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Assessment of the Suitability of Irrigation Water Used in Leafy Vegetable Production in some part of the Rainforest Zone in Nigeria

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ABSTRACT

This study highlights the physical and chemical composition of surface water bodies that serves as source of irrigation water used in Ijebu East (IE), Yewa North (YN) and Ewekoro (EW) LGAs for leafy vegetable cultivation in Ogun state. Analytical results from water samples collected from surface water from farms across the selected study locations shows that the Total dissolved solids (TDS) (IE=118.60mg/L YN=114.7mg/L EW=116.7mg/L), Sodium Adsorption Ratio (SAR) (IE=0.71meq/L YN=0.50meq/L EW=0.44meq/L) and Soluble sodium percentage (SPP) (IE=0.711.5% YN=0.4% EW=0.5%) in the three study locations were found to be within the FAO permissible. The permeability index (PI) (IE=92% YN=98% EW=97%) and Electrical conductivity (EC) ((IE=0.45ds/m YN=0.58ds/m EW=0.49ds/m) were also within the permissible limits of the FAO. Na, K, Mg, Ca and HCO^{3-} ion results were found to be within the FAO permissible limit suitable for irrigation of crops. The pH of the sampled waters was found to be within the 6.5-8.5 FAO permissible limits. Heavy metals tested in the sampled water are Fe, Zn and Cu and were found to be lower than the Fipps (2003) permissible limit. Amaranthus hybridus, Celosia argentea, Corchorus olitorius and Telfairia occidentalis cultivated using irrigation system were tested for Fe, Zn and Cu concentrations, results were found to be within the FAO/WHO permissible limits. Hazard index (HI) for all the metals in the sampled leafy greens across the study locations were found to be less than 1.0, suggesting no adverse health effects. The overall findings indicate that the water sources for irrigation were suitable for irrigation.

Keywords: Irrigation, Water Analysis, Suitability, Leafy Green, Health Risk Assessment, Heavy Metal

INTRODUCTION: One of the most important factors of Plant growth in agricultural production is water, a component that is estimated to make 80% to 90% of all living organisms (Philips A. T., Baba, A. L., Peter C. E., Saheed G. A., and Onmisi, I. S. 2014) When soil moisture derived from rainfall is not sufficient enough to encourage plant growth, it is made up by irrigation. Irrigation water quality is an important environmental issue faced by the agricultural production today as a result of human activities like urbanization, agricultural activities, over use of fertilizers/chemicals, inadequate management of land use and sewage disposal have directly or indirectly affected the quality of water and making it not suitable for irrigation purpose (Philips et al. 2014). According to Dinka (2016), Poor quality irrigation water may lead to the following potential problems may cause the following problems, crop yield reduction or even total crop failure (due to salinity, toxicity and osmotic effect), impaired crop quality which may result in inferior products or pose health risk to consumers, destruction of soil structure as a result of degradation of soil properties and accumulation of undesirable constituents or toxic constituents. All water sources used in irrigation contain impurities and dissolved mineral salts with changeable concentrations which are beneficial to crop production and soil conditions for farming provided their concentrations are within the recommended threshold level of concentration (kirda, 1997). It is therefore important to test for irrigation water fitness prior to usage. Arshad and Shakoor (2017), opined that irrigation water, whether diverted from streams or pumped from tube wells, contains appreciable quantities of harmful substances in solution that may reduce crop yield, quality and tamper with soil fertility. Irrigation water used in farms originates from variety of water sources so much knowledge is needed to relate risk factors that is associated with the use of such waters for irrigation for crop production. In the study area of this work there is no periodic water quality assessment by any authority as regards irrigation water use. In view of this, the thrust of this research work is to test some physical and chemical compositions of the different surface water sources used for irrigation in some leafy green producing communities in the study area and with the aim of evaluating their suitability for irrigation purpose. Physical and chemical quality parameters play a very important role in classifying and assessing water quality for irrigation. Parameters evaluated in this research are pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR), soluble sodium percentage (SPP), permeability index (PI), specific ions such as such as sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Potassium (K^+), Bicarbonate (HCO3-), heavy metals tested include Iron (Fe), Copper (Cu) and Zinc (Zn). The presence of heavy metals such as Fe, Cu and Zn in the irrigated leafy greens produced in the area were also evaluated to assessment their safety for consumption. This study provides valuable information of water quality status in the study area and important for future development of irrigation management. It also supplies information of the safety of leafy green produced in the study in relation to human health.

MATERIALS AND METHODS :STUDY AREA: BRIEF DESCRIPTION

:The study area is located in Ogun state southwestern Nigeria, a rainforest zone in the country. The study was carried out in three purposively selected Local Government Areas (LGAs) were leafy greens are cultivated in commercial quantities using irrigation techniques in the dry season. These LGAs cut across the three senatorial districts of the state. The LGAs are Ijebu East (IE) in Ogun east senatorial districts (Lat: $6^0$56’18.58’’N, Long: $3^0$39’46.33’’E and Lat: 6039’13.42’’N, Long: $4^0$33’.36’’E) Yewa North (YN) in Ogun west senatorial district (Lat: $7^0$24’29.38’’N, Long: $2^0$40’35.24’’E and Lat: $6^0$47’55.00’’N,Long:$3^0$11’8.83’’ E) and Ewekoro (EW) in Ogun central senatorial districts (Lat: $7^0$7’56.92’’N,Long: $3^0$28.73’’E and Lat: 6047’51.98’’N, Long: $3^0$22’33.59’’E). The General rain fall pattern in the study area enters its peak between the months of June and September, which are the wet/rainy season and the hot/dry season is usually between November and January. Monthly average rainfall ranges between 7.1mm in the month of January to 208.27mm in the month of June and annual mean temperature is 26^0C. Leafy greens are produced in commercial quantities in the dry season using irrigation methods from surface water available in the study area.

WATER ANALYSIS:

Water samples were analyzed for pH using electrometric pH meter according to procedure described by McLean (1982), concentration of total dissolved solids and Electrical conductivity was determined using standard methods adopted from APHA (1989). Calcium and Magnesium ions were determined by Atomic Adsorption Spectrophotometer (AAS), Sodium and Potassium ions were determined by flame photometry, bicarbonate is determined by titration method. Determination of heavy metals comprising iron, copper and zinc were determined by the Atomic Adsorption Spectrophotometer. Sodium Adsorption Ratio (SAR), soluble sodium percentage (SPP) and permeability index (PI) were derived using equations 1 to 3

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$$ ……………………………………….1

SAR is expressed in meq/L

$$SSP = \frac{(Na^+ \times K^+)100}{Na^+ + Ca^+ + Mg^{2+} + K^+}$$ …………………………………2

SPP will be expressed in %

$$PI = \frac{Na^+ + \sqrt{HCO^{3-}}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100$$ …………………………………3

PI will be expressed in %

LEAFY GREEN SAMPLES Leafy green samples (leafy parts) were collected in the four farms selected in each of the three LGAs making a total of 12 farms from the three locations. Samples collected are *Telfairia occidentalis* (Fluted pumpkin) from farm 1, *Corchorus olitorius* (Jew's Mellow) from farm 2, *Amaranthus hybridus* (Greens) from farm 3 and *Celosia argentea* (amaranth) from farm 4. Three points within a grid with dimension of 50m by 50m were marked as collection points in each of the farms where leave were collected to ensure randomness of samples. 1kg of leafy green samples were collected from the three points of each of the four farms in the LGAs selected, making a total of 36 samples of 1kg collected across the farms.

LEAFY GREEN SAMPLE ANALYSIS

Determination of heavy metals (Cu, Fe and Zn) in the sampled leafy greens was done by dry ashing and atomic absorption spectrophotometer (AAS) according to AOAC (1995).

HEALTH RISK ASSESSMENT OF HEAVY METALS IN VEGETABLES

:Health risk assessment of the heavy metals (Cu, Fe and Zn) determined in the sampled vegetables were estimated using the following indices; Average Daily Dose (ADD), Non-Carcinogenic Risk and Hazard index

AVERAGE DAILY DOSE (ADD)

Average Daily Dose (ADD) of heavy metals through Leafy Vegetable consumption, the ADD is used to quantify the oral exposure dosage for deleterious substances and was estimated using the formula (Taiwo *et al.* 2021);

$$ADD = \frac{C \times IR \times ED \times EF}{BW \times AT}$$ ………………………………………………………………4

Where,

ADD = Average daily dose of metals in vegetables ($mgkg^{-1}day^{-1}$).

IR = ingestion rate of vegetables = $100gday^{-1}$ (Zeng *et al.* 2015)

C = Concentration of metals in vegetable sample ($mgkg^{-1}$)

BW = Body Weight (Kg); 60kg for an adult (Taiwo *et al.* 2021)

EF = Exposure Frequency (day Year^{-1}) = 350 days year^{-1}

ED = Exposure duration (years) = 30 years (Taiwo *et al.* 2021).

AT = Averaging time = life expectancy (years).

AT = ED for non-carcinogenic effects, while AT = 54.5 years for carcinogenic effects in adult (WHO 2015; Taiwo *et al.* 2020).

NON-CARCINOGENIC RISK: Non-Carcinogenic Risk for an average adult was calculated using reference dose (RfD) previously established by the joint FAO and WHO Expert committee on food additives in 2015 and the United States Environmental Protection Agency in the year 2001. The Non-Carcinogenic risk was determined by calculating the hazard quotient (HQ) which is a ratio of average daily dose to the reference dose (RfD) which will show non-carcinogenic adverse effects due to exposure to toxicants. (Zeng *et al.* 2015; Taiwo *et al.* 2021). RfD value used for Fe was 0.7 (PPRTV, 2006), Zn and Cu were 0.3 and 0.4 respectively (Taiwo *et al.* 2021).

$$HQ = ADD/RfD \quad \ldots\ldots\ldots\ldots 5$$

Where RfD is the estimated maximum permissible dose of the metals tested in the vegetables for humans through daily exposure. If the HQ< 1, adverse health effects would be unlikely experienced, whereas potential non-carcinogenic effects would occur when HQ≥1 (Taiwo *et al.* 2021).

HAZARD INDEX : The hazard index (HI) is calculated to evaluate the potential risk of adverse health effects from a mixture of chemical elements/metals in the Leafy Vegetables sampled across the study area described as assuming additive effects. (Zeng 2015).

$$HI = \sum HQ \quad \ldots\ldots\ldots\ldots 6$$

If the value of HI<1, chronic risks are assumed to unlikely happen, whereas non-cancer risks are likely to occur if the value of HI≥ 1 (Zeng 2015).

RESULTS AND DISCUSSION: The analytical results of the quality parameters of the irrigation water samples of the studied locations are given in table 1. The study shows that the mean values of the pH of the sampled waters across the three study location are slightly acid. The mean values obtained are within the 6.5-8.5 FAO irrigation water limits recommended as suitable for crop production. The results were similar to the study of Aboyeji and Ogunkoya (2017) in a similar environment that also found mean values of sampled irrigation water to be slightly acidic. Very acidic water can cause corrosion of the metal parts of the irrigation equipment the waters will be best in use with irrigation equipment without metallic component. Polyvinyl chloride (PVC), Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) pipes that are corrosion free are advisable. pH >8.2 and very high HCO-3 has negative impacts on crops and result in clogging problems when micro-spray and drip irrigation systems are in use. High pH has been identified to cause salts to precipitate and reduce the efficiency of pesticide (Bauder et al. 2014). Ec is a measure of total soluble salt concentration in water and ability of water to conduct electric current (Philips et al. 2014 and Dinka, 2016). Ec is an indicator of salinity hazard in water and a high salt level in irrigation water can significantly reduce crop yield and quality and bring total crop failure under extreme conditions (Ayers and Westcot, 1985, Nishanthiny et al. 2010). The Ec in this study were found to be within the permissible limit of 0-3.0ds/m recommended by Bauder et al. (2014) and the FAO as presented in table 1. A high Ec value above this permissible limits affects crop water availability, these results therefore shows that the waters sampled across the three study locations in the study area have Ec that is suitable for irrigation purpose. Total dissolved solid (TDS) indicates the general nature of water quality, salinity behavior of water is also indicated by the TDS (Philips et al. 2014). TDS measures the amount of materials dissolved in water including organic and inorganic ions. A high TDS can make the density of water harmful as it determines the flow of water into and out of an organism's cell (Arshad and Shakoor, 2017). In this study the TDS were found to be 111.60mg/L, 114.7mg/L and

116.7mg/L in Odogbolu, Yewa North and Ewekoro respectively and these mean values fall below the maximum permissible limit between 0-200mg/L of the FAO which implies that the sampled waters are suitable for irrigation and safe for the cultivated crops. The results obtained for the SAR across the study locations indicates that the samples are suitable for irrigation use and posing no threat to the leafy greens cultivated in the area. The results are lower than the maximum permissible limit of the FAO of 0-15meq/L. SAR is a measure of tendency of the irrigation water to cause the replacement of ions of Mg and Ca attached to the soil minerals with sodium (Na) ions (Maas, 1986). SAR is also a means by which sodium hazard (sodicity) is estimated (Dinka, 2016). Extreme SAR (too much Na relative to Ca and Mg) in irrigation water significantly affect the crop yield (reduce quality and quantity) and impair soil physical condition (due to reduced soil permeability and increased tendency of hard-setting (Ayers and Westcot, 1985). From the mean values obtained for the SAR across the study area it shows that the SAR in the irrigation waters is moderate and therefore safe for the cultivation of the leafy greens across the study locations. Measuring the amount of soil exchange capacity occupied by sodium is usually measured as Soluble Sodium Percentage (SPP). A high SPP connotes more exchangeable sodium to be present which has a negative impact for soil and the crops grown on such soils. According to Joshi *et al.* (2009), a high sodium percentage may cause stunted growth for crops and poor permeability in soils. SSP in soils with percentage more than 60% according to Fipps (2003), may lead to accumulation of sodium in the soil causing poor soil permeability which is detrimental to the water-oxygen ratio, hence not good for irrigation purpose. The results for this study showed that across the three study locations, the mean SPP obtained for each of the sampled waters were suitable for irrigation Fipps (2003) classification with no negative effect on the soil permeability of the farms of the study area. According to Doneen (1964), Permeability Index (PI) of water can be classified as Class I, Class II, and Class III orders. Class I and II waters are categorized as good for irrigation with 75% PI or more while Class III water category with 25% of maximum permeability is regarded as unfit for irrigation (Naseem *et al.* 2010 and Aboyeje and Ogunkoya, 2017). The results obtained from these study indicates that the samples have PI ≤75% which is categorized as fit for irrigation according to Doneen (1964) this is also in line with the FAO recommendation for PI fit for irrigation purpose. The findings are similar to that of Aboyeje and Ogunkoya (2017) who got mean values of 167.1%, 125.0% and 53.8% in irrigation waters of some areas in the southwest Nigeria to belong to the category of waters good for irrigation. Sodium concentrations in the samples across the study area were found be below the 200mg/L Maximum limit recommended by the WHO to be non-toxic to plants and 0-800mg/L of the FAO recommended for irrigation of crops. Mean values obtained for calcium across the study area were lower than the maximum permissible limit of the FAO which is put at 200mg/L in irrigation water. The concentrations across the study area are there for regarded as safe for the soil and crops. Mean values of K and Mg ions were found to be moderate, very high concentrations may cause toxicity and accumulation in plants themselves and when such plants are consumed by human and livestock, possible health hazards can be developed (Philips et al. 2014). In the case of this study the mean values were found to be within the recommended threshold of the FAO which is put at 200mg/L for both Ca and Mg ions. For specific ion toxicity, management practices such as the addition of Na ions problems can be avoided by the addition of Ca and Mg to water for irrigation to reduce SAR. HCO^{-3} is a principal alkaline constituent in almost all water sources influencing hardness and alkalinity of water. Concentration of HCO^{-3} should be under limit as excess HCO^{-3} may be harmful to humans, animals and plants. The mean values obtained across the three study locations of this study area falls within this bracket of the FAO threshold for HCO^{-3} in irrigation water which is set at 0-10meq/L. The heavy metals tested which includes Fe, Cu and Zn ions (table 2) in the sampled waters were found to be in concentrations that are regarded as safe for use as irrigation water. The mean values for Fe, Cu and Zn were found to be lower than 5.0mg/L, 0.2mg/L and 2.0mg/L respectively as recommended by Fipps (2003) as the maximum safe limits required for irrigation water safe for crop production. Excess of these heavy metals can accumulate in the plants and pose a health hazard to humans on consumption.

The health risk assessment data for average daily dose (ADD) of heavy metals in the LVs sampled are presented in table 3. This was calculated by the assumption that an adult of 60kg would ingest 0.1kg of each vegetable type daily for 350 days in a year. The ingestion rate found across the study area is far below the recommended rate 0.4kg per day given by FAO/WHO. The mean values for Fe content in *Telfairia occidentalis* (6.0mgkg^{-1}), was found to have the highest value in Odogbolu and for *Corchorus olitorius* (4.970mgkg^{-1}) it was found to be in Yewa North. .*Amaranthus hybridus* (10.12mgkg^{-1}) and *Celosia argentea* (5.85mgkg^{-1}) have their highest mean values in Ewekoro and Odogbolu Respectively. These values fall within the permissible safe limit of 425ppm of the FAO for Fe content in vegetables. The results for copper concentration in the sampled leafy greens obtained across the study areas are found to be lower than the FAO/WHO permissible limits in vegetables which are valued at 4.0mg/100g. The values obtained across the study area are lower than the established PMTDI level of 0.35-1.20mg kg^{-1}day^{-1} for Zn (modified for 60kg body weight; FAO/WHO 2011). The average mean values for the ADD values for Cu in the Leafy green samples across the study locations were lower than PMTDI level of 0.58mg kg^{-1}day^{-1} recommended for 60kg body weight by the FAO/WHO. The HQs of Fe, Zn and Cu in the sampled LVs in the three study locations were generally less than 1.0, as presented in table 4 indicates no health risk of exposure to these metals in vegetables similar to the results of Taiwo *et al.* (2021). The hazard index (HI) values are presented in tables 4 for the three study locations and are less than 1.0, suggesting no cumulative non-carcinogenic adverse health effects as described in Taiwo et al. (2021).

Table 1: **Physical and chemical properties of sampled irrigation water**

Parameter	Ijebu East	Yewa North	Ewekoro	FAO Irrigation Water Limits
Ph	6.8	6.7	5.9	6.0-8.5
TDS (mg/L)	118.60	114.7	116.7	0-200
SAR (meq/L)	0.71	0.50	0.44	0-15
SPP (%)	1.5	0.4	0.5	< 60
PI (%)	92	98	97	≥75
EC (ds/m)	0.45	0.58	0.49	3.0
Na (meq/L)	0.70	0.50	0.45	0-800
K (meq/L)	0.06	0.02	0.03	0-2
Mg (meq/L)	0.68	0.72	0.76	0-200
Ca (meq/L)	1.34	1.32	1.37	0-180
HCO^{3-}	3.24	3.98	4.20	0-10

Table 2: **Mean Values of Heavy Metals in Sampled Irrigation Water**

Study Location	Fe (mg/L)	Cu (mg/L)	Zn
Odogbolu	0.03	0.002	0.001
Yewa North	0.31	0.002	0.003
Ewekoro	0.21	0.003	0.002
Fipps (2003) Maximum Permissible Limit	5.0	2.0	3.0

Table 3: Available Daily Dose of Heavy Metals Found in the Sampled Leafy Green

Metal	Leafy Green	ADD		
		Odogbolu	Yewa North	Ewekoro
Fe (**Mgkg^{-1} day^{-1}**)	*Amaranthus hybridus*	0.03	0.02	0.016
	Celosia argentea	0.007	0.01	0.008

	Corchorus olitorius	0.006	0.01	0.008
	Telfairia occidentalis	0.01	0.005	0.009
Zn (**Mgkg^{-1} day^{-1}**)	*Amaranthus hybridus*	0.0016	0.003	0.0004
	Celosia argentea	0.0015	0.002	0.0016
	Corchorus olitorius	0.0003	0.0002	0.002
	Telfairia occidentalis	0.0002	0.0007	0.0006
Cu (**Mgkg^{-1} day^{-1}**)	*Amaranthus hybridus*	0.0019	0.0002	0.0002
	Celosia argentea	0.00016	0.00003	0.00017
	Corchorus olitorius	0.000021	0.00006	0.0002
	Telfairia occidentalis	0.00019	0.0001	0.00004

Table 4: Hazard Quotient and Concentration of Metals in the Leafy Green Vegetables

Metal	Leafy Vegetable	Ijebu East			Yewa North			
		Mean concentration	RfD	HQ	Mean Concentration	RfD	HQ	Mean Concentrat
Fe (mg/kg)	*Amaranthus hybridus*	17.2	0.7	$4.3x10^{-2}$	12.20	0.7	$3.0x10^{-2}$	10.01
	Celosia argentea	4.25	,,	$1.0x10^{-2}$	5.89	,,	1.4x10-2	5.04
	Corchorus olitorius	4.01	,,	$8.6x10^{-3}$	5.02	,,	$1.4x10^{-2}$	4.92
	Telfairia occidentalis	6.72	,,	$1.4x10^{-2}$	2.79	,,	$7.0x10^{-3}$	5.38
Zn (mg/kg)	*Amaranthus hybridus*	1.01	0.3	$5.0x10^{-3}$	1.59	0.3	$1.0x10^{-2}$	0.25
	Celosia argentea	1.00	,,	$5.0x10^{-3}$	1.01	,,	$7.0x10^{-3}$	1.03
	Corchorus olitorius	0.17	,,	$1.0x10^{-3}$	0.12	,,	$6.0x10^{-4}$	1.25
	Telfairia occidentalis	0.10	,,	$6.0x10^{-4}$	0.41	,,	$2.3x10^{-3}$	0.39
Cu (mg/kg)	*Amaranthus hybridus*	0.12	0.4	$4.8x10^{-4}$	0.13	0.4	$5.0x10^{-4}$	0.14
	Celosia argentea	0.1	,,	$4.0x10^{-3}$	0.02	,,	$7.5x10^{-5}$	0.11
	Corchorus olitorius	0.13	,,	$5.3x10^{-4}$	0.04	,,	$1.5x10^{-4}$	0.13
	Telfairia occidentalis	0.12	,,	$4.8x10^{-4}$	0.06	,,	$2.5x10^{-4}$	0.02

Table 5: Hazard Index for the Metals in the Leafy Green Vegetables

Leafy Green Vegetables	Ijebu East	Yewa North	Ewekoro
Amaranthus hybridus	0.05	0.05	0.02
Celosia argentea	0.02	0.02	0.01
Corchorus olitorius	0.01	0.01	0.02
Telfairia occidentalis	0.02	0.01	0.02

CONCLUSION: Based on the FAO irrigation water limit standards for irrigation water, the results of analysis and assessments of the water quality of the irrigation water used in the three study locations revealed that the samples are suitable for irrigation purpose as they fall within the permissible limits of the FAO irrigation water standard. Water quality assessment should be properly carried out and should be part of the requirement to design an appropriate management practice in irrigated agriculture. This will ensure soil conservation and improve soil productivity with the benefits of high crop yield under irrigation. Leafy green samples collected in the study area were assessed for health risk and found to be safe for consumption and found to pose no non-carcinogenic adverse health risk effect when consumed.

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