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PHYSIO-CHEMICAL PROPERTIES OF WATARI IRRIGATION WATER

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ABSTRACT

Much of the interpretation of results of water analysis is based on a prediction of the consequences for the soil. Typically, the quality of irrigation water is assessed based on the salt contents and salt inducing parameters, abundance of nutrients, trace elements, alkalinity, acidity, hardness and the amount of suspended solids. The physiochemical properties of the Watari irrigation water were assessed and the Findings indicated that the mean pH of water ranged from 7.10 to 7.50, while the EC values across the sectors ranged from 50 to 60µS/m. Metal cations in the water ranged from 15.00 to 20.07; 5.41 to 16.22; 3.29 to 6.57; 14.83 to 15.00cmol/l for Na, Ca, Mg and K respectively. The SAR ranged from 6.87 to 10.17, while the range of TDS values was from 31.00 to 36.00mg/l. The mean carbonates concentration detected in the irrigation water was from 4.00 to 12.00cmol/l, while the mean bicarbonate content ranged from 22.00 to 55.00cmol/l. Chloride and nitrate were within 9.87 to 31.58 and 1.00 to 1.65mg/kg, respectively. The residual sodium carbonate (RSC) ranged from 8.00 to 30.69.There was no detectable NH_4 in the irrigation water. It was recommended that adequate drainage with emphasis on surface drainage should be provided to reduce the risk of salinity whereas salt and sodium build up should be monitored regularly.

Keywords: Irrigation water, Watari, Physio-chemical properties and Quality.

INTRODUCTION

Irrigation water always contains some soluble salts irrespective of its source. The suitability of waters for a specific purpose depends on the types and amounts of dissolved salts. Some of the dissolved salts or other constituents may be useful for crops. However, the quality or suitability of waters for irrigation purposes is assessed in terms of the presence of undesirable constituents, and only in limited situations is irrigation water assessed as a source of plant nutrients. Some of the dissolved ions, such as NO3, are useful for crops.

The primary goal of water analysis is to examine the effect of the water on the soil, and ultimately on the plants grown on the soil. As such, much of the interpretation of the water analysis is based on a prediction of the consequences for the soil. Typically, the quality of irrigation water is assessed based on the salt and salt inducing contents, the presence and abundance of micro and macro nutrients, trace elements, alkalinity, acidity, hardness and the amount of suspended solids(U. S. Salinity laboratory Staff, 1954, Ajayi *et al.,* 1990).

Another effect of carbonates and bicarbonates is on the alkalinity status of the soil. High alkalinity indicates that the water will tend to increase the pH of the soil or growing media, possibly to a point that is detrimental to plant growth. Low alkalinity could also be a problem in some situations. This is because many fertilizers are acid-forming and could, over time, make the soil too acid for some plant. Another aspect of alkalinity is its potential effect on sodium. Soil irrigated with alkaline water may, upon drying, cause an excess of available sodium.

Among the components of water alkalinity, bicarbonates are normally the most significant concern. Typically, bicarbonates become an increasing concern as the water increases from a pH of 7.4 to 9.3. However, bicarbonates can be found in water of lower pH. Carbonates become a significant factor as the water pH increases beyond 8.0 and are a dominant factor when the pH exceeds about 10.3 (Maurya, 1982).

Chloride (Cl^-) ions are one of the anions in irrigation water for the potential of the water for phytotoxicity. The normal and safe limit for chloride ions in irrigation water should not exceed 30cmol/l (Landon, 1991) by which standard only sector 8 could be described as having potential risk in the area studied. If the chloride contamination in the leaves exceeds the tolerance of the crop, injury symptoms develop such as leaf burn or drying leaf tissue (FAO, 1976). These symptoms occur when leaves accumulate from 0.3 to 1.0 percent chloride.

Nitrate (NO_3^-) is also another important anion assessed for irrigation water. The normal ranking for nitrate nitrogen is a maximum of 10mg/l (Landon, 1991) by which standard all the sectors studied could be described as within safe limit. Although it may be seen as nitrogen in whatever form may be desirable for plants' growth, the risk associated with excess nitrogen, especially the nitrate form which is not adsorbed at exchange sites is the tendency for it to be leached into underground water or being washed away via drainage water to sundry water bodies where it can cause eutrophication.

The influence of bicarbonate and carbonate on the suitability of water for irrigation purpose is empirically assessed based on the assumption that all Ca^{2+} and Mg^{2+} precipitate as carbonate (Michael, 1985). Based on this, the concept of residual sodium carbonate (RSC) for the assessment of high carbonate waters is used. Waters with high RSC have high pH, and land irrigated with such water becomes infertile owing to deposition of sodium carbonate; as known from black colour of the soil. RSC values more than 2.5cmol/l are considered as unsuitable for irrigation (Landon, 1991). This paper attempts to examine the quality of the water used in the Watari irrigation project with a view to ascertaining its suitability or otherwise.

Study Area

Watari Irrigation Scheme is a medium scale irrigation project located on the slopes of the Watari River valley in Bagwai Local Government, which is about 18km from Bichi. It is located at the North-western part of Kano between latitudes $12^0 6'$ 54.54''N and $12\ ^0\ 9'$ 17.8''N and longitudes 08^o 11' 50.62''E and 08^o 16' 28.05''E. The main canal is about 10km long, while the command area consists of 5 sectors numbered 1 through 4 and sector 8 the Kanyu pilot farm. The net irrigable land area in rounded figure per sector is as follows:

Table 1. The Area of Irrigable Land in Watari River Irrigation Scheme

Sector	Hectare
1	160
2	170
3	216
4	72
8	72
Total	**690**

Source: KNARDA (2011)

METHODOLOGY

Seven water samples were collected and analysed for physiochemical and salinity related parameters. One sample was collected from the Dam water which is the main source of water in the scheme. Six other samples were collected from the sectors: one, two, three, four, five and eight. The water samples collected from six sectors of the irrigation scheme were analysed according to American public health association standards method for examination of water and waste water (1985). Digital pH meter was used for determining P^H of the samples. Conductivity was determined by using conductivity cell containing platinised electrodes. Ammonia was determined by the Nessle's method. Nitrates were determined by the phenoldisusphoric acid method. Turbidity was determined by spectrophotometric method. Phosphorus (P) content determination was done using the colorimeter (CECIL CE 373) method using the sodium hydrogen carbonate extraction. The determination was according to the Bray and Kurtz (1945) method. The determination was according to the Bray and Kurtz (1945) method. The metal analyses and determination of exchangeable bases was done with flame photometer (JENWAY

PFP7) and Atomic absorption spectrometer (BUCKS) after extraction using ammonium acetate extraction technique and dilute acids.SAR was computed using the appropriate formula.

RESULTS AND DISCUSSION

General Water Quality of the Watari Irrigation Scheme

Salinity and Cations

The general quality of irrigation water can generally be described by. The values are shown for both samples taken from the dam and the water flowing in the canals serving the sectors. The pH ranged from 7.10 to 7.50, while the mean EC values across the sectors ranged from 50 to 60µS/m. The metal cations in the water ranged from 15.00 to 20.07; 5.41 to 16.22; 3.29 to 6.57; 14.83 to 15.00cmol/l for Na, Ca, Mg and K respectively. There was no detectable NH_4 in the irrigation water. The SAR ranged from 6.87 to 10.17, while the range of TDS values was from 31.00 to 36.00mg/l.

Generally pH values for normal irrigation should be between 6.00 and 7.00, while values above 7.00 are considered as of increasing hazard (Singh *et al.,*1996; Danko, 1997). The pH is logarithmic, meaning that a change of 1.0 unit is a ten-fold change in either acidity or basicity. Therefore, changes of even less than 1.0 unit may be significant. This characteristic of the water has a significant influence on other characteristics or reactions in the soil and water, as well as the way plants perform.

The concentration of total salt content in irrigation waters is estimated in terms of EC and it may be the most important parameter for assessing the suitability of irrigation waters (Maurya, 1976). Generally, the ranges considered for irrigation water suitability are 20 to 300µS/cm being normal, which is increasingly severe with respect to salinity hazards (Schoeneberger, 1998). From this perspective, none of the sectors could be described as under any immediate threat, as even the highest mean recorded at sector 3 was still within the normal range. These low EC values further corroborates the values in the soil which also falls much lower than the ranges (Adamu, 2011). The amount of Na ions in the water predicts the potential sodicity of the water (Singh, 2000). Sodium ions are important criteria for irrigation water quality because of its effect on soil permeability and water infiltration. Sodium also contributes directly to the total salinity of the water and may be phyto-toxic. Sodium ions cause deflocculation of particles and subsequent sealing of soil pores thereby preventing water passage into the soil (Alhassan, 1996). Generally, values greater than 9.0cmol/l in terms of Na concentrations are regarded as posing increasing severity of sodicity especially in soils high in clay content (Davis & Dewest, 1966). The values recorded across all the sectors may therefore be interpreted as posing severe risk factor of sodium toxicity to the soil. The low EC values (50-60 µS/cm) obtained may be as a result of the fact that the soil is also low in clay content which is the principal particle that deflocculates in the presence of excess sodium. Sodium toxicity to sensitive crops may however not be ruled out with increasing application.

Of greater importance in terms of irrigation water quality evaluation than the Na content is the sodium absorption ration (SAR). The SAR relates the relative concentration of Na to the combined concentrations of Ca and Mg ions (Landon, 1991). Increasing sodicity hazards may be associated with values exceeding 6. As SAR is a factor of sodium against calcium and magnesium, the high values of SAR recorded in the water samples may not be a surprise as the sodium values are also relatively high. These further elaborate the risk factor associated with this irrigation water.

The normal range of Ca^{2+} in irrigation water should be 0 – 20cmol/l, while that of Mg^{2+} should be between 0 – 5cmol/l (Christenson *et al.,*1977). By these criteria the calcium content within the sectors could be described as within safe limit. This also applies to the magnesium content with exception of those levels recorded for sectors 3- 5 and 8.The relatively lower amounts of magnesium compared to the calcium may be beneficial because Mg deteriorates soil structure particularly where waters are sodium-dominated (as is the case with most of the sectors assessed here) and highly saline. The reason for this structural degradation is that high level of Mg usually promotes a higher development of exchangeable Na in irrigated soils (Maurya,1982) Generally, magnesium content of water is considered as important qualitative criteria in determining the quality of water for irrigation because more magnesium in water will adversely affect crop yields, as the soils become more alkaline. The combined effect of calcium and magnesium ions in irrigated soils counter the negative effect of the sodium by lowering the SAR. Their cumulative lower value relative to sodium has resulted in significantly higher SAR value across the sectors.

The presence of potassium ions in excessive amounts does not constitute any risk and may even supplement crops' needs as only values exceeding 50cmol/l may be considered as posing any serious risk factor with irrigation water (Adamu, 2011).

One of the miscellaneous ions assessed for evaluation of irrigation water quality is the level of ammonium nitrogen (NH_4-N). Values that exceed 30mg/l may increasingly pose a risk in irrigation water (Maurya, 1976). By this standard therefore the sectors may be regarded as critically lacking this form of ion as each of them recorded 0.0mg/l. This does not however mean the water is unsafe for irrigation and may be satisfactory especially with the slightly acidic nature of the soil. However the presence of ammonium nitrogen (NH_4-N), may compliment crops' supply.

TDS is also another criterion for the assessment of salt content in the water as salts constitute important part of TDS (Binnes *et al.,* 2003). Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts (Michael, 1985). They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil mineral salts (Belan, 1985). These salts are carried with the water to sites of use. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop.

Irrigation water with total dissolved solids (TDS) less than 450mg/l is considered good, and that with greater than 2000 mg/l is unsuitable for irrigation purpose (FAO,1985). By this therefore, the waters in all the sectors could be considered for irrigation.

Management Implication

The results here reveal water that may have the potential to be hazardous to the soil as well as to the crop grown, because the two most important parameters used in assessing the safety of irrigation; namely, Sodium ions and the associated SAR are within the unsafe limits. This is notwithstanding the fact that some other factors of salinity are within safe limit. The implication of these high values is that there is the tendency for the soil to be saline and therefore what are recommended here may be measures aimed at mitigating the development of saline or sodic soil at Watari irrigation scheme.

Table 2. General Irrigation Water Quality Parameters for the Watari Irrigation Scheme (Salinity and Cations)

Sample ID	pH	EC µS/m	Na (cmol/l)	Ca cmol/l)	Mg (cmol/l)	K (cmol/l)	NH_4 (mg/l)	SAR	TDS (mg/l)
DAM	7.10	51.67	15.74	9.01	3.63	15.00	0.00	8.85	31.00
SECTOR 1	7.13	53.33	20.07	12.92	3.97	14.83	0.00	9.77	32.00
SECTOR 2	7.10	50.00	15.00	5.41	3.29	15.50	0.00	10.17	30.00
SECTOR 3	7.40	60.00	15.28	13.52	5.48	15.00	0.00	7.01	36.00
SECTOR 4	7.20	50.00	16.00	16.22	5.48	15.50	0.00	6.87	30.00
SECTOR 5	7.50	50.00	15.28	10.81	6.57	15.00	0.00	7.33	30.00
SECTOR 8	7.10	50.00	15.00	13.52	5.48	15.00	0.00	6.88	30.00

Anions

The quality of the irrigation water across the sectors in terms of anions is shown in Table 3. Carbonate concentration detected in the irrigation water was from 4.00 to 12.00cmol/L, while the bicarbonate

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content ranged from 22.00 to 55.00cmol/L. The conc. ranges for chloride and nitrate were 9.87 to 31.58 and 1.00 to 1.65mg/kg respectively. The residual sodium carbonate (RSC) was between 8.00 to 30.69.

Interpretation

The carbonate (CO_3^{2-}) and bicarbonates (HCO_3^-) are 1.00 and 10.00cmol/l respectively (Landon, 1991). By this criteria therefore, the irrigation water in the study area assessed could be described as being at severe risk with regards to carbonates and bicarbonates. High CO_3^{2-} and HCO_3^- tend to precipitate calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$), thereby increasing sodium hazard in the soil relative to Ca and Mg, and consequently the SAR.

Management Implications

High levels of bicarbonates can be directly toxic to some plant species. Bicarbonate levels above 3.3cmol/l will cause lime (calcium and magnesium carbonate) to be deposited on soils and even on foliage especially when irrigated with overhead sprinklers. This may be undesirable for vegetable plants.

Table 3. General Irrigation Water Quality Parameters for the Watari Irrigation Scheme (anions)

Sample ID	CO_3^- (cmol/l)	HCO_3^- (cmol/l)	Cl^- (cmol/l)	NO_3^- (mg/l)	RSC (cmol/l)
Dam	6.67	36.67	9.87	1.00	3.69
Sector 1	6.67	41.67	16.45	1.65	3.44
Sector 2	4.00	20.00	8.88	0.90	1.30
Sector 3	12.00	15.00	14.80	1.50	0.80
Sector 4	8.00	55.00	14.81	1.50	4.13
Sector 5	6.00	40.00	12.83	1.30	2.86
Sector 8	8.00	25.00	31.58	3.16	1.40

Heavy Metals

The quality of the irrigation water in terms of trace elements presence in water is as shown in Table 6. Cu and As were not detected in all the sectors, but Cd and Pb were detected at sector 4 and 1at 0.1cmol/l level respectively. On the other hand Mn and Fe were 0.00 to 0.06 and 0.00 to 0.17cmol/l respectively.

Interpretation

The maximum levels (ML) allowed for these metals in irrigation water are 1.7, 10, 0.1, 20, 50 and 5.0mg/l for Cu, As, Cd, Mn, Fe and Pb respectively (Landon, 1991). By this standard therefore, none of the sectors is at any potential hazard risk except sectors 4 and 8 which have high Cd levels.

This is not surprising as high concentrations of heavy metals are only expected in waste water. However, heavy metals in all forms of irrigation water are assessed because they have the tendency to get into surface waters via runoff coming through agricultural fields in which agrochemicals and fertilizers are applied, because they form constituents of many of such chemicals. Monitoring trace elements in irrigation water is as important as monitoring salinity status because of their potential to build up in soil and be absorbed by plants thereby being introduced into food chain. When such happens, they constitute further risks to human and livestock in terms of health and wellbeing.

Management Implication

The fact that the levels in water is much lower than prescribed values does not translate into total safety of the water because the trace amounts detected for some elements is still worthy of consideration and further monitoring to ensure that levels do not exceed what has been detected. Monitoring should be on regular basis and different spatial and temporal settings because they are key factors with which concentrations vary.

Table 4. Concentrations of Trace Elements in the Waters of the Watari Irrigation Scheme

Sample ID	Cu (mg/l)	As (mg/l)	Cd (mg/l)	Mn (mg/l)	Fe (mg/l)	Pb (mg/l)
Dam	Nil	Nil	0.00	0.02	0.03	0.00
Sector 1	Nil	Nil	0.00	0.04	0.12	0.01
Sector 2	Nil	Nil	0.00	0.00	0.00	0.00
Sector 3	Nil	Nil	0.00	0.06	0.17	0.00
Sector 4	Nil	Nil	0.01	0.00	0.05	0.00
Sector 5	Nil	Nil	0.00	0.00	0.00	0.00
Sector 8	Nil	Nil	0.01	0.05	0.17	0.00

CONCLUSION AND RECOMMENDATION

The general quality of the irrigation water in terms of salinity and cations is assessed based on the parameters shown in Table 4. The values are shown for both samples taken from the dam and the water flowing in the canals serving the sectors. Generally pH values for normal irrigation should be between 6.00 and 7.00 pH and 7.10 to 7.50 respectively, while the mean EC values across the sectors ranged from 50 to 60µS/m. The mean metal cations in the water ranged from 15.00 to 20.07; 5.41 to 16.22; 3.29 to 6.57; 14.83 to 15.00cmol/l for Na, Ca, Mg and K respectively.

The following measures are worthy of note and implementation singly or in combination:

1. Provision of adequate drainage with emphasis on surface drainage, as the textural property of the soil indicates soil with potency for good internal drainage. If however, barriers restrict movement of water through the root zone especially in those sectors with appreciable clay content (Table 1) additional emphasis should be given to internal drainage.
2. Although the soil has not as yet indicated clear symptoms of salts development, provision should be made for use of clean water to meet the necessary leaching requirement over-irrigation. This is necessary to avoid build-up of salts in the soil solution to levels that will limit crop yields. Effective rainfall can be considered part of the leaching requirement.
3. The soil should be maintained at high available moisture level (always moist and not soaked) and should not be allowed to become more than moderately dry, since the crop cannot remove all the normally available water due to the higher salt content.
4. Salt and sodium build up should be monitored regularly (every 1 to 2 years). Development of a sodium hazard usually takes time and therefore soil tests for SAR or percent exchangeable sodium can detect changes before permanent damage occurs. Soil samples to be analyzed should represent the top soil and occasionally the sub soil.
5. Soluble calcium such as gypsum should be added to decrease the SAR to a safe value. The gypsum can be dissolved into the water or it can be broadcasted over the field. It should be broadcasted directly before irrigation or thoroughly incorporate into the tillage layer to avoid crusting problems. The soil can alternatively be tested for free lime; and when present

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elemental sulphur could be broadcasted. The sulphur solubilizes the calcium from the free lime already in the soil. If gypsum is used, the fresh water for leaching may have to be increased.

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