ASSESSMENT OF IRRIGATION WATER PARAMETERS OF GURARA RESERVOIR IN KADUNA STATE, NIGERIA

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ABSTRACT

This study was carried out to assess the quality of water in Gurara reservoir for irrigation purpose. Water samples were collected from forty five (45) different locations along the reservoir i.e. upstream, midstream and downstream for the determination of sixteen (16) physicochemical parameters following standard methods, based on these analyses, some irrigation parameters like, SAR, RSC, PI, KI, and SP were also calculated following standard equations. The data ranged from 6.5 to 6.8pH, 70 to 75.6µmhocm^{-1}, 44.8 to 48 mgL^{-1}TDS, 2.4 to 4.2NTU turbidity, 23.8 to 26.1 ^{o}C temperature,5 to 30 mgL^{-1} total hardness, 9.4 to 10.1 mgL^{-1}Cl^{-}, 0.033 to 0.41 meqL^{-1} HCO^{-}_{3}, 0 to 1meqL^{-1}CO_3^{-2}, 0.02 to 0.399meqL^{-1}Ca^{2+}, 0.016 to 0.255 meqL^{-1} Mg^{2+}, 0.11 to 0.123meqL^{-1}Na^{+},0.024 to 0.27meqL^{-1} K^{+}, 3.1 to 8.5mgL^{-1} PO^{-3}_{4}, 0.2 to 1.08mgL^{-1} NO_3^{-} ,0.01to 0.08mgL^{-1} SO_4^{2-}, -0.148 to 0.871meqL^{-1}RSC, 0.201 to 0.392meqL^{-1}SAR, 27.2 to 116.8meqL^{-1}PI,18.2 to 43.2meqL^{-1}SP and 0.185 to 0.607meqL^{-1}KI. Based on the guideline by FAO (Food and Agricultural Organization) interpretation of water quality for irrigation, the results of analyses and assessment of water quality from Gurara reservoir revealed that they are suitable for irrigation purposes.

KEYWORDS: *Irrigation, Water quality, Gurara, Reservoir*

INTRODUCTION

Water is essential to life only when it is safe. The term water quality describes a broad spectrum of items related to how we identify water concerns and how we collectively address them. Thus, the term water quality can be confusing and mean different things to different people. The most widely used definition of water quality is "the chemical, physical and biological characteristics of water, usually in respect to its suitability for designated use" when water quality assessment reveals that a water body does not support its designated uses, then it is considered impaired.

Impairments result from two major categories of water pollution: point source or non-point source pollution. Both natural processes and human activities influence the quality of surface water and ground water. Water naturally contains dissolved substances, non-dissolved particulate matter and living organisms; indeed, such materials and organisms are necessary components of good quality water, as they help maintain vital biogeochemical cycles. The quality of irrigation water has a significant effect on the soil salinity, growth and yield of agricultural crops. In general, water used for irrigation always contains different concentrations of dissolved salts which are generated naturally (precipitation rate, weathering of rocks and dissolving of other salt sources) or anthropological i.e. domestic and industrial sources (Jarvie et al, 1998).

Poor quality of irrigation water affects both soil quality and crops production adversely (Bello, 2011) Therefore, the study of irrigation water quality has become essential because it shows whether the quality of the water is suitable for irrigation and does not cause formation of saline or alkaline soils in addition to being an indicator of whether this kind of water cause toxicity to plants and crops.

Regardless of its source, irrigation water contains some dissolved salts (Michael, 1985). The amount and characteristics of these dissolved salts depend on the source and chemical composition. The concentration and proportion of these dissolved ions among other things determine the suitability of water for irrigation (Ajayi et al, 1990). The suitability of water for irrigation varies according to crops, types, and permeability of soil and climate.

The quality of irrigation water available to farmers and other irrigators has a considerable impact on what plants can be successfully grown, the productivity of these plants and water infiltration and other soil physical conditions. The most ordinarily dissolved ions in water are sodium, magnesium, calcium, sulphate, nitrate, chloride, boron, carbonate, and bicarbonate. The concentration and proportion of these dissolved ions among other things determine the suitability of water for irrigation (Ajayi et al 1990). Irrigation water quality is generally judged by some determining factors such as sodium absorption ratio (SAR), residual sodium carbonate (RSC), and electrical conductance (EC) (Richards, 1954). Along with the above indicators, some additional indices to categorize the surface water for irrigation like magnesium content (MC), Kelly's index (KI), total hardness (TH), permeability index (PI) sodium percent (SP), should be studied.

According to Ayres and Westcot. (1994), the most important criteria that needs to be considered when assessing the quality of irrigation water are:

Salinity: if the total concentration of salts dissolved (TDS) in irrigation water is high enough to accumulate in the root zone of crops, the crop will have the additional difficulty in extracting sufficient quantities of water from salty soil solution. Salinity can lead to slow growth, low yield, and early symptoms of wilt. Commonly, the electrical conductivity (EC) parameter can be used to explain the salinity of water.

Permeability: irrigation water quality has an effect on reducing the soil permeability. Low salts and the relative high content of sodium to calcium and magnesium in water can reduce the rate of infiltration through the soil. So, the crop is not sufficiently supplied with water and yield is reduced. The most common water quality parameter which influences the natural rate of water infiltration is the relative concentration of sodium, magnesium and calcium ions in water that is known as the sodium absorption ratio (SAR)

Toxicity ions: The most toxic ions in the irrigation water are chloride, sodium and boron which, if taken by the crop in sufficient amounts would result in reduced yield.

Other problems: such as the high bicarbonate concentration, suspected abnormalities indicated by an unusual pH of the water and excessive nitrogen in water. Therefore , the study of irrigation water quality has become essential because it shows whether the quality of the water is suitable for irrigation and do not cause formation of saline or alkaline soils in addition to being an indicator of whether this kind of the water cause toxicity to plants and crops.

Therefore, the objective of the study was to determine the water quality of Gurara dam and to ascertain it's suitability for irrigation purpose

STUDY AREA

The dam is situated on the Gurara River at 9^{o} 05′N and 7^{o} 30′E. The Gurara River extends to about 570km from high land at over 700m, 530m through Jere and into the Niger confluence at a height of 40m. The river flows northeast to southwest and then turns southward as it flows through FCT to its confluence with River Niger. The study area is bounded to the south by Niger state to the north by Kachia Local Government Area and to the east and west by Kagarko local government area respectively. The Gurara dam is a multipurpose dam for water supply, hydropower, irrigation and ancillary uses. It is the source of Nigeria's largest and pioneer water transfer scheme. The dam has a total embankment of about 8 million cubic meters, is 52.5 meters deep and 3.1 km long. The reservoir has a surface area of 61 square kilometers and a maximum capacity of 880 million cubic meters of water. The dam also has a 1.16km tunnel with 42 meter high intake tower on the right bank which has been equipped with hydraulic valves that will transfer the water to the conveyance pipeline to Abuja.(Musa et al,2015 and Chris Maduabuchi 2004) The irrigation component of the scheme was developed in phases, the first of which was a test irrigation farm, where groundnuts, rice, maize, sugarcane and pineapple were grown. The second phase was on a 2000 hectares irrigation scheme, which is also on and is being irrigated through surface, sprinkler and drip irrigation. The 2000 hectares is located close to the local community for their benefit and has Banana, Pineapple, Citrus, Sugarcane, Tomatoes, Onions, Maize and Wheat. The third phase involves a 14000 hectare scheme which covers part of FCT, Kaduna State and Niger State with potential of producing 100000 tons of food annually. In addition to irrigation, electricity generation and water supply, the dam is expected to serve as a source of fish farming and possible development of tourism. (Tony Akowe, 2013)

MATERIAL AND METHODOLOGY

SAMPLE COLLECTION AND ANALYSIS

The procedure for sampling was adopted from Prabu (2009). A total of forty-five (45) grab water samples, were collected at different locations. Global coordinates of each sampling location were recorded with the help of global positioning system (Gamin GPS 78 SC) from Gurara dam on the 12th to 29th January, 2017. The collection was done at the depth of 20-30 cm directly into one liter clean plastic bottles and placing them into sample transport box (cooler) containing ice pack in order to maintain the integrity of the sample collected prior to analyses.

Temperature, pH, electrical conductivity, turbidity, and salinity of the water samples were measured in situ using water quality meter model WQC-24. The water samples were analyzed for alkalinity, total hardness, bicarbonates, carbonates, calcium hardness and magnesium hardness, calcium, magnesium phosphates, sulphates, fluorides and nitrates at the field using Wagtech photometer 7100, while chloride was determined titrimetrically using standard method as detailed in (Aneja, 2005) Sodium and potassium were determined using atomic absorption spectrophotometer(AAS). Total dissolved solids (TDS) was calculated by using the formula TDS = EC × 0.64 (Lloyd & Heathcote, 1985).

Fig.1: Gurara reservoir showing sampling locations.

Based on the result of physicochemical analyses, irrigation quality parameters like magnesium content, sodium absorption ratio, residual sodium carbonate, sodium percent, Kellys index and permeability index were calculated as follows:

Sodium absorption ratio (SAR): Sodium absorption ratio is an important parameter to determine the suitability of irrigation water and is calculated by the following formula (Richard 1954). :-

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

(Concentrations are in meq/L)

Residual sodium carbonate (RSC): The concept of residual sodium carbonate (RSC) is employed for evaluating high carbonate waters and is calculated by the formula given below by (Todd, 1980, and Raghunath, 1987).:-

$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$

(Concentrations are in meq/L)

Permeability index (PI): Permeability index is calculated by the method suggested by (Todd, 1980 and Raghunath 1987). PI is used to evaluate the sodium hazards of irrigation water, where all concentrations are expressed in meq/L as:-

$PI = [(Na^{+} + HCO_{3-}) / (Ca^{2+} + Mg^{2+} + + Na^{+})] 100$

Kelly's index (KI): The waters with an index value over 1 are assessed as unsuitable for irrigation (Kelly, 1940). Kelly index was calculated by using equation below:-

$KI = [Na^{+}/Ca2^{+} + Mg^{2+}]$ (Concentrations are in meq/L)

Sodium Percentages (SP): Wilcox (1955) describes the method of calculating the sodium percentages where all concentrations are expressed in meq/l as:-

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

RESULTS AND DISCUSSION

The analytical results of the quality parameters of the irrigation water samples of the studied location are given in table 1 while table 2 shows the recommended guidelines for the interpretation of water quality for irrigation.

The water quality for irrigation is considered using the following indices:

Table1. Descriptive Statistics Result For Physicochemical and Irrigation Parameters for Gurara Dam Water Quality

S/N	PARAMETER	UNIT	AVERAGE	RANGE	STANDARD DEVIATION
1	Temperature	^{o}c	25.22	23.8 – 26.1	0.57
2	Turbidity	NTU	3.54	2.4 – 4.2	0.45
3	Electrical Conductivity (EC)	μScm^{-1}	70.88	70 – 75.6	0.84
4	pH		6.62	6.5 – 6.8	0.11
5	Total dissolved solid	mgL^{-1}	45.34	44.8 - 48	0.49
6	Dissolved oxygen	mgL^{-1}	14.24	10.5 – 16.7	1.65
7	Total hardness	mgL^{-1}	14.98	5 -30	5.23
8	Total alkalinity	mgL^{-1}	24.11	10 - 40	6.42
9	Phosphate	mgL^{-1}	5.18	3.1 – 8.5	1.05
10	Sulphate	mgL^{-1}	0.03	0.01- 0.08	0.015
11	Nitrate	mgL^{-1}	0.864	0.2 – 1.08	0.164
12	Fluoride	mgL^{-1}	0.044	0.01- 0.09	0.017
13	Chloride	mgL^{-1}	9.964	9.4- 10.1	0.142
14	Carbonate	$meqL^{-1}$	0.487	0- 1	0.274
15	Bicarbonate	$meqL^{-1}$	0.156	0.033 - 0.41	0.079
16	Sodium ion	$meqL^{-1}$	0.116	0.11- 0.123	0.003
17	Potassium ion	$meqL^{-1}$	0.032	0.024- 0.27	0.036
18	Calcium ion	$meqL^{-1}$	0.189	0.02-0.399	0.083
19	Magnesium	$meqL^{-1}$	0.116	0.016- 0.255	0.066
20	Kelly index (KI)	$meqL^{-1}$	0.412	0.185-0.607	0.116
21	Residual sodium carbonate (RSC)	$meqL^{-1}$	0.338	-0.148-0.871	0.262
22	Sodium absorption ratio(SAR)	$meqL^{-1}$	0.305	0.201-0.392	0.047
23	Permeability index (PI)	$meqL^{-1}$	66.55	27.2-116.8	20.167
24	Sodium percent (Na %)	$meqL^{-1}$	33.07	18.2-43.2	6.317

Table2: Classification of water quality parameter from Gurara dam for agricultural purposes using food and agriculture organization (FAO) guidelines of United Nations

Parameter	Sample range	FAO guidelines	Classification	% of sample compliance
Kelly index(KI)meqL^{-1}	0.185-0.607	< 1 >1	Safe and suitable unsuitable	100% _
Residual sodium carbonate (RSC) meqL^{-1}	-0.148-0.871	<1.25 1.25 – 2.5 >2.5	Excellent Good poor	100% _ _
Sodium absorption ratio (SAR)	0.201-0.392	0-10 10-18 18-26 >26	Excellent Good Fair poor	100% _ _ _
Permeability index (PI)meqL^{-1}	27.2-116.8	Class1>75% Class2 25%-75% Class3 <25%	Excellent Good Unsuitable	28.9% 71.1% _
Sodium percent (Na %) meqL^{-1}	18.2-43.2	0-20 20-40 40-60 60-80 >80	Excellent Good Permissible Doubtful unsuitable	4.4% 68.9% 26.7% _ _
Electrical conductivity (EC)µScm^{-1}	70-75.6	<250 250-750 750-2250 >2250	Low salinity(Good) Medium salinity(moderate) High salinity(poor) Very high salinity(very poor)	100% _ _ _
pH	6.5-6.8	6.5-8.4	Normal range	100%
Chloride(Cl^-)mgL^{-1}	9.4-10.1	<70 70-300 >300	suitable Moderate suitable unsuitable	100% _ _
Bicarbonate meqL^{-1}	0.033-0.41	<1.5 1.5-8.5 >8.5	Suitable Moderate Unsuitable	100% _ _
Total dissolved solid(TDS) mgL^{-1}	44.8-48	<450 450-2000 >2000	Suitable Moderate unsuitable	100% _ _

Electrical Conductivity (EC):
The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity. Electrical conductivity or the total dissolved solids (TDS) analysis could be used in monitoring the salinity of water because the conductance is a strong function of the total dissolved ionic solids. As EC increases, the less water is available to plants even though the soil may appear wet because plants can only transpire "pure" water. Thus, usable plant water in the soil solution decreases dramatically as EC increases. According to FAO (2000) and Ayers and Westcot (1994) irrigation water is considered good for use when EC < $250\mu Scm^{-1}$ and TDS <$450mgL^{-1}$ In this study, the electrical conductivity ranges from 70 to 75.6 μScm^{-1} with an average value of $70.88\mu Scm^{-1}$ and total dissolved solids (TDS) ranges from 44.8to $48mgL^{-1}$ with an average value of $45.34mgL^{-1}$ as compared to Sabke dam and Oyan dam with an average values of 47.49 mgL^{-1} and $90.5mg/L^{-1}$ consequently Gurara dam water can be considered safe for irrigation purposes.

Alkalinity:
The alkalinity of natural waters is due to salts of carbonate, bicarbonates, borates, silicates and phosphates along with hydroxyl ions in Free State. The weathering of rocks is the potential source of alkalinity. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Bicarbonates and carbonates ions combined with calcium or magnesium will precipitate as calcium carbonate (CaCO3) or magnesium carbonate (MgCO3) when the soil solution concentrates in drying conditions. The concentration of calcium and magnesium decreases relative to sodium and the sodium absorption ratio index will be bigger or increase. This will cause an alkalizing effect and increase the pH. Therefore, when water analysis indicates high pH level it may be a sign of high content of carbonate and bicarbonates ions. High alkalinity impart a bitter taste, harmful for irrigation as it damages soil and hence reduces crop yields (Sundar et al, 2008). In this study the alkalinity of the water from Gurara dam ranges from 10 to 40 mgL^{-1} with an average value of $24.11mgL^{-1}$ (Table 1) which is within the permissible limit (WHO, 2006) of $500mgL^{-1}$ as compared to Oyan dam with an average of 46.72 mg/L^{-1} hence, indicating excellent water for irrigation.

Chloride:
The most common toxicity is from chloride (Cl^-). If it is not adsorbed or held back by soils, it moves readily with the soil water, then is taken up by the crop, moves in the transpiration stream, and accumulates in the leaves. If the chloride concentration in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying of leaf tissue. Normally, plant injury occurs first at the leaf tips (which is common for chloride toxicity), and progresses from the tip back along the edges as severity increases, excessive necrosis (dead tissue) is often accompanied by early leaf drop (FAO 1985). In this study, the chloride (Cl^-) concentration ranged from 9.4 to 10.1 mgL^{-1} with an average 9.964 mgL^{-1} Table 1, The values obtained for Chloride did not exceed the permissible limits (FAO, 2000) of 700 – 300 mgL^{-1} indicating excellent water for irrigation purposes for crop growth and development.

Sodium absorption ratio:
The suitability of water for irrigation purposes can be determined by sodium absorption ratio value because it measures alkali/sodium hazard to crop. If irrigation water is high in sodium ion and low in calcium ion the ion – exchange complex may be saturated with sodium ion. This might lead to the destruction of the soil structure

due to the dispersion of the clay particle (Todd, 1980. and Joshi et al 2009) and consequently could reduce the plant growth. In addition, studies have shown that excess salinity reduces the osmotic activity of plants (Subramani et al, 2005; Ishaku et al, 2011). In the study area, the value of SAR ranges from 0.201 to 0.392 $meqL^{-1}$ with an average of 0.305 $meqL^{-1}$ (Table 1 and 2). Since the values are generally less than 3, it is regarded as excellent for irrigation (FAO, 2000). The water can be used for irrigation on almost all soil types with no danger of the development of harmful levels of sodium hazard.

Residual sodium carbonate (RSC):
RSC represents the amount of sodium carbonate and sodium bicarbonate in water when total carbonate and bicarbonate levels exceed total amount of calcium and magnesium. It is usually expressed as meqL-1 of sodium carbonate. Considering this hypothesis, Eaton (1950) proposed the concept of residual sodium carbonate (RSC) for assessment of high carbonate waters. The water with high RSC has high pH and land irrigated with such water becomes infertile owing to deposition of sodium carbonate; as known from black colour of the soil. Residual carbonate levels less than 1.25$meqL^{-1}$ are considered safe. Waters with RSC of 1.25-2.50 $meqL^{-1}$ are within the marginal range and those with values more than 2.5$meqL^{-1}$ are unsuitable for irrigation (FAO, 2000). In the present study, RSC values were found to be below 1.25$meqL^{-1}$ from Table 1and 2, so water of Gurara dam can be considered safe for irrigation.

Kelly index (KI):
Kelly index is one of the parameters used for the classification of water for irrigation purposes, sodium measured against calcium and magnesium was considered by Kelly (1957, 1963). For calculating Kelly's index, the values for the dam water ranges from 0.185 to 0.607 $meqL^{-1}$ with an average of 0.412 $meqL^{-1}$ (Table1). Hence, the values are within the permissible limit of < 1.0 Table 2 above, and are therefore considered suitable for irrigation and free from alkali hazards (Karanth, 1987).

Permeability Index (P.I.):
The soil permeability is affected by long term use of irrigation water. Sodium, calcium, magnesium and bicarbonate contents of the soil influence it. Doneen (1954) evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. Accordingly, waters can be classified as class I, Class II and Class III orders. Class I and Class II waters are categorized as good for irrigation with 75% or more maximum permeability. Class III water are unsuitable with 25% of maximum permeability. In the present study the value of the permeability index ranges from 27.2 to 116.8, with an average value of 66.55% from (Table 1). Hence water of Gurara dam ranges from excellent to good for irrigation, (Table 2).

Sodium percent (SP):
Sodium percent is another important factor to assess sodium hazard. It is calculated as the percentage of sodium and potassium against all cationic concentration. It is also used to determine the quality of water for agricultural purposes. The use of water with high percentage sodium for irrigation would stunts the plant growth (Dhirendra et al. 2009). Sodium reacts with soil to reduce its permeability. Sodium percent in water is a parameter computed to evaluate the suitability of the water for irrigation. In the present study the value of the sodium percent ranges from 18.2 to 43.2, with an average of 33.07 $meqL^{-1}$ (Table 1 and 2) Hence, it is within the permissible limit, indicating the water from Gurara dam to be suitable for irrigation.

pH:

pH is an important parameter to measure the acidity or alkalinity of irrigation water. As shown in Tables 1 and 2, the range of pH values for the water samples from Gurara dam was found to be 6.5 to 6.8 which is within the normal range which is between (6.5 to 8.4). Irrigation water outside the normal range of pH may cause a nutritional imbalance or may contain toxic ions (Prescod, 1985).

CONCLUSION

The main objective of this study is to evaluate the irrigation water quality of Gurara Dam in Kaduna State. Based on the guidelines for interpretation of water quality for irrigation, the results of analysis and assessments of water quality from Gurara Dam revealed that they are suitable for irrigation purposes. However, water from the dam is of excellent quality and considered to be highly suitable without any restriction on its use.

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