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IRRIGATION WATER QUALITY ASSESSMENT OF RIVER WUPA, ABUJA NORTH CENTRAL NIGERIA

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Abstract
Irrigation water quality assessment of River Wupa, located in the Federal Capital Territory, Abuja, Nigeria, was carried out. Thirty water samples were collected from ten locations along the river in Abuja. Irrigation water quality parameters such as pH, turbidity, EC, TDS, B, Fe, Mn, Ca, Mg, K, Na, ammonium ion, SAR, sulphate, nitrate, phosphate, chloride, bicarbonate, and RSC were determined using standard methods prescribed by FAO and WHO. The results obtained show that pH (7.13±0.09), turbidity (8.73±4.35 meq/dm^3), EC (0.247±0.046 dS/m), TDS (156.80±39.74 mg/dm^3), B (0.10±0.04 meq/dm^3), Fe (0.35±0.10 mg/dm^3), Mn (0.12±0.13 mg/dm^3), Ca (0.63±0.63 meq/dm^3), Mg (0.26±0.02 meq/dm^3), K (1.64±0.20 meq/dm^3), Na (0.001±0.001 meq/dm^3), ammonium (0.39±0.11 mg/dm^3), SAR (0.002±0.001 meq/dm^3), sulphate (20.55±0.50 meq/dm^3), nitrate (12.12±2.08 meq/dm^3), phosphate (0.70±0.11 meq/dm^3), chloride (40.96±3.53 meq/dm^3), bicarbonate (0.23±0.01 meq/dm^3), carbonate (0.43±0.03 meq/dm^3) and RSC (-0.24±0.03 meq/dm^3). The parameters determined had mean values within the respective safe limits for those parameters in irrigation water recommended by FAO, except for sulphate and chloride, which had values higher than the recommended safe limits. High levels of sulphates affect crop yield and production generally. Chloride in irrigation water at elevated levels is toxic to plants, affects plant function and productivity, degrades the soil and, under severe conditions, affects soil fertility. However, the danger that elevated levels of chloride and sulphate pose can be easily handled; therefore, it can be concluded that water from River Wupa is safe for irrigation.

Keywords: Irrigation, Water quality, River Wupa, Salinity, Surface water

Introduction

Water is an essential and indispensable resource that is pivotal to the very existence of the life of all living organisms. However, for water to play this role in the sustenance of the life of living organisms, it must be of good quality. Water plays different roles, from domestic usage to industrial purposes, irrigation for agricultural practices, and a host of others. Water quality standards are different depending on the purpose the water is meant for. Assured water quality is mandatory before it applies to different uses, including drinking, agricultural, recreational and industrial (Khan and Abbasi, 2003, Sargonkar and Deshpande, 2003).

Irrigation is the process of applying water to the soil, primarily to meet the water needs of growing plants. Water from rivers, reservoirs, lakes, or aquifers is pumped or flows by gravity through pipes, canals, ditches or even natural streams. It ensures all-year-round food production, which helps to alleviate the problems of food shortage and consequently alleviates poverty. Surface water bodies are the most used for irrigation purposes. Water sources for agriculture may be of poor quality due to natural influences, contamination or both (Ayers and Westcot, 1985). Surface water of poor quality certainly affects the irrigation water quality. In the last decades, surface resources have been polluted to such a level that they could no longer be of any benefit in irrigation for agricultural practices (Simsek and Gunduz, 2007). The irrigation water quality has to be evaluated to avoid or, at least, minimise impacts on agriculture (Mohammed, 2011).

In irrigation agriculture, the quality of the soil and the crops grown on the soil are determined by the irrigation water quality. Poor irrigation water quality hurts crop productivity, crop product quality, and the public health of consumers and farmers who come in direct contact with the irrigation water (Retno *et al.*, 2015). Problems originating from irrigation water quality can be categorised into four groups; salinity hazards, infiltration and permeability problems, specific ion toxicity, and miscellaneous problems (Simsek and Gunduz, 2007).

The quality of irrigation water is determined by its characteristics and varies with the water source. Water from different sources has different features. For instance, the ones of surface water sources like rivers and ponds would be different from those groundwater sources with varying geology. The chemical composition of irrigation water could affect plant growth negatively directly through toxicity or deficiency as well as alteration of nutrients available for growth (Islam and Shamsad, 2009).

The quality of irrigation water could also vary greatly depending on the type and quantity of dissolved salts which originates from the dissolution or weathering of rocks and soil, including the dissolution of lime, gypsum and other dissolved soil minerals which are always carried with water to the point of usage (Islam and Shamsad, 2009). The major problem of dissolved salts is the influence on the osmotic relationship between the plant roots and the soil moisture. Irrigation water of good quality must have suitable salt concentrations and have physical, chemical and biological parameters in check. When irrigation water contains high levels of salts, it affects plant growth, structure, aeration, permeability and texture of soils (Hussein *et al.*, 2017).

There are many activities; natural (weathering of rocks and soils) and anthropogenic (runoffs from agricultural farmlands, domestic and industrial wastes discharge) along the length of River Wupa. All these affect the quality of water from this source generally regardless of the purpose it could be meant for; drinking, domestic and industrial usage, irrigation, agriculture or recreation. This research aims to determine the irrigation water quality parameter to ascertain the suitability of River Wupa water for irrigation. There is a paucity of information on the irrigation water quality of River Wupa, Abuja. Therefore, the report of this research work will form the basis for a survey on the irrigation water quality of the lotic ecosystem.

Material and Methods

Study area

The study area is Abuja, located in the north-central geo-political zone of Nigeria. It lies between latitudes 8º58′30″N to 9º7′30″N and longitudes 7º19′30″E to 7º31′30″E. River Wupa originates from Aso Rock in Abuja (Figure 1). The altitude of Abuja is 360 m, the average annual rainfall is 1469 mm, and it is underlain by crystalline rocks consisting of migmatites and granitic gneisses intruded by granites. The vegetation of Abuja is purely a savannah with limited forest areas. Abuja lies in one of the very warm regions in Nigeria. The climate is very warm, with an annual temperature of 32ºC but has few truly tropical and sultry months. During the dry season, the water from the river is used frequently for irrigation along the banks of the river. The river receives heavy inflows of wastes from both point, and non-point source discharges, especially during the wet season. Anthropogenic activities occur along the riverbank, from car wash, block moulding and auto mechanic workshops. Discharge of domestic wastes, industrial wastes, and runoff also contribute significantly to the pollution of the river.

Sample collection and preparation

A total number of thirty water samples were collected; from ten points at a distance of 1 km intervals, and the samples were taken 5.0 cm below the water surface (to minimise the contamination of the water sample by surface films). Samples were collected into 1.0 dm^3 plastic bottles that had been washed. Water samples were filtered using Whatman filter paper number 1.0 to remove suspended particles and preserved in the refrigerator pending analysis of physicochemical parameters.

Water samples were collected into prewashed plastic bottles rinsed with dilute HNO_3 acid for metal analysis. The water sample was thoroughly mixed by shaking, after which 100.00cm^3 of the sample was transferred into a glass beaker, and 5.00cm^3 of concentrated nitric acid was added. The beaker with the contents was placed on a hot plate and was allowed to evaporate down to about 20 cm^3. The beaker was allowed to cool, and another 5.00cm^3 of concentrated nitric acid was added. The beaker was covered with watch glass and returned to the hot

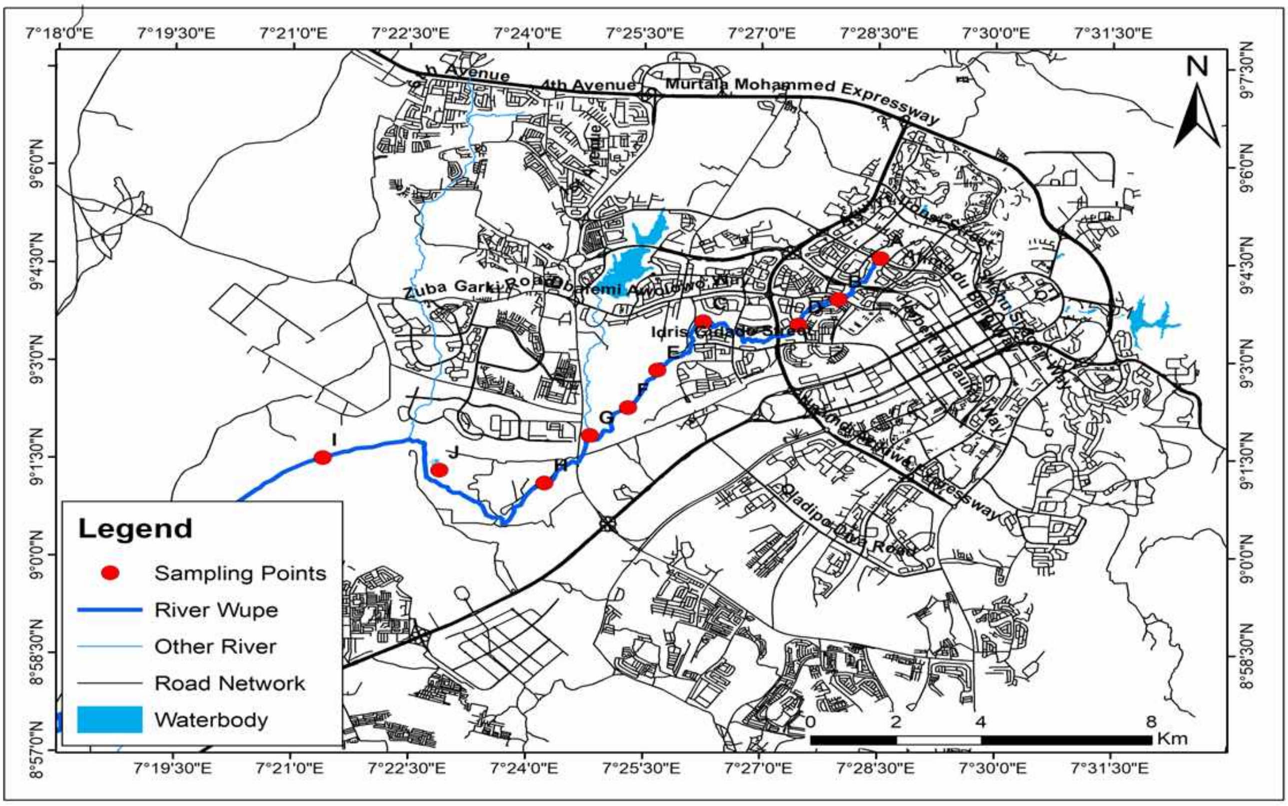

Figure 1: River Wupa in the Federal Capital Territory, Abuja

plate. The heating continued until the solution appeared light-coloured and clear. After cooling, the sample was filtered through Whatman No.1 filter paper into a 100.00cm^3 volumetric flask and made up to the mark with deionised water (Aloke *et al.*, 2019, Singh *et al.*, 2012).

Methods of analyses

The temperature was measured at collection using a mercury bulb thermometer. The thermometer was immersed vertically into the samples. It was allowed to stand straight, the temperature reading of the samples became stable, and the values were taken and recorded (Onuorah *et al.*, 2019).

The turbidity was determined using the Attenuated Radiation Method (direct reading) with a compliant portable turbidity meter (Model No: HI88713-02). 25.00 cm^3 of deionised water (the blank) was placed into the cell holder, and then the light shield closed; the display showed, after which zero was pressed. Then 25.00 cm^{3}of a sample was poured into another sample cell, and the light shield was immediately closed, read and pressed. The result was displayed in Formazin Attenuation Unit and recorded (APHA, 2002).

$$1 \text{ mg/dm}^3 = 3\text{NTU}$$

The pH was determined using a pH meter (JENWAY 430). The meter probe was standardised using pH buffers 4.0 and 7.0 accordingly. The water sample was measured into a 100.00 cm^3 beaker, and the meter was switched on and allowed to stabilise before being lowered into the beaker. The pH value was taken when the meter reading stabilised, and the weight was recorded (Onuorah *et al.*, 2019).

The EC of water samples was determined using a multipurpose HANNA digital model conductivity/TDS meter on the field. About 250.00cm^3 water samples were taken into a 500.00cm^3 white glass bottle; the electrical conductivity was taken immediately by dipping the probe of the conductivity meter inside the water samples for about two minutes. The values obtained were expressed in micro-Siemens per centimetre (μS/cm) (Ioryue *et al.*, 2018).

$$1000 \text{ μS/cm} = 1\text{dS/m}$$

The total dissolved solids (TDS) of water samples were determined using a multipurpose HANNA digital portable model conductivity meter/TDS on the field. 250.00 water sample was taken into 500.00cm^3 white glass, and the TDS was taken immediately by dipping the probe inside the water samples for about two minutes. The values obtained were expressed in milligrams per centimetre cube (mg/cm^3) (Ioryue *et al.*, 2018).

A water sample, 100 cm^3, was passed through a filter paper into a conical flask, and 10 cm^3 of barium nitrate was introduced into it. A new filter paper was weighed, and the mixture was passed through it. The new filter paper was after that oven-dried at 105°C for 30 seconds, and the weight was recorded (Onuorah *et al.*, 2019).

$$Sulphate = \frac{(A-B) \times 1000}{Volume\ of\ Sample}$$

A = weight of filter paper + suspended particles

B = weight of filter paper

1000= one litre

Aliquots of 0.1, 0.2, 0.3 and 0.4 cm^3 of the stock solution were measured into different 100 cm^3 volumetric flasks. To these, 2 cm^3 of 0.1mol/dm^3 NaOH was added, followed by 1, 2, 3 and 4 cm^3 of colour-developing reagent, respectively. The mixtures were diluted to the 100ml mark forming 0.25 μg/cm^3, 0.50 μg/cm^3, 0.75 μg/mg and 1.00 μg/$cm^{3,}$ respectively. A straight-line graph of absorbance at 543nm versus concentration passing through the origin was obtained for the prepared standard solutions. An aliquot of 2 $cm^3$of 0.1mol/dm^3NaOH solution and 1 cm^3 of colour-developing reagent was added to a 50ml sample. The mixture was allowed to stand for 15 to 20 minutes. The nitrate or nitrite concentration was determined at wavelength 543nm of absorbance. A blank analysis was performed with all the reagents without samples for all the analysis (APHA, 2002).

In the Palintest -Tube tests Phosphate/12P method, the phosphate reacts under acid conditions with ammonium molybdate to form phospho-molybdic acid. The compound was reduced by ascorbic acid to form the intensely coloured 'molybdenum blue' complex. A catalyst was incorporated to ensure complete and rapid colour development, and an inhibitor was used to prevent interference from silica. The reagents are provided as a pre-dispensed tube and two tablets for maximum convenience. The test was simply carried out by adding a sample of the water and one of each tablet. The photometer was used in conjunction with a special Tube tests Adaptor (PT 586), which fits into the test chamber. The adaptor must be located with the position mark facing the user and pushed fully home to the bottom of the test chamber (SAPWA, 1999).

A water sample, 100 cm^3, was introduced into a 250 cm^3 conical flask. 1 cm^3 of potassium dichromate indicator solution was added, and the mixture was titrated with silver nitrate solution till a colour change from yellow to reddish brown was observed. The titre value was thereafter recorded (Onuorah *et al.*, 2019).

Chloride Ion Concentration (mg/dm^3)

$$Cl^- = \frac{(Volume\ of\ AgNO_3\ -\ 0.2)\ \times\ 500}{Volume\ of\ Sample}$$

A water sample of 25 cm^3 was transferred into a clean, dry flask using a pipette. Five drops of phenolphthalein were added. The solution turns pink, showing the presence of carbonates. The acid from the burette was added drop-wise until the solution became colourless and the reading was noted; now, 3 drops of methyl orange were added to the same bulk of the solution. The solution turns yellow. Titrate further, adding the acid from the burette dropwise until the colour changes to orange. Note the reading. This procedure should be repeated several times with a fresh quantity of sample water until constant readings are obtained (SAPWA, 1999).

If X cm^3.of 0.05 mol/dm^3, H_2SO_4 is required to convert the quantity of carbonates in 25 cm^3 sample water to bicarbonate (phenolphthalein reading), then 2X cm^3. of 0.05 M H_2SO_4 will be required to neutralise the total amount of carbonates. If Y cm^3. of 0.05 M H_2SO_4 are required to neutralise bicarbonates (Methyl orange reading), then Y-X cm^3. of 0.05 mol/dm^3 H_2SO_4 will be needed to neutralise the bicarbonates present in 25 cm^3 of the sample water because X cm^3. are required to neutralise the bicarbonates obtained from carbonates.

The Palintest Tube tests Ammonia (Indophenol) which is based on the indophenol blue method was used. Ammonia reacts with alkaline salicylate in the presence of chlorine to form a green-blue indophenols complex. Catalysts are incorporated to ensure complete and rapid colour development. The reagents are provided in the form of a pre-dispensed tube and a tablet for maximum convenience. The test is simply carried out by adding a water sample and a tablet to a tube. The intensity of the colour produced in the test is proportional to the ammonia concentration and is measured using a Palintest Photometer (SAPWA, 1999).

The sodium absorption ratio (SAR) measures the amount of sodium relative to calcium and magnesium in a water sample. Specifically, SAR is the ratio of the sodium concentration divided by the square root of half the sum of the calcium and magnesium concentration (SAPWA, 1999).

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

SAR = Sodium Absorption Ratio

Residual sodium carbonate (RSC) is the difference between the sum of the concentrations of bicarbonate and carbonate and the sum of the concentrations of calcium and magnesium ions expressed in meq/dm^3 (SAPWA, 1999).

$$\text{RSC index} = [HCO_3 + CO_3] - [Ca + Mg]$$

These metals B, Fe, Ca, Mg, K, and Na, were analysed in water samples from the River Wupa in FCT, Abuja, Nigeria, to ascertain their suitability for irrigation purposes. The concentrations of B and Fe in the digested water samples were determined with an Atomic Absorption Spectrophotometer, AAS (Model No.AA280FS), manufactured by Agilent Technologies, USA. Ca, mg, K and Na in water samples were determined using a Jenway flame photometer (Model No: PFP7).

Results and Discussion

The various parameters of irrigation water quality are shown in Tables 2 and 3. Hence the irrigation water quality for water samples from River Wupa is categorised into salinity, permeability, toxicity and various effects.

Salinity effects

The salinity effects depend on pH, electrical conductivity, calcium, magnesium and sodium (FAO, 1994).

pH is an essential parameter in determining the irrigation quality of water such that a change of less than 1.0 unit can be very significant because it influences other characteristics of water, reactions in water and the growth of the irrigated plant (Adamu, 2013). The mean pH of water from River Wupa was 7.13±0.09. This value is slightly alkaline, and regular application of this water to the soil may be harmful due to the slightly alkaline nature of the soil during the dry season and the fact that more salt will be added to the soil during each period of irrigation (Ajon et al., 2021). However, the pH of the water under study is within the value of 6.50 – 8.50 recommended by FAO (1994).

The electrical conductivity of water from River Wupa was 0.25±0.05 dS/m which is low compared to the maximum permissible value recommended by FAO (1994) of 3.00 dS/m as the safe limit of electrical conductivity for irrigation water. Following this, the water from River Wupa is suitable for irrigation.

Calcium had a mean concentration of 0.634±0.05 meq/dm^3 in water samples from River Wupa. Calcium is an important parameter in irrigation water quality studies as its presence in excess could lead to salinity problems and much scale formation (Ajon *et al.*, 2021). With the value of calcium, the Ca/Mg ratio is greater than one and as such the potential effect of sodium is reduced, and the sodium absorption ratio (SAR) and exchangeable sodium percentage (ESP) would also decrease (Malgwi *et al.*, 2020). The calcium contents of water from River Wupa are within the range values 0 – 20 meq/dm^3 recommended as permissible limits for calcium in irrigation water; hence, the water is safe for use, and it will not cause any salinity problems.

Magnesium had a mean concentration of 0.26±0.02 meq/dm^3 in water samples from River Wupa. This value falls with the values 0 – 5 meq/dm^3 recommended as the permissible standard values by FAO (1994) for magnesium in irrigation water. Also, the Ca/Mg ratio is greater than one, so the water would not pose any salinity problem when used for irrigation. If the concentration of magnesium is higher compared to that of calcium in the water, the Ca/Mg ratio would be less than one (Ca/Mg<1) and if higher in soil, then the soil-water ratio for Ca/Mg would also be less than one and therefore there may be the danger of potential effect of sodium (Ayers and Westcot, 1994).

Sodium is a critical parameter in determining the salinity level of soils constantly under irrigation. High sodium concentrations in irrigation water could lead to sodicity in irrigated soils (Singh, 2000). The mean sodium concentration in water from River Wupa was very low, 0.001±0.001 meq/dm^3. This value is far lower than 3.00 meq/dm^3 and, therefore, cannot cause any sodicity problem (Ajon *et al.*, 2021). Also, the mean sodium concentration from the present study falls within FAO's recommended standard values of 0 – 40 meq/dm3 (1994); therefore, there would be no salinity problem.

Table 2: Irrigation Water Quality Parameters for the Water Samples from River Wupa (Physical Parameters and Cations)

Parameters	Sample Location										Mean	SD	FAO (1994)
	A	B	C	D	E	F	G	H	I	J			
pH	7.20	7.01	7.12	7.12	7.10	7.14	7.21	7.29	7.04	7.04	7.13	0.09	6.50 - 8.50
Turbidity (meq/dm^3)	10.33	7.00	7.00	10.00	10.07	3.67	7.67	19.67	6.00	5.67	8.73	4.35	50 – 100
EC (dS/m)	0.286	0.172	0.182	0.198	0.293	0.239	0.287	0.272	0.271	0.271	0.247	0.046	0 – 3
TDS (mg/dm^3)	206.00	102.00	128.00	103.00	207.00	130.00	186.00	150.00	182.00	174.00	156.80	39.74	0 – 2000
B^{+++} (meq/dm^3)	0.10	0.12	0.13	0.11	0.14	0.10	ND	0.13	0.09	0.08	0.10	0.04	0 – 2
Fe^{++} (mg/dm^3)	0.40	0.30	0.30	0.20	0.30	0.50	0.30	0.50	0.40	0.30	0.35	0.10	0 – 1.5
Mn^{++} (mg/dm^3)	ND	ND	0.20	ND	0.20	0.30	0.30	0.30	0.20	ND	0.12	0.13	0 – 2
Ca^{++} (meq/dm^3)	0.64	0.675	0.67	0.645	0.635	0.645	0.59	0.55	0.695	0.59	0.634	0.05	0 – 20
Mg^{++} (meq/dm^3)	0.27	0.28	0.28	0.27	0.27	0.27	0.25	0.22	0.27	0.25	0.26	0.02	0 – 5
K^+ (meq/dm^3)	1.79	1.41	1.41	1.67	1.79	1.79	1.79	1.67	1.79	1.28	1.64	0.20	0 – 2
Na^+ (meq/dm^3)	0.001	0.003	ND	0.002	0.001	0.001	ND	0.001	0.001	0.002	0.001	0.001	0 – 40
NH_4^+(mg/dm^3)	0.30	0.20	0.40	0.50	0.40	0.30	0.30	0.50	0.50	0.50	0.39	0.11	0 – 5
SAR (meq/dm^3)	0.001	0.004	ND	0.003	0.001	0.001	ND	0.002	0.001	0.003	0.002	0.001	0 - 15

SD = Standard Deviation, ND = Not Detected

Table 3: Irrigation Water Quality Parameters for the Water Samples from River Wupa (Anions)

Parameters	**Sample Locations**										**Mean**	**SD**	**FAO (1994)**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**			
SO_4^{2-}(meq/dm^3)	20.65	19.95	21.35	20.55	20.00	20.00	21.15	21.05	20.35	20.40	20.55	0.50	0 – 20
NO_3^-–N (meq/dm^3)	10.00	13.00	10.00	12.20	10.00	10.00	12.00	15.00	15.00	14.00	12.12	2.08	0 – 10
PO_4^{3-} (meq/dm^3)	0.67	0.57	0.63	0.60	0.67	0.80	0.83	0.90	0.63	0.67	0.70	0.11	0 – 5
Cl^-(meq/dm^3)	45.00	40.40	39.00	41.00	37.00	40.20	40.00	49.00	40.00	38.00	40.96	3.53	0 – 30
HCO_3^- (meq/dm^3)	0.23	0.24	0.24	0.23	0.23	0.23	0.21	0.21	0.24	0.21	0.23	0.01	0 - 10
CO_3^{2-} (meq/dm^3)	0.43	0.46	0.46	0.43	0.43	0.43	0.40	0.39	0.46	0.40	0.43	0.03	0 – 1
RSC (meq/dm^3)	-0.250	-0.255	-0.250	-0.255	-0.245	-0.255	-0.230	-0.170	-0.265	-0.230	-0.24	0.03	-

SD = Standard Deviation

Permeability effect

Permeability has to do with water infiltration through the soil, which could be reduced due to some specific salts or the absence of some salts such that the water supply system to crop plants are affected. This could eventually lead to low yield of the irrigated crop plants. The factors that determine whether the water for irrigation could cause permeability problems are electrical conductivity, sodium, calcium and magnesium contents, SAR, TDS, carbonates and bicarbonate contents and residual sodium carbonate (RSC) (FAO, 1994).

The electrical conductivity of water from River Wupa was 0.25±0.04 dS/m. When the EC of water is low, it could cause infiltration problems due to reduced salinity. EC of water <0.2 dS/m, which implies low salinity causes the leaching of soluble mineral elements from the surface soils, particularly calcium, reducing their impact on soil aggregation and soil structure (low infiltration rate). But when the EC of irrigation water is >0.3 dS/m, high salinity will cause a very low infiltration rate. Therefore, electrical conductivity (EC<0.2 dS/m) and (EC>0.3 dS/m), which invariably implies low salinity and high salinity respectively, are associated with problems of low infiltration and very low infiltration rates respectively and could eventually culminate in heavy run-off (Ayers and Westcot, 1994). However, the EC 0.25±0.04 dS/m falls between low salinity and high salinity (moderate salinity) and, therefore, would pose any problem of permeability.

The calcium concentration in water from River Wupa was 0.634±0.05 meq/dm^3. FAO (1994) recommended permissible range values for water to be used for irrigation is 0 – 20 meq/dm^3. Since the value of water from River Wupa is within the range for calcium, it will pose no permeability problem. Low calcium could cause a low infiltration rate because, with low calcium, the soil disperses, and the finer particles would end up sealing the smaller pore spaces on the surface soil and greatly inhibiting water infiltration from the soil surface (Ajon *et al.*, 2021). From the calcium and magnesium values, the Ca/Mg ratio is greater than one, and the eminent potential sodium effect would be greatly reduced; therefore, sodium would also not pose any danger in terms of permeability problems. Also, low magnesium contents in water that is to be used for irrigation could cause a low infiltration rate. The mean concentration of magnesium in water from River Wupa was 0.26±0.02 meq/dm^{3,} which is within the FAO (1994) recommended permissible range of 0 – 5 meq/dm^3 as a safe level for magnesium in the water meant for irrigation. Therefore, magnesium in River Wupa water would not constitute any permeability problems on the soils if used for irrigation.

Sodium adsorption ratio (SAR) is an important parameter in determining irrigation water quality, and it is used in managing the sodium effect in irrigation water. It helps to indicate the suitability of water for irrigation use. It is determined by the concentrations of the main alkaline and earth alkaline cations in the water. Aside from decreased water infiltration and availability, high SAR may also lead to temporary over-saturation of surface soil, high pH, soil erosion, inadequate nutrient availability, and increased risk of plant diseases. Generally, calcium and magnesium maintain an equilibrium state in most waters, and their combined effect in countering the negative effect of sodium ions lowers SAR (Sodium Adsorption Ratio). The mean value of SAR in water samples from River Wupa was found to be 0.002±0.001 meq/dm^3, within the recommended range of 0 – 15 meq/L by FAO (1994). Therefore, the SAR would not be a problem with permeability since it determines the salinity of irrigation water.

The mean value of total dissolved solids in River Wupa was 156.80±39.74 mg/dm^3. This value is within the FAO (1994) recommended permissible limit of 0 – 2000 mg/dm^{3,} which is the safe limit for TDS in irrigation water; hence, water from River Wupa is suitable for irrigation and portends no danger of permeability problems.

Carbonate (CO_3^{2-}) and bicarbonates (HCO_3^-) in irrigation water play vital roles. High levels of carbonates and bicarbonates precipitate carbonates of calcium and magnesium when the soil solution concentrates during soil drying, thereby removing calcium and magnesium from soil water. This increases the proportion of sodium which leads to increasing sodium hazards. Reduced levels of calcium and magnesium in soil solution relative to sodium make the SAR of the soil solution tend to increase (Adamu, 2013). High level of bicarbonates causes low infiltration rate and excessive white scale formation on leaves and fruits (Ajon *et al.*, 2021). However, the mean values of carbonate and bicarbonate in water samples from River Wupa had mean values of 0.43±0.03 and 0.23±0.01 meq/dm^{3,} respectively. These values are within the FAO (1994) recommended permissible values of 1.00 and 10.00 meq/dm^3 for carbonate and bicarbonate, respectively. Therefore, since the values for the current study are within the safe limit for irrigation water, the River Wupa water as they would not constitute any permeability problems if it is to be used for irrigation purpose.

Residual sodium carbonate (RSC) is the difference between the sum of the concentrations of bicarbonate and carbonate and the sum of the concentrations of calcium and magnesium ions expressed in meq/dm^3. The mean value of RSC in the water samples from River Wupa was -0.24±0.24 meq/dm^3. It is negative, and a negative RSC indicates that sodium build-up is unlikely since it invariably shows that calcium and magnesium are more than what can be precipitated as carbonates. A positive RSC in water suggests that sodium build-up is possible in the soil to be irrigated with such water. With the value of RSC for water from River Wupa, it will not constitute any infiltration rate problems.

Toxicity effect

The toxicity problems in the water meant for irrigation come up when crop plants take up some water constituents. The bio-accumulation of these substances gets to a particular level that will negatively affect crop yield. Some of these constituents of water that could constitute toxicity problems include iron, manganese, sodium ion, boron ion and chloride ion.

The water samples from River Wupa had mean concentrations of 0.35±0.10 and 0.12±0.13 mg/dm^3 for iron and manganese, respectively. High concentrations of iron and manganese in irrigation water could lead to deposits in irrigation pipes, de-colouration and iron bacteria (Ajon *et al.*, 2021). Also, high concentrations of iron and manganese in irrigation water would constitute toxicity problems. However, the concentrations of iron and manganese in water from River Wupa are within the recommended range values by FAO (1994). Therefore, water from River Wupa has no potential toxicity that would have resulted from iron and manganese.

Sodium at high concentration in irrigation water can lead to sodium toxicity (Ayers and Westcot, 1994). This increased sodium concentration in irrigation water can lead to sodium build-up on the soils irrigated with the water. It could accumulate at a level that will be more than crop plants can tolerate (Ajon *et al.,* 2021). The mean sodium concentration in River Wupa water samples was 0.001±0.001 meq/dm3, within the safe limit of 0 – 40 meq/dm^3 recommended by FAO (1994). Therefore, the water from River Wupa is highly suitable for irrigation purposes.

Boron is rarely present at concentrations to be toxic in surface water, and its toxicity can affect nearly all types of crop plants (Ajon *et al.*, 1994). The mean concentration of boron in water from River Wupa was 0.10±0.04 mg/dm^{3,} which is within the safe limit for boron in irrigation water as recommended by FAO (1994). Therefore, boron toxicity would not be a problem to the suitability of water from River Wupa for irrigation.

Another critical parameter that determines water quality for irrigation is the chloride concentrations in the water. Irrigation water is always associated with chloride toxicity problems because it cannot be adsorbed or held back by soil and moves freely within the soil water (Ajon *et al.*, 1994). The mean concentration of chloride in River Wupa water samples was 40.96±3.53 meq/dm^3. This high chloride level could be from natural and anthropogenic sources; road salts, sewage contamination and water softeners. The chloride mean concentration in water from River Wupa is higher than the safe limit of chloride in irrigation water, as recommended by FAO (1994). Therefore, water from River Wupa has the problem of chloride toxicity. This could lead to leaf burn or dry up of leaf tissues. This chloride toxicity could lead to necrosis (dead tissues) and eventual leaf drops or defoliation.

Miscellaneous effect

The miscellaneous parameters that could cause problems in irrigation water at elevated levels include turbidity, sulphate, nitrate, potassium and ammonium ions.

Turbidity is the measure of the relative clarity of a liquid. Clay, silt, finely divided inorganic and organic matter, algae, soluble coloured organic compounds, plankton and other microscopic organisms are the materials that cause water to be turbid. A high turbidity level in irrigation water could lead to the clogging of the entire irrigation system (Hassan, 1998). The turbidity of water from River Wupa is 8.73±4.35 mg/dm^3. This value is far less than the safe limit for turbidity of irrigation water recommended by FAO (1994). Therefore, turbidity would not constitute any problem in using River Wupa water for irrigation.

The mean concentrations of sulphate and nitrate in water from River Wupa were 20.55±0.50 and 12.12±2.12 meq/dm^{3,} respectively. The sulphate concentration is slightly higher than the safe limit for sulphate in irrigation water recommended by FAO (1994). Therefore, sulphate would be a problem to the use of River Wupa water for irrigation as it will lead to an increase in the salinity of the water, which will lead to low crop yield. Nitrate in River Wupa water is also slightly higher than nitrate's safe limit in irrigation water. This high level of nitrate would also constitute a severe problem in the use of River Wupa water for irrigation because it would be like fertiliser nitrogen applied to soils which, when in excess, leads to overstimulation of growth, delay in the period of maturity and poor quality of crop yield (Ajon *et al.*, 2021).

Phosphate in water samples from River Wupa had a mean concentration of 0.70±0.11 meq/dm^3. This is within the safe limit of phosphate in water to be used for irrigation, as recommended by FAO (1994). Therefore, water for River Wupa is very safe for irrigation concerning the level of phosphate.

The mean concentration of potassium in water from River Wupa was 1.62±0.20 meq/dm^3. This value falls within the safe limit for potassium in irrigation water; therefore, the River Wupa water is safe for irrigation. Research has shown that potassium is not toxic to plants, but at a higher concentration could lead to the deficiency of ions such as calcium and magnesium, also that Nigerian soils do not have sufficient nitrogen, phosphorus and potassium; therefore, potassium in irrigation water helps to correct the imbalance of the ion in the soils (Ajon *et al.,* 2021).

Ammonium nitrogen (NH_4-N) is another critical parameter assessed for evaluating irrigation water quality. According to FAO, 1994 the concentration of ammonium in irrigation water within the safe limit is 0 – 5.00 meq/dm^3. Anything above this could indicate danger or risk factors to irrigation water quality. For all the water samples from River Wupa, the mean concentration of ammonium nitrogen was 0.39±0.11 meq/dm^{3,} which is far below the recommended tolerable limit and safe for irrigation.

Conclusion

Irrigation is an important practice for farmers to increase their production and productivity. Irrigation water quality parameters include pH, turbidity, EC, TDS, B, Ca, Mg, K, Na, ammonium ion, SAR, sulphate, nitrate, phosphate, chloride, bicarbonate, and RSC were determined. The general irrigation water quality results show that all the parameters determined had mean values within the respective safe limits for those parameters in irrigation water recommended by FAO except for sulphate and chloride, which had values higher than the recommended safe limits. High levels of sulphate increase the level of soil salinity which affects plant yield and production generally. A high chloride concentration in irrigation water is toxic to plants and may affect plant function and productivity. Also, high chloride levels deteriorate soil fertility and, under severe conditions, may make the soil unproductive. However, knowing the soil clay content and clay type, irrigation method, evaporation condition, plant type and composition, the level of chloride can be reduced drastically by leaching with excess good quality irrigation water or removed from soil by exported vegetable plant parts. Sulphate can also be reduced through leaching but with good drainages. From the foregoing, the water from River Wupa can be said to be safe for irrigation with the remedial measures in place for chloride and sulphate.

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