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Rapid Assessment of Reservoir Water Quality and Suitability indices for Irrigation purpose: A Case Study of Ero and Ele Reservoirs in Ekiti State Nigeria

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Abstract

The quality of water determines its usage for any intended purpose. The quality of the surface water in Ero and Ele reservoirs located in Ekiti State, South–West of Nigeria were assessed for their suitability for irrigation purpose. These reservoirs supplies drinking water to nearby towns and will also be used for irrigating the new Ero and Ele irrigation schemes covering a total 1600 hectares. Surface water samples were collected in six (6) sampling points for the purpose of assessing its suitability for irrigating the new proposed Ele and Ero irrigation schemes. The samples were collected during the dry season in March 2013. Irrigation surface water quality samples were analysed by standard methods for hydrogen ion concentration (pH), electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS) and important cations such as calcium, magnesium, sodium, potassium as well as anions such as bicarbonates, chlorides and sulphates. The water samples were also analysed for Sodium Percentage (SP) and Sodium Adsorption Ratio (SAR). The overall results indicated the suitability of both reservoir waters for agricultural use.

Keywords: *Surface (Reservoir) Water Quality, Irrigation Development, Ero and Ele, Ekiti State, Nigeria.*

1. Introduction

Water is a most important natural resource, a basic human need and a valuable natural asset. It is indeed required in all aspect of life including health, agricultural activity for food production, energy generation and maintenance of environment and therefore considered as central to life and development (Gupta *et al.* 2009). An understanding of the quality of water used for irrigation and its potential negative impacts on crop growth is essential to avoid problems and to optimize production. Water quality is a concern to everyone who uses water (Sudhakar & Narsimha, 1981). 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. Virtually all water contains dissolved salts and trace elements, many of which result from natural weathering of the earth's surface (Fipps, 2003). In addition to the dissolve salts, which has been the major problem for centuries, irrigation water always carry substances derived from its natural environment or from the waste products of man's activities (domestic and industrial effluents). Furthermore, drainage waters from irrigated lands can impact water quality. In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield. However, a number of trace elements are found in water which can limit its use for irrigation. Generally salt is thought of as ordinary table salt (sodium chloride). However, many types of salts exist and are commonly found in waters. Most salinity problems in agriculture result directly from the salts carried in the irrigation water. As water evaporates, the dissolved salts remain, resulting in a solution with a higher concentration of salts.

The composition of surface water may depend on various factors such as topography, rainfall, geology, biology, temperature, land use, impact of humans etc. Intentional storage of surface water has many purposes like hydroelectric power generation, irrigational supply through canals; to prevent wide damage from floods in the downstream, recreational purpose like boating, swimming etc. Hence it is necessary to evaluate the quality of water of any area in order to assess its suitability for various uses and to evolve policies for the best use of water resources (Gupta *et al.* 2009).

The government of Ekiti State recognized that, there is no sector that has the capacity to create jobs as quickly and sustainably as the agriculture sector. Therefore, in order to key into the state economic policy of poverty alleviation, attainment of food security, and sustainable economic development, there is the need to harness and develop its water resources for agricultural purposes using the two reservoirs located at Ero and Ele. This

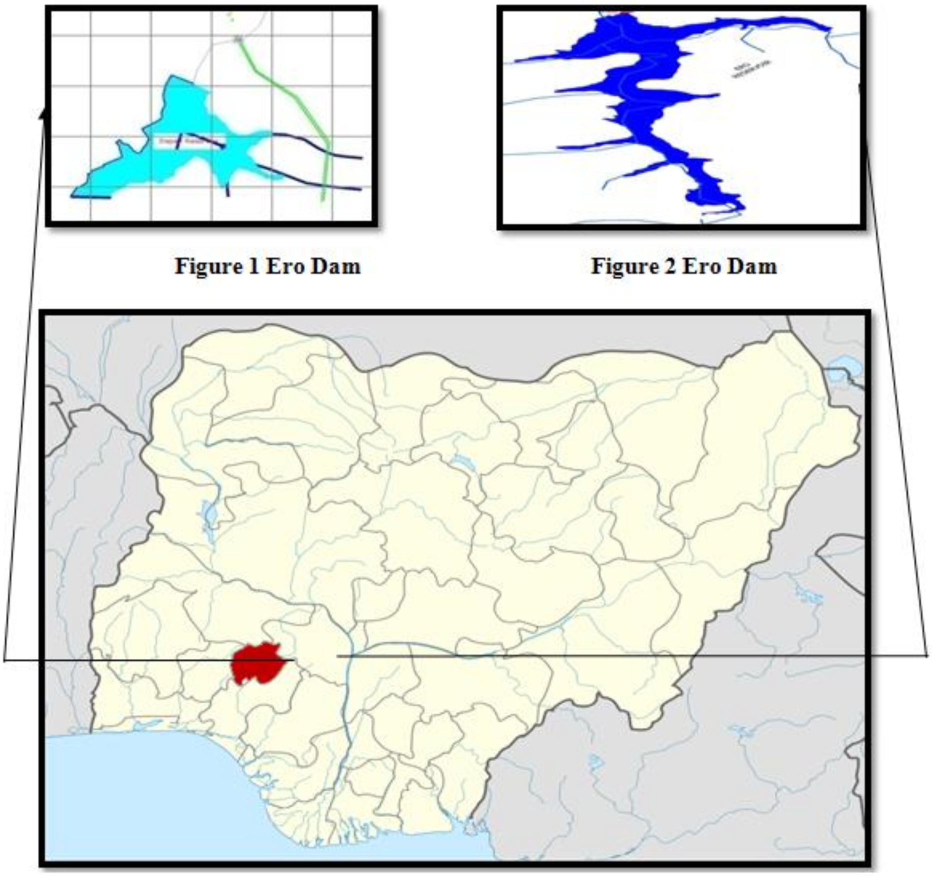

Figure 1 Ero Dam   **Figure 2 Ero Dam**

Figure 3 Map of Nigeria showing Ekiti State (Source www.ekitistate.gov.ng)

reservoirs are used for supply water to meet the domestic needs of nearby towns. To utilize these waters for irrigation, there is the need to determine their suitability based on quality parameters for irrigation, and their potential negative impacts on crop growth for optimum production.

The paper attempts to present the suitability of the Ero and Ele Reservoirs in Ekiti State, Nigeria for Irrigation Usage.

1.1 Study Area

The Ero and Ele rolled earth dams were commissioned in 1985 and 1975 respectively. The reservoirs were constructed basically to provide water for domestic purposes. These reservoirs were constructed on rivers Ero and Ele in Ekiti Moba and Ikole Local Government Areas of Ekiti State. They are located on latitude 7^0 57′′ N, 7^0 59′′ N and longitude 5^0 29′′ E, 5^0 11′′ E. The design capacities of the dams are 105,000 m^3/day for Ero and 5,175m^3/day for Ele. The annual rainfall of the state is over 2000mm (Oloniteru & Ojo, 2013, www.ekitistate.gov.ng). The areas of the reservoirs are located within the tropical climate which experiences two distinct seasons i.e. the rainy seasons (April to October) and the dry season (November to March). The temperature ranges from 21^0C and 28^0C with high humidity (www.ekitistate.gov.ng). The state is well endowed with abundant arable land and natural conditions which allows a diversity of crop and livestock production activities.

2. Methodology

Surface water samples were collected from three sampling points i.e. samples were taken at six (6) sampling points starting from sampling points 1, the entry point (upstream) of the River Ele and River Ero into the reservoirs, sampling point 2 at the middle of the dams and sampling points 3 at the downstream of the reservoirs in March of 2013. Irrigation surface water quality samples were analysed by standard methods for hydrogen ion concentration (pH), electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS) and important cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) as well as anions such as bicarbonates (HCO^{3-}), chlorides (Cl^-) and sulphates (SO_4^{2-}). The pH and EC values were measured in the field using a portable conductivity and pH meter. TDS were computed from EC multiplied by a factor of 0.64 (Lloyd & Heathcote, 1985). Na^+ and K^+ were determined by flame photometer, SO_4^{2-} was analysed spectrophotometrically. TH, such as $CaCO_3$, Ca^{2+}, CO_3^{2-}, HCO^{3-} and Cl^- were analysed by volumetric method. Mg^{2+} was calculated from TH and Ca^{2+} contents. Magnesium Content (Mc), Sodium Percentages (Sp), Sodium

Tables 1 Comparison of the values observed for different parameters obtained from Ero reservoir with the FAO Standard

Parameter	Up stream	Reservoir	Down stream	FAO	Remark
pH	7.34	6.8	6.98	6.5 - 8.0	Ok
EC (µs/cm)	294	212	214	0.7 - 3.0	Ok
TDC (ng/l)	150	108	109	450 - 2000	Ok
TH (mg/l)	66	56	70	-	-
Ca^{2+}	1.16	0.64	0.68	20	Ok
Mg^{2+}	0.16	0.48	0.73	0 - 5	Ok
Cl^{-}	0.45	0.34	0.31	0 - 30	Ok
Na^{+}	0.43	0.30	0.39	0 - 40	Ok
K^{+}	0.09	0.09	0.22*	0 - 20	-
HCO_3^{-}	0.68	0.68	0.42	0 - 10	Ok
SO_4^{2-}	0	0	0.10	0 - 20	Ok
SAR	0.53	0.53	0.31	0 - 15	Ok
SP	25.1	20.1	13.7	-	-

Tables 2 Comparison of the values observed for different parameters obtained from Ele reservoir with the FAO Standard

Parameter	Up stream	Reservoir	Down stream	FAO	Remark
pH	8.8*	7.33	7.1	6.6 - 8.0	Ok
EC (µs/cm)	0.789	0.247	0.665	0.7 - 3.0	Ok
TDC (mg/l)	407	128	339	450 - 2000	Ok
TH (mg/l)	110	64	80	-	-
Ca^{2+}	1.24	0.56	0.94	0 - 20	Ok
Mg^{2+}	0.97	0.73	1.66	0 - 5	Ok
Cl^{-}	0.85	0.28	0.28	0 - 30	Ok
Na^{+}	0.90	0.39	0.30	0 - 40	Ok
K^{+}	0.46	0.06	0.07	0 - 20	Ok
HCO_3^{-}	1.54	0.55	0.59	0 - 10	Ok
SO_4^{2-}	0	0.02	0.10	0 - 20	Ok
SAR	0.86	0.48	0.26	0 - 15	Ok
SP	25.3	22.4	10.1	-	-

Adsorption Ratio (SAR) and Permeability Index (PI) were computed by standard methods described below.

Sodium Percentages (SP)

Wilcox (1955) describes the method of calculating the sodium percentages where all concentrations are expressed in meq/l as;

$$Na\ \% = [(Na^{+} + K^{+}) / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})]\ 100 \quad (1)$$

Magnesium Content (Mc)

Magnesium content is considered as one important criterion in determining the quality of surface water for irrigation. Szabolcs & Darab, (1964) calculated the magnesium content using the below formulae where ions are expressed in meq/l.

$$Mc = Mg/ (Ca + Mg) \times 100 \quad (2)$$

Sodium Adsorption Ratio, (SAR)

Sodium Absorption Ratio (SAR) was calculated based on the chemical composition of calcium, magnesium and sodium (Modi, 2000),

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (3)$$

Permeability Index (PI)

To identify the suitability of surface water for irrigation Doneen (1964) gave a formula for permeability index as;

$$PI = \frac{(Na^{+} + \sqrt{HCO^{3-}} \times 100}{(Ca^{2+}+Mg^{2+}+Na^{+})} \quad (4)$$

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) was calculated by using the formula TDS = EC X 0.64 (Lloyd & Heathcote, 1985).

3. Results and Discussions

Irrigation water samples collected were tested for cations i.e. Calcium Ca^{2+}, Magnesium Mg^{2+}, Sodium Na^{+} and Potassium K^{+} and anions such the chlorides (Cl^{-}), Biocarbinates (HCO_3), Sulphate (SO_4^{2-}) and Nitrates (NO^{3-}) and other measurements recommended for characterizing irrigation water quality like the Electrical conductivity (EC), Total dissolved solids (TDS), Sodium adsorption ratio or sodium hazard (SAR) and Acidity/alkalinity (pH).

The analytical results obtained from analyses of the surface water from Ero and Ele Reservoirs are shown in Table 1 & 2. The results revealed irrigation water quality of the reservoirs during the period of study

Water pH

Water pH generally is not a problem itself, but it is an indicator of other problems such as sodium and carbonates (Bryan *et al.* 2007). Irrigation water tends to be alkaline, commonly in the range of pH 7.2 to 8.5. As irrigation water pH increases above 8.2, the potential for sodium problems increases (Bryan *et al.* 2007). It is a quantitative expression for acidity or alkalinity of water. Most of the biological processes and biochemical reactions are pH dependent. The pH of sampled reservoir waters ranged between 6.8 to 7.3 and 7.1 to 8.0 (for Ero and Ele respectively) during the study, indicating alkaline nature of the reservoir water (Table 1). FAO (2006) criteria suggest values between pH 6.5 – 8.4 as normal range. The result of the study suggests that the quality of water is good for the proposed schemes.

Sodium (Na) percentage and Electrical Conductivity (EC)

Sodium percentage is used for adjudging the quality of water for agricultural purpose. The use of high percentage of sodium water for irrigation purpose retards plant growth and reacts with the soil to reduce its permeability (Todd, 1980). EC and sodium concentration are very important in classifying irrigation water. The salts present in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. The total concentration of soluble salts in irrigation water can thus be expressed for the purpose of classification of irrigation water as low (EC = < 250 µS/cm), medium (250 – 750 µS/cm), high (750 – 2,250 µS/cm) and very high (2,250 – 5,000 µS/cm) salinity classes (Sudhakar and Narsimha, 1981 and Richard, 1955). The values obtained in this study were compared with FAO standards (Table 2). All values obtained were within the acceptable limits of FAO for SSP and EC, suggesting that the total concentration of salts has no potential irrigation problems.

Total Dissolved Salts (TDS)

In natural water dissolved solids are composed of carbonates, bicarbonates, chlorides, sulphate and phosphate. Salts are present in irrigation water; they originate from dissolution or weathering of rocks and soil. These salts are carried by water to wherever it is used. In the case of irrigation the salts applied through irrigation water remains after evaporation. Accumulation of salt in the root zone makes the crop unable to extract sufficient water resulting in moisture stress for a significant period of time (Modi, 2000). The total dissolved solids (TDS) indicate the general nature of salinity of water. Surface water with TDS less than 450mg/l is considered good for irrigation and that with TDS greater than 450 - 2000mg/l is slight to moderate and greater than 2000 mg/l is unsuitable for irrigation (FAO, 2006). The average total dissolved salts for the surface water for Ero and Ele are 108mg/l and 128mg/l respectively which are considered very suitable for irrigation (Table 1).

Sodium Adsorption Ratio (SAR)

An equation used to predict irrigation water sodium hazard is the sodium adsorption ratio (SAR). SAR is the ratio of sodium to calcium and magnesium. The higher the SAR, the greater the sodium hazard. The sodium adsorption ratio (SAR) indicates the effect of relative cation concentration on sodium accumulation in the soil. The water having SAR less than or equal to 3 are said to be excellent quality, 3 - 9 are good and greater than 9 are said to be unsuitable for irrigation (FAO, 2006). Sodium adsorption ratios for water samples of the reservoirs are less than 3 (0.40 and 0.48 for Ero and Ele respectively). The results indicate excellent water quality for irrigation purposes. Hence, there is no potential hazard due to sodium and salinity for crop growth in the proposed schemes.

Potassium (K)

The main sources of potassium in surface water comes from irrigation and in ground water it comes from different sources which include rain water, weathering of potash silicate minerals and use of potash fertilizers. The Potassium content obtained during the period of study (March/2013) from the two reservoirs are 0.06 and 0.07 for Ele and Ero reservoirs respectively. The FAO has prescribed the guideline level of potassium at 0 - 20 mg/l in irrigation water. As per the criteria, all values of reservoirs fall within the guideline level of FAO.

Magnesium content (Mg)

Magnesium content is one of the most important qualitative criteria in determining the quality of surface water for irrigation. Generally, calcium and magnesium maintain a state of equilibrium in most waters. If magnesium is in excess amount, it leads to adverse effects on the soils which results into poor crop yield (Taak & Singh, 2014). The average magnesium content for the two reservoirs (Ero and Ele reservoirs) are 0.48 and 0.73 respectively. The surface water is suitable for irrigation use, because the water is within good range of FAO irrigation water quality guidelines (0 - 5).

Bicarbonate alkalinity (HCO_3)

The alkalinity of natural waters is due to salts of carbonate, bicarbonates, borates, silicates and phosphates along with hydroxyl ions in free State. The primary source of carbonate and bicarbonate ions in groundwater is the dissolved carbon dioxide; water charged with carbon dioxide dissolves carbonate minerals, as it passes through soil and rocks, to give bicarbonates. The bicarbonate alkalinity varies from 0.42 - 0.68 and 0.55 to 1.54mg/l for Ero and Ele surface waters respectively during the study period (Table1). Natural water with high alkalinity is generally rich in phytoplankton and is considered as conductive for fish production.

Chloride (CL)

Excess chloride deposited on leaves causes foliar burn. Some plants are more susceptible to chloride than others (Bryan *et al.* 2007). The values obtained for Chloride did not exceed the permissible limits of FAO criteria (Table 1) indicating that crops proposed for both schemes should have normal crop growth and development.

Conclusion

The Ero and Ele reservoirs in Ekiti State South-West of Nigeria supplies water to meet the domestic needs of nearby towns. The rapid assessment study revealed that they can also supply irrigation water for the new proposed irrigation schemes. The surface water samples were collected from these reservoirs (Ero and Ele) in March, 2013 during the dry season. Parameters were analysed and compared with international standard namely FAO guidelines for Irrigation Water to determine suitability for irrigation usage. All the water samples collected and analysed confirmed the suitability of the surface water for irrigation.

Based on present investigation it is concluded that the reservoir waters are fit for irrigation and should be properly managed accordingly. It is also recommended that regular monitoring of water quality and pollution are necessary to help farmers and the irrigation department for making water policy to the state government. This would help develop appropriate management strategies and sustainable irrigation development.

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