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AN APPRAISAL OF SURFACE IRRIGATION WATER QUALITY IN SOME SELECTED IRRIGATION PROJECTS IN GOMBE STATE NIGERIA

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ABSTRACT

An appraisal of surface irrigation water quality of the three irrigation projects in each of the senatorial districts of Gombe State, Nigeria was conducted. Water samples were collected from each of the three (Dadin-Kowa, Balanga and Nafada) irrigation project areas which served as the principal water sources for irrigation. The water samples' pH, sodium, calcium, magnesium, chlorine, carbonate, bicarbonate, sodium ion adsorption ratio, total hardness, total alkalinity, total dissolved solids (TDS) and the residual sodium carbonate were among the parameters analyzed. The result obtained showed that from Dadin-Kowa irrigation project, the mean values of pH, TDS, EC., Na^+, Ca^{2+}, Mg^{2+}, $C1^-$ and HCO_3 were 7.03, 0.70, 0.10, 1.3, 0.18, 0.18, 0.07 and 0.10 respectively. Results from Balanga irrigation project, showed that the mean values of pH, TDS, EC, Na^+, Ca^{2+}, Mg^{2+}, $C1^-$ and HCO_3, were 7.02, 0.62, 0.02, 1.98, 0.22, 0.30, 0.76 and 0.06 respectively. While results from Nafada irrigation project showed that the mean values of pH, TDS, EC., Na^+, Ca^{2+}, Mg^{2+}, $C1^-$and HCO_3 were 7.10, 0.69, 0.13,1.74, 0.17, 0.21, 0.76 and 0.03 respectively. It was concluded that the results obtained from the three sources indicated that the parameters obtained are within the acceptable range for irrigation, as provided by FAO and therefore recommended for irrigation.

KEYWORDS: Surface irrigation; Water quality; Water sample point; Ion concentration.

1. INTRODUTION

Gombe state is one of the thirty six states in Nigeria located in the north eastern part of the country with an area of approximately 20,269 km^2 and having a population figure of about 2.4 million people (Census, 2006) .The state is endowed with abundant surface water resources. The three main dams situated at different parts of the state are Dadin Kowa, Balanga and Nafada. Most of the people of Gombe State are subsistence farmers. They also engage in small scale irrigation practices around the environment of these dams. They produce both food and cash crops while others are hunters. Irrigation is the artificial application of water to soil for the purpose of crop production. Irrigation is applied to supplement the water available from rainfall and to contribute to soil moisture from ground water sources. In many areas of the world, the amount and timing of rainfall are not adequate to meet the moisture requirement of crop and irrigation is therefore essential to raise crops necessary to meet the need of food and fibre (Adams and Grove 1983). Irrigation water is obtained from surface and ground water sources. Surface sources include lakes, reservoirs, rivers, streams, water use association distribution facilities and recycled waste water, while the primary ground water sources are wells, boreholes and springs.

However, the suitability of a type of water source for irrigation depends on several factors which include legal constraint, the quality of water that is the amount of suspended and dissolved materials in the water as well as the total irrigation water requirement and seasonally varying irrigation requirement year after year (James, 1988). Irrigation depends on water being available elsewhere whenever the soil moisture is insufficient to maintain crop growth due to lack of rain from surface or underground sources including the under drainage of the water holding itself. However, the availability of water from these sources tends to diminish as the need for irrigation increase resulting from the excess of evaporation during the growing season of the crops. The solution to this problem in most cases is to provide reservoir so that water can be abstracted and stored when it is available usually in the dry season for use during the irrigation session (Cole, 1982). Irrigation is then a clear option for agriculture in such places but there are other places in which irrigation is not all that essential but yet it can serve a very useful purpose. There are also these areas with dry season for example, Gombe state in which irrigation help extend the growing period and therefore improve the yield of crops. There are areas with unreliable rainfall where irrigation serves as an insurance against crop failure (Morris, 1985). However, characteristics relevant to the type of irrigation system required are whether plant water needs must be supplied totally or in part, all year or some years, all the year round or just part of the year. Generally, irrigation is a factor of climate, topography, soil type, crop type, water quality and quantity as well as the economic resources that can be utilized (James, 1988).

Moreover, it should be noted that, the world population will become increasingly difficult to manage, because limits on food production are being approached in many of these countries. However, the global food shortage can be averted if adequate planning is made. This can be effectively achieved by irrigation in addition to the normal rain fed agricultural practice. Nigeria has a population of about 167million and about 80% percent of this figure live in rural areas and earn their living by farming (National Population commission, 2012). Unfortunately, food production is almost restricted to the rainy season, except in some of part of the northern states of Nigeria where little irrigation practice is done. It is therefore, regrettable that Nigeria that is naturally endowed with land, water and human resources should be facing serious food crisis. In the light of the fact mentioned above, the prevailing high cost of food items in the country can be reduced if attention is given to this project (irrigated agriculture). Irrigation water quality is usually assessed in terms of soluble salt content, percentage of Sodium, Boron and Bicarbonate content using electrical conductivity values. Public health and socio-economic development of an area can also be enhanced if there is adequate safe water supply. Therefore the objective of this study is to determine the quality of surface irrigation water in the three selected irrigation projects in Gombe State so as to compare the water quality with the standard water status for irrigation as recommended by Food and Agriculture Organization (FAO).

2. MATERIALS AND METHOD

2.1 Materials

2.1.1 Location of the study sites: The study was conducted on three main dams which include Balanga, Dadin Kowa and Nafada situated in Southern, Northern and central senatorial districts, respectively. Balanga irrigation project is in Balanga/Talase local government of Gombe state. The location is between latitude of 9^{o}45 ̋and 10^o and longitude of 11^{o}30' and 11^{o}5' east of the equator) with an estimated mean annual rainfall of 968 mm. The radius of the irrigation area comprises many villages of families with more than 980 compounds who cultivate mainly maize, wheat, rice and guinea corn. Dadinkowa irrigation project (latitude of 40°14" to latitude of 13°48" and longitude of 2°42^{1}E) is situated in Yamaltu-Deba local government area with an average temperature of 30-32°C, relative humidity between 17-90% and annual rainfall of 2000 mm. The crops cultivated by the settlements in the radius of the irrigation project include maize, rice, wheat, guinea corn. Nafada irrigation project is located in Nafada local government area with sub-Saharan climate characterized by long dry season of about five (5) consecutive months (November to March) every year. The irrigation project lies on latitude 10^{o}19'N and longitude of 11^{o}30"E of the equator. The crops cultivated and irrigated in the settlements in the radius of the project include tomato, pepper and potato.

2.1.2 Instrumentation: The materials used in the experiments analysis are total dissolved solid, chemical/reagents, buffer solution, distilled water, ammonia butler solution, sample of water, methyl orange and phenolphthalein indicator. While the equipment used in the study were: pH-meter, electrical conductivity meter, spectrometer, flame photometer, galvanometer reagent bottle, water sampling container, beaker (l0 ml), conical flask and test tube, pipette (l0 ml) and burette (50ml).

2.2 Methods

2.2.1 Data Collection

Samples were taken at the water surface level from three different linear points along each irrigation projects. Three points were chosen at a distance of 1000 m apart: One point at the upstream part of the irrigation (sample point 1); the second point at the mid-stream of the irrigation (sample point 2); and the third point at the downstream part of the irrigation scheme (sample point 3). The collected samples from these three different points were analyzed in accordance to Food and Agricultural Organization (FAO) recommended standard for evaluation of physical-chemical properties of irrigation water.

2.2.2 Analyses

Determination of pH: The pH value of water sample was obtained using pH meter. The meter was standardized using buffer solution pH 7.0. The meter was rinsed into distilled water and cleaned with a cotton tissue. The standardized pH meter was then agitated for a while and allowed to stabilize before taking readings (James, 1988).

Total dissolved solid (TDS): The procedures outlined by Uyigue (2003) were adopted in order to determine the total dissolved solids in this study. A porcelain dish was oven dried at 105^{o}C for an hour before the porcelain was weighed. 50 mls of the water sample was filtered into the pre-weighed porcelain and the filtrate was evaporated to dryness using an evaporating bath. The porcelain was dried again for another one hour in an oven at 105^{o}C. The porcelain was subsequently reweighed. The total dissolved solid (mg/l) is calculated using the relationship:

$$TDS = \frac{((weight\ of\ poreclain\ +residue\ )-(weight\ of\ poreclain\ ))\times 10^4}{Volume\ of\ sample} \quad \ldots \quad (1)$$

Electrical Conductivity (EC): The electrical conductivity (EC) and were determined using the conductivity meter. The water sample was thoroughly shaken and about l00 mls was transferred into a beaker which has already been washed, rinsed and dried. The meter rod was inserted into the sample after rinsing with distilled water and the bottom or knob which reads conductivity was passed, and the readings were allowed to stabilize before recording (Raymond and Roy, 1990).

Total hardness ($CaCO_3$): The sample was thoroughly shaken and 20 mls was transferred into a conical flask using Erlenmeyer flask and 5 mls of ammonia buffer solution and a pinch of eriochrome black indicator was added which gave a red colour indicating the presence of $CaCO_3$. This was titrated against 0.01 EDTA solutions to a blue end point which was read as the titre value. Total hardness was calculated using the relationship given by James (1988).

$$CaCO_3 = T\frac{100}{V} \quad (2)$$

Where: T = Titre value; V = Volume of the samples.

Total alkalinity: The total alkalinity test was used to obtain the carbonate ion concentration indirectly. To determine this, the water sample was shaken thoroughly and 50 mls was transferred in to a conical flask while 3-4 drops of methyl orange indicator was added and titrated against 0.01M HCl until the end point achieved as reported by James (1988).

Calcium ion concentration: Spectrometer method was adopted in determining the calcium ion concentration. The test tube and pipette were rinsed thoroughly with distilled water and allowed to dry. The calcium standard (mg/1) was then transferred into the test tube. The content were thoroughly mixed and allowed to stand for 2-3 minutes. The sample was then taken into spectrophotometer where the direct reading was measured.

Sodium ion concentration: Flame photometric method was used to determine the sodium ion concentration. The sodium filter was inserted in to the water sample of about 25 mls and the galvanometer switched on. The gas supplied was then turned on fully. The air pressure supplied was adjusted to 689.4 kN/m^2 and the gas was adjusted smoothly to obtain discrete cone shape flame. The galvanometer scale was then set to zero with water and then the galvanometer reading was set to 80 using working standard. The galvanometer reading was set to zero again and the reading recorded. The same procedure was repeated for the rest of the samples. The sodium concentration (meq/l) was estimated as the galvanometer reading multiplied by the number of changes (2 in this case).

Magnesium ion concentration: Magnesium was determined by subtracting calcium ion from hardness ($CaCO_3$) using the relationship as given by James (1988);

Bicarbonate ion concentration: Procedures outlined by Wilkerson (2007) to determine bicarbonate ion was adopted. 50 mls of the water sample was pipetted in to a conical flask and 9 mls of 0.0l m NaOH was added. 50 mls of ten percent barium chloride was added and titrated against 0.0l m HC1 using phenolpthalein as titer value.

Carbonate ion concentration: The carbonate ion concentration was determined using the formula of Wilkerson (2007) by subtracting the values of bicarbonate ion from total alkalinity.

Residual sodium carbonate (RSC) and sodium adsorption ratios (SAR): The following relationship, a suggested by James (1988) was used to calculate the residual sodium carbonate:

$$RSC = (CO_3 + HCO_3)-(Ca^{2+} + Mg^{2+}) \ldots \quad (5)$$

Where: RSC is the residual sodium carbonate (mg/l); CO_3 is the carbonate ion concentration (mg/l); HCO_3 is the bicarbonate ion concentration (mg/1); $Mg^{2+}$is the magnesium ion concentration (mg/l); Ca^{2+} is the calcium ion concentration (mg/1)

While the Sodium adsorption ratios (SAR), is determine as

$$SAR = \frac{2Na^+}{(Ca^{++}+Mg^{++})^{1/2}} \quad (6)$$

Where: Na^+ is the sodium ion concentration; Ca^+ is the calcium ion concentration; Mg^+ is the magnesium ion concentration.

3. RESULTS AND DISCUSSION

3.1 Results

Table 1 presents the mean values of the three sampling points of the parameters obtained from the three irrigation project; Balanga, Dadin-Kowa, and Nafada and the FAO compliance limit for irrigation water. Table 1 presents the mean values of the three sampling points of the parameters obtained from three irrigation projects

Table 1: Mean project parameters

Parameter	Irrigation Project			
	Dadin-Kowa	**Balanga**	**Nafada**	**FAO Compliance limit**
pH	7.03	7.02	7.10	6.5-8.4
TDS (mg/l)	0.70	0.62	0.69	81.5-165
EC (mg/l)	0.10	0.02	0.13	< 0.25
Na^+(mg/l)	1.30	1.98	1.74	< 2
Ca^{2+}(mg/l)	0.18	0.22	0.17	1.0
Mg^{2+}(Meq/l)	0.18	0.30	0.21	0-5
Ci^-(mg/l)	0.07	0.76	0.76	200-600
HCO_3^-(mg/l)	0.10	0.006	0.03	1.0
CO_3^-(Meq/l)	NIL	NIL	NIL	0-1

Note: Each value is average of three readings

3.2 Discussion of Results

pH values: The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic > 7.0 basic). The normal pH range for irrigation water ranges from 6.5 to 8.4. Abnormally low pH is not common but may cause accelerated irrigation system corrosion where they occur. High pH above 8.5 is often caused by high bicarbonate (HCO_3^-) and carbonate (CO_3^-) concentration. Therefore, all the pH values obtained from the three Dams fall between the range of 6.5 to 8.4 which shows that the water is suitable for irrigation purpose.

Total dissolved solids: The total dissolved solids may generally clog the pore spaces of the soil. It may also reduce the rate of infiltration of water in the soil through the crop root zone hence causing reduction in crop growth. Generally, total dissolved solids greater than 500–1000 mg/L hampers crop performance and make irrigation system work inefficient due to clogging. From the results for total dissolved solids, it was observed that, the Dadin-Kowa, Balanga and Nafada Dams are recommended for irrigating crops since the results are within the range of 81.5 mg/L, 165 mg/L 107 mg/L respectively.

Electrical conductivity (EC): The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC). The primary effect of high EC water on crop productivity is the inability of the plant to compete with ions in the soil solution for water physiological drought. High salinity water is dangerous to crops as it constitutes salinity problems by influencing the absorption of water and nutrients. From the results obtained (Table 1) 0.10, 0.02 and 0.13 mg/L are excellent for irrigation water, since the values are less than 0.25 as the most recommended irrigation water standard.

Sodium ion concentration: Sodium ion is one of the principle cation compositions present in irrigation water. Sodium ion is important to crop growth, performance and when in excess will increase the soil osmotic pressure thereby reducing the crop growth and subsequently low yield. The result of sodium ion concentrations obtained was less than 2.0 mg/L in the three irrigation projects, hence any crop can irrigated in the project would have adequate growth and yield.

Calcium ion concentration: Calcium is also one of the principal cations that are important for enhancing the growth of crops when it's at a reasonable concentration limit 0.18, 0.22 and 0.17 are within the recommended range for irrigation because they are less than 1.0 mg/L limit set for irrigation water.

Magnesium ion concentration: Basically, magnesium like sodium and calcium as mentioned earlier, is one of the principal cat ions found in irrigation water. These important elements (Na, Ca and Mg), when in excess, affect the general performance of crops. However, based on the result obtained (0.18, 0.3 and 0.21 mg/L respectively), they are within the recommended range for irrigation water as recommended by FAO.

Chloride ion concentration: Chloride is an anion (negative charge ion) frequently occurring in irrigation water. Chloride determination is used to establish the relationship to total acidity as well as to indicate possible toxicities to sensitive crops. From the results obtained 0.76, 0.76 and 0.07 respectively showed that the water is suitable and therefore recommended for irrigation without any danger to the crops.

Bicarbonate ion concentration: Bicarbonate ion concentration in water, particularly where there is high residual sodium carbonate tends to precipitate calcium and magnesium as well as carbonate in the soil. Invariably high bicarbonates concentrations in water for irrigation affect the performance of crops and constitute a serious hazard to the soil. The results obtained for all sources showed that the average concentration of bicarbonate is low (less than 1.0 mg/L) as such, the problem mentioned above may not occur.

Carbonate ion concentration: It is shown in Table 1 that there was absence of carbonate ions in the three irrigation project investigated. Hence, all samples collected after analyses were colorless as against the pink color to show the presence of carbonate ion concentration where is present.

Sodium Adsorption Ratio (SAR): Sodium (Na) is another cation occurring in most irrigation water along with Ca and Mg. sodium is present in total amount usually exceeding 0.1%. It is often responsible for salinity problems when linked to chloride (C1) and sulphide (SO_4) but seldom from Ca or Mg. Sodium is expressed in terms of the sodium adsorption ratio (SAR). However, the results obtained from this study are within the range of 3 – 5 mg/l which is acceptable for FAO compliance limit for irrigation water.

Residual sodium carbonate (RSC): Generally, residual sodium carbonate is used for evaluating high carbonate water. From the results obtained, it was indicated that all sources have negative residual sodium carbonate; hence the suitability of the water is not affected for irrigation purposes.

4. CONCLUSION

The chemical parameters of these three samples were determined. These include Na^+, Mg^{2+}, Ca^{2+}, Cl, HCO_3, CO_3, TDS, SAR, total hardness, total alkalinity of the samples in which some little changes were observed. Based on the results obtained, the water quality at the irrigation projects can be said to be of good quality since all the quality indicators that constituted the criteria for judging the quality or suitability of irrigation water were within the acceptable range.

Based on the findings of this study, the results obtained from the three dams showed that the quality of water was suitable for irrigation purposes and the farmers have absolute guarantee to continue irrigating their crops with the water from the three sources. This is because the change found from 2004 to 2007 is not much to the extent that the crops and soil will be affected.

However, for further study the following suggestions are made;

i) The quality of water should be checked at least biannually so as to monitor the trend of the change that may occur with time.

ii) In the event of any change, suitable crops should be cultivated relative to the water condition based on their tolerance levels.

iii) With industrial growth, there should be a body to monitor industrial water disposal systems so as to protect the water sources from contamination by industrial bye-products.

iv) Finally, it was noticed that refuse is being dumped near the dams hence, the relevant authorities should relocate the refuse disposal site so as to reduce the rate of contamination by domestic waste.

REFERENCES

1. Adams, W.M. and Grove, AT. (1983). Irrigation in Tropical Africa, Problems and Problem Solving, Cambridge African monographs 3, pp.42-43.
2. Agunwamba, J.C. (2000). Water Engineering System, 2nd edition, UNN, Enugu, Nigeria pp.49.
3. Cole, G. (1982). Water for Irrigation Supply and Storage 2nd edition, Newcastle University, London, pp.7— 9.
4. James, L.G (1988). Principles of Farm Irrigation Systems and Design, 2nd edition, Singapore, Canada, pp.40 —48.
5. Raymond, W.M and Roy, L.D (1990). Soil and Plant growth Prentice Hall International, pp.325 —330.
6. Uyigue, L. (2003). Surface Water Assessment on the Influence of Space Distribution on the Physico-chemical Parameters of Refinery Effluent Water. *Journal of Applied Science and Technology*; Vol.3 No.2
7. Wilkerson, D. (2007). Monitoring the Quality of Irrigation Water 2ujd edition, Texas A & M University pp.13 — 14.