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EVALUATION OF RIVER WATER QUALITY FOR IRRIGATION PURPOSE IN NIGER STATE, NIGERIA.

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Abstract

Quality of water has meaning only with respect to its particular use. Therefore, we collected water samples from Barkin-Sale ($9^0$34'N, $6^0$31'E) and Chanchaga ($9^0$41'N, $6^0$38'E) rivers from Minna and Upper Landzun ($9^0$53'N, $6^0$32'E) and Lower Landzun ($9^0$36'N, $25^0$33'E) rivers from Bida, and all locations are in Niger State, Nigeria to ascertain its current quality status and suitability for irrigation purpose. The samples were compared with standard guidelines (FAO) for interpretation of water quality for irrigation. The water samples were slightly acidic to slightly alkaline with their pH values ranging from 6.52 to 7.53. In terms of salinity hazard measures as electrical conductivity (ECw), the water samples had very low salinity (ECw = 0.60 - 1.24ds m^{-1}). With respect to sodicity hazards, Sodium Adsorption Ratio (SAR) values obtained for all the water samples ranged from 2.12 to 7.25. This indicates a low risk of sodium build up. When compared with standard guidelines for interpretation of water quality for irrigation, the parameters were within the limits indicating that the water is of good quality for irrigation of arable crops.Their suitability/quality for irrigation purpose occurred in the order of Upper Landzun > Lower Landzun > Chanchaga > Barkin-Sale. It is recommended therefore that continued monitoring of irrigation quality should always be conducted.

Keywords: Electrical conductivity; Total dissolve solids; Sodium adsorption ratio; Specific ion toxicities

INTRODUCTION

Irrigation waters whether derived from springs, diverted from streams or pumped from wells contain appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility (Mahmud *et al.*, 2007).Major concern for water use for irrigation is decreased crop yields and land degradation as a result of excess salts being present in water and soils (Tsado *et al.*, 2014).

Irrigation water always carries substances derived from its natural environment or from the waste products of man's activities (domestic or industrial effluents). Water quality concerns have often been neglected because good quality supplies have been plentiful and readily available. The situation is now changing in many areas. Intensive use of nearly all good quality supplies means that new irrigation projects and old ones seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems associated with poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use (George, 2004 and Chandu *et al.,* 2008)

Mahmud *et al*., (2007) in their investigations reported that the suitability of water for irrigation is determined not only by the total amount of salts present but also by the kind of salts. Various soil and cropping problems develop as the total salt content increases, and special management practices may be required to maintain acceptable crop yield. Water quality or suitability for use is judged on the potential severity of the problems that can be expected to develop during long-term use. Gibbs (1970) observed that problems that result varies both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of water user. As a result, there is no set limit on water quality; rather, its quality/suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems.

Most irrigation waters in southern guinea savanna of Nigeria is of excellent/good quality (Anikwe *et al.*, 2002 and Ige *et al,* 2008). Since water quality is a minor problem in this agro-ecological zone, virtually little or no local research has been conducted. But due to urbanization and rapid population growth in this agro-ecology, the extent of surface water pollution along the downstream of the rivers ranges from low to increasingly severe. Therefore, the principal objective of the present study is to evaluate the chemical composition of the waters of the study area with respect to specific ions such as Sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Potassium (K^+), Boron (B), Bicarbonate (HCO_3^-), Chloride (Cl^-), Nitrate (NO_3^-); pH values and Electrical Conductivity (ECw), Total Dissolved Solids (TDS), Sodium Adsorption Ratio (SAR) and hence to assess their quality and suitability for irrigation of arable crops in this agro-ecology.

MATERIALS AND METHODS

The study area comprises of four different locations: Barkin-Sale River ($9^0$34'N, $6^0$31'E), Chanchaga River ($9^0$41'N, $6^0$38'E) in Minna and Upper Landzun river ($9^0$53'N, $6^0$32'E) and Lower Landzun River ($9^0$36'N, $25^0$33'E) in Bida. Both Minna and Bida are located in Niger State, Southern Guinea Savanna of Nigeria. Irrigation water samples were taken from the fastest flowing part, the mid-way along the width of the river. About 2 liters of water was collected in polyvinyl chloride (PVC) bottles. Samples were brought to the Laboratories of Department of Water Resources, Aquaculture and Fisheries Technology and Soil Science and Land Management of Federal University of Technology, Minna and analyzed immediately without delay to prevent biological transformation.

Water samples were analyzed for pH using electrometric pH meter according to procedure described by McLean (1982).

Electrical conductivity was determined electrometrically using digital conductivity meter (Gosh *et al.*, 1983). Calcium and magnesium ions were determined by Atomic Adsorption Spectrophotometer (AAS), sodium and potassium ions were determined by flame emission spectrophotometer (Golterman, 1971). Phosphorus, boron and nitrate were determined colourimetrically (Gosh *et al.*, 1983 and APHA, 1989), while chloride and bicarbonate were determined by titration method (Christiansen *et al.*, 1977 and APHA, 1989).

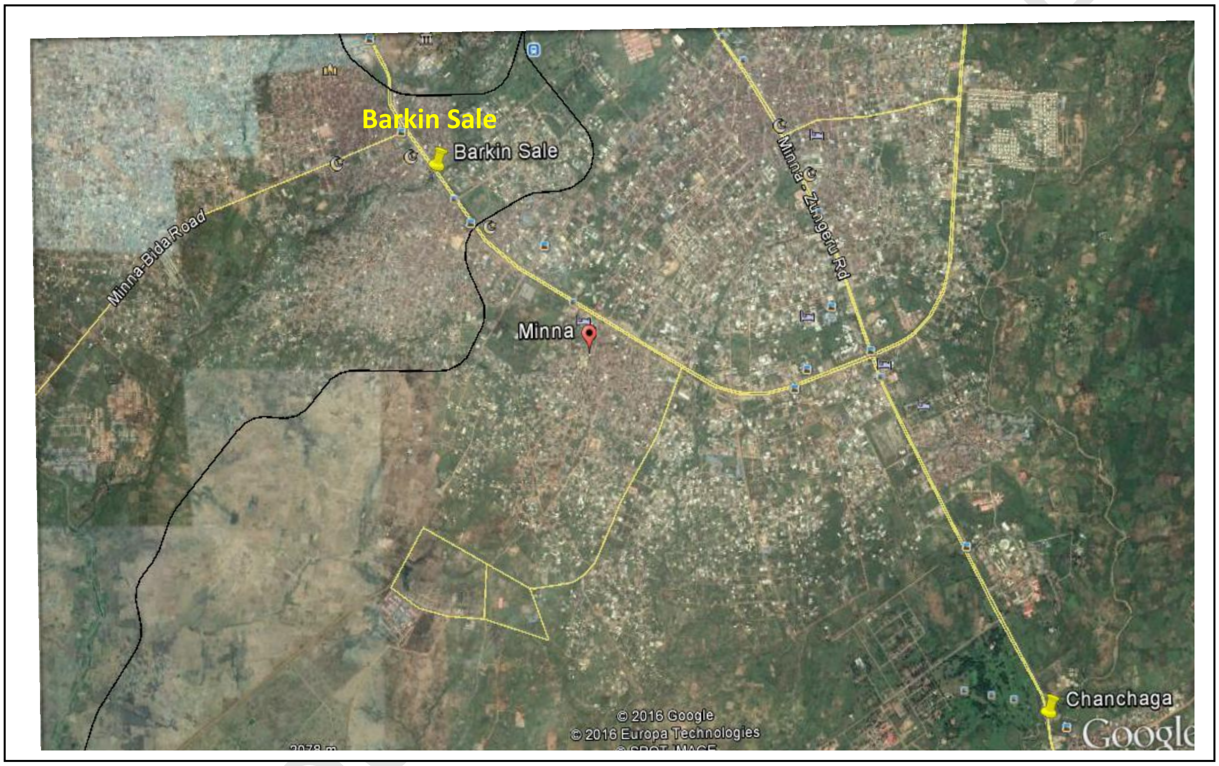

Figure 1: An imagery of Minna, Niger State, showing sampling locations

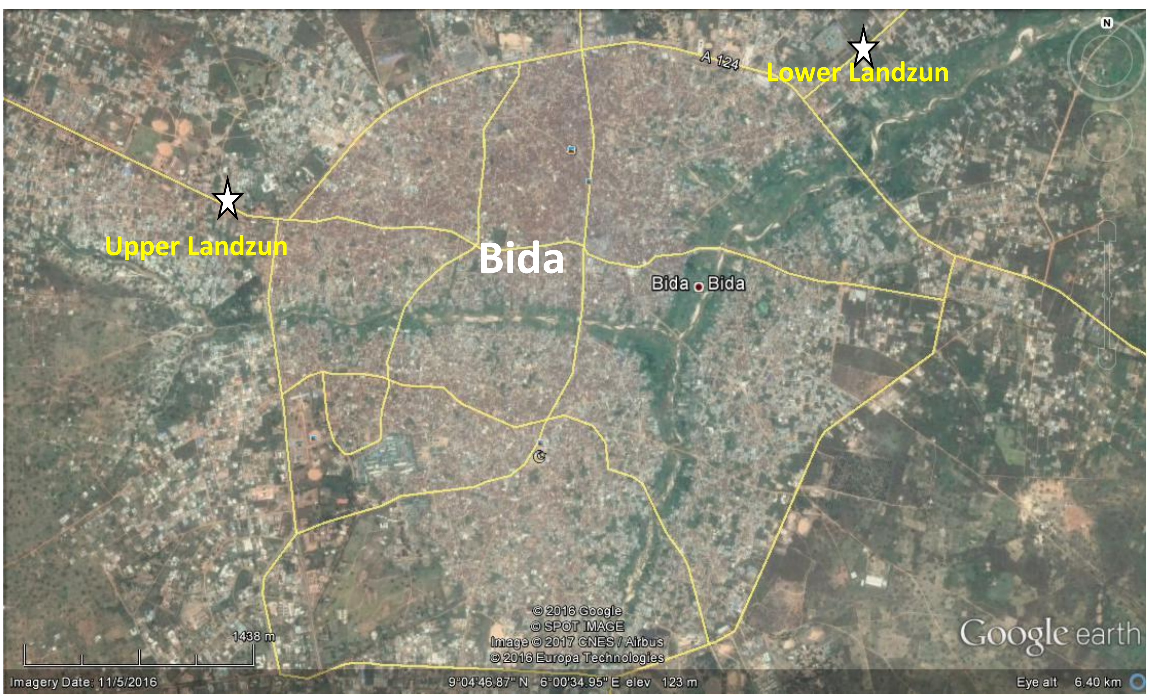

Figure 2: An imagery of Bida, Niger State, showing sampling locations

RESULTS AND DISCUSSION

Acidity/Alkalinity

The results of the quality parameters of the irrigation water samples of the studied locations are presented in Table 1, while Table 2 shows the recommended general guidelines for the assessments of quality of irrigation water. The analytical result of the water samples indicates that they are slightly acidic to slightly alkaline in nature and their pH values were found to be within the standard recommended limit of 6.5 – 8.5(Ayers and Westcott, 1976). The slightly lower pH value of water sample from Barkin-Sale River as compared to the other locations may be partly due to high content of humic acids in the sediment as also suggested by Olajire and Imeokparia (2001). Most water samples have a pH greater than 7.0 as acidic water (< 6.0) could cause corrosion of metal parts in irrigation equipment (George, 2004) and also results to physical breakdown of root cells (Rhoades, 1983).

SALINITY

Water salinity is usually measured as electrical conductivity (ECw) and/or Total dissolve solids (TDS) and is a measure of the total soluble salt concentration in water. The results presented in Table 1 revealed that the ECw of water samples ranged from 0.60 to 1.24ds m^{-1} indicating that they are highly suitable for irrigation purpose in their respective locations with the exception of Barkin-Sale river source that is moderately suitable. Regarding ECw values samples from Upper Landzun, Lower Landzun and Chanchaga rivers are excellent (EC< 250 μScm^{-1}) and Barkin-Sale sample is good (EC= 250 – 750 μScm^{-1}) in quality (Mahmud *et al.*, 2007). The amount of TDS ranged from 384 - 794 mgL^{-1}. Water containing TDS of less than 1000 mgL^{-1} is considered to be of 'fresh water' category (Rowe and Abdelmagid, 1985) and accordingly all water samples were rated as 'fresh water'. Higher salinity results in higher ECw and as the salt level increases, the plant must expend more energy to take in nutrients dissolved in the water from fertilizer and the soil. A wide range of crops including vegetables, fruits, fodder and grain crops were reported to tolerate these levels of salinity water (George, 2004 and Abdullahi *et al.*, 2010). Although the guidelines (Table 2) indicates that the ECw and TDS levels of water from Upper Landzun, Lower Landzun and Chanchaga rivers present no plant problem, their levels in Barkin-Sale river are just in the zone of increasing problem. The relatively higher values of ECw and TDS of water samples Barkin-Sale River as compared to the other locations could be attributed to the discharge of waste waters (domestic sewage and municipal), dirt and suspended inorganic matter and automobile effluents from Mechanic workshops which are located close to the source of the water. Olajire and Imeokparea (2001) reported that high levels of TDS in irrigated water may be an indication of seepage of filthy surface waters into the ground water and soil beneath the ground surface as water percolate through them. Increase in dissolve solids in irrigation water affects soil efficiency and growth and yield of crops (Abdullahi *et al.*, 2010). But George (2004) concluded that when a water quality parameter is in the range of increasing problems (75 – 300 mS m^{-1}) increasing care is required in the selection of plant species and proper management (improved irrigation system and proper irrigation schedule) are needed to minimize salt damage.

Water infiltration rate

The infiltration of irrigation water is expressed in terms of SAR (Sodium Absorption Ratio). SAR value is a measure of relative concentrations of sodium to calcium and magnesium. The result (Table 1) of the analyzed water samples shows that sample from Upper Landzun had the least SAR value of 2.12, while sample from Barkin-Sale recorded highest SAR value 7.25 Guideline (Table 2) indicate that only water sample from Barkin-Sale has a moderate value of SAR.This water has a medium sodium level indicating that the water is highly suitable when used in coarse – textured soils or organic soils with good permeability and the use of good sodium tolerant crop species (Bernstein, 1980 and Yakubu *et al.*, 2014). Sodium hazard can be reduced under proper management especially in light soils with good infiltration and internal drainage with no impermeable layer (Tsado *et al.*, 2014). Samples from other three locations have low SAR value. Ige *et al.*, (2008) reported that only water with SAR's value greater than 9.0 that are unacceptable for irrigated agriculture. SAR is used to estimate the sodicity or sodium hazard of irrigation water and higher SAR values will potentially cause damage to the soil structure (Maas, 1986) and this will reduce water infiltration into the soil surface and down the profile, and limit aeration, leading to reduce crop growth (Chandu *et al.*, 2008). All water were classified 'excellent' (SAR < 10) for irrigation based on SAR criteria after Hossain and Ahmed (1999).

Specific ion toxicities

All waters contain varying amounts of different soluble constituents of cations and anions. Out of the soluble constituents, Ca, Mg, Na, Cl, SO_4, HCO_3 and B are of prime importance in judging the water quality for irrigation (Rowe and Abdelmagid, 1985). Some of these ions are beneficial and few ions in excess amounts are more or less detrimental for plant growth and soil properties (Ige and Olasehinde, 2011).

The result of these soluble constituents is presented in Table 1. Ca and Mg content of water samples varied from 6.01 to 10.81 and 5.20 to 9.22 meq L^{-1}respectively. Ca and Mg content were dominant in Chanchaga and Lower Landzun river water samples respectively. K and Na content of the water samples ranged from 0.17 to 0.31 and 3.10 to 7.75 meq L^{-1} respectively. The concentrations of Ca, Mg, K and Na of water samples were suitable for irrigation (Hossain and Ahmed 1999). Boron concentration in water samples ranged from 0.08 to 0.16 mg L^{-1}. According to water quality classification after Wilcox (1945), all water samples were within the safe limit (B< 0.75mg L^{-1}) and graded as 'excellent' for irrigation. This finding confirmed the result ofIge and Olasehinde, (2011). P content (0.6 to 0.82 mg L^{-1}) in all the water was not found problematic for irrigating agricultural crops on all soils, where the maximum recommended concentration of P was 2.0 mg L^{-1} (Ayers and Westcot, 1985).

The NO_3 concentration of water samples varied from 0.40 to 0.81 mg L^{-1} (Table 1). NO_3 content was higher in Barkin – Sale and lower in Upper Landzun river water samples. NO_3 content in all water samples were not found problematic for irrigating agricultural crops on all soils (Table 2). HCO_3 and Cl contents of the water samples ranged from 0.80 in Upper Landzun to 2.12 meq L^{-1}in Barkin-Sale and 1.08 in Upper Landzun to 2.34meq L^{-1} in Chanchaga respectively.HCO_3 and Cl contents of the water samples were within the safe limit for irrigation (Ayers and Westcot, 1985). All the water samples were free from CO_3. Although specific ion toxicities rarely occurs in irrigation water. Ayers (1977), Maas (1986) and Cooper and Lipe (1992) observed that different crops vary in their tolerance for toxic elements and the actual toxic concentration of the elements vary from crop to crop. These authors concluded that, most tree crops and woody ornamentals are sensitive to specific ion toxicities especially Na, Cl, B and HCO_3, but most annual crops are tolerant. It was further observed that in each of the locations with their various levels of specific ion concentrations, a wide range of crops including vegetables, fruits, fodders and grain crops can be grown.

CONCLUSION

The results of analysis and evaluation of water from four different locations in Bida and Minna, Niger State for irrigation purpose revealed that the water is suitable and good for irrigation based on results of ECw, TDS, SAR and Specific ion toxicities. The variations in the chemical parameters of these water sources could be attributed to the differences in locations and as well as the anthropogenic activities taking place around the environment. Their suitability/quality for irrigation purpose occurred in the order; Upper Landzun > Lower Landzun > Chanchaga > Barkin-Sale. This is due to the fact that the Upper Landzun River is located close to the source, Lower Landzun and Chanchaga rivers are located out skirts of the town and Barkin-Sale river is located within Minna metropolis, close to automobile mechanic workshop. It is recommended therefore that continued monitoring of irrigation quality should always be conducted.

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Table 1. Maximum parameter values registered in irrigation water samples

Potential Irrigation problem	Symbols	Units	Locations B. Sale	Chanchaga	U. Landzun	L. Landzun
Alkalinity/Acidity		pH	6.52	7.53	7.34	7.42
Electrical conductivity	ECw	ds m^{-1}	1.24	0.68	0.60	0.65
Total Dissolve Solid	TDS	mg L^{-1}	794	435	384	416
Sodium Adsorption Ratio	SAR		3.02	1.47	1.23	1.38
Sodium	Na	meq L^{-1}	7.75	4.30	3.10	3.81
Magnesium	Mg	meq L^{-1}	5.20	6.21	5.41	9.22
Calcium	Ca	meq L^{-1}	8.05	10.81	7.10	6.01
Potassium	K	meq L^{-1}	0.21	0.27	0.31	0.17
Phosphorus	P	mg L^{-1}	0.60	0.69	0.82	0.71
Bicarbonate	HCO_3	meq L^{-1}	2.12	1.42	0.80	1.31
Chloride	Cl^-	meq L^{-1}	1.12	2.34	1.08	1.35
Nitrate	NO_3^-	mg L^{-1}	0.81	0.78	0.40	0.47
Boron	Bo	mg L^{-1}	0.14	0.16	0.08	0.13

B. Sale = Barkin – sale, U. Landzun = Upper Landzun, L. Landzun = Lower Landzun

Table 2: FAO Guidelines for interpretation of water quality for irrigation.

Irrigation Problems	Degree of Problem: No Problem	Degree of Problem: Increasing Problem	Degree of Problem: Severe Problem
Salinity (affects crop water availability)			
ECw (ds m^{-1})	< 0.7	0.7 – 3.0	> 3.0
TDS (mg L^{-1})	< 450	450 - 2000	> 2000
Permeability (affects infiltration rate into soil)			
ECw	> 0.5	0.5 – 0.2	< 0.2
adj.SAR	< 3.0	3.0 – 9.0	> 9.0
Specific ion toxicity (affects sensitive crops)			
Sodium (adj.SAR) (meq L^{-1})	< 6.0	6.0 – 9.0	> 9.0
Chloride (meq L^{-1})	< 4.0	4.0 – 10.0	> 10.0
Boron (mg L^{-1})	< 0.7	0.7 – 3.0	> 3.0
Miscellaneous (affects susceptible crops)			
NO_3-N (mg L^{-1})	< 5.0	5.0 – 30	> 30
HCO_3 (meq L^{-1})	< 1.5	1.5 – 8.5	> 8.5
pH		Normal range 6.5 – 8.4	

Source: Ayers and Westcott, (1976)