Assessment of Soil Salinity and Irrigation Water Quality of Chanchaga Irrigation Scheme I, Minna, Niger State

1Ibrahim A. Kuti, 2Bolaji A. Adabembe, 1John J. Musa, 1Peter A. Adeoye, 1Murtala I. Animashaun,
2Hillary Aroboinosen and 1Michael E. Akhare
1Department of Agricultural & Bioresources Engineering, Federal University of Technology, Minna, Nigeria
2Department of Water Resources Management and Agro-meteorology, Federal University Oye -Ekiti, Nigeria

Abstract — The extent to which salinity is increasing in arid and semi-arid regions recently has become a concern in irrigation and non-irrigation land. In view of this, the study evaluated soil salinity and irrigation water quality at Chanchaga Irrigation Scheme I, Minna, Niger State with the aim of assessing the soil fertility status and irrigation water source of the scheme. The study took soil samples at 0 - 30cm depth from irrigated and non-irrigated plots and water was taken from the main point of the border irrigation system. Both soil and water sample collected were subjected to laboratory analysis. The study determined sodium absorption ratio and exchangeable sodium percentage of soil and water parameters analyzed in the laboratory. The Levene’s test for equality of variances was performed on the concentration of the parameters analyzed in both soil (irrigated and non-irrigated) and water of the scheme. The study reveals that the sodium concentration was found higher in the irrigated plot than control plot and the EC and SAR values of the irrigated plot was classified as sodic. The SAR and other exchangeable values in both irrigated and non-irrigated plot have equal variances (> 0.10) with the exception of chloride which is significant. The level of potassium in the water was higher and sodic in nature. The study concluded that the sodium hazard in both soil and water was higher than the desirable limits. It is important to take the soil sample of the whole plots so as to examine the salt variation in the scheme.

Keywords — Chanchaga Irrigation Scheme I, Irrigation Water, Physical and Chemical Properties, Soil Salinity

1. INTRODUCTION

Globally, salinization is a source of risk to soil, water and human health (Shrivastava and Kumar, 2015). It is the main problem of irrigation agriculture because it has negative impact on the stages of crop growth and restricts both phosphorus and water uptake from soil (Shrivastava and Kumar, 2015). Salt-affected soils are either saline or sodic. Saline soils are those soils with electrical conductivity above 4dS/m that affect the crops growth (Aderoju and Akomolafe, 2013). Chlorides and Sulphate of sodium, calcium, aluminium and magnesium are the principal elements of soluble salts. There exist two categories of salinity and these include primary and secondary salinity. The former come naturally due to accumulation of salts while the later occurs due to irrigation land or dry land.

Sodic soils refer to soils with exchangeable sodium percentage above 15, with sodium salts such as alkaline hydrolysis and sodium carbonate (Aderoju and Akomolafe, 2013). Aderoju and Akomolafe, (2013) reported that alkaline hydrolysis and sodium carbonate of salts-affected soils dissents physically, chemically, biologically, and their geographical and geochemical dispersion. Salinity is one of the severe environmental factors limiting crop productivity. It is important because most crops are sensitive to salinity caused by high concentration of salts in the land while few crops are not. Furthermore, salinization is becoming prominent factor for salinity because of evaporation phenomenon in irrigation (Shrivastava and Kumar, 2015).

*Corresponding Author

Poustiti (2004) reported that increase in food demand during the last 3 to 4 decades aggravated the use of irrigation by about 300% which in turn make the use of ground water to be prominent since surface water is scarce in both arid and semiarid regions thereby increasing soil salinization. Numerous studies employed EC, SAR, ESP, and osmotic potential methods to determine the nature of soil salinization (Chemura et al., 2014; Munns, 2005). Both sodium absorption ratio (SAR) and exchangeable Sodium percentage (ESP) are effective because they involve laboratory analysis of physical and chemical properties of soil and irrigation water. Adamu (2013) reported that exchangeable Sodium percentage (ESP) in Watari River Irrigation Project, Kano State was low. Ethan et al., (2014) reported that the concentration of SAR at Baddegi and Edozighi irrigation scheme is low. Maina et al., (2012) accounted that the mean value of EC, SAR and TDS are normal at Kano River irrigation project. Little study has shown that the soil salinity and alkalinity level in the scheme were normal. Due of this, the study is assessing the soil fertility status and water source of the Chanchaga Irrigation Scheme I for ascertaining the extent of salinity in soil and water source.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study was carried out in Chanchaga irrigation scheme I and it is located at Chanchaga Local Government area of Minna, Niger State. It lies between 941’ 00” N and Longitude 638’ 00”. The scheme was established in 1975 and it is situated behind Chanchaga main - market. The scheme has 10 hectares of land and uses surface irrigation. It is extended on the bank of river Chanchaga and uses river Chanchaga as source of water as shown in Fig 1. The scheme experiences both dry and wet seasons. The average annual temperature and rainfall were 27.5°C and 1229 mm respectively. Soils underlyed by sand stones and it has loamy and sandy loam textures that are reasonably
fertile and well drained. The soil has high water infiltration rates. Rice, spinach, okra, maize and sorghum were the major crops grown in the scheme.

2.3 Soil Sampling
This plot was divided into two equal blocks for the purpose of soil sampling. Each block was further subdivided into four homogeneous blocks. Thirty-two soil samples were collected at 0-15cm and 15-30cm depth on both the irrigated plot and the control plot and the sample handling was carried out as described by Okalebo et al., (2002). In each block, four soil samples were collected at random and mixed together to form a composite sampling. Also, control samples were collected approximately 540m away from the plot using composite sampling method.

2.4 Soil Analysis
The soil samples were collected and analyzed between 27th July and 4th August 2016 at WAFT Federal University of Technology, Minna in accordance with Ogunwale (1978). The soil parameters analyzed were pH, EC, K⁺, Ca²⁺, Mg²⁺, Na⁺ and total exchangeable bases.

2.5 Water Analysis
The water samples were collected on 27th July, 2016 at the main irrigation line on the field. The samples were kept in ice domestic cooler and transported to WAFT Federal University of Technology, Minna laboratory and stored in the refrigerator at 4°C prior to analysis. The samples were analyzed in accordance with Ogunwale (1978). The water parameters analyzed were pH, Ca²⁺, Mg²⁺, Na⁺, HCO⁻ and Cl⁻.

2.6 Method
2.6.1 Determination of sodium absorption ratio
The study used equation 1 to determine the sodium absorption ratio of both soil and water as described by Leticia et al., (2015). The sodium absorption ratio was interpreted as shown in Appendix A. It is calculated as follows;

\[
SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})}}
\]  

Where,
SAR= Sodium absorption ratio.
Na⁺, Ca²⁺, and Mg²⁺ are exchangeable bases of sodium, calcium and magnesium cations.

2.6.2 Determination of Exchangeable Sodium Percentage
The study used equation 2 to estimate Exchangeable Sodium Percentage of both soil and water of the scheme as described by Leticia et al., (2015). The exchangeable Sodium Percentage was interpreted as shown in appendix B. It is calculated as follows;

\[
ESP = \left( \frac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \right) \times 100
\]  

Where,
Na⁺, Ca²⁺, Mg²⁺ and K⁺ are exchangeable bases of sodium, calcium, magnesium and potassium.cat ions

2.7 Data Analysis
Levene’s Test for Equality of Variances was performed on the data obtained from the laboratory. The results were presented in Tables 1, 2 and 3.

3. RESULTS AND DISCUSSION
3.1 Determination of Physiochemical Properties of Soil in the Scheme
3.1.1 Soil Exchangeable Bases
Table 1 shows the mean concentration of soil exchangeable bases in Chanchaga irrigation scheme 1. For the irrigated plot, the mean values of Potassium (K⁺), Calcium (Ca²⁺), Sodium (Na⁺) and Magnesium (Mg²⁺) were 14.82, 40.0, 58.65 and 8.40 (mg/l) while that of the control plot were 68.87, 20.00, 37.44 and 1.46 (mg/l) respectively. From the results obtained, it is observed that sodium has the highest concentration in the irrigated plot while magnesium has the least concentration value. Sodium concentration was found high whereas magnesium gave
lowest concentration in the control plot. The concentration of Ca$^{2+}$ and Na$^+$ were slightly different from each other for both irrigated and control plot. This finding concurs with work conducted by Chemura et al. (2014).

3.1.2 Soil SAR and ESP
Table 2 shows the Mean values of soil pH, EC, SAR and ESP for Chanchaga irrigation scheme I. The pH, EC, SAR and ESP of the irrigated plot were 7.33, 0.624(dS/m), 10.68, and 48.13% whereas that of control plot were 6.50, 0.079(dS/m), 3.49 and 56.93% respectively. The pH value shows that the soil in the irrigated plot was alkaline whereas the control plot was found to be acidic. The values of electrical conductivity and sodium absorption ratio of the soil in irrigated plot were higher than that of the control plot but the exchangeable sodium percentage in the control plot was higher than that of irrigated plot. The values of 48% and 56.93% on both irrigated and control plot depicted that the ESP was ranked excessive on control plot followed by irrigated plot. The higher ESP value obtained in results came due to the distance (540m) of the control plot to the river and this means that river Chanchaga was the source of the sodium concentration such as hospital wastes. This study implies that the soil experienced dispersion resulting in poor physical condition and poor plant growth due hospital wastes discharge into river Chanchaga. According to the EC values obtained, the study shows that the level of potassium in the water was higher than that of FAO (1994) and this shows that the level of potassium in the water was higher and sodic in nature (Leticia et al., 2015).

### Table 1: Mean Concentration of Soil Exchangeable Bases in Chanchaga Irrigation Scheme I

| Soil Exchangeable Bases | K$^+$ (mg/l) | Ca$^{2+}$ (mg/l) | Na$^+$ (mg/l) | Mg$^{2+}$ (mg/l) |
|-------------------------|-------------|-----------------|--------------|-----------------|
| Irrigated plot          | 14.82       | 40.00           | 58.65        | 8.40            |
| Control plot            | 6.87        | 20.00           | 37.44        | 1.46            |

Appendix C shows test for equality variances between, SAR, pH, Temperature and other exchangeable bases. The, SAR, pH, and other exchangeable bases do not show any level of significance because their value were greater than 0.10 meaning that the variances were equal. In addition, the chloride has its value less than 0.10 meaning that there is a significant difference in both irrigated and control plot of Chanchaga irrigation scheme I.

3.2 Determination of Physiochemical Properties of Irrigation Water Samples
Table 3 shows physiochemical properties of irrigation water in Chanchaga irrigation scheme I. The values of Ca$^{2+}$, Mg$^{2+}$, EC, SAR, Na$^+$, temperature, K$^+$, and the ESP of the scheme were 10.0, 3.70, 0.163, 7.6, 2.18, 5.70, 28, 2.90 and 25.6 respectively. These water parameters were within the limit of FAO (1994) except electrical conductivity, potassium and ESP that have higher concentration. The value conductivity (0.163dS/m) was higher in the river compared to FAO (1994) limits (3 × 10$^{-6}$dS/m) meaning that the soil was sodic i.e. sodium hazard. Furthermore, the pH values show that the water was found to be alkaline (FAO, 1994). The potassium concentration of the water was higher than that of FAO (1994) and this shows that the level of potassium in the water was higher and sodic in nature (Leticia et al., 2015).

### Table 2: Mean values of soil pH, EC, SAR and ESP for Chanchaga irrigation scheme I

| Parameters | pH | EC (dS/m) | SAR | ESP |
|------------|----|-----------|-----|-----|
| Irrigated plot | 7.33 | 0.624 | 10.68 | 48.13 |
| Control plot | 6.50 | 0.079 | 3.49 | 56.93 |

### Table 3: Physiochemical properties of irrigation water samples

| Attribute | Irrigation water | FAO (1994) Limits |
|-----------|------------------|-------------------|
| Ca$^{2+}$ (mg/l) | 10.0 | 800 |
| Mg$^{2+}$ (mg/l) | 3.70 | 120 |
| EC(dS/m) | 0.163 | 3 × 10$^{-6}$ |
| pH | 7.6 | 6.5-8.5 |
| SAR | 2.18 | 15.0 |
| Na$^+$ (mg/l) | 5.70 | 920 |
| Temperature (0C) | 28 | - |
| K$^+$ (mg/l) | 2.90 | 2.0 |
| ESP (%) | 25.6 | |

**REFERENCES**
Aderoju, D. O. & Akomolafe, G. F. (2013). Influence of salinity on soil chemical properties and surrounding vegetation of Awe salt mining site, Nasarawa State, Nigeria. *African Journal of Environmental Science and Technology*, 7(12), 1070-1075. Doi: 10.5897/AJEST2013.1600.
Adamu, G. K. (2013). Quality of irrigation water and soil characteristics of Watari irrigation project. *American Journal of engineering research*, 2(3), 59-68.
Chemura, A., Kutywayo, D., Chagwesha, T. M., & Chidoko, P. (2014). An assessment of irrigation water quality and selected soil
parameters at Mutema irrigation scheme, Zimbabwe. *Journal of Water Resource and Protection*, 6(2), 132-140.

Ethan, S. Olagoke, O. & Yunusa, A. (2014). Assessment of the quality of irrigation water at the Badeggi and Edozighi Irrigation schemes. *International Journal of Geology, Agriculture and Environmental Science*, 2(3) 35-37.

FAO (1994). Water quality for agriculture. Rome, Italy.

Leticia, S. S., Uttam, S. & Davis, E. K. (2015). Soil salinity: testing, data interpretation and recommendations. *University of Georgia Agricultural Extension Circular* (pp. 1019).

Maina, M. M., Amin, M. S. M., Aimrun, W., & Sani, I. (2012). Soil salinity assessment of Kadawa Irrigation of the Kano River Irrigation Project (KRIP). *Journal of Food, Agriculture & Environment*, 10(3&4), 1028-1034.

Munns, R. (2005). Genes and salt tolerance: bringing them together. *New Phytologist*, 167(3), 645-663.

Ogunwale, J. A. (1978). Laboratory manual for the analysis of soil, plants and water.

Okalebo J.R., Gathua K.W., Woomer, P. L. (2002). Laboratory Methods of Soil and Plant Analysis: A Working Manual. Kenya: Sacred African Publishers

Poustini, K. Siosemarjeh, A. (2004). Ion distribution in wheat cultivars in response to salinity stress. *Field Crops Research*, 85(2), 125-133.

Shrivastava, P., & Kumar, R. (2015). Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi Journal of Biological Sciences*, 22(2), 123-131.

**APPENDICES**

**Appendix A: General Interpretation of Data on EC and ESP from Saturated Paste Extracts**

| EC (dS/m) | Salt Result | Interpretation |
|-----------|-------------|----------------|
| 0-2       | Low         | Very little chance of injury on all plants |
| 2-4       | Moderate    | Sensitive plants and seedlings of others may show injury |
| 4-8       | High        | Most non-salt tolerant plants will show injury; salt sensitive plants will show severe injury |
| 8-16      | Excessive   | Salt tolerant plants will grow; most other show severe injury |

**Interpretation of ESP from saturated soil paste extract.**

| ESP | Rank | Interpretation |
|-----|------|----------------|
| 0-10| Low  | No adverse on soil is likely |
| 10+ | Excessive | Soil dispersion resulting in poor physical condition and poor plant growth are likely.

Source: Leticia et al., (2015)

**Appendix B: Classification of salt-affected soils using the saturated soil paste extraction: Natural Resources Conservation Service (NRCS)**

| Class     | EC (dS/m) | SAR | ESP | Typical Soil Structural Condition |
|-----------|-----------|-----|-----|----------------------------------|
| Normal    | Below 4.0 | Below 13 | Below 15 | Flocculated |
| Saline    | Above 4.0 | Below 13 | Below 15 | Flocculated |
| Sodic     | Below 4.0 | Above 13 | Above 15 | Dispersed |
| Saline-Sodic | Above 4.0 | Above 13 | Above 15 | Flocculated |

Source: Leticia et al., (2015)

**Appendix C: Test for equality variances between, SAR, Temperature, and Exchangeable bases**

| Attributes | Levene’s Test for Equality of Variances | F | Sig. | T | Df | Sig. (2-tailed) |
|------------|----------------------------------------|---|------|---|----|----------------|
| PH         |                                        | 3.734 | .125 | 4.789 | 4 | .009 |
| SAR        |                                        | 3.208 | .148 | 123.916 | 4 | .000 |
| Na         |                                        | .800 | .422 | 1642.920 | 4 | .000 |
| K          |                                        | 2.462 | .192 | 135.024 | 4 | .000 |
| Mg         |                                        | .000 | 1.000 | 849.973 | 4 | .000 |
| Ca         |                                        | 3.455 | .137 | 34.525 | 4 | .000 |
| ESP        |                                        | 3.734 | .125 | -66.532 | 4 | .000 |
| EC         |                                        | .800 | .422 | 0.000 | 4 | 1.000 |
| Chloride   |                                        | 8.000 | .047 | 287.182 | 4 | .000 |

Source: Leticia et al., (2015)