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EVALUATION OF WATER FROM BOKRO STREAM FOR IRRIGATION AND ITS EFFECT ON SOIL

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ABSTRACT
This study focused on evaluating the water quality of the Bokro stream for its suitability for irrigation purposes. Among the water quality parameters examined were pH, total dissolved solids, conductivity, dissolved oxygen, hardness, major ions and concentration of some trace metals. The results revealed that most of the parameters examined were below the FAO limits for irrigation water. The results also indicated that nutrient concentrations (Sulphate, Nitrate-Nitrogen and Phosphate-Phosphorus) from the stream were far below the usual ranges in irrigation water. Based on values calculated for Sodium Adsorption Ratio and electrical conductivity, the water source could be described as possessing low salinity hazard and therefore no permeability problems are expected for the soils. In addition, human activities along the banks of the stream and inflow of untreated domestic sewage from communities in the catchment area of the stream were found to have great impact on the quality of water from the stream. Water from the stream will have no adverse effect on the soil when it is use for irrigation.

Keywords: *Bokro stream, Irrigation, Salinity hazard, Self purification, Waste water*

INTRODUCTION

The suitability of water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. Various soil and cropping problems develop as the total salt content increases (Ayers and Westcot, 1994). Water quality or suitability for use in irrigation is judged on the potential severity of problems that can be expected to develop during long-term use. The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of the water user. As a result, the suitability of water for use in irrigation is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as basis to evaluate water quality are those related to salinity, water infiltration rate, phytotoxicity and a group of other miscellaneous problems such as high nitrogen concentrations in the water which supplies nitrogen to the crop and may cause excessive vegetative growth, lodging, and delayed crop maturity (Ayers and Westcot, 1994).

The physical and mechanical properties of the soil, such as dispersion of particles, stability of aggregates, soil structure and permeability, are very sensitive to the type of exchangeable ions present in irrigation water (Ayers and Westcot, 1994). Another aspect of agricultural concern is the effect of dissolved solids (TDS) in irrigation water on plant growth. Dissolved salts increase the osmotic potential of soil water; this will lead to increase in the amount of energy which plants use to take up water from the soil. As a result, respiration is increased and the growth and yield of most plants decline progressively as osmotic pressure increases. In addition ions which are beneficial at relatively low concentrations may become toxic to plants at high concentration, either through direct interference with metabolic processes or through indirect effects on other nutrients, which might be rendered inaccessible (Morishita, 1988).

In urban and peri-urban areas of most developing countries, the use of wastewater for irrigation is a common practice. Even in areas where other water sources exist, small farmers often prefer wastewater because its high nutrient content reduces or even eliminates the need for expensive chemical fertilizers. Wastewater is also used in agriculture because of the competition for freshwater by other water users (domestic and industrial). However, the use of wastewater in its untreated form could have negative impact on public health and the environment.

The upsurge of urban populations has far outpaced urban sanitation infrastructure. About 2.4 billion people in the developing world lack access to basic sanitation and about two-thirds of the population in developing world have no hygienic means of disposing of excreta with even a greater number lacking adequate means of disposing of wastewater**.** In Ghana about 85% of wastewater generated from urban centers ends up in streams and drainages in their untreated form. This water is used by small-holder farmers to irrigate their crops (Drechsel *et al.*, 2006). It is estimated that about 3,300 ha of land is irrigated with wastewater mainly in the dry seasons. This is an equivalent of about 60% of the total area currently under formal irrigation schemes in the country (Keraita, 2002).

In this study, water quality in the Bokro stream which is used for irrigation of vegetables in Kumasi was assessed. The stream serves as sink for industrial and domestic wastes generated in townships such as Kentinkrono, Boadi and Ayeduasi through which the stream passes. Human and other developmental activities are sited very closely to the banks of this river. In Kentinkrono and Boadi, most of the drains and gutters in the entire township are channeled into the stream. Water from this stream is used to irrigate vegetable farms along its banks during the dry season. The aim was to measure some physico-chemical parameters of the Bokro stream and to ascertain whether water from this stream is suitable for irrigation.

MATERIALS AND METHODS

Sampling procedure

Six sampling sites were selected at irrigated areas along the stream. Three were at Kentinkrono upstream and the other three at Boadi downstream of the Bokro stream. Water samples were collected from these sites during the dry seasons of 2007 and 2008. Water samples were collected into 1L plastic bottles. The bottles had previously been cleaned by washing with detergent, thoroughly rinsed with tap water, soaked in 10% HNO_3 solution overnight and finally rinsed with deionised water and dried in an oven. At the sampling sites, sample bottles were rinsed three times with stream water before filled. The samples were kept in ice box and transported to the laboratory immediately and stored in the refrigerator at about 4^oC prior to analysis. Electrical conductivity (EC), pH and turbidity were measured while collecting the samples using Hanna portable conductivity meter [model: HI 8733], Fisherbrand Hydrus 100 pH meter equipped with glass electrode and Hanna Instruments LP2000 Turbidity meter respectively. Procedures outlined in the Standard Methods for the Examination of Water and Wastewater were followed for the analyses of all the chemical parameters (APHA, 1998).

Sample digestion

Digestion of the samples was done using the open-beaker procedure (DWAF, 1992; Fatoki and Mathabatha, 2001). Concentrated nitric acid (5 ml) was added to 50 ml of sample of water in a 100 ml beaker. This was heated on a hot plate to boil until its volume reduced to 20 ml. Another 5 ml of concentrated nitric acid was added and then heated for another 10 min and allowed to cool. About 5 ml of nitric acid was used to rinse the sides of the beaker; the solution was quantitatively transferred into a 50 ml volumetric flask and made up to the mark with distilled water. A blank solution was similarly prepared. Heavy metal analysis was done using Perkin Elmer (5100) atomic absorption spectrophotometer (AAS) with deuterium background corrector. Determinations were carried out in air/acetylene flame using hollow cathode lamps of each metal as radiation source. Prior to analysis the AAS was calibrated according to the manufacturer's manual. Calibration curves were established using internal and external standards. Recovery value were nearly quantitative (>95%) for all the metals. Limits of detection of the analysed metals were determined as thrice standard deviation of the lowest detectable concentrations by the AAS from the mean of three replicate analyses. Procedural blanks and duplicates were run alongside as part of the quality assurance program.

RESULTS AND DISCUSSION

The accepted pH for irrigation water range from 6.5 to 8.4 (Ayers and Westcot, 1994). Results recorded mean values of pH as 6.88±0.02 and 6.30±0.30 for USW and DSW respectively. Since these values were within the standard range for irrigation, the water source could be termed as good for irrigation purposes and may not give problems either in system corrosion or causing calcium and magnesium to

Table 1: Average concentration of physico-chemical parameters measured in the water samples from the Bokro stream (n = 24)

Parameters	Average Values USW	DSW	Accepted values for irrigation water (FAO, 1985)
Temperature (^oC)	27.0±0.14	26.8±0.72	-
pH	6.88±0.02	6.30±0.30	6.0 – 8.5
TDS (mg/l)	102.01±2.92	55.11±2.0	0 – 2,000
EC (dS/m)	0.164±0.01	0.09±0.003	0 – 3
Turbidity (NTU)	14.23±0.12	34.01±2.0	-
SO_4^{2-} (mg/l)	1.0±0.20	2.3±0.20	0 – 2,000
Br^- (mg/l)	0.59±0.07	0.22±0.034	-
Cl^- (mg/l))	0.32±0.05	0.12±0.02	0 – 1,100
Ca^{2+} (mg/l)	4.40±0.17	6.11±0.30	0 – 800
Mg^{2+} (mg/l)	2.65 ±0.25	2.01±0.86	0 -120
Na^+ (mg/l)	10.01±0.33	13.12±2.81	0 – 900
NH_4^+-N (mg/l)	0.01±0.02	0.04±0.01	0 – 5
NO_3^--N (mg/l)	0.006±0.01	0.004±0.01	0 – 10
PO_4^{3-} (mg/l)	0.08±0.03	0.04±0.02	0 – 2

*USW = upstream water sample
*DSW = downstream water sample

form insoluble minerals leaving sodium as the dominant ion in solution.

Total salt concentration (total dissolved solids) is one of the most important agricultural water quality parameters. This is because the salinity of the soil water is related to, and often determined by, the TDS of the irrigation water (Kandiah, 1990). Dissolved salts in irrigated water can reduce water availability to the crop such that crop yield and rate of plant growth are affected. Yield reductions occur when the salts accumulate in the root zone to that the crop is no longer able to extract sufficient water from the salty soil solution. Equally, the rate of accumulation of salts in the soil, or soil salinization, is also directly affected by the salinity of the irrigation water. According to guidelines for evaluation of water quality for irrigation (Hergert and Knudsen, 1997), water with EC values less than 0.7 dS/m and TDS values less than 450 mg/l has low salinity level. From Table 1, the mean values of EC and TDS obtained for USW and DSW samples were below these recommended values. The irrigation water can therefore be classified as having low salinity hazards and therefore may not pose any injury to the crops.

Sodium is a unique cation because of its effect on soil. It can causes adverse physico-chemical changes in soil when present in exchangeable form, particularly to soil structure. It has the ability to disperse soil when present above a certain threshold value, relative to the concentration of calcium and magnesium. Dispersion of soils results in reduced infiltration rates of water and air into the soil. Irrigation water could be a source of excess sodium in the soil solution and hence it should be evaluated for this hazard (Hergert and Knudsen, 1997).

The most reliable index of sodium hazard of irrigation water is Sodium Absorption Ratio (SAR). The (SAR) is defined by the formula (Richards, 1954):

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

where: Na represent sodium ion concentration; Ca represent calcium ion concentration and Mg represent magnesium ion concentration. The ionic concentrations are expressed in meq/l.

Sodium, absorption ratio (SAR) value between 1-3 and EC less than 0.7 dS/m indicates that the water has no potential to affect infiltration rate of water into the soil (Davidson *et al.*, 2000). Mean SAR calculated for the USW and DSW samples were 0.9 and 1.4 respectively. With SAR values less than 4, no permeability problems are expected for soils irrigated with water from this stream and therefore there is no degree of restriction on use of water from this stream in this connection (Davidson *et al.*, 2000: Hergert and Knudsen, 1997).

Sulphate ion is a major contributor to salinity in many irrigation waters. However, toxicity is rarely a problem, except at very high concentrations where high sulphate may interfere with uptake of other nutrients. Sulphate in irrigation water also has fertility benefits. The values obtained (1.0±0.20 mg/l and 2.3±0.20 mg/l) for samples taken from upstream and downstream respectively fall within the United State Environmental Protection Agency (US EPA) permissible range of 0-2000 mg/l (EPA, 2004). Results for NO_3^- and NH_4^+ were extremely low and may not pose any significant effect on the usability of the water from this stream for irrigation purposes.

Irrigation water that contains certain ions (Boron, sodium and chloride) at concentrations above threshold values can cause plant toxicity problems. The degree of damage depends on the crop, its stage of growth, the concentration of the toxic ion, climate and soil conditions (James *et al.*, 1982).

The most common phytotoxic ions that may be present in municipal sewage and untreated effluents are B^{3+}, Cl^- and Na^+. The mean concentrations of Cl^- in the Bokro stream were 0.32 ±0.05 mg/l and 0.12±0.02 mg/l, for upstream and downstream respectively. This will not cause toxicity to sensitive crops. Na^+ concentrations were 10.02±0.33 and 13.0±2.81 for upstream and downstream, respectively. These levels are above the recommended values that can cause toxicity problems to sensitive crops (Hergert and Knudsen, 1997).

Table 2: Average concentration of some trace metals measured in the Bokro stream (n=24)

Parameters	Mean concentration (mg/l)		FAO recommended val. (mg/l)
	USW	DSW	
Cu	0.03±0.01	0.20±0.17	0.2
Fe	6.92±0.03	13.9±0.17	5.0
Mn	0.38±0.03	0.60±0.08	0.2
Zn	<0.01	0.02±0.012	2.0
Pb	<0.01	0.01	0.01
Co	0.03±0.01	0.05±0.02	0.05
Cd	<0.01	0.02±0.01	0.01
Ni	0.05±0.02	0.10±0.01	0.2

Municipal wastewater may contain variety of potentially toxic trace elements such as Cd, Cr, Cu Pb and Hg. Even if toxic materials are not present in concentrations likely to affect humans, they might well be at phytotoxic levels, which would limit their agricultural use (Asano *et al.*, 1985). Table 2 reports the mean concentrations and standard deviations of trace metals in upstream and downstream of river Bokro in Kumasi. Trace metals that were analyzed in the samples were Fe, Cu, Mg, Zn Pb Co, Cd and Ni. Of all the metals analysed, Fe recorded the highest concentration of 6.92 mg/l and 13.90 mg/l for USW and DSW, respectively. Concentrations obtained for Fe in both samples were higher than the recommended maximum concentration quoted by FAO as 5.0 mg/l. This could cause soil acidification and loss of availability of essential phosphorus and molybdenum. However, this water could still be good for irrigation if soils are well aerated (Abdel-Magid, 1995). Concentrations of Lead were less than 0.01 mg/l which is the recommended maximum concentration of the elements in irrigation water quoted by FAO. Hence the water source considered good for irrigation purposes because it is not likely to pose any inhibition effects on plants growth and yield. Nickel plays an important role as an essential element in all living systems. In this work the concentration of nickel was found ranging from an average of 0.05 ±0.02 mg/l to 0.10±0.01 mg/l in the upstream and downstream samples respectively. Reduced toxicity to sensitive crops is expected since concentrations were below the recommended value of 0.2 mg/l set by the FAO for irrigation water (FAO, 1985).

Cadmium strongly adsorbs to organic matter in soils. Soils that are acidified enhance the cadmium uptake by plants. This is a potential danger to animals that depend on plant for survival. Earthworms and other essential soil microorganisms are extremely susceptible to cadmium poisoning. They die at very low concentrations and this has consequences on the soil structure. Cadmium is biopersistent and once absorbed by an organism, remains resident for many years. Cadmium concentration in this study ranged from <0.01 in upstream to 0.02±0.01 mg/l in downstream, respectively. Cadmium concentrations were generally low, close to those reported for unpolluted water. Moreover, the metal displayed quite homogeneous distributions across the sampling area and therefore had lower standard deviations, thus suggesting a major natural (i.e. indigenous lithologic) source. Cadmium was within permissible limit in all the samples. Manganese recorded mean concentrations of 0.38±0.03 mg/l for sample

USW and 0.60±0.08 mg/l for sample DSW as reported in Table 2. The observed values exceed the maximum limit for irrigation water of 0.2 mg/l set by FAO. Since concentration of Manganese above this limit is toxic to a number of crops, the expectation would be that continuous use of water from this stream can cause phytotoxicity to sensitive crops (Al-Subu *et al*, 2003: Ayers and Westcot, 1994).

A mean Cobalt Concentration of 0.05±0.2 mg/l was observed in downstream sample and the upstream sample also recorded a mean value o f 0.03±0.01 mg/l. All the samples contain lower amount of cobalt except in few samples from the DSW where it was below the acceptance limit of cobalt which is 0.05 mg/l permitted by the FAO. Continuous use of water from DWS for irrigation can cause phytotoxicity to sensitive crops such as tomatoes and carrot. Copper and zinc are essential nutrients, but at high doses they have been shown to cause phytotoxicity to sensitive crops (Cobbett and Goldsbrough, 2002). The mean levels of zinc were below 0.01 mg/l and 0.02 mg/l in USW and DSW samples, respectively. These values were below the acceptance limit of zinc which is 2.0 mg/l permitted by the FAO. Therefore, Zn concentration is adequate if the water is used for only irrigation purposes. Copper had the minimum mean concentration value of 0.03±0.01 mg/l in the upstream sample and a maximum of 0.20±0.17 mg/l in the downstream samples.

Levels of contaminants on upstream samples were compared with those recorded in samples from downstream using t-test. Most of the parameters increased in concentration from upstream to downstream. This shows that although the stream has self-purification capacity, the capacity is strained by persistent pollution overloads. The pollution plight of the stream is because it is flanked by expanding human settlements; institutional and socio-economic activities are also scattered uncontrollably within the communities along its banks.

CONCLUSION

The results indicated that most of the physico-chemical parameters analysed were within the FAO limits for irrigation water and, therefore, water from this stream may be suitable for irrigation purposes. SAR value indicates that the water has no potential to affect infiltration rate of water into the soil and no permeability problems are expected for soils irrigated with water from this stream. Self-purification ability of the stream revealed that, although the stream has an appreciable self-purification capacity, the capacity is stressed by persistent pollution overloads along the cause of water flow by expanding human activities.

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