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QUALITY ASSESSMENT OF IRRIGATION WATER OF KANO RIVER IRRIGATION PROJECT (KADAWA SECTOR)

[1]Nuhudeen Z. O., [1]Adamu A. and [2]Ibrahim F.B.
[1]Department of Water Resources & Environmental Engineering,
Ahmadu Bello University, Zaria
[2]Centre for Irrigation and Desertification Studies,
Federal University Gashua
Corresponding author: fbibrahim@abu.edu.ng

ABSTRACT

The quality of water used for irrigation is a very important aspect of irrigated agriculture as the use of poor quality irrigation water affects the crop and the physical conditions of the soil. This work assessed the irrigation water quality of Kano River Irrigation Project (Kadawa sector). Water samples for the pre and post irrigation water were collected and tested for electrical conductivity, pH, Total Dissolved Solids (TDS), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Carbonate (CO_3^{-}), and Bicarbonate (HCO_3^{-}), Chloride (Cl^{-}), Nitrate-Nitrogen (NO_3-N), Ammonia-Nitrogen (NH_3-N), Phosphate-Phosphorus (PO_4-P), Potassium (K^{+}) and Boron (B). The result of the analysis showed that the salinity of the water was very low as the electrical conductivity ranged from 0.063 - 0.065ds/m. The sodium adsorption ratio of the water was also very low as it was calculated to range between 0.27 and 0.29. However, infiltration problems might still arise even with the low sodium adsorption ratio due to low calcium/magnesium ratio of the water (far less than 1). The sodium, chlorides and boron concentrations of the water ranged between 0.23 and 0.26, 0.32 and 0.35, 0.82 and 0.91 respectively. However, the results obtained revealed that the pre - irrigation water quality was within the limit for irrigation water standard. On the other hand, the range for the post irrigation water quality samples collected were as follows: pH (6.98 - 7.30), TDS (328 - 446 mg/l), SS (312 - 334 mg/l), Cl (11.3 - 12.1 mg/l), SO_4 (1.2 - 1.4 mg/l), NO_3 (15.92 - 17.64 mg/l), PO_4(6.76 - 7.8 mg/l) DO (1.86 - 2.18 mg/l), BOD (38 - 44 mg/l) and COD (40.4 - 43.2 mg/l). These results showed shows that the post irrigation water had high suspended solids and nutrients concentration. This indicates that its disposal into water bodies through surface runoff may have detrimental effects.

Keywords: irrigation, water quality, salinity, crop yield, SAR.

INTRODUCTION

Agriculture heralded the era of development of human civilization involving mainly food production which changed slowly to modern agriculture through a continuous evolution of agricultural technologies. Irrigated agriculture, the restoration of soil water storage through methods other than natural precipitation, is an age old practice and in fact as old as man's first attempt at crop production. Irrigation has decided largely this pace and process of agricultural development (Majumdar, 2006).

The first attempt at irrigation occurred about 5,000 years ago. This was typically a simple form of flood irrigation, where channels or furrows were dug in fields and water flooded into them by either hand or with a bucket. In Nigeria, elemental irrigation systems were used by traditional farmers long before the colonial period. These systems included seasonally inundated depressions in upland areas of the south and parts of the middle belt that received heavy rainfall, shallow swamps, and seasonally flooded riverine land. In the north, shadoof irrigation was also used along rivers, and some made use of wells. Smallholder farmers were using traditional methods to irrigate about 120,000 hectares in the 1950's and about 800,000 hectares in the late 1970's (International Commission on Irrigation and Drainage ICID, 2012).

Although irrigation has lots of benefits, it also has ill-effects. According to Punmia and Pande (1992), the major problem of irrigation is land degradation and decreased crop yield. Water logging is a form of land degradation that occurs as a result of over irrigation of land in areas where the water table is near the ground surface. The water completely saturates the crop root-zone, causes efflorescence and the whole area becomes water logged.

Salinity is the term used when referring to the presence of soluble salts in soils or water. Whatever may be the source of irrigation water (river, canal, tank, tube or open well), some soluble salts are dissolved in it. The nature and quality of dissolved salts depends upon the source of water and its course before use (Paliwal and Yadav, 1976). When water with poor quality is used for irrigation, the problem of salinity and alkalinity can develop. As such, good management practices such as the provision of drainage and leaching may be required to maintain crop production at a profitable level.

Suitable management practices can only be applied when the quality of irrigation water and its suitability (taking into consideration other factors aside water quality such as soil characteristics, crop tolerance and climate) are assessed. For this reason, an assessment of irrigation water quality prior to crop production and during the course of production is very essential to ascertain the effects of the pre and post irrigation water quality on the crops and receiving water bodies respectively.

Several researches have been carried out in the Kadawa irrigation station of Kano River Irrigation Project (KRIP) and the report of one of the researches which was carried out by NAERLS (2003) stated that there have been problems of low soil fertility, declining crop yield and visible signs of salinity/sodicity in the sector. Judging from reviewed literature, these problems might have arose from the irrigation water used in the agricultural sector; more so, the researches carried out on water quality in the sector did not put into consideration the effects of the post irrigation water quality on the receiving water bodies.

Many people in the northern part of Nigeria particularly Kano rely on irrigated agriculture as a source of income. The Kadawa irrigation sector of KRIP is relied on by many of the inhabitants of Kadawa and environs as a source of income. Also, given the uncertainties of food supply in Nigeria, there is urgent need to improve the productivity and sustainability of irrigated agriculture (Orfega, 2009). It is in this context that an assessment is being carried out in the project area to obtain useful information that can help in suggesting suitable recommendations that would help improve the overall efficiency of the irrigation scheme.

Hence, this study aims to evaluate the irrigation water quality of the Kano River Irrigation Project (Kadawa station), and to ascertain the effects of the post irrigation water on the receiving water bodies.

Materials and Methods

Study Area

The Kano River Irrigation Project (KRIP) lies between longitudes $8^o20'$E to $8^o40'$E and latitudes $11^o30'$N to $11^o51'$N within the Sudan savannah zone of Nigeria. KRIP 1 which constitutes the Kadawa sector is situated in Garun Mallam Local Government Area of Kano State as shown in Figures 1 and 2 . KRIP has a planned gross irrigable area of 25,606 ha. However, only 13,280 ha has been fully developed and utilized for irrigation presently.

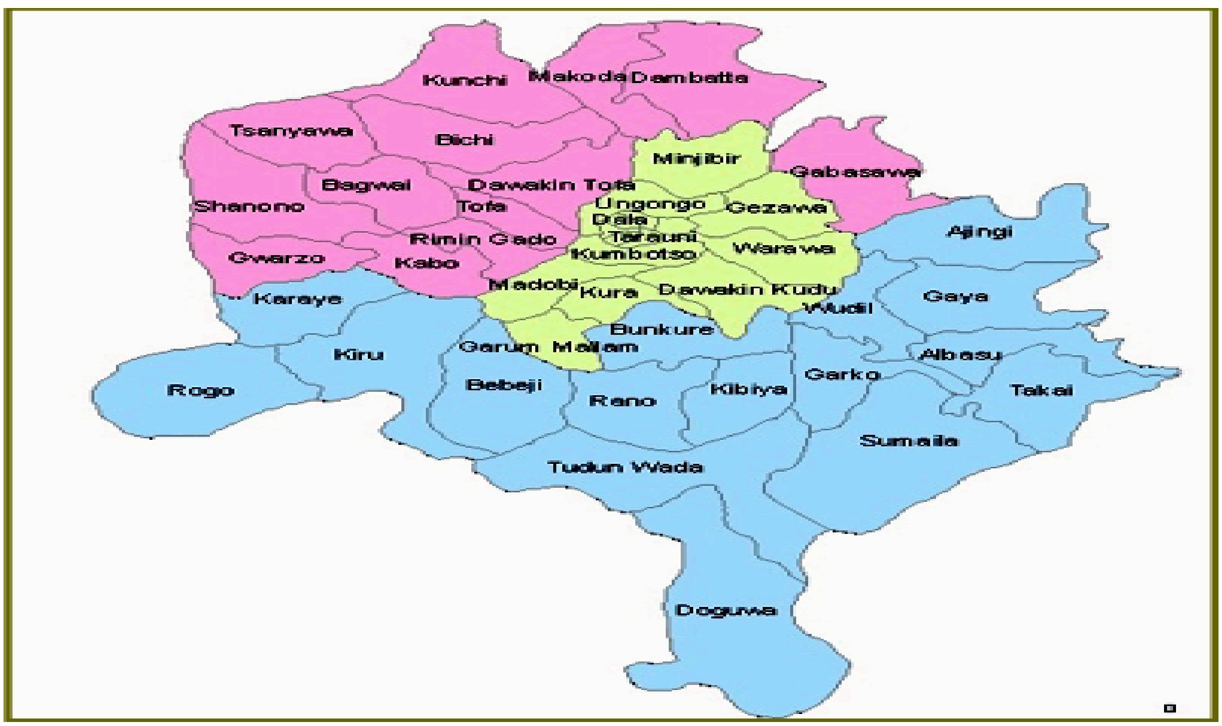

Figure 1: Map of Kano state showing all the Local Government Areas.

Figure 2: Google map showing Kadawa in Garum Mallam Local Government Area.

The project area has three distinct climates: the warm rainy season from June to September, the cool dry season from November to February and the hot dry season from March to May. Generally, the air mean daily temperature is 26^{o}C with the maximum value of 39^{o}C occurring in the month of April/May and the lowest of 14^{o}C in December. The five months period of rainfall and seven months period of dry season allow farmers to cultivate crops two to three times per year through irrigation (NAERLS, 2003). The crops grown in the area include tomatoes, rice, millet, and maize.

Sampling Method

The technique used in collecting the water samples from the Kano River Irrigation Project (Kadawa station) involves the use of five (5) plastic containers (150cl). The containers were properly washed, cleaned and rinsed with distilled water. At the sampling point, the containers were rinsed again with water from which sampling is to be made before they were later filled. Three of the plastic containers were used to collect the pre irrigation water from the main irrigation canal at considerable intervals while the remaining two (2) containers were used to collect the post irrigation water at two different points of considerable distance apart as the water leaves the farmland. At each point of sampling, the sample bottle was submerged below the water surface and with its mouth facing the water current. The samplings were conducted in the morning between 7 and 8 am when the weather was calm to avoid sampling of suspended sediments once every week for 10 weeks between June and August 2016.

Sample Storage

All samples collected were delivered within twenty-four hours (24hrs) to the laboratory for analysis. The samples from the site were stored in a black polythene bag filled with ice cubes and then in the refrigerator for preservation when it reached the laboratory. This was done to in order to maintain the samples at stable conditions to prevent further microbial action which might lead to deterioration of the samples. This is because all parameters of the samples could not be determined on the same day.

Sample Analysis

The water samples of the pre irrigation water collected were analyzed for the following parameters; Electrical conductivity (EC), Total Dissolved Solids (TDS), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^-), Chloride (Cl^-), Sulphate (SO_4^{2-}), Nutrient; Nitrate-Nitrogen (NO_3^-), Ammonia-Nitrogen (NH_3-N), Phosphate-Phosphorus (PO_4-P), Potassium (K^+), and pH and Boron while the samples of the post irrigation water collected were analyzed for; Total solids (TS), Suspended solids (SS), pH, Sulphates (SO_4^{2-}), Nutrient; Nitrate-Nitrogen (NO_3^-), Ammonia-Nitrogen (NH_3-N), Phosphate-Phosphorus (PO_4-P), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The samples were analyzed using standard methods (APHA 1998) in the Department of Water Resources and Environmental Engineering and Institute of Agriculture, Ahmadu Bello University Zaria.

RESULTS AND DISCUSSION

Pre-irrigation Water Quality of the Study Area

(a) Salinity

The average value of the electrical conductivity in the samples analyzed ranged between 0.063 and 0.065ds/m as given in Table 1. This is within the safe limit (≤ 0.7ds/m) expected for electrical conductivity in irrigation water (Ayers and Welscot, 1994).. Also, the average value of the total dissolved solids (TDS) ranged from 150-154mg/l which is also within the safe limit (≤ 450mg/l) expected for TDS in irrigation water. The result of these two parameters clearly indicates a generally low value of salinity in the irrigation water. Hence, the irrigation water falls under the lowest level of classification (class C1) as shown in Table 2. Therefore in respect to salinity, it is safe for irrigation.

(b) Sodicity

The average values of the SAR in the samples analyzed ranged from 0.27 to 0.29me/l. This is within the safe limit (≤ 3) of SAR (Ayers and Welscot, 1994)expected for irrigation water. The result indicates low values of sodicity and hence, falling in the low sodicity class (S1) as given in Table 2.. Although the SAR of the irrigation water falls within an acceptable range, the possibility of infiltration problems occurring from the irrigation water is very high. This is due to the EC of the water being too low (below 0.2ds/m). According to Ayers and Welscot (1994), very low salinity water (EC less than 0.2ds/m) almost invariably results in water infiltration problem regardless of the SAR. This is due to the corrosive nature of low salinity water which tends to leach surface soil free of soluble nutrients such as calcium, reducing their strong stabilizing influence on soil aggregates and soil structure.

More so, the results in Table 1 show that the calcium/magnesium ratio is far less than 1.0. This is not acceptable as the potential effect of sodium may be slightly increased in magnesium dominated water (ratio Ca/Mg <1). Aside the infiltration problem, productivity is sometimes reported to be low on soil being irrigated with high magnesium water even though infiltration problem may not be evident. The effect may be due to a magnesium induced calcium deficiency caused by high levels exchangeable magnesium in the soil (Ayers and Welscot, 1994).This suggests that effective management practices are required in Kadawa to cope with the low calcium to magnesium ratio of the irrigation water in order to avoid problems of infiltration and poor productivity.

(c) Specific ion toxicity

The average value of the sodium, chlorine and boron content in the samples analyzed ranged within 0.23 and 0.26, 0.32 and 0.35, 0.82 and 0.91 respectively. It is clearly indicated in Table 1 that the sodium and chloride content is within the safe limit. As for the boron content, it is just within the permissible region for crops sensitive to boron (crops like orange, cowpea, onions) but for moderately tolerant and tolerant crops like maize, tomatoes, lettuce, cabbage, sorghum etc. it falls within the excellent region (according to the classification given by Thorne, 1954). Hence with respect to sodium and chlorides, the water is suitable for irrigation with little caution of sodium and chloride toxicity arising. But with respect to boron, proper caution must be taken if it is to be used for the production of boron sensitive crops like the ones listed above.

(d) Other Miscellaneous Parameters

The average value of the pH, nitrates, phosphates and bicarbonates in the samples analyzed ranged within 7.22 and 7.52, 8.38 and 9.50, 2.16 and 2.68, and 0.78 and 0.84. It is indicated in Table 1 that the pH and bicarbonates level are within the safe limit in irrigation water. As for the nitrates and phosphates, their concentrations are not acceptable.

Nitrates and phosphates are nutrients necessary for the growth of crops but in high concentrations can cause excessive vegetative growth. This would cause unwanted species to grow, resulting in additional stress to the farmers while trying to weed the unwanted species. Also high concentration of nitrogen reduces the quality of some crops. The high nutrient level of the water may be due to the discharge of agricultural runoff rich in nutrients into the irrigation water source (Tiga Dam). Contamination of the irrigation water source with human and animal faeces, plant residue such as decayed leaves may have also led to the high nutrient level of the water.

The protection of the water source from agricultural runoff, contamination from human and animal faeces, and other sources of contamination would help prevent further increase in the nutrient level of the water.

Post-Irrigation Water Quality

(a) pH Level

The average values of the pH for the samples analyzed ranged between 6.98 and 7.30. This result falls within the FEPA's effluent limit for discharge into surface water (6-9) as shown in Table 3. This implies that with respect to pH, the post irrigation water from the farm would not have detrimental effect on the receiving water bodies.

(b)Total Solid

The average values of the total solids for the samples analyzed ranged between 328 and 446mg/l. This result falls within the FEPA's effluent limit for discharge into surface water (2000mg/l) as shown in Table 3. This implies that the effect the total amount of solids from the post irrigation water might have on the receiving water bodies is negligible.

(c) Suspended Solids

The average values of the suspended solids for the samples analyzed ranged between 312 and 334mg/l. This result does not fall within the FEPA's effluent limit for discharge into surface water (30mg/l) given in Table 3. The discharge of the post irrigation water into water bodies due to surface runoff would greatly increase the amount of suspended solids in the water bodies and this is not desirable. High level of suspended solids in surface water can be very detrimental. Suspended solids could block the gills of fishes if swallowed, thereby making respiration difficult, which could result in death. The habitat of some aquatic plants and other aquatic organisms could be destroyed due to the deposition of suspended solids into the water. More so, the design life of reservoirs in the area, most especially the Tiga reservoir, would greatly reduce due to the deposition of sediments. Hence discharge of the post irrigation water into the nearby water bodies needs to be reduced in order to avoid the detrimental effects of high concentration of suspended solids in water.

(d) Sulphates

The average values of sulphate concentration for the samples analyzed ranged between 1.2 and 1.41mg/l. This result falls within the FEPA's effluent limit for discharge into surface water (500mg/l) as shown in Table 3. The low concentration of sulphates in the water showed that the post irrigation water would not have detrimental effects from sulphates on receiving water bodies.

(e) Nutrients

The average values of phosphates and nitrates for the samples analyzed ranged between 6.76 to 7.80 and 15.92 to 17.64mg/l, respectively. The concentration of phosphates in the water does not fall within the FEPA's limit (5mg/l) while that of the nitrates fell within the limit (20mg/l) as given in Table 3. Though the nitrates concentration fell within FEPA's limit, the concentration is high. These two results imply that the nutrient concentration in the water is very high. Hence with respect to nutrients, the water is not fit to be discharged into water bodies.

The discharge of water high in nutrients into surface water bodies would result in the excessive growth of some species (e.g.

Algae) of aquatic organisms in the water. When these organisms die, they settle at the bottom of the water bodies as oxygen demanding materials. These materials continue to deplete the available dissolved oxygen in the water, hence putting the life of some aquatic species like fish at risk. This is because at certain low level of dissolved oxygen (mostly less than 5mg/l), some aquatic organisms cannot survive.

More so, some toxins (such as cyanobacterial toxin) might be released into the water due to the growth of some species (like cyanobacteria) as a result of the high nutrient level in the water.

(f) Oxygen Demand

The average values of the Biochemical Oxygen Demand and the Chemical Oxygen Demand for the samples analyzed ranged between 38 to 44 and 40.2 to 43.3mg/l, respectively. These results fell within the FEPA's effluent limit for discharge into surface water (50mg/l BOD, 150mg/l for COD) as shown in Table 3. Also the results of COD for all the samples analyzed were generally higher than the BOD. This shows that the post irrigation water from Kadawa contains more of materials that require chemical stabilization. This might be due to the use of fertilizers in the farm containing substances that can only be stabilized chemically. Nevertheless, the BOD and COD concentration of the water is within acceptable limits.

From the results obtained, it was clearly stated that all the parameters analyzed fell within the limit given by FEPA (1991), except for suspended solids and phosphate which did not fall within the limit. This suggests that the discharge of the post irrigation water could cause detrimental effects on the receiving water bodies because of those parameters that did not fall within the limit. Hence, the runoff of the post irrigation water needs to be prevented through management practices such as proper irrigation scheduling, to avoid excessive irrigation that would lead to surface runoff.

CONCLUSION

Most of the physio-chemical characteristics of the Kadawa irrigation water analyzed fell within the acceptable limit for irrigation water. The electrical conductivity of the water is very low, which shows the water has low salinity. Though salinity problems may not occur in the project area, the very low salinity of the water might cause the leaching of soluble nutrients such as calcium from the surface soil, which could lead to infiltration problems.

The calcium/magnesium ratio of the water is also very low, thus indicating calcium deficiency in the water, which could cause infiltration and low productivity problems. Amendment of the soil with gypsum ($CaSO_4$)can be employed to increase the calcium content of the soil in order to minimize infiltration problems in the soil.

Not all the physico-chemical characteristics of the post irrigation water tested, satisfies the limit for its discharge into water bodies. Hence the discharge of the post irrigation water into water bodies due to surface runoff should be greatly reduced as the post irrigation water might have adverse effects on the receiving water bodies.

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Table 1: Physico-chemical characteristics of pre-irrigation water in the study area

Parameter	Unit	Station				
		A	B	C	*Usual range in irrigation water	*Safe limit in irrigation water
Electric conductivity (EC)	dS/m	0.063	0.065	0.065	0-3	≤ 0.7
TDS	mg/l	154	152	150	0-2000	≤ 450
pH	mg/l	7.24	7.22	7.52	6 - 8.5	6.5-8.5
Calcium (Ca^{++})	me/l	0.55	0.47	0.54	0-20	-
Magnesium (Mg^{++})	me/l	0.94	0.94	1.23	0-5	-
Sodium (Na^{+})	me/l	0.23	0.24	0.26	0-40	≤ 3
Chloride (Cl^{-})	me/l	0.32	0.35	0.32	0-30	≤ 4
Carbonate (CO_3^{-})	me/l	0.00	0.00	0.00	0-1	-
Bicarbonate (HCO_3^{-})	me/l	0.84	0.81	0.78	0-10	≤ 1.5
Nitrate-Nitrogen (NO_3-N)	mg/l	9.50	9.98	8.38	0-10	≤ 5
Ammonia-Nitrogen	mg/l	0.06	0.06	0.06	0-5	-
Phosphate-Phosphorus (PO_4-P)	mg/l	2.52	2.68	2.16	0-2	-
Potassium (K^{+})	me/l	0.14	0.097	0.093	0-2	-
Boron (B)	mg/l	0.91	0.87	0.82	0-2	≤ 0.7
SAR	me/l	0.27	0.29	0.28	0 – 3	≤ 3

*Source of usual range and safe limit: Ayers and Welscot (1994)

Table 2: Classification of Kadawa Irrigation Water

Sample Points	EC (at 25^0C Dsm^{-1}	Salinity Class	SAR	Sodicity Class	Boron Conc. (Mg/L)	Boron Class	Bicarbonate Conc. (Me/L)
A	0.063	C_I Low Salinity Water	0.27	S_I Low Sodicity Water	0.91	Permissible	0.84
B	0.065	C_I Low Salinity Water	0.29	S_I Low Sodicity Water	0.87	Permissible	0.81
C	0.065	C_I Low Salinity Water	0.28	S_I Low Sodicity Water	0.82	Permissible	0.71

Source of irrigation water classes: Richard, 1954; Thorne, 1954.

Table 3: Physico-chemical parameters of the post-irrigation water

Parameter	Unit	Station A	Station B	*FEPA's Effluent limit for discharge into surface water.
pH	-	6.98	7.30	6-9
Total Solids (TS)	mg/l	328	446	2000
Suspended Solids (SS)	mg/l	312	334	30
Chloride (Cl^-)	mg/l	11.30	12.10	600
Sulphates (SO_4^{2-})	mg/l	1.20	1.41	500
Nitrate-Nitrogen (NO_3-N)	mg/l	15.92	17.64	20
Phosphate-Phosphorus (PO_4-P)	mg/l	6.76	7.80	5
Dissolved Oxygen (DO)	mg/l	2.18	1.86	-
Biochemical Oxygen Demand (BOD)	mg/l	38	44	50
Chemical Oxygen Demand (COD)	mg/l	40.40	43.20	150

*Source of effluent limit for discharge into surface water: FEPA, 1991.