional approaches to assess water quality are based on comparing experimentally determined parameter values with existing guidelines. However, it does not readily give an overall view of the spatial and temporal trends in the water quality in a watershed (Debels *et al*., 2005).

The classification, modelling and interpretation of monitoring data are the most important steps in the water quality assessment. The quality is difficult to evaluate from a large number of samples each containing concentrations for many parameters (Almeida *et al*., 2007). The concept of Water Quality Index (WQI) is based on the comparison of the water quality parameters with respect to regulatory standards and gives a single value to the water quality of a source, which reflects the list of constituents and their concentrations present in a sample (Abbasi, 2002; Khan *et al*., 2003; Sanchez *et al*., 2007). It is a mechanism for presenting a cumulatively derived numerical expression defining a certain level of water quality (Bordalo *et al*., 2006).

The WQI has been considered as one criterion for surface water classifications, based on the use of standard parameters for water characterization. It is a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin (Avdullahi *et al*., 2013; Effendi and Romanto, 2015). The objective of this study is to determine the water quality status of the Maikunkele stream using Water Quality Index (WQI).

2 Materials And Methods

2.1 Study Site

The study was conducted on Maikunkele Stream water in Bosso Local Government Area, Minna, Niger State, Nigeria. Minna, capital of Niger State lies in the savannah zone of the tropics between latitude 8° 10′′ N and 11° 3′′ N and longitude 3° 20′′ E and 7° 30′′ E. Minna has two distinct seasons: rainy and dry. The rainy season begins in April and ends in October- November of the same year. The average annual rainfall of 1,312 mm is obtained for the study area with an average temperature of 30 °C and the average relative humidity of 61.00% (Musa & Egharevba, 2009; Ahaneku & Sadiq, 2014). The Maikunkele stream water is a major source of water in the study area, which is of agricultural and domestic significance. It supplies water for the fadama farmers along its bank for irrigation and for domestic purposes. Some of the activities that are carried out around the study area contaminate the stream. Such activities include domestic waste (sewage), dumping of refuge and agricultural runoff.

2.2 Water Sample Collection

The samples were randomly collected with purified plastic bottles. The plastic bottles were washed thoroughly with distilled water and dried at room temperature before being put to use for sample collection. The bottles were marked and labelled in reference to the sampling points as stated in the works of Musa & Ahanonu (2013). Water samples were collected from five points along the stream and replicated five times across each point. Before the collection of water samples at the various points, each bottle was rinsed with the source of water to be collected and firmly corked after sample collection to prevent contamination and they were transported immediately to the laboratory in ice packs.

The samples were then analysed for fifteen physiochemical parameters namely: temperature, pH, conductivity, dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), chemical oxygen demand (COD), total hardness, alkalinity, nitrates (NO_3^-), phosphorus (PO_4), sodium (Na), potassium (K), Magnesium (Mg), and calcium (Ca) and five heavy metals (Mn, Cu, Zn, Fe, Pb).

2.3 Determination of Water Quality Index (WQI)

Determining the water quality index (WQI) of any source of water is dependent upon the relative importance of the intended use. The calculation of WQI was done using weighted Arithmetic index method. Weighted arithmetic WQI method classified the water quality according to the degree of purity by using the most commonly measured water quality variables. The equations according to the works of Al-Badaii & Shuhaimi-Othman (2014); Effendi & Romanto (2015) which recommended the formula for determining WQI are as stated in equation 1

$$WQI = \frac{\sum Q_i W_i}{\sum W_i} \quad (1)$$

While the quality rating scale (Q_i) for each parameter is calculated using the:

$$Q_i = 100\left(\frac{V_i - V_o}{S_i - V_o}\right) \quad (2)$$

Where V_i is the estimated concentration of the parameter in the analysed water and V_o is the ideal value of this parameter in pure water

V_o = 0 (except pH and DO)

S_i = Recommended standard value of parameter

W_i = unit weight for each water quality parameter

$$W_i = \frac{K}{S_i} \quad (3)$$

Where K = proportionality constant $\left(K = \frac{1}{\Sigma\left(\frac{1}{S_i}\right)}\right)$

The rating of WQI as stated in the work of Al-Badaii & Shuhaimi-Othman (2014) is presented in Table 1 below. The results obtained were statistically analysed using the Microsoft office excel of 2013.

Table 1. Showing water quality index grading

WQI Value	Rating of water Quality	Grading
0 – 25	Excellent Water Quality	A
26 – 50	Good Water Quality	B
51 – 75	Poor Water Quality	C
76 – 100	Very Poor Water Quality	D
Above 100	Unfit for Irrigation Purpose	E

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3 RESULT AND DISCUSSION

All the mean values, maximum, minimum and standard error values of all the parameters for the study area are presented in Table 2. The mean temperature value ranged between 29.5°C and 30.4°C for the five-study location. The probable cause of variation in temperature of the various water samples may include irrigation activities within the study area and sedimentation. The variations in temperature were not statistically significant at 5% level. The pH values observed at the various study points according to the descriptive statistical analysis showed that mean value range between 6.49 and 6.66 with the maximum value of 7.18 and the minimum value of 5.95 both at study location A which shows that the stream is slightly acidic and slightly basic in nature.

The increase in pH can be attributed to organic pollution and the domestic waste discharge into the stream. The electrical conductivity ranged between 174 and 274 μs/cm which falls within the maximum recommended permissible limit of 300 μscm^{-1} allowed for drinking waters as recommended by WHO (2009). The highest electrical conductivity was observed during the second month (February) of collection of samples. This may be due to high introduction of domestic waste water from the neighbouring community.

The lowest value of the dissolved oxygen (DO) was recorded in the month of March which may be due to a one-time rainfall within the study area, thus diluting the waste water from domestic homes from the neighbouring community. DO has been identified as an important parameter which is essential to the metabolism of all aquatic organisms that possess aerobic respiration. The DO values obtained in the study are within recommended WHO (2009) standards. The maximum value observed is 12 mgL^{-1} and the minimum value observed is 6 mgL^{-1} while the mean values ranged between 7.75 and 9.60 mg/L. This low value can be attributed to the low addition of effluents containing oxidizable organic matter and consequent low biodegradation and decay of vegetation at higher temperature leading to low consumption of oxygen from water. Biochemical oxygen demand (BOD) for the stream ranged between 2.0 and 7.0 mgL^{-1}. The increased levels of BOD indicated the nature of chemical pollution within the stream during the dry season. All the study points were observed to have high BOD values, which exceed the recommended WHO (2009) standard value of 5.0 mgL^{-1}., thus, leading to decreases in the level of dissolved oxygen. The total hardness (TH) ranged from 49 and 153 mgL^{-1}, which are within limits of WHO (2009) standard. Sodium concentration ranged from 2.83 to 5.61 mgL^{-1}. The highest Sodium ion concentration was 4.56 mgL^{-1} at station E that is within the permissible limit of 40 mgL^{-1} for irrigation water.

Magnesium ion concentration had a minimum value of 29.00 mgL^{-1} at point A with the maximum value of 35.20 mgL^{-1} at location E. the obtained values for Mg ion were observed to be higher when compared with the maximum permissible limit of 5 mgL^{-1}for irrigation water. The average mean concentration of Calcium ion ranged between 3.98 and 42.75 mgL^{-1}. The highest maximum value of 59.75 mgL^{-1} for calcium ion was obtained in study location c while the lowest value of 21.08 mgL^{-1} was observed at location D. The obtained values were not within the permissible limits of 20 mgL^{-1} recommended by WHO (2009). The maximum concentration of Fe obtained from location B was 1.48 mgL^{-1} while the minimum value of 0.13 mgL^{-1} was observed at location E. The values of iron concentration in the various water samples were within permissible WHO (2009) limit of 5.00 mgL^{-1}.

The mean average values of Cu at the various locations have all values less than 1 with the lowest values obtained at study locations A, B and D respectively while location E had the highest value of 0.02 mgL^{-1}. The observed values found within the study area were within the permissible limit of 0.20 mgL^{-1} as recommended by WHO (2009). The lowest average mean value of Zn within the study was observed at study location D to have a value of 0.05 mgL^{-1} while the maximum values were observed study locations B and C with a value of 0.10 mgL^{-1} was observed at location D. This shows that there is a high contamination intensity and strong diffusivity of Zn. The minimum and maximum value of Zn concentration for the area ranged between 0.01 to a maximum of 0.17 mg/L. Thus, the values of Fe concentration in the water were within the recommended limits of 2.00 mgL^{-1}. The concentration of Manganese obtained in the water ranged between 0.01 mgL^{-1} to 0.06 mgL^{-1}. However, the highest mean value of Manganese concentration recorded in the study area was 0.035 mgL^{-1}. The observed values were within the permissible maximum limit of 0.20 mg/L.

4 WATER QUALITY INDEX (WQI)

WQI for each of the samples were analysed by using the weighted arithmetic index using for the various physiochemical parameters (Temperature, pH, Electrical Conductivity, Nitrate, Phosphate, Copper, zinc, Iron, Manganese, Sodium, Potassium, Magnesium and Calcium) are considered. The values for Q_i, V_i, S_i, W_i, and (Q_iW_i) with their respective WQI are presented in Table 3. The observed temperature for study location A had values for Q_i, V_i, S_i, W_i, and (Q_iW_i) as 101.72, 29.5, 29, 0.013 and 1.322 respectively. The water quality index of station A, B, C, D and E were calculated to be 46.41, 46.16, 43.46, 44.40 and 47.12 respectively.

The suitability of the water samples used for irrigation within the study area was calculated for using the WQI formula and the results obtained were ranked as presented in Table 4. The results show the overall status of the water quality if it is suitable or fit for irrigation purpose. In this study, the WQI for Stations A, B, C, D and E respectively were calculated to be 46.410, 46.163, 43.469, 44.403 and 47.120 respectively. Table 2 presents the results from the samples collected from the study area.

Table 4. Water Quality Index Ranking of the Investigated Water Samples

Location	WQI	Ranking
Station A	46.410	Good Water Quality
Station B	46.163	Good Water Quality
Station C	43.469	Good Water Quality
Station D	44.403	Good Water Quality
Station E	47.120	Good Water Quality

Table 2. Descriptive statistic of water quality parameter of investigated water sample

Station	Statistical tool	Temp oC	pH	Cond	DO mg/L	BOD mg/L	COD mg/L	TH mg/L	Alkali mg/L	NO_3 mg/L	PO_4 mg/L	Na mg/L	K mg/L	Mg mg/L	Ca mg/L	Mn mg/L	Cu mg/L	Zn mg/L	Fe mg/L
A	Mean	29.50	6.50	225.50	7.50	4.00	202.93	98.00	64.00	0.15	0.09	3.87	4.22	25.30	40.58	0.04	0.005	0.08	1.11
	Maximum	30.00	7.18	258.00	8.00	5.00	401.00	115.00	78.00	0.18	0.12	4.90	6.74	29.00	47.26	0.05	0.01	0.13	1.33
	Minimum	29.00	5.95	186.00	7.00	3.00	4.86	81.00	50.00	0.12	0.06	2.83	1.70	21.40	33.90	0.03	0.00	0.03	0.88
	SD	0.57	0.50	29.68	0.50	0.95	197.68	16.54	11.88	0.02	0.02	2.85	2.24	3.83	6.56	0.01	0.01	0.04	0.18
B	Mean	30.50	6.51	241.50	8.00	3.50	5.15	103.00	55.00	0.13	0.06	3.77	3.41	2.70	42.75	0.03	0.00	0.10	0.93
	Maximum	32.00	6.74	274.00	8.00	5.00	6.26	138.00	84.00	0.15	0.08	4.33	6.36	32.40	56.18	0.06	0.00	0.17	1.48
	Minimum	29.00	6.28	209.00	8.00	2.00	4.03	68.00	26.00	0.11	0.03	3.20	1.28	16.80	29.33	0.01	0.00	0.03	0.19
	SD	1.09	0.18	26.90	0.00	1.09	0.79	29.64	22.00	0.01	0.02	0.46	2.21	7.31	11.69	0.02	0.00	0.05	0.49
C	Mean	30.50	6.72	208.10	9.00	4.50	5.66	107.50	62.00	0.10	0.06	4.39	3.15	2.37	3.98	0.03	0.01	0.10	0.97
	Maximum	31.00	6.80	242.00	12.00	7.00	7.97	153.00	96.00	0.11	0.09	5.36	6.03	34.70	59.75	0.05	0.02	0.17	1.40
	Minimum	30.00	6.40	174.00	6.00	2.00	3.35	62.00	28.00	0.08	0.03	3.41	1.78	14.90	24.90	0.02	0.00	0.07	0.24
	SD	0.54	0.17	27.89	3.28	2.30	1.99	36.00	27.57	0.01	0.02	0.81	1.69	7.77	13.35	0.01	0.01	0.03	0.44
D	Mean	30.00	6.79	199.50	9.00	5.00	6.20	84.50	49.00	0.13	0.05	3.89	3.56	21.65	34.84	0.02	0.01	0.07	1.28
	Maximum	32.00	7.25	223.00	10.00	6.00	7.28	120.00	76.00	0.16	0.06	4.88	5.22	31.20	48.60	0.01	0.01	0.12	1.36
	Minimum	28.00	6.32	176.00	8.00	4.00	5.11	49.00	22.00	0.09	0.03	2.90	1.90	12.10	21.08	0.03	0.00	0.01	1.19
	SD	1.14	0.32	18.52	1.09	0.83	0.87	26.74	21.81	0.03	0.01	0.70	1.38	7.47	10.57	0.04	0.00	0.03	0.44
E	Mean	30.00	6.65	233.50	8.00	3.50	4.94	100.00	58.50	0.10	0.07	4.50	3.78	24.55	41.34	0.02	0.04	0.50	0.65
	Maximum	32.00	6.90	258.00	10.00	4.00	5.96	144.00	88.00	0.14	0.09	5.61	5.35	35.20	58.58	0.01	0.07	0.11	1.16
	Minimum	28.00	6.40	209.00	6.00	3.00	3.91	56.00	29.00	0.06	0.05	3.39	2.20	13.90	24.10	0.02	0.00	0.88	0.13
	SD	1.48	0.17	18.88	2.00	0.54	0.93	38.44	28.50	0.03	0.01	0.83	1.20	9.31	15.37	0.05	0.03	0.02	0.42

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Table 3. Calculation of water quality index for the various sample points

Sample	Parameters	Temp.	pH	E. cond. (µs/cm)	$N0_3$ (mg/L)	$P0_4$ (mg/L)	Cu (mg/L)	Zn (mg/L)	Fe (mg/L)	Mn (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Total	WQI = ∑QiWi/∑Wi
A	Observed values (V_i)	29.5	6.5	225.5	0.15	0.08	0.002	0.08	1.09	0.03	3.93	3.43	2.53	4.08		
	standard values (S_i)	25-29	6.5 – 8.4	250	30	2	5	2	5	5	40	2	5	20		
	Quality rating (Q_i)	101.72	77.38	90.2	0.5	4	0.04	4	21.8	0.6	9.83	171.5	50.6	20.4		
	Unit weight (W_i)	0.013	0.046	0.0015	0.012	0.194	0.077	0.194	0.077	0.077	0.0009	0.194	0.077	0.019	0.9905	45.97/0.9905 = 46.410
	($Q_i W_i$)	1.322	3.559	0.135	0.006	0.776	0.003	0.776	1.678	0.046	0.088	33.271	3.896	0.387	45.97	
B	Observed values (V_i)	30.2	6.49	235.8	0.12	0.06	0	0.09	0.93	0.03	3.81	3.41	2.7	4.44		
	standard values (S_i)	25-29	6.5 – 8.4	250	30	2	5	2	5	5	40	2	5	20		
	Quality rating (Q_i)	104.13	77.26	94.32	0.4	3	0	4.5	18.6	0.6	9.52	170.5	54	22.2		
	Unit weight (W_i)	0.013	0.046	0.0015	0.012	0.194	0.077	0.194	0.077	0.077	0.0009	0.194	0.077	0.019	0.9905	45.725/0.9905 = 46.163
	($Q_i W_i$)	1.353	3.553	0.141	0.0048	0.582	0	0.873	1.432	0.046	0.085	33.077	4.158	0.421	45.725	
C	Observed values (V_i)	30.4	6.64	208.2	0.1	0.05	0.008	0.1	0.97	0.03	3.96	3.15	2.37	3.98		
	standard values (S_i)	25-29	6.5 – 8.4	250	30	2	5	2	5	5	40	2	5	20		
	Quality rating (Q_i)	104.82	79.04	83.28	0.33	2.5	0.16	5	19.4	0.6	9.9	157.5	50.6	20.4		
	Unit weight (W_i)	0.013	0.046	0.0015	0.012	0.194	0.077	0.194	0.077	0.077	0.0009	0.194	0.077	0.019	0.9905	43.057/0.9905 = 43.469
	($Q_i W_i$)	1.362	3.635	0.124	0.003	0.485	0.012	0.97	1.493	0.046	0.089	30.555	3.896	0.387	43.057	
D	Observed values (V_i)	30.4	6.66	207.4	0.12	0.04	0.02	0.06	0.92	0.06	3.89	3.35	2.23	3.68		
	standard values (S_i)	25-29	6.5 – 8.4	250	30	2	5	2	5	5	40	2	5	20		
	Quality rating (Q_i)	104.82	79.28	83.2	0.4	2	0.04	3	18.6	1.2	9.72	167.5	44.6	18.4		
	Unit weight (W_i)	0.013	0.046	0.0015	0.012	0.194	0.077	0.194	0.077	0.077	0.0009	0.194	0.077	0.019	0.9905	43.982/0.9905 = 44.403
	($Q_i W_i$)	1.362	3.646	0.124	0.004	0.388	0.003	0.582	1.416	0.092	0.087	32.495	3.434	0.349	43.982	
E	Observed values (V_i)	29.8	6.65	232.6	0.16	0.06	0.016	0.068	0.87	0.06	4.56	3.58	2.37	3.99		
	standard values (S_i)	25-29	6.5 – 8.4	250	30	2	5	2	5	5	40	2	5	20		
	Quality rating (Q_i)	102.75	79.16	93.04	0.53	3	0.32	3.4	17.4	1.2	11.4	179	47.4	19.95		
	Unit weight (W_i)	0.013	0.046	0.0015	0.012	0.194	0.077	0.194	0.077	0.077	0.0009	0.194	0.077	0.019	0.9905	46.673/0.9905 = 47.120
	($Q_i W_i$)	1.335	3.641	0.139	0.006	0.582	0.024	0.659	1.339	0.092	0.102	34.726	3.649	0.379	46.673	

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5 CONCLUSION

Some of the physico-chemical parameters of the Maikukele fadama stream water was assessed and the stream water quality status was evaluated using weighted arithmetic mean water quality index. Based on the data generated from this study, it can be concluded that the stream water can be ranked as good, because almost all the parameters are within the limits of the established standard of WHO (2009). Thus, the stream does not require any treatment before being used for irrigation purposes. It is therefore recommended that the stream can be used for irrigation activities but the WQI of the stream be continuously monitored so as to ensure the quality of water do not deteriorate.

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