Irrigation Water Analysis at River Ahungwa Dam in Yandev, Gboko, Benue State, Nigeria

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ABSTRACT

Water quality analysis for irrigation at river Ahungwa dam in Yandev (longitudes $8^0$36' and $8^0$45'E and latitudes $7^0$45' and $8^0$00'N), Gboko Local Government areas of Benue State, Nigeria was carried out in both wet and dry seasons of 2020. Water samples from the dam were collected in air-tight plastic containers, analyzed for quality-related parameters and compared with the FAO (1994) Water Standards for Irrigation. The investigation was carried out in the wet and dry seasons of 2018. Water quality was found to be suitable for irrigation as the values of the parameters related to the general irrigation problems of salinity, permeability, toxicity and 'miscellaneous' fell within the 'tolerable' limits.

KEY WORDS: *Water quality, irrigation, salinity, permeability, tolerable limit*

INTRODUCTION

Water quality refers to the characteristics of water supply that will influence its suitability for a specific use. Quality is defined by certain physical, chemical, and biological characteristics (FAO, 1994; Ajon *et al*., 2014). In irrigation water evaluation, emphasis is placed on chemical and physical characteristics of the water and only rarely is any other factors considered important (Ayers and Westcot, 1994; Rogers *et al.*, 2003).

Irrigated agriculture is dependent relative on adequate water supply of usable quality. Water quality concern have often been deserted because good quality water supplies have been abundant and readily available. This situation is now changing in many areas (Ayers and Westcot, 1994). Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental provisions must rely on lower quality and less attractive sources (FAO, 1994). To avoid problems when using these poor quality water provisions, there must be sound planning to ensure that the quality of water available is put to the best use (FAO, 1994; Ajon *et al*., 2014).

The arable lands in Benue State consist of upland and fadama lands (flood plains) (Ajon *et al*., 2014). The upland is refined to many high value agronomic and horticultural crops. Fadama farming depends on rains in the wet season and residual soil moisture in the dry season. To alleviate the problem of moisture stress during the long-lasting gaps between rains as well as in dry season, additional irrigation is provided. This is done by lifting the water from recurrent surface water bodies and deep or shallow wells.

Considering large hectares of land which are agriculturally productive within Yandev area, there is a felt need to encourage irrigated agriculture. This can support year round crop production on medium scale and will alleviate the present food shortage in the state and consequently alleviate poverty.

Notwithstanding the dam relevance to socio-economic development of the area, there is dearth of knowledge on water quality of this dam. It is necessary, therefore, to investigate and evaluate the quality of surface water of the dam. The main aim of the research was to assess the quality of water in river Ahungwa dam for irrigation purposes.

MATERIALS AND METHODS

Study Area

The research was carried out at river Ahungwa dam in Yandev, Gboko Local Government area of Benue State. The Dam is located along river Ahungwa in Yandev at about 2 km NW from Yandev – Makurdi road. The study area is bounded by longitudes $8^0$36' and $8^0$45'E and latitudes $7^0$45' and $8^0$00'N (Fig. 1). The learn area relief ranges from 90 to 262m above mean sea level (a.m.s.l). The study area is undulating plains. River Ahungwa's Dam is one of the biggest surviving dams in Benue State, Nigeria. The main river that drains river Ahungwa is river Katsina-Ala in Buruku Local Government Area. Then, river Benue drains rivers Katsina-Ala. River Ahungwa is a tributary of river Katsina-Ala. The climate of the learn area is tropical savanna. The minimum temperature is 25^0C and maximum is 33.5^0C. The mean monthly temperature is 27.3^0C. The total annual rainfall varies between about 900 and 1200 mm. The learn area has distinct dry and wet seasons. Rainy period starts in March/April and ends in October/November. The vegetation in the study area is Guinea Savannah type, branded by grasses with few scattered shrubs and trees. There are forests along the river of the study area. The study areas are underlain by the rock units of the undifferentiated basement complex. The following rocks units were also observed; limestone (dominant rock), alluvium, Ezeaku shale, sandstone and the tertiary basalt.

The land in the study area is used for farming of crops such as yam, cassava, guinea corn, maize, millet, groundnut, soyabean, benniseed, rice, melon, and other vegetable crops. Tree crops such as mango, palm trees, citrus, cashew and other economic trees are also found in the area.

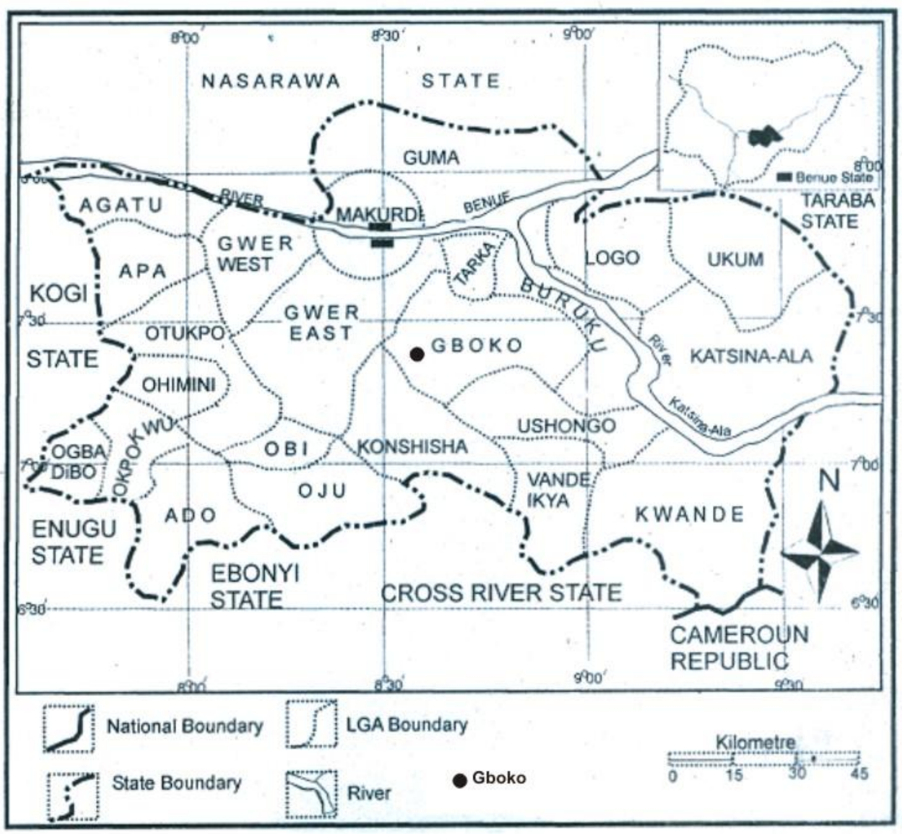

Figure 1. Map of Benue State showing Gboko
Source: Ministry of Land and Survey, Makurdi (The NAFRN, 1978)

Field and Laboratory Methods

Water samples from the dam were taken in both wet and dry seasons of 2020. Water samples were collected in three different points namely; the upper, middle and lower positions of the Dam. Thus giving a total of three (3) collection points designated as follow; W_1, W_2 and W_3. Where 'W' stands for dam water samples. While 1, 2, and 3 represent upper, middle and lower positions of the dam respectively. A total of six (6) water samples for wet and dry seasons were obtained.

The water samples from the dam were collected below the water surface using air-tight plastic containers which were transported to laboratory for immediate analysis of the samples. The pH of water was measured electrometrically using glass electrode pH meter (Udo *et al*., 2009). Electrical conductivity was measured with electrical conductivity meter. Sodium, potassium, chlorine and boron were determined using flame photometer, while calcium, magnesium, iron and manganese were determined using atomic absorption spectrophotometer (AAS) (Udo *et al*., 2009). Bicarbonate was determined by the titrimetric method using naphthalene and methyl orange as indicator (Udo *et al*., 2009). Total dissolved solids in water were determined by evaporation-drying (Udo *et al*., 2009). The temperature of the water samples was measured by thermometer (mercury-in-glass). Sodium adsorption ratio was calculated to determine the concentration of cation in water (Udo *et al*., 2009). All the parameters were determined based on the FAO water quality standards for irrigation.

Water Quality Evaluation

The mean values of the physical and chemical parameters of the water in the dam were compared with FAO (1994) water standards for irrigation (Table 1). Water quality problems were presented in four general categories namely: salinity, permeability, toxicity and miscellaneous effects as described by the FAO (1994) water standards.

RESULTS AND DISCUSSION

Salinity Effects;

A salinity problem related to water quality may occur if the total quantity of salts in the irrigation water is high enough that salts accumulate in the crop root zone. The crop has extra difficulty in extracting enough water from the salt soil solution (FAO, 1984).

The pH of the surface water in the dry season (7.77) was generally higher than in the wet season (7.60) due to high degree of saturation with base-forming cations (Ca, Mg, K and Na) in the dry season. The cations were expectedly leached down the soil profile thereby increasing the base concentration in the water. All the values indicate a slightly alkaline condition, but fall within the recommended standards range of 6 – 8.5 (FAO, 1994). The pH values of water in the dam indicated slightly alkaline condition; continuous application of this water to the soils within the study areas may be harmful. This is because of the slightly alkaline status of the soils in the dry season. At each irrigation, more salt is additional with the applied water. The portion of the added salt must be leached from the root zone before the concentration affects crop yield (Ayers and Westcot, 1994).

The electrical conductivity (ECw) in the dry season (0.05 ds/m) were higher than that of the wet season (0.03 ds/m). Water quality in the dam is often related to flow. The dilution due to runoff in the rainy periods usually keeps total salt concentration low (Ayers and Westcot, 1994). Generally, the EC values for the water samples were low. Based on the FAO (1994) standards the value of 3.0 ds/m is the highest safe limit of EC for irrigation water. The water in the dam is, therefore, very safe for irrigation.

The dam water had higher concentration of calcium in the dry season (0.49 meq/l) than in the wet season (0.24 meq/l). The high amount of calcium in the water could be due to the presence of limestone within the lithology and pollution from Dangote Cement Factory, Tse-kucha. Calcium, also being a biophile element, when bush is burnt, more calcium gets into the surface water. The ratio of Ca/Mg is greater than one. Therefore, potential effect of sodium is reduced. The SAR and ESP would also decrease. The values are generally low and fall within the safe limit (0 – 20meq/l) for irrigation as suggested by FAO (1994). Excess concentration of calcium may give rise to salinity problem and excessive scale formation. The low concentration of calcium in the water would not cause salinity problem.

Mg concentration in the dam water was higher in the dry season than in the wet season (Table 3). The ratio of Ca/Mg is greater than one. Generally, the result shows low concentration of magnesium in the water. This would not cause salinity problem. The FAO (1994) safe range is 0 – 5meq/l. In a Mg dominated water (ratio of Ca/Mg<1) or Mg soil (soil-water ratio of Ca/Mg<1), the potential effect of sodium may be slightly increased (Ayers and Westcot, 1994).

The concentration of sodium in water was generally very low. The values ranged from 0.09 to 0.20 meq/l in the water. The values were below 3 meq/l which means that sodicity problem is not expected. High Na concentration in water leads to sodicity development in soils (Singh, 2000).

The guidelines for evaluating salinity problems are presented in Table 1. The values of pH, EC, Ca, Mg and Na point to that the water has no salinity problems. The water in the dam is, therefore, good quality for irrigation and indicating ‘no degree of restriction of use’ as also reported by FAO (1994).

Permeability Effects;

A permeability problem related to water quality may occur when the rate of water infiltration into and through the soils is reduced by the effect of specific salts or lack of salts in the water to such an extent that the crop is not adequately supplied with rate and yield is reduced. Factors to determine soil permeability are sodium content relative to calcium and magnesium; bicarbonates and carbonate content, and the total salt concentration of the water (FAO, 1994).

The electrical conductivity values (ECw) of the water were generally very low (0.03 - 0.05 ds/m). The water in the dam is very safe for irrigation, but could lead to infiltration problems due to the low salinity status of the water. Ayers and Westcot (1994) reported that, low salinity water (< 0.5 ds/m and especially below 0.2 ds/m) is corrosive and tends to leach surface soils free of soluble minerals and salt, especially calcium, reduce their strong stabilize influence on soil aggregate and soil structures. High salinity of irrigation water (ECw >0.3ds/m) causes very low infiltration rate, whereas very low salinity (ECw < 0.2ds/m) results in low water infiltration rate and this could lead to excessive runoff (Ayers and Westcot, 1994).

Infiltration rate generally increases with increasing salinity and decreases with either decreasing salinity or increasing sodium content relative to calcium and magnesium – the sodium adsorption ratio.

The SAR of the dam water is generally low. The SAR of the water ranged from 0.19 to 0.29 meq/l. Such low SAR values are expected in view of the fairly low sodium content. Irrigation water with SAR value of 2 – 6 mg/l is considered to have low sodium (Landon, 1991). According to FAO (1994), irrigation water with SAR <3meq/l, the electrical conductivity would have values from >0.07 to <0.2 ds/m. The results show that the values of SAR are well below 3 meq/l indicating 'no degree of restriction of use'. A permeability problem, therefore, is not expected since the sodium hazard of the dam water is low. The usual range for SAR in irrigation water is 0 – 15 meq/l (FAO, 1994).

Permeability problems, however, are also related to the bicarbonate content in irrigation water. The dam water analysis shows lower concentration of bicarbonate in the wet season (1.0 meq/l) compared to the dry season (1.51 meq/l). When drying of the soil occurs between irrigations, a part of the CO_3 and HCO_3 could precipitate as Ca-$MgCO_3$ thus removing Ca and Mg from the soil water and increasing the relative proportion of Na which would increase the sodium hazard (Ayers and Westcot, 1994).

The values of HCO_3 are below 1.6 meq/l indicating 'no degree of restriction of use'. A permeability problem, therefore, is not expected to occur. The values fall within the acceptable limit (<10 meq/l) for irrigation water as suggested by FAO (1994) and is, therefore, highly suitable for irrigation. High bicarbonate causes low infiltration rate and excessive white scale formation on leaves and fruits (Ayers and Westcot, 1994).

The values for total dissolved solids in the water ranged from 106 to 208 mg/l. The dam water has values of TDS below 450 mg/l indicating 'No problem' which means the water could be used for irrigation without permeability problem. The FAO, (1994) safe limits for TDS in irrigation water are shown in Table 1. The water in the dam could be classified as "good" for irrigation purposes with no permeability problem.

The concentration of calcium in the water is generally low (Table 1). The low concentration of calcium could lead to low infiltration rate. The ratio of Ca/Mg is greater than one; therefore, potential effect of sodium is reduced. Without salts and specifically, calcium, the soil disperses and the dispersed finer particles fill the many of the smaller pore spaces, sealing the surface and greatly reducing the rate at which water infiltrates the soil surface (Ayers and Westcot, 1994). The FAO (1994) range for calcium in irrigation water is 0 – 2 meq/l.

The concentration of magnesium in the water is generally low. The values ranged from 0.23 to 0.41 meq/l. The low concentration of magnesium would cause low infiltration rate. The FAO (1994) safe range for irrigation water is 0 – 5 meq/l.

Permeability problems may not easily develop in the soils of the catchment areas due to the sandy loam and loamy sand textural classes of the soils. The values of SAR, HCO_3, TDS, ECw, Ca and Mg of the water fall within the 'usual range' and indicating 'no degree of restriction of use' as shown in Table 1. The water is, therefore, highly suitable for irrigation.

Toxicity Effects;

A toxicity problem may occur when certain constituents in the water are taken up by the crop and accumulate in amounts that would result in a reduced yield. This is regularly related to one or more specific ion in the water namely, boron, chloride and sodium. Other trace elements which may cause toxicities are iron and manganese.

The concentration of sodium in water is very low (0.09 – 0.20 meq/l) and could not lead to sodium toxicity. Therefore, the water is highly suitable for irrigation. The FAO (1994) safe limit is <40meq/l. High concentration of sodium leads to toxicity problems (Ayers and Westcot, 1994). Use of irrigation water high in sodium will result in soil of high sodium but it may take several irrigations to cause the change. Damage (toxicity) can result if sodium accumulates to concentration that exceeds the tolerance of a crop (Maas, 1984).

Relative tolerance levels of selected crops to exchangeable sodium include: (i) Sensitive crop (beans, cotton, maize, peas, citrus, groundnut and cowpea). (ii) Semi-sensitive crops (lettuce, bajara, sugarcane, onion, rice, sorghum and tomato), and (iii) Tolerant crops (cotton, garden egg and alfalfa) (Maas, 1984).

The most common toxicity problem is from chloride in the irrigation water. This is because chloride is not adsorbed or held back by soils. Therefore, it moves readily with the soil-water (Maas, 1984). Chloride concentration in the dam water was low for both wet and dry seasons (Table 1). Generally, chloride concentration in the water is low and falls within the safe limit for irrigation. The safe limit for chloride is <30 meq/l (FAO, 1994). The low chloride concentration might be due to the presence of basalt which prevents marine cretaceous sediments from getting in touch with the fresh water. Therefore, chloride toxicity is not expected if the water is used for irrigation. Citrus (*citrus spp*) and tobacco are chloride tolerant (6.7 – 16.6meq/l) (Maas, 1984)

One to two milligram per litre of boron may be toxic for some crops. Surface water rarely contains enough boron to be toxic, but well water or springs occasionally contain toxic amounts. Boron toxicity can affect nearly all crops (Maas, 1984). Boron concentration in the water ranged from 0.10 to 0.12 mg/l for dry and wet seasons respectively. Generally, the concentration of boron is low and falls within the tolerable range. The FAO (1994) safe range is 0-2 mg/l. The water has no boron toxicity problem. Relative boron tolerance levels of agricultural crops include: (i) Very sensitive crops (<0.5mg/l) (lemon and blackberry), (ii) Sensitive (0.5 – 0.75mg/l) (citrus, cowpea and onion), (iii) Sensitive (0.75 – 1.0mg/l) (garlic, sweet potato, beans and groundnut), (iv) moderately sensitive (1.0 – 2.0mg/l) (pepper and cucumber). (v) Moderately tolerant (2.0 – 4.0mg/l) (lettuce, maize, tobacco and mustard), (vi) Tolerant (4.0 – 6.0mg/l) (sorghum and tomato), and (vii) Very tolerant (6.0 – 15.0mg/l) (cotton and asparagus) (Maas, 1984).

Toxicity problem can occur in soils when a high concentration of Fe and Mn in water is continuously used for irrigation (Hassan, 1998). The concentration of Fe ranged from 0.75 to 1.0 mg/l. The high concentration of Fe in the water is probably due to the lateritic soft overburden in the dam. Similar results were also obtained by Jimba and Adegoye (2000). Mn concentration ranged from 0.14 to 0.15 mg/l. The values fall below 1.5 mg/l and 2 mg/l considered as safe limits for Fe and Mn respectively. This implies that the water has no Fe and Mn toxicity problems. High concentration of Fe and Mn in water may give rise to deposits in irrigation pipes, decolouration, and iron bacteria (Jimba and Adegoye, 2000).

In evaluating the potential for a toxicity problem in Ahungwa Dam for irrigation, the values of Na, Cl, B, Fe and Mn fall within the values of the tolerable limits set by the FAO (1994). Toxicity, therefore, is not expected to be a problem.

Miscellaneous Effects;

Nitrate concentration in the water ranged from 0.0004 to 0.002mg/l. The concentration is very low. The values are within the recommended range. Nitrate form (NO_3-N) occurs most frequently in irrigation water. Nitrogen in irrigation water has much the same effect as soil-applied fertilizer nitrogen and an excess causes over-stimulation of crop growth, delayed maturity or poor quality (Ayers and Westcot, 1994).

Turbidity is caused by suspended solids in water. The turbidity of the water ranged from 18.66 to 60.33 mg/l (Table 3). The higher values were observed in the wet season. These may be due to runoff from the nearby fields to the rivers during the rainy periods. Higher turbidity of the water in the wet season leads to suspended matter, silt and clay particles mainly from the soft overburden (Jimba and Adegoye, 2000). Excess turbidity may cause clogging of irrigation systems. The values in both the dry and wet season fall within the recommended limit of 50 – 100mg/l (Hassan, 1998).

Sulphate concentration in the water ranged from 0.05 to 0.08 meq/l. The value in the dry season were lower than the wet season values. The sulphate concentration of water is within the tolerable limit for irrigation, the recommended standard being 0 – 2 meq/l (FAO, 1994).

Potassium concentration in water ranged from 1.46 to 2.45 mg/l. The water had K concentration that was within the tolerable limits in the dry season. The wet season showed high concentration of K in water. The high values could be as a result of contamination from inorganic fertilizers (as farmers within the area make large use of NPK), feldspar, micas and clay. Leaching of these minerals into water could cause the high concentration of K in water. The FAO (1994) safe range is 0 – 2 mg/l. Potassium is not toxic. The value of K in the wet season is above the standard range in the water, but could be used for irrigation. According to Ojeniyi (2002) and Agbede (2009), Nigerian soils lack NPK. Therefore, the K in water would rather correct nutritional imbalance of K in the soils of the study area. Excess application of K in the soils may lead to deficiency of other cations such as Ca and Mg.

The values of NO_3, turbidity, SO_4 and K in water are safe for irrigation.

Table 1: Physical and Chemical Composition of Water in River Ahungwa Dam

Parameters	Water Sample (Dry Season)	Water Sample (Wet Season)	FAO Water Standards for Irrigation
Temperature (^{0}C)	26.5	28.0	-
Turbidity mg/l	18.66	60.33	50-100 mg/l
pH	7.77	7.60	6.0-8.5
EC ds/m	0.05	0.03	0-3 ds/m
Ca me/l	0.49	0.24	0-20 me/l
Mg me/l	0.41	0.23	0-5 me/l
Na me/l	0.20	0.09	0-40 me/l
K mg/l	1.46	2.45	0-2 mg/l
Cl me/l	0.33	0.49	0-30 me/l
B mg/l	0.10	0.12	0-2 mg/l
Fe mg/l	1.00	0.75	0-1.5 mg/l
Mn mg/l	0.15	0.14	0-2 mg/l
NO_3 mg/l	0.002	0.0004	0-10 mg/l
SO_4 me/l	0.05	0.08	0.-20 me/l
HCO_3 me/l	1.51	1.00	0-10 me/l
TDS mg/l	106	208	0-2000 mg/l
Hardness mg/l	30.0	27.0	<80 mg/l
SAR me/l	0.29	0.19	0-15 me/l

CONCLUSION

An evaluation of the quality of water in river Ahungwa dam, Yandev, Gboko Local Government Area of Benue State reveals that the water is suitable for irrigation. The water parameters investigated for salinity, permeability, toxicity and miscellaneous fall within the tolerable limit for irrigation purposes.

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