Short Research Article

Stream Water Quality Assessment for Irrigation at Nasarawa - Kakuri Area of Kaduna, Nigeria

Abstract

This study aimed at examining some physic-chemical properties of the water samples taken from Nasarawa stream in Kaduna South Local Government Area with a view to determining its suitability as a major source of water for irrigation farming of vegetables and other crops cultivated along the course of the stream in the area. Six sampling points were located to the upstream and downstream sides of the stream with the Nasarawa bridge as a reference point. Grab samples were taken in the month of March at an interval of 100m in plastic containers each of 1.5-litre capacity after being properly washed, cleaned and sterilized. The laboratory analyses were used to determine the experimental physic-chemical concentrations of pH, electrical conductivity, carbonate, bicarbonate, sulphate, chloride, sodium, potassium, calcium, magnesium, boron, sodium adsorption ratio (SAR) and and residual sodium carbonate (RSC) index in the stream water samples. Out of these parameters tested, four of them constitute major cause for concern. Electrical conductivity and potassium ion concentrations of the water samples exceeded the irrigation guideline values at all the six sampling points, boron ion concentration is close to guideline value at two points, while the SAR indicated severe case of potential sodium pollution at four points, hence the need for restriction in the use of water for irrigation. This study, therefore, showed the need for the Nasarawa stream water to be subjected to some level of treatment especially during the dry season when the water will be required for irrigation, and when dilution by rain water will be totally absent.

Keywords: Stream water, irrigation, contamination, water quality, physic-chemical properties.

1.0 INTRODUCTION

Nasarawa stream is located in Kaduna South Local Government area of Kaduna State, Nigeria on latitude 10° 28.770' and longitude 7° 22.600'. It traverses Kakuri – Nasarawa area through fadama land (flood plain or valley swamps), along which farming activities take place, and it discharges finally into the River Kaduna. One of the major sources of industrial pollution of the stream is the textile wastewater, among others, from Kakuri industrial area. Stream water is a ready source of irrigation water for most small scale farmers especially those cultivating along stream banks. Stream water is susceptible to contamination resulting from point and non-point sources, anthropogenic activities and solid or liquid waste disposal along the stream [1, 2]. All these contaminant sources lower the quality of water available from the stream for irrigation through the addition of silt or certain dissolved salts. The quality of irrigation water is mainly determined by the concentration of the soluble salts such as chlorides, sulphates, carbonates and bicarbonates of sodium, potassium, calcium and magnesium. Salts of some heavy elements such as lead, zinc, chromium, selenium, arsenic, boron, cadmium etc. are injurious to plants even when in small quantities [3, 4].

Generally, irrigation water must have low concentration of salts. A high concentration of dissolved salts affects the water intake of the plant. The plant may result in dehydration or wilting due to high osmotic pressure. As such, water with a high concentration of salt should not be used. However, the tolerable concentration of salts in water will also

depend upon the type of soil. The water with salts may however be tolerable or even useful for irrigation on some types of soils. For example, heavy clayey soil with a low permeability and plenty of soluble salts will not tolerate the water with a concentration of salts, but light sandy soil may tolerate such water [3, 5, 6].

Although many tree crops are sensitive to sodium, the major concern from high concentrations of sodium in soils and irrigation waters is the eventual deterioration of soil structure, resulting in decreased water infiltration and permeability. When calcium and/or magnesium are the predominant cations adsorbed on the soil exchange complex, the soil tends to have a granular structure that is easily tilled and readily permeable [7]. However, when the amount of absorbed sodium exceeds 10 to 15 % of the total cation exchange capacity (CEC), soil mineral particles tend to disperse and permeability decrease. Water of very low salt content can aggravate a sodium problem because it allows a maximal swelling and dispersion of soil minerals and organic matter, and also has a tremendous capacity to dissolve and remove calcium. The most common anions are bicarbonate, sulphate and chloride, while other solutes such as nitrate, carbonate and trace elements may also affect water quality in some instances. High nitrate levels in irrigation water are beneficial to crop production, but can potentially degrade water quality. Appreciable amounts of carbonate are present only at pH values above 8.5. Trace elements are not common in irrigation waters, but minute concentrations can severely limit production of certain crops [8, 9].

The purpose of the study is to examine some physico-chemical properties of the water samples taken from Nasarawa stream in the study area and hence its suitability as a major source of water for irrigation of vegetables and other crops cultivated along the course of the stream in the area.

2.0 MATERIALS AND METHOD

The study approach for this investigation consists of field survey, selection of sampling points for water sample collection, laboratory analysis and interpretation of results. Sampling points were located to the upstream and downstream sides of the stream with the Nasarawa bridge as a reference point. Six water samples were taken in duplicates with two to either side of the bridge at an interval of 100m in the month of March (dry season) during low streamflows. Grab samples were taken in plastic containers each of 1.5-litre capacity after being properly washed, cleaned and sterilized using sulphuric acid, and again rinsed with distilled water. At the point of collection, each bottle was half-filled with the water sample, shaken and poured away being later filled up and covered. The laboratory analyses conducted on the water samples were targeted at the following parameters: pH, electrical conductivity, carbonate, bicarbonate, sulphate, chloride, sodium, potassium, calcium, magnesium, boron, sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) Index. They were computed by using the following relationships:

The S.A.R. is defined by

$$S.A.R. = \frac{Na^{+}}{\sqrt{\left(Ca^{2+} + Mg^{2+}\right)/2}}$$

where all ion concentrations are expressed as equivalents per million [= (mg/l)/ atomic weight].

On the other hand, the RSC Index formula is given by

$$\left[RSC\,Index = [HCO_3/61 + CO_3/30] - [Ca/20 + Mg/12]\right]$$

The laboratory analyses of the parameters were carried out using methods specified in the Standard Methods for the Examination of Water and Wastewater [10].

3.0 RESULTS AND DISCUSSION

The results of the physico-chemical analysis of the water samples are presented in Table 1 below:

pH. The pH value of a solution is the negative logarithm of the concentration of hydrogen ions in moles per litre. From the result presented in Table 1, the pH values of water samples range from 6.8 to 7.7. When compared with FAO irrigation water quality guideline, the pH values are all within the permissible limit. However, if these values can be maintained and monitored, there will be no significant threat to water resources quality.

Electrical Conductivity. Conductivity is the measurement of the ability of a solution to conduct electric current. As this ability is dependent upon the presence of ions in solution, a conductivity measurement is an excellent indicator of the total dissolved solids in water. It is measured in mhos/cm, or micromhos/cm at 20 – 25°C. The presence of dissociated ions in water renders it conductive, although different salts have different conductivities for a given concentration. The values obtained ranged between 40 to 47 µmhos/cm which is far beyond the maximum allowable value of 3.0 µmhos/cm at all the six sampling points. Thus, the dissolved salt content of the water is excessive for use as irrigation water.

Table 1: Results of Physico-chemical analysis of water samples from Nasarawa stream compared with irrigation water guidelines for Agriculture

Site Code	pH	EC µmhos /cm	CO_3^{2-} mg/l	HCO_3^{2-} mg/l	SO_4^{2-} mg/l	Cl^- mg/l	Na^+ mg/l	K^+ mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	B mg/l	SAR	RSC Index
$S1_{ave}$	7.4	40	0	5.8	9	2.1	32	41	29	18	0.90	2.07	-2.85
$S2_{ave}$	7.7	43	0	8.7	11	1.5	33	48	22	19	0.73	2.38	-2.54
$S3_{ave}$	7.2	40	0	6.4	7	2.8	32	32	25	18	0.81	2.17	-2.65
$S4_{ave}$	7.5	41	0	7.1	8	2.9	34	43	22	18	0.91	1.62	-2.48
$S5_{ave}$	6.9	44	0	5.7	12	3.9	37	46	38	25	1.92	6.59	-3.89
$S6_{ave}$	6.8	47	0	6.3	15	4.4	36	44	35	23	1.76	6.69	-3.56
FAO*	6.0-8.5	0-3	0-6	0-610	0-1920	0-1065	0-920	0-2	0-800	0-120	0-2	>5.0 <2.9	<1.0

pH-Hydrogen ion concentration; EC-Electrical Conductivity; CO_3^- -Carbonate; HCO_3^- Bicarbonate; SO_4^{2-} -Sulphate; Cl^- Chloride; Na^+- Sodium; K^+ - Potassium; Ca^{2+} - Calcium; Mg^{2+}-Magnesium;B- Boron; SAR-Sodium Adsorption ratio; RSC-Residual Sodium Carbonate; FAO, (1994)-Irrigation and drainage maximum permissible limits of water. * *Sources: [8, 11]*

Carbonate and Bicarbonate. Apart from the atmospheric carbon dioxide in rain which dissolves more carbon dioxide as it enters soil to form carbonate and bicarbonate, the decay of organic matter also releases carbon dioxide for dissolution. Water charged with carbon dioxide dissolves carbon minerals, as it passes through soil and rocks, to give bicarbonates. Concentrations of carbonates and bicarbonates in water affect its acidity or alkalinity and hence corrosiveness of pipes and growth of plants [4, 11]. The values obtained from tests range from 5.8 to 8.7mg/l for Bicarbonates and zero value for Carbonates This shows that the guideline value for bicarbonates and carbonates in irrigation water has not been exceeded.

Sulphate. Sulphates may originate from sulphides of other metals introduced into the water. When sulphides are oxidized, they give rise to soluble sulphates which make the receiving water have low pH and corrosive. The values obtained from the samples range from 7 – 15 mg/l, while the irrigation water limit is 1920 mg/l, which shows that there is no excessive sulphate concentration in the stream water.

Chloride. Chloride salts, commonly sodium chloride, are highly soluble and free from chemical reactions with soil rock minerals, and so remain stable once they enter into solution. Abnormal concentrations may occur from municipal wastes, especially those containing coconut residue. The values obtained from samples range from 1.5 – 4.4 mg/l and are all within the maximum allowable range of 1065 mg/l for irrigation water.

Sodium. Sodium is the most abundant cation in the hydrosphere by virtue of its abundance in the ocean. It is derived in rivers and streams through weathering actions in the form of sodium carbonate which is readily soluble. Sodium ion occurring in soluble form in water takes part in exchange reaction that could increase sodium hazard in soil. The sodium ion level in the stream water ranges between 32 – 37 mg/l and is within the permissible range for irrigation water.

Potassium. Potassium salts are less abundant in water because of its tendency to be either absorbed or fixed in clays, and are more resistant to chemical weathering than sodium minerals. The maximum concentration recommended in irrigation water is 2.0 mg/l, and the values obtained from this investigation

range between 32 – 48mg/l. These values are grossly excessive at all the sampling points. The water is, therefore, not suitable for irrigation in its present form especially because it is injurious to plants and is capable of creating high osmotic pressure, dehydration and wilting in plants.

Calcium. Calcium is a major constituent of most igneous, metamorphic and sedimentary rocks. The carbonate and sulphates of calcium are soluble in most natural waters, and is therefore present almost everywhere in groundwater. Calcium carbonate dissolves continuously in the presence of water containing carbon dioxide in dissolved form, but may be precipitated again once the acid is used up. The guideline value for calcium in irrigation water is 800 mg/l, whereas the highest value encountered from samples is 37.0mg/l at sample point 5(S5), which shows that calcium ion content of the stream is within acceptance levels.

Magnesium. Magnesium is an important component of most rocks, and it occurs in the form of insoluble silicates, which become more soluble carbonates as they are weathered. In the presence of carbonic acids in water, magnesium carbonate is converted into soluble bicarbonate. In ordinary atmospheric conditions the solubility of magnesium carbonate in water, in the presence of carbon dioxide, is nearly ten times that of calcium carbonate. The maximum permissible limit for irrigation is 120mg/l, which is far greater than the values obtained from the six samples analyzed with the highest value of 25mg/l.

Boron. Boron, like other trace constituents, normally occurs in indeterminate quantities or traces generally not exceeding 1.0 mg/l. It may be ingested through plants when water with high concentration is used for irrigation. Ingestion of large amount of boron can affect the central nervous system as well as physiological effects on plants [2, 4]. The guideline value for boron in irrigation water is 2.0 mg/l, and the values of 1.92 and 1.76mg/l obtained at sample points S5 and S6 respectively call for concern because of the potential for boron ion contamination.

Sodium Adsorption Ratio (S.A.R.). Sodium adsorption ratio is generally a good indicator of sodium hazard in water. When exchangeable sodium occurs in irrigation water and soil at high concentrations, it causes eventual deterioration of soil structure and a resulting reduction in hydraulic conductivity. Generally, water with SAR<10 is low sodium water, 10-18 is medium, 18-26 is high, and SAR>26 is very high sodium water. However, for water with SAR>5, there is no restriction in use for irrigation. Water with SAR< 2.9 is a severe case and should not be used for irrigation [11]. From the results in Table 1, SAR values for samples S1, S2, S3 and S4 are below 2.9, indicating sodium hazard in the stream water.

Residual Sodium Carbonate (R.S.C.) Index. The residual sodium carbonate index of irrigation is used to determine the suitability of water for irrigation. When dissolved calcium and magnesium is high in water, clay soil swells or undergoes dispersion which drastically reduces its infiltration capacity [12]. The RSC index values computed for this study as presented in Table 1 showed that they ranged below the guideline value of 1.0, which ruled out the possibility of alkalinity hazard in the stream water.

CONCLUSION

The result of this investigation has shown that thirteen (13) parameters were tested from the water samples taken from Nasarawa stream to determine its suitability as a source of water for irrigation. Out of these, electrical conductivity and potassium ion concentrations of the water samples were above the irrigation guideline values at all the six sampling points, boron is close to guideline value at two points, while the SAR values exceeded the guideline value at four of the six sampling points. This result showed the need for the Nasarawa stream water to be subjected to some level of treatment especially during the dry season when the level of dilution by rain water will be absent, and the water will be required for irrigation.

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