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Analysis of water quality of small scale irrigation scheme in Kwadon, Yamaltu-Deba LGA of Gombe state, Nigeria

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Abstract
This study assess the physio-chemical composition of different water sources available at Kwadon small-scale irrigation site and evaluate their suitability for irrigation purpose. Surface and groundwater samples were collected from stream and boreholes using 1.5 liters sterilized bottles and then analyzed for important physio-chemical quality parameters include pH, EC_w, TDS, Ca^{++}, Mg^{++}, Na^{+}, HCO^{-}_{3}, Cl^{-}, SO^{-}_{4}, NO_3^{-}, K^{+}, SAR and SSP following standard procedures. The quality rating for each parameters of water sources were rated for irrigation suitability following FAO standard guidelines. A very high positive correlation was established in the concentration level of water parameters sources from boreholes and stream. The findings of the study revealed that all the water sources were of good quality and found suitable for irrigation as must of the measured parameters were within the recommended FAO threshold level for irrigation. Thus, opportunities for scaling small-scale irrigation exist in the site. However, emphasize the need for proper application of the water and avoid activities such as washing of vehicles along the stream that could affect the quality of water.

Keywords
irrigation, water quality, standard, Kwadon

Introduction

Irrigation refers to the artificial application of water to land to assist in the growing of crops and pastures or to maintain vegetation growth. (Sule, et al. 2019). The practice of irrigation, be it instinctive or scientifically based, concerns human intervention in management of soil moisture in the crop root zone, while ensuring the continued fertility of the soil itself (Rydzewski, 1990). Poor quality of irrigation water affects both soil quality and crops contains some dissolved quality of groundwater is equally important as its quantity owing to the suitability of water for various purposes. Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and anthropogenic activities (Abdallah, 1990).

The performance of agricultural use of irrigation water in sub-Sahara Africa, as compared to Asia, has been characterized by inefficiency and poor management (Nwa, 2003). However, Nigeria irrigation system has recently started receiving due attention and there is an observed facelift in its development. The development has been faced with inconsistent and unstable policies and inappropriate legal framework as well as the poor attitudes and interests of the participating farmers in the operation and maintenance of the irrigation scheme (Bashir and Kyung-Sook, 2018). Adekunle et al. (2015) found out that poor knowledge of irrigation techniques among the farmers was one of the factors affecting their participation in large-scale irrigation scheme. Those that manage to participate are not equipped with the

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requisite knowledge for the operations and maintenance of the facilities. As a result, the performances of many irrigation schemes have fallen short of expectations due to low productivity. Because high yields are essential, most farmers depends upon the continued addition of chemical fertilizer to soil, which may cause unbalanced combination of soil nutrients if only applied without a knowledge or idea on the particular soil properties and water quality (Sule et al, 2017). At present, great emphasis is being placed on the assessment of irrigated soil and farmers see other agricultural inputs and services such as fertilizers, tractors, harvesters, as more important than agricultural water. They tend to seek more government interventions on these agricultural inputs more than the provision of agricultural water through irrigation facilities. However, water resources development for irrigation plays a key role in agricultural and economic growth (Mugagga and Nabaasa, 2016). There is therefore a need to assess the quality of water used for irrigation in the study area.

The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. For example, the physical and mechanical properties of the soil, ex. soil structure (stability of aggregates) and permeability, are very sensitive to the type of exchangeable ions present in irrigation waters (Lenntech, 2020). Quality criteria may also differ considerably from one country to another, due to different annual application rates of irrigation water. Water quality criteria for irrigation water generally take into account, analyst other factors, such characteristics as crop tolerance to salinity, sodium concentration and phytotoxic trace element. The effect of salinity on the osmotic pressure on the unsaturated soil zone is one of the most important water quality considerations because this has an influence on the availability of water for plant consumption. Sodium in irrigation water can adversely affect soil structure and reduce the rate at which water moves into and through soils. Phytotoxic trace elements such as boron, heavy metals and pesticide may stunt the growth of plants or render the crop unfit for human consumption or other intended uses. In order to address this problem there is a need to find out the quality of water used for irrigation as that will serve as a guide in monitoring, planning and maintenance of water resources (Bauder et al 2007).

The study sought to assess the suitability of water sources in kwadon small scale irrigation scheme. The parameters used were Acid/Basicity (pH), Calcium(Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^{+}), Bicarbonate (HCO^{-}_{3}), Chloride (Cl^{-}), Sulphate (SO^{-}_{4}), Nitrate–Nitrogen ($NO_3^{-}N$), Potassium (K^{+}), Electrical conductivity (EC_w), Total Dissolved solids (TDS), Sodium Adsorption Ratio (SAR), and Soluble Sodium Percentage (SSP). The knowledge generated will guide irrigation water uses and other stakeholders on agricultural policy for sustainable small holder irrigation development in the area.

Study area

Yamaltu-Deba Local Government Area is located on latitudes 10^0 00' to 10^0 30' N and longitudes 11^0 15' to 11^0 45' E. It covers an area of 1,981km^2 and has the population of 255,726 according to population census 2006 (NPC 2006). The irrigated area is located at kwadon, Yamaltu-Deba LGA, Gombe State. It lies between latitude 10°17'24.9"N to 10°17'74.7"N and longitude 11°17'51.3"E to 11°18'28.0"E. (Fig. 1).

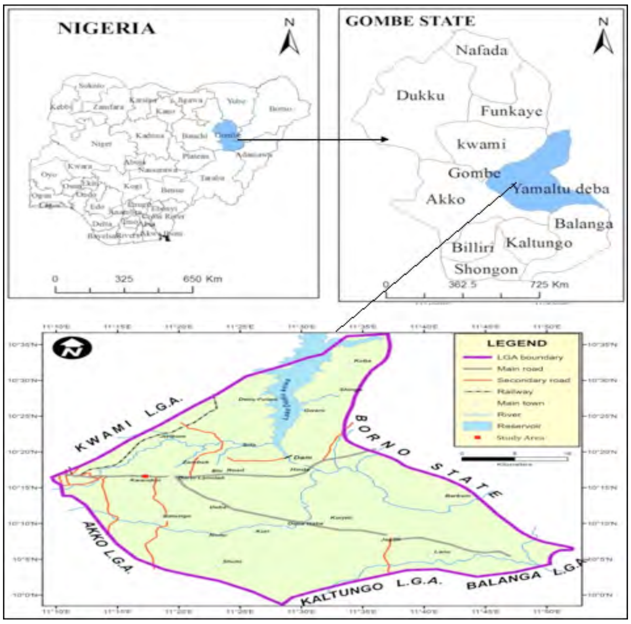

Figure 1. *Map of study area.*

The climate of the area is characterized by two distinct seasons (Dry and wet seasons), with an average annual rainfall of 850mm (Wanah and Mbaya, 2012). Temperature is between 35-40OC in the month of March and April while minimum temperature is recorded during the harmattan period (Baminda and Dabi, 2011). The vegetation is characterized by scattered shrubs and thorn bushes which fall within the open Sudan savannah vegetation zone of Nigeria (Mbaya, 2016). Gombe formation is the main outcrop

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in the study area and its hydrology consists of numerous seasonal streams, however, there is a perennial river known as Gongola which has been dammed at Dadin-kowa and was use for irrigating over a total of about 20,000 hectares of land.

Materials and methods

Water samples were collected in 1.5 liters sterilized bottles from the streams and boreholes in the area. The samples were sealed and stored in a low temperature and transported to the Federal Ministry of Water Resources Department of Water Quality and Sanitation for laboratory analysis using the following instruments and methods: EC and pH measurements were made using EC and pH Meters which were calibrated prior to taking readings. Calcicol and Magnicol test methods were used to determine Ca^+ and Mg^+ respectively. A flame photometric method was used to determine Na^+ and K^+. Cl^- was analysed using argentometric titration method. HCO^-_3 was measured by calculation from titration method of alkalinity determination using 0.01M HCl, Phenophtherlien and methyl orange indicators. While NO_3^-N was measured by colorimetric method (Sule, et al. 2019).

The Total Dissolved Solids was calculated using equation TDS (mg/L) = EC (dS/m) × K. Where, K = 640 in most cases for EC: 0.5 -5 dS/m (Kahlown and Khan, 2002). The Sodium Adsorption Ratio was calculated from the ratio of sodium to calcium and magnesium (USDA, 1954), while the Soluble sodium percentage was also calculated using the ration of sodium in epm (equivalents per million) to the total cation epm multiplied by 100 (Todd, 1959).

The results obtained from the laboratory water quality analysis were statistically analysed using descriptive statistics such as relative frequencies, mean and standard deviation. While the non-parametric two tailed Spearman rank correlation coefficient (rs) was used to determine the relationship among the volume of parameters in the water sources from boreholes and streams. All the statistical analysis was performed using SPSS statistics software.

Results and Discussion

Water quality characterization

The measured chemical parameters of the irrigation water sources from borehole and stream showed a different trend of concentration level (table 1).

Table 1. *Characteristics for water sources and FAO usual range.*

Water parameter	Symbol	Unit	Borehole	Stream	FAO usual range in irrigation water
Acid/Basicity	pH	1-14	7	8	6.0 – 8.5
Electrical conductivity	EC_W	dS/m	0.3	0.2	0 – 3
Total Dissolved solids	TDS	mg/1	192	128	0 – 2000
Calcium	CA^{++}	me/1	30	34	0 – 20
Magnesium	Mg^{++}	me/1	20	30	0 – 5
Sodium	Na^+	me/1	1	4	0 – 40
Bicarbonate	HCO^-_3	me/1	209	336	0 – 10
Chloride	CI^-	me/1	26	65	0 – 30
Sulphate	SO^-_4	me/1	19	20	0 – 20
Nitrate – Nitrogen	$NO_{3\_}N$	me/1	0	0.1	0 – 10
Potassium	K^+	me/1	6	6	0 – 2

Author's fieldwork 2019 and FAO (2005).

pH is the degree of acidity (or alkalinity) of the sample. A pH of less than 7.0 is acidic, 7.0 is neutral and above 7.0 is alkaline. The pH of water and soil could not harm the plant growth directly (Tahir et al., 2003). pH highly affects the efficiency of coagulation and flocculation process (Kahlown et al., 2006). The pH levels for water used in kwadon small scale irrigation site ranged from 7 to 8 with a mean of 7.5 ± 0.70. The minimum and maximum values recorded was within the acceptable FAO permissible limits for irrigation water (6.0 – 8.5) and therefore could have no hazardous effect to crops in the site. However, pH (>7.0) may reduce the availability of various metals and micronutrients causing deficiency symptoms. High pH is often accompanied by high

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alkalinity. High pH problems can be corrected by acid injection or in some cases by using an acid fertilizer (Bryan, 2016).

Electrical conductivity (EC_w) is the capacity of water to transmit the electric current. it is a good estimator of the total amounts of mineral salts dissolved in water (Warrence et al. 2003). When the EC of water is high, it shows that there is high concentration of ions in the water and also affects the plant growth. The overall EC of the sampled water from stream and borehole in kwadon small scale irrigation site range from 0.2 to 0.3 ds/m respectively and within the FAO permissible limits of 0 to 3 ds/m and therefore pose no threat to crops in the site. However, to avoid problems from excessive salts, raw water before fertilizer additions should be below 1 mmhos/cm for plugs and below 1.5 mmhos/cm for other growing conditions. Raw water conductivity above 3 mmhos/cm can be expected to cause severe growth effects on many plants (Swistock, 2016).

Total Dissolved Solids (TDS) the salinity behavior of water is indicated by total dissolved solids (TDS). TDS change the color and properties of water, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature (Kahlown et al., 2006). Plants can wilt due to insufficient water absorption by the roots compared to the amount lost from transpiration, even though the soil may have plenty of moisture. TDS levels should be below about 640 mg/L to avoid problems in plugs and below about 960 mg/L to avoid problems with other plant growing conditions (Swistock, 2016). The calculated level of TDS in all the boreholes and stream water sampled at the irrigation site were 192 to 120 Mg/L respectively and were within the acceptable threshold of the FAO 0 – 2000 Mg/L and pose no threat to the vegetable production in the site.

Calcium (Ca^{++}) is generally found in all natural waters. When adequately supplied with exchangeable calcium, soils are friable and usually allow water to drain easily. The level of Ca^{++} in all the boreholes and stream water sampled at the irrigation site were variably higher. The overall mean calcium concentrations of the water was 32.0 ± 2.83 Mg/L^{-1} and were above the acceptable FAO limits of 0 – 20 Mg/L^{-1} and could pose a threat to vegetable production in the area. According to Bryan (2016), high levels of calcium may also lead to clogged irrigation equipment due to scale formation (CaCO3 and other compounds precipitating out of solution). Water softening (cation exchange) is typically used to reduce calcium levels in water but softening for irrigation should use potassium for regeneration rather than sodium to prevent damage by excess sodium in the softened water.

Magnesium (Mg^{++}) is also found in most natural waters. Together with calcium, Mg may be used to establish the relationship to total salinity and to estimate the sodium hazard. The total concentrations of calcium and magnesium is referred as water hardness. The Mg^{++} concentration recorded in the sampled water sources from boreholes and stream ranged from 20 to 30 Mg/L respectively. The mean levels recorded were 25.0 ± 7.07 Mg/L and were considered above the FAO acceptable threshold of 0 – 5 Mg/L and could limit vegetable production due to elevated pH and lack of some nutrients to the crops in the site. Magnesium can also cause scale formation at high concentrations which may require softening (Bryan, 2016).

Sodium (Na+) is often found in natural waters due to its high solubility. When linked to chloride (Cl) and sulphate (SO_4), sodium is often associated with salinity problems. Irrigation water containing large amounts of Na^+ is of special concern due to sodium's effects on the soil and poses a sodium hazard. The Na^+ level recorded in boreholes and stream water sources in kwadon irrigation site ranged from 1.0 to 4.0 Mg/L respectively. The mean Na^+ level was 2.50 ± 2.10 Mg/L and were acceptable within the FAO permissible range of 0 – 40 Mg/L with no anticipated problem to vegetable production in the site.

Bicarbonate (HCO^-_3) are also salts of carbonic acid and are common in natural waters. As soil moisture is reduced, calcium and magnesium bicarbonates can separate calcium from the clay colloid, leaving sodium to take its place. The HCO^-_3 concentrations recorded in both the boreholes and stream water sampled in the site were very high (209 to 336 Mg/L) respectively with the mean value of 272.5 ± 89.8 Mg/L and were above the FAO permissible threshold of 0 to 10 Mg/L therefore may contribute to a soil dominant in sodium, with a resulting reduction in water infiltration rates and soil gas exchange. Also it tends to be problematic because it can lead to elevated pH of the growth media which can cause various nutrient problems e.g., iron and manganese deficiency, calcium and magnesium imbalance (Bryan, 2016).

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Chloride (Cl^-) is an anion that is commonly found in irrigation water. Chlorides contribute to the total salt (salinity) content of soils. Necessary for plant growth in small amounts, while high concentrations will inhibit plant growth or be toxic to some plants. Irrigation water high in chloride reduces phosphorus availability to plants. The Cl^- concentrations recorded in the boreholes water was 26.0 Mg/L and were within the acceptable threshold of the FAO of 0 – 30 Mg/L while the Cl^- concentration recorded in the stream source of water has the highest value of 65 Mg/L. However, the overall mean value recorded were 45.50 ± 27.58 Mg/L which was above the FAO permissible threshold.

Sulphate (SO^-_4) is relatively common in water and has no major impact on the soil other than contributing to the total salt content. Irrigation water high in sulfate ions reduces phosphorus availability to plants. The SO^-_4 concentrations recorded was 19.0 to 20.0 Mg/L for boreholes and stream sources of water respectively with the mean value of 19.50 ± 0.71 Mg/L and were within the acceptable threshold of the FAO 0 – 20 Mg/L and pose no threat to the vegetable production in the site.

Nitrate (NO_3^-) the levels of nitrate in both the boreholes and stream water sampled in the site were very low (0.0 to 0.1 Mg/L) respectively and were within the acceptable threshold of the FAO 0 – 10 Mg/L and pose no threat to the vegetable production in the area.

The **potassium (K^+)** cation behaves similarly to sodium in the soil and is commonly found in natural waters in only small amounts. The levels of k^+ recorded form boreholes and stream water sampled in the irrigation area were 6.0Mg/L respectively given the mean of 6.0 ± 0.0 mg/L which was above the acceptable limits of FAO 0 – 2 mg/l and could pose a threat to vegetable production in the site. According to Bryan (2016) high potassium is generally not a concern for plant growth, however may indicate water contamination from fertilizers or other man-made sources.

Sodium Adsorption Ratio (SAR)

This is an expression of the sodium hazard of irrigation water. It is the measure of the proportion of sodium to calcium and magnesium in the water. The SAR is also an index of the sodium permeability hazard as water moves through the soil. The main problem with a high sodium concentration is its effect on the physical properties of soil. This breakdown disperses the soil clay and causes the soil to become hard and compact when dry and reduces the rate of water penetration when wet. A breakdown in the physical structure of the soil can occur with continued use of water with a high SAR value. SAR is calculated from the ratio of sodium to calcium and magnesium (USDA, 1954). Where all the concentrations of the cations are expressed in meq/L.

$$\mathrm{SAR} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \qquad [1]$$

Water having an SAR less than or equal to 10 is of excellent quality, 10 – 18 is of good quality, 18 – 26 is of medium quality and greater than 26 is of bad quality and therefore considered unsuitable for irrigation (FAO, 2013). The calculated SAR of water sampled from boreholes and stream were 0.2 to 0.7 respectively, thus indicating excellent quality water for irrigation based on the Irrigation water quality standards given by US Regional Salinity Laboratory and Food and Agriculture Organization (FAO). Typically a SAR value below 2.0 is considered very safe for plants especially if the sodium concentration is also below 50 mg/L. (Swistock, 2016).

Soluble Sodium Percentage (SSP)

The SSP is also used to evaluate sodium hazard. SSP is defined as the ration of sodium in epm (equivalents per million) to the total cation epm multiplied by 100. The SSP was calculated using the formula adopted from Todd (1959). Where all the concentrations of the cations are expressed in meq/L.

$$\mathrm{SSP} = \frac{(Na^+ + K^+) \times 100}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \qquad [2]$$

A water with a SSP greater than 50% may result in sodium accumulations that will cause a breakdown in the soil's physical properties. It may also cause stunted growth in plants and reduce soil permeability (Joshi et al, 2009). The calculated SSP of water sampled from boreholes and stream were 10.53% to 13.51% respectively and were all less than 50%, indicating that all the water sources are suitable for irrigation with no anticipated problem.

Parameters' relationship

Two tailed Spearman rank correlation coefficient (rs) was used to determine the relationship among the volume

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of parameters in the water sources from boreholes and streams Formula is:

$$rs = 1 - \frac{6\sum d^2}{n(n^2-1)} \quad [3]$$

Where, *n* is the number of pairs of occurrence being considered and *d* is the difference between the pairs of ranked values. While the degree of freedom (df) is equals the number of ranked pairs (n). Therefore, the calculated value of rs is 0.99 which is greater than the critical value 0.623 at 0.05 significance level, this shows that there is a very high positive correlation between the concentration levels of parameters of the water sampled from the different sources (boreholes and stream) in kwadon small-scale irrigation site.

Conclusion and recommendations

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. Thus, a great need to find out the quality of water used for irrigation as that will serve as a guide in monitoring, planning and maintenance of water resources (Bauder, et al 2007). This study assess the physio-chemical composition of different water sources available at Kwadon small-scale irrigation site and evaluate their suitability for irrigation purpose. In relation to the findings on the quality of water in the study area, a very high positive correlation was established in the concentration level of water parameters sources from boreholes and stream. While we found all the water sources including boreholes and stream suitable for irrigation as must of the measured parameters were within the recommended FAO threshold level for irrigation. There is therefore a great opportunities for scaling small-scale irrigation in the site. However, the high level of potassium records indicated water contamination from fertilizers or other man-made sources. Thus, suitable measures such as land levelling to apply water more uniformly; Better training and extension efforts; Furrow diking to promote soil infiltration and reduce runoff; Establishing water user organizations for better involvement of farmers as well as the need to avoid activities such as washing of vehicles along the stream that could affect the quality of water.

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