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WATER QUALITY ASSESSMENT OF OWIWI RIVER FOR POTENTIAL IRRIGATION OF VEGETABLES

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ABSTRACT
Understanding water quality used for irrigation and its potential negative impacts on crop growth are important for optimization of crop production. The study involved the assessment of hydro-chemical properties and chemical indices of Owiwi river for irrigation of vegetables from the measured quality parameters and analyzed for important quality indices following standard test procedures. The study revealed that pH of water was acidic in nature resulting in low residual sodium carbonate (RSC) values showing dominance of dissolved CO_3, attributed to dissolution of limestone dominant in the study area. The water was regarded as permissible water based on electrical conductivity (EC) and total dissolved solids (TDS), implying non detrimental salinity hazard in the soils. Excessive Na content (> 250 MMg/L) in water reduces the permeability thereby influencing availability of water for the plant usage, obviously associated with low EC and sodium adsorption ratio (SAR) observed in the river water. The excess hardness resulting from high content of calcium and magnesium ions derived from limestone and chalk is undesirable mostly for esthetic reasons like plumbing of irrigation systems. Generally, the water can be classified as good for irrigation of vegetable on the bases of PI, MAR, % Na, SAR and % yield.

Keywords: *Hydro-chemical, permeability, soil, limestone, yield.*

1. INTRODUCTION

Water contamination resulting from natural and anthropogenic activities over the last few decades has led to continuous social and economic development problems and consequently, it's effect on human health. The extent of pollution depends largely on the degree and volume of contamination from sources [1]. Water quality monitoring is important for the protection of public health (drinking or domestic use), agriculture, industry, fishing, recreation, tourism and protection of aquatic ecosystems. The use of various types of water for irrigation and the ability to predict problems that may arise in the course of their use, invoked the need to create a water quality classification system that should be completely different from the systems used for geochemical, industrial, recreational, sanitary and other purposes. However, that irrigation water produces good yield in crop production does not imply good crop quality. This is because some of the contaminants in the irrigation water can be mobilized in soil solution by different biological and chemical mechanisms resulting in potential contamination of water adsorbed by vegetation [2]. Furthermore, irrigation water quality also influences water infiltration potentials as a result of dispersal of soil aggregates which reduces the number of large pores in the soil. With the recent support for increased consumption of vegetables in particular tomatoes for its lycopene richness and anti-oxidant activities, the need to investigate its potential use in environmental concern cannot be over emphasized.

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The development of Owiwi dam water supply scheme within Abeokuta in Ogun State is borne out of the increasing population of the state. However, due to the geological formation coupled with the visible iron content of the river and the subsequent cost of treatment, the dam was initially abandoned. Nevertheless, as a result of the urgent need of irrigation facility for the Agricultural development necessary for handling the Federal Government proposed school feeding program, the Ogun State Government decided to use the facility for irrigation of vegetable in other to cultivate all year round. In other to achieve this government objective, knowledge and understanding of the hydrochemical properties of the river will contribute to its sustainable development and effective management. Hence, the characterization of the hydro-chemistry of the Owiwi River is of paramount importance, this is more so that the knowledge on comprehensive hydro-chemical characterization of the river for irrigation use is rare. Studies [3, 4] addressed aspects of flooding and water quality review. The present study, was therefore, initiated with the objective to asses Owiwi River water quality for irrigation purpose, the potential water infiltration and problem of yield potential.

2. METHODOLOGY

2.1. Study area

The study was conducted at Owiwi river, located in Abeokuta (Lat. 7° 15¹N, Long. 3° 25¹E), Ogun state, which lies in the tropical rain forest zone of Nigeria. Owiwi river has a tropical climate, characterized by an unpredictable rainfall distribution. It has a long-term average annual rainfall and evaporation of about 1200 mm and 1408mm, respectively. The average temperature of the area ranging from 28^{o}C in July/ August to 32^{o}C in February/March [5]. The soil at the experimental site was categorized as a well-drained tropical ferruginous soil (A horizon of an Oxic Paleudulf of Iwo series) with 83% sand, 5% silt and 12 % clay with a pH of 6. [5]. Figure 1 shows the map of the study area.

2.2. Water sampling and analysis

Water samples were collected from two different water sources available in the area, namely dam and farm discharge point. A total of 12 representative water samples from each water source were collected using clean half liter polyethylene bottles. The water samples were collected during dry season November and December which marked the period irrigation is needed for vegetable cultivation in the study area. First the bottles were cleaned by diluted H_2SO4 acid washing and then labeled with an identification number. Then, the number of the bottle was recorded on the sampling datasheet in line with the sampling location. All water samplings were completed in the morning (on the same day) and immediately taken to the Federal University of Agriculture, Abeokuta Central Laboratory for the analysis of important major cations and anions following standard methods (Table 1). Other chemical indices were derived from the measured water quality parameters. The formula adopted and sources for the calculated water quality indices are summarized in Table 2.

2.3. Soil routine physical and chemical analysis

Soil sample was collected at 0-20cm depth using soil ugar in the Federal University of Agriculture, Abeokuta experimental farm. The soil sample was air-dried, sieved in 2mm diameter mesh and analyzed using the following methods in Table. 3.

3. RESULTS AND DISCUSSION

3.1. Properties of soils sample from the farm

Results of the analysis of the soil samples is presented in Table. 4. The result indicated that the texture of the soils is loamy sand with organic matter content of 2.96 mg g^{-1}having a neural pH of 7.03. The organic carbon, total nitrogen and the available phosphorus at the farm was 1.72 %, 0.10 % and 1.62 mg kg^{-1} respectively. The exchangeable calcium, exchangeable magnesium, exchangeable sodium, exchangeable potassium and exchangeable hydrogen are also 3.61 cmol kg^{-1}, 1.54 cmol kg^{-1}, 0.52 cmol kg^{-1}, 0.58 cmol kg^{-1} and 0.18 cmol kg^{-1},respectively. The effective cation exchange capacity (ECEC) was 6.30 cmol kg^{-1}.

3.2. Hydro-chemical composition and estimates of water quality indices of Owiwi River

It was observed from the mean value of the measured water quality parameters and chemical indices derived from the laboratory analyzed water quality parameters of Owiwi River at the Dam and Farm area pin Table 5 that the pH at both sampling sources is acidic in nature (pH < 7) and showed variability between the different water sources.

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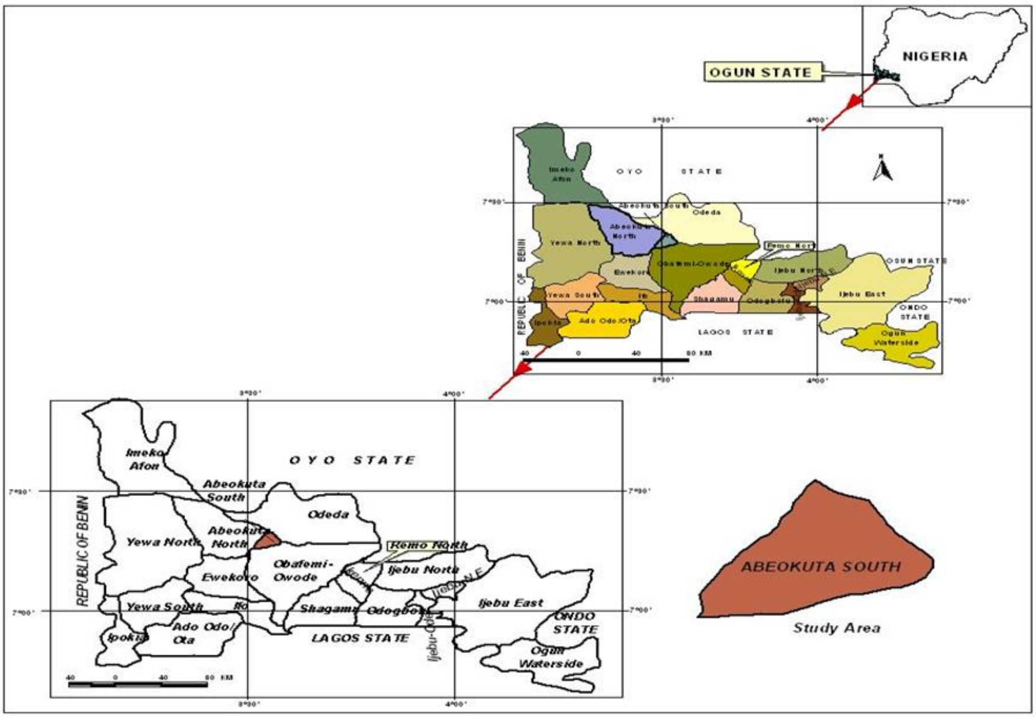

Fig. 1: Map of the study area.

Table 1: Methods adopted for water quality analysis

Quality parameter	Symbol	Method used
Ph	pH	Potentiometric (1:2.5 H2O, v/v)
Electrical Conductivity	EC	Conductometery (1:2.5 H2O, v/v)
Calcium	Ca^{2+}	EDTA (0.05 N) titrimetric
Magnesium	Mg^{2+}	EDTA (0.05 N) titrimetric
Sodium	Na^{+}	Flame photometric
Potassium	K^{+}	Flame photometric
Chloride	Cl^{-}	Titration using 0.05 N AgNO3
Carbonate	CO_3	CaTitration (with 0.01 N H2SO4)
Bicarbonate	HCO_3	Titration (with 0.01 N H2SO4)
Sulphate	SO_4	Spectro Photometric

Sources: [6,7]

Table 2: Water quality parameter estimation methods from measured parameters (All the ionic concentrations are in meq L−1.)

Quality parameters	Symbol	Formula adopted	Reference/source
Total dissolved solids	TDS	TDS = 640 × EC (for EC < 5 dS/m) TDS = 800 × EC (for EC > 5 dS/m)	[8]
Potential salinity	P.S	P:S = Cl_ + ½SO_4 $^{2-}$	[9]
Sodium adsorption ratio	SAR	$SAR = \frac{Na+}{\sqrt{Ca2++Mg2+/2}}$	[10]
Residual sodium carbonate	RSC	RSC = (CO−3 + HCO−3) − (Ca2+ + Mg2+)	[9]Doneen (1964)
Permeability index	PI	$PI = \frac{Na+ + \sqrt{HCO-3}}{Ca2++Mg2+} \times 100$	[9] Doneen (1964)
Total hardness	TH	TH = (Ca2+ + Mg2+) x 50	[11]Ragunath (1987)
Sodium percentage	%Na	$\%Na = \frac{Na++K+}{Na++K++Ca2++Mg2+} \times 100$	[12]Khodapanah et al. (2009)
Magnesium ratio	MAR	$MAR = \frac{Mg2+}{Ca2++Mg2+} \times 100$	[13]Paliwal (1972)
Yield Potential	% Yield	% Yield = 100 − b(Ece − a)	[14]

Source: [15]

Table 3: Methods adopted for soil analysis

Quality parameter	Symbol	Method used
Particle size		Pipette method [16]
pH	pH	pH meter with a combination electrode
Organic-mater	O.M	Walkley Black dichromate oxidation method. Percentage organic matter was calculated by [17].
Exchangeable bases		flame Atomic Absorption Spectrophotometer (FAAS) adopted by [18]
Exchangeable acidity (H^+)		extracting with 1N KCl and determined by NaOH titration [19].
Effective cations exchange capacity	ECEC	estimated by summing the exchangeable bases plus exchangeable acidity cations.
Total nitrogen		Kjeldahl method [20]
Available phosphorus		extracted by 0.03 M NH4F+ 0.025 M HCl [21]
Electrical Conductivity	EC	Conductometery (1:2.5 H2O, v/v)
Calcium	Ca^{2+}	EDTA (0.05 N) titrimetric

The water at the farm are slightly more acidic (pH = 5.54) than the water in reservoirs (pH = 6.51).

This may be due to mixing of nearby factory effluent water with Owiwi River water within the area of discharge to the farm. The acidic nature of water indicating the dominance of dissolved

CO_3 rather than HCO_3 ions which are known to affect pH of most waters. The pH of Owiwi River is not in the range of the recommended range for (6–8.5) for irrigation purpose [22].

Salinity is very important in the determination of river water for irrigation purpose, this is because high salt content in water will renders the soil saline and also affects the salt intake capacity of the plants through the roots. Salinity in water can be evaluated using both electrical conductivity (EC) and total dissolved salts (TDS). The EC and TDS values of both water sources are different. The measured EC value was higher at the farm (65 μS/cm) than at the dam (50 μS/cm). Accordingly, TDS for both sampling points can be classified as fresh water (TDS < 1000 ppm) according to [23], since there values range of 24 -41 ppm thereby indicating the absence of elevated concentrations of salts. According to the EC grading standards as suggested by [24], both water sources are classified as permissible water category. Therefore, the continuation use of this low saline water for irrigation in the long term may not have any detrimental salinity hazard in the soils of the studied area.

Among the cations, the concentrations of Ca_2, Mg_2, Na and K ions are of paramount importance in irrigation water assessment. In this study, the soluble cations Na concentration is higher at the dam (320.2 MMg/L) than at the farm discharge point (234.6 MMg/L). The K values are higher than the Na concentration at both sampling points. Furthermore, the K is higher at the dam (426.7 MMg/L) than at the farm (398.5 MMg/L). On the basis of 200 and 30 ppm for Na and K, respectively permissible limits, the water samples are unsuitable for irrigation.

The excessive sodium content in water sample reduces the permeability, and hence, the available water for the plant is reduced [25]. The high concentration of K in the area is as a result of the sedimentary rock nature of geology the area. Consequently, allowing K minerals exhibit its weak migratory ability [26] and resistant to decomposition by weathering [23]. The dominance of Na and K in the sampling point is as a result of weathering of Na and K bearing minerals/rocks(such as halite, feldspar and montmorilonite), ion (cation)-exchange process and/or agricultural activities in the area. The main source of K in the area would be weathering of potash silicate minerals and agro-chemicals while the source of Na ion may be due to weathering of rocks (limestone), and its displacement from absorbed complex of rocks and soils by Ca and Mg. Even though Ca and Mg are among the most abundant elements on Earth, their concentrations in the study area are relatively low. The concentration of Ca of 190 Mg/L for the dam and 175 Mg/L for the farm while the concentration of Mg of 150 Mg/L for the dam and 130 Mg/L for the farm were above the maximum permissible limit of 80 and 35 ppm for Ca_2 and Mg_2, respectively in irrigation water [27, 28]. In the case study area, Ca is dominant as compared to Mg in both sampling. However, it is possible to suggest that the erosion of limestone and magnetite which are the respective rock and mineral in the area are the most common source of Ca and Mg. It was obvious from table that Boron concentration of 31.3 Mg/L at the dam and 25.2 Mg/L at the farm are also higher than the maximum permissible limit of 3 ppm at the sampling points indicating its non-suitability for irrigation based on Boron content. The concentration of boron was higher at the dam area (31.8 Mg/L) than at the farm area (25.2 Mg/L). The concentration of iron was also higher at the dam area (0.67 Mg/L) than at the farm area (0.52 Mg/L).

The Carbonate is the dominant anion in the water sources at the sampling point followed by the Sulphate ion. The concentration of CO_3 and SO_4 are higher at the dam (119.5 and 91.2 Mg/L, respectively) than at the farm (96.4 and 77.2 Mg/L, respectively). The HCO_3 was observed to be relatively low with 55.4 Mg/L at the dam and 44.5 Mg/L at the farm. The concentration of SO_4 and HCO_3 at the dam and the farm were below the maximum permissible limit of 180 and 250 ppm, respectively in irrigation water. However, the concentration of CO_3 at the dam and the farm were higher than the maximum permissible limit of 15 ppm in irrigation water [27, 28]. The primary source of these ions in water is the dissolved CO_2 in rainwater that on entering in the soil dissolves more CO_2. Both $CO_3$and HCO_3 ions occur in the form of carbonate system of chemical equilibrium, usually associated with hardness of water which gives an unpleasant taste to water. The sources of $CO_3$and HCO_3 ions are dissolution of limestone which is a carbonate rocks dominant in the study area, which results in precipitation of CO_2 [26]. The sources of SO4 include rock weathering derived from lithology and agricultural activities around the area (phosphatic fertilizers).

Sodium adsorption ratio (SAR) is use in the assessment of sodium hazard in irrigation water, hence, it can be used in considering the suitability of water source for irrigation [29]. It is an easily measured property that gives information on the comparative concentrations of Na^+, Ca_2^+, and Mg_2^+ in soil solutions. From Table 5, the SAR values of water sampled at the Dam (4.28) and Farm (2.34) makes the water to be classified as excellent for irrigation [6].

According to [30], Irrigation water quality on the bases of hazardous effect of sodium on water can also be classified using sodium percentage (SP). It is obvious from study that the irrigation water quality can be classified as 'good to permissible' (52.5 %), as sodium percentage values of the Dam area samples is 54% and the farm is 51.8 %.

Accordingly, both water at sampling sources (Dam = 1059 and farm = 949) are classified hard (TH > 1000). The Excess hardness associated with the sampling points is undesirable mostly for economic or esthetic reasons [11]. Hard water as observed in Owiwi River water can be associated with high content of calcium and magnesium ions, and in particular other dissolved compounds which is dominant in Owiwi River. Calcium is believed to have enters the water as calcium carbonate ($CaCO_3$), in the form of limestone and chalk, the predominant mineral in the study area. The predominant source of magnesium is dolomite ($CaMg(CO_3)_2$). In general, water with hardness more than 200 ppm as $CaCO_3$ will lead to scale deposits in the piping system [31]. Thus, the result suggests that most of the water samples can be problematic for plumbing of irrigation systems.

From the Table 5, it can be interpreted that the Owiwi River water at sampling points shows Residual sodium carbonate (RSC) values of -16.33 and -15.07 meq/l at the Dam and Farm, respectively. Based on the [10], water samples have values < 1.0 meq/l and are safe for irrigation; hence, with low RSC values, indicated low pH and land irrigated by such water becomes fertile owing non deposition of sodium carbonate as indicated by the sandy loam nature of the soil (Table 2)

Water can be classified as Class I, Class II and Class III orders with regard to permeability index (PI). Class I and Class II waters are categorized as good for irrigation with 75 % or more of maximum permeability. Class III waters are unsuitable with 25 % of maximum permeability [9]. From the Table 5, it can be demarcated that the PI values are 67.28% for the Dam area and 58.11% at the Farm area, hence, the water at sampling points fall into the Class I Category of Donnen's chart and are categorized as good for irrigation.

Generally, calcium and magnesium maintain a state of equilibrium in most waters. Though, Ca is dominant as compared to Mg in both sampling in the study area as a result of erosion of limestone and magnetite which are the respective rock and mineral in the area are the most common source of Ca and Mg, it is obvious that magnesium in water will adversely affects the crop yield. For this reason, in this study magnesium hazard was evaluated by two following methods including "magnesium ratio" (% MAR) and "calcium to magnesium molar ratio". From the Table 5, it is seen that the magnesium ratio for the Dam was 55.9% and 55.2% for the farm. In this study, water from both sampling points has Mg ratio more in the vicinity 50 %, which will not affect the crop yield [13]. The moderate values of observed 'magnesium ratio' are likely due to the influence of magnetite in these areas. The result support that Ca:Mg molar ratio in the surveyed water samples with >1 (Dam = 3.3 and Farm = 3.1). [32, 33] have pointed out that water with a Ca:Mg molar ratio > 1, results in an decreased SAR value, hence, indicating non detrimental effects on soil structure and crop yield as the soils is not saline.

The yield potential as estimated using the relationship between salinity in irrigation water (electrical conductivity of irrigation water) and the average rootzone salinity according to [14] revealed that electrical conductivity of irrigation water value at 50% yield for tomato with long term use of irrigation water of different quantities based on 15 to 20% leaching fraction and 50 and 65 µS/cm for dam and farm respectively indicating a moderately sensitive water quality for irrigation

Table 4: Some properties of soils sample from the farm.

Quality parameter	Symbol/ Units	**Farm**
pH	pH :H_2O 1:2	7.03
Organic Carbon	O.C(%)	1.72
available phosphorus	AV. P(mgkg^{-1})	1.62
Sodium	Na^+ cmol^{-1}kg^{-1}	0.52
Potassium	K^+ cmol^{-1}kg^{-1}	0.58
Calcium	Ca^{++} cmol^{-1}kg^{-1}	3.61
Magnesium	Mg^{++} cmol^{-1}kg^{-1}	1.54
Hydrogen	H^+ cmol^{-1}kg^{-1}	0.18
Total nitrogen	T. N (%)	0.10
Sand	Sand (%)	75.2
Clay	Clay (%)	9.1
Silt	Silt (%)	13.8
Organic matter	O.M mg g^{-1}	2.96
ECEC cmol^{-1}kg^{-1}	ECEC cmol^{-1}kg^{-1}	6.30
Textural class	Textural class	Sandy loam

Source: Field (September 2017)

Table 5: Result of hydro-chemical composition and estimates water quality indices analysis of Owiwi water sources

Quality parameter	Symbol/ units	Mean Dam Source	Mean at Discharge point to the farm
Ph	pH	6.51	5.54
Electrical Conductivity	EC (µS/cm)	50.00	65.00
Total Dissolved Solid	TDS (MMg/L)	24	41
Calcium	Ca^{2+} (Mg/L)	186.7	170.2
Magnesium	Mg^{2+}(Mg/L)	142.1	125.7
Sodium	Na^+ (Mg/L)	320.2	234.6
Potassium	K^+(Mg/L)	426.7	398.5
Boron	B^+ (Mg/L)	31.3	25.2
Iron	Fe (Mg/L)	0.67	0.52
Carbonate	CO_3^{2-}(Mg/L)	119.5	96.4
Bicarbonate	HCO_3^-(Mg/L)	55.4	44.5
Sulphate	SO_4^-(Mg/L)	91.2	77.2
Sodium adsorption ratio	SAR	4.28	2.34
Residual sodium carbonate	RSC^-(meq/l)	-16.33	-15.07
Permeability index	PI %	67.28	58.11
Total hardness	TH	1059	949
Sodium percentage	%Na	54.0	51.8
Magnesium ratio	%MAR	55.9	55.2
Yield Potential	% Yield	50	50
Water infiltration problem		Likely	Likely

Source: Field (September 2017)

When the irrigation water was assessed for potential water infiltration problem using the electrical conductivity of irrigation water and SAR, it was obvious that the low electrical conductivity of irrigation water and SAR in both the dam and the farm will result in water infiltration problem.

4. CONCLUSION

The hydrochemical composition of Owiwi river water has been analyzed and characterized based on their chemical compositions. Hydro-chemical analysis data has revealed that the pH of Owiwi River water is acidic in nature resulting in low RSC values an indication dominance dissolved CO_3 with average value greater than 100 Mg/L. This is an attribute of dissolution of limestone a carbonate rocks dominant in the study area. The use of this water for irrigation makes the land fertile owing non deposition of sodium carbonate as indicated by the sandy loam nature of the soil. The water can be regarded as permissible water on the bases of EC and TDS, implying that the continuous usage of water for irrigation in the long term may not have any detrimental salinity hazard in the soils. The excessive sodium content (> 250 Mg/L) in water sample reduces the permeability thereby influencing available of water for the plant usage, a phenomenon that was obvious in the low electrical conductivity and SAR observed in the river water. The excess hardness associated river water is undesirable mostly for aesthetic reasons in particular plumbing of irrigation systems. The Hard water as observed in Owiwi River water can be associated with high content of calcium and magnesium ions, believed to have entered the water as calcium carbonate (CaCO3), in the form of limestone and chalk, the predominant mineral in the study area. Generally, the water can be classified as good for irrigation on the bases of PI. % MAR, % Na and SAR. The potential percentage yield of vegetable production is assured from moderately sensitive water quality for its irrigation as obviously noticed from the study.

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