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Effects of water pollution on soil physical and hydrological properties of a valley bottom at the University of Ibadan, Ibadan, Oyo State, Nigeria

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ABSTRACT:

Unpredictable rainfall patterns and climate change has lead to high competition among different water-use sectors vis-à-vis its decreased allocation to irrigation. The use of valley bottoms for agricultural production is also prone to the pollution of soil and waters in these valleys form various sources. Therefore, the effects of water pollution on soil physical and hydrological properties of a valley bottom were evaluated during 2010 dry season at the Agricultural students' Practical Year Training Farm within the University of Ibadan, Ibadan, Nigeria. Geo-referenced ground and surface water samples and soil samples were collected from the field and analyzed for their physical and chemical properties. Soil samples were also collected from the river sediments and analyzed for their relative distribution of Sand, Silt and Clay fractions. All soil, water and vegetable plants collected from the field were also analyzed for their metal contents. Collected data were compared with World Health Organization (WHO) and Federal Environmental Protection Agency (FEPA) standards to assess the level of pollution in the valley bottom

Pollution to surface water comes from drainage and sewage channels alongside remnants from adjacent recently constructed roads. The physical and chemical properties of the surface water shows a high concentration of sodium ion, and Sodium Adsorption Ratio (SAR) with values ranging from 29mg/l to 3400 mg/l and SAR values of 5.2 meq/l to 439.8meq/l respectively. However, ground water samples have a lower sodium ion concentration of 38.2mg/l to 605mg/l and a mean SAR value of 6.9meq/l. A Biological Oxygen Demand (BOD) value range of 105mg/l to 279.2mg/l was recorded alongside with TSS of 357.6mg/l to 978.5mg/l. The turbidity, total dissolved solids trend is in the same direction with BOD and Total Suspended Solids (TSS). The soil expressed a high total porosity that shows no correlation with volumetric moisture content. Recommendations for the prevention of pollution of surface water to ensure sustainable agricultural land resources management of valley bottom were suggested.

***Key words**: Water pollution, Valley bottom, Soil physical and Hydrological properties*

Introduction

The cultivation of valley bottom soils has been one of the means of coping with the water crisis situation arising from unpredictable rainfall patterns and climate change which has impacted negatively on Nigerian agriculture and regional food security. The lower elevation of these valley bottom soils also make them prone to pollution from drainage/sewage channels, alongside erosion from roads/bridges constructed on adjacent plains which can render the valleys unproductive through salts and other pollutants build-ups.

Water pollution is a major problem in the global context. It has been suggested as the leading worldwide cause of deaths and diseases (Pink, 2006). West (2006) reported that water pollution accounts for the deaths of more than 14,000 people daily. In addition to the acute problems of water pollution in developing countries, industrialized countries also continue to struggle with pollution problems. In a recent national report on water quality in the United States, 45 percent of assessed stream kilometres, 47 percent of assessed lake hectartes, and 32 percent of assessed bay and estuarine square kilometres were classified as polluted (EPA, 2008). An assessment of the water quality of Ogun River in south western Nigeria has been found to contain a lot of contaminants traced to the industrial effluents from Lagos and Abeokuta (Jaji *et al*., 2007). Other forms of pollutants from industrial and domestic sources reported in this study include a high level of turbidity, oil and grease, faecal coliform and iron; while the valleys that convey water are also prone to pollution from human activities such as road/bridge constructions which are major yardsticks for good governance in Nigeria.

However, with the recent trends of unpredictable rainfall patterns and climate change, these polluted water bodies and valleys (*Fadama*) are often used in augmenting inland agricultural production. Polluted irrigation water may completely render agricultural soils unproductive through salt built-up in the soil. It is as a result of such accumulation that extensive area in the arid and semi arid region of Nigeria have gone out of cultivation (Zata *et al.*, 2008). Hence, the assessment of water quality is thus an important priority in agricultural production.

The Federal Government of Nigeria established the Federal Environmental Protection Agency (FEPA) by Decree 58 of 30th December, 1988. The FEPA has statutory responsibility of ensuring the protection of the environment. The World Health Organization (WHO), (1993) defines water quality as its fitness for beneficial uses, which is provided for drinking by man and animals, the support of marine life, irrigation, industry, recreation and aesthetic purposes.

This study focused on the assessment of the effects of water pollution on the soil physical and hydrological properties of a valley bottom within University of Ibadan with the aim of proffering sustainable management practices. The objectives are to investigate the quality of water being used in irrigating dry season vegetable and the effects of water pollution on soil physical and hydrological properties.

MATERIALS AND METHODS

Site Description

The study was conducted at the valley bottom, University of Ibadan Students' Practical Year Training Farm, Faculty of Agriculture and Forestry. It lies approximately between longitude N07°26'850" and N07^{0} 27'087" and latitude E003^{0}53'899" to 003^{0}53'552 with elevation ranging from 205m-227m above sea level in the sub humid tropics (Fig. 1). The soil of the area was derived from sedimentary rocks of south Western Nigeria and this has been classified as an Alfisol under subgroup Oxic Paleustalf according to the USDA classification (Soil Survey Staff, 2006).

The climate of the area is divided into wet season (April-October) and dry season (November- March). A reconnaissance visit was undertaken on 6th of January, 2009 (during the dry season) to the area for the purpose of assessing the use and the level of contamination of the valley bottom. The valley bottom has been under continuous use for over two decades. It gets its main water supply from drainage water, sewage water and ground water. The site is also highly exposed to different sources of pollution due to its relatively lower elevation.

The valley changes its shape from V shape at the stream head to concave gentling rolling to flat bottom at the downstream. The valley is seasonally wet and under the influence of high ground water table, poor drainage and almost inaccessible during the rainy season. In the dry season the water are found in pockets, which marginally flow into each other. Apart from the surface water, it also contains some few hand dug wells that serves as alternative source of water. Because of its inaccessibility during the raining season, herbs and shrubs with few scanty perennials are found in the study area. In the dry season, it is cultivated by students of the Faculty of Agriculture and Forestry as practical training site for crop production. The crops mostly cultivated are vegetables such as *Amaranthus spp, Celosia spp*, and *Abelmoschus esculentus*.

Sampling

Nine water samples were taken from surface water while three ground water samples were taken from the wells. Each water sample was collected in plastic container and analyzed immediately. Twelve bulk soil samples were collected from 0-15cm soil depth to describe the soil physical properties of the areas. The soil sampling points were also geo-referenced with a hand held Geographic Positioning System (GPS). Twelve geo-referenced soil samples were also collected from the stream flow to analyze for the heavy metals and the relative distribution of sand, clay and silt (Fig. 1).

Soil and Water Analysis

Physical properties determined include particle size distribution, bulk density and volumetric moisture content. Particle size distribution of the soil samples (< 2mm) was analyzed using hydrometer method (Gee and Or, 2002). Core samples of 269 cm^3 volume, 7 cm diameter were taken from the depth of 0-15 cm to determine bulk density by core method (Grossman and Reinsch, 2002). Bulk density was estimated by dividing the oven dry mass of the soil at 105^0C by the volume of the soil as:

$$\rho b = \frac{M_s}{V_b}$$

Where M_s is oven dry mass of the soil and V_b is the volume of soil in the core.

Soil moisture at the time of sampling was determined gravimetrically (Lowery *et al.*, 1996) and the values obtained were multiplied by their respective bulk densities to obtain volumetric soil moisture content (Ɵ) (Hillel, 2003).

The appearance of the water was accessed based visual assessment and characterized into either clear or not clear. The water samples were analyzed for the following parameters as described by Udo (1986). Water sample pH was determined using the glass electrode pH meter in 1:2 soil:water suspension for soil and directly in water samples, Temperature; using the mercury in glass thermometer; Total Suspended Solids (TSS) determined by cycles of oven drying, cooling, desiccating and weighing method and Total Dissolved Solids (TDS) by weighing method. Turbidity, Biological oxygen demand (BOD) and Dissolved oxygen (DO) were determined by the Winkler method (American Public Health Association (APHA), 1998); Chloride by titration with $AgNO_{3;}$ Sulphate by turbidimetric method, Sodium concentration determined by flame photometry method, Carbonate and Bicarbonate by titration method. Calcium, magnesium, Iron, lead, cadmium, copper and cobalt were determined in water samples using the flame atomic absorption spectrophotometer while total hardness was determined by the EDTA titration method (Udo, 1986). Sodium Absorption Ratio was determined as described by FAO (1985). The values obtained were compared with the drinking and irrigation water quality standards of FAO (1985), FEPA (1991), WHO (1993), and SON (2007). They were also subjected to statistical technique of dispersion and central tendencies while parameters that were above the FAO irrigation standard were tested for significance using t-test. The variability is measured for each parameter and is indicated by percent Coefficient of Variability.

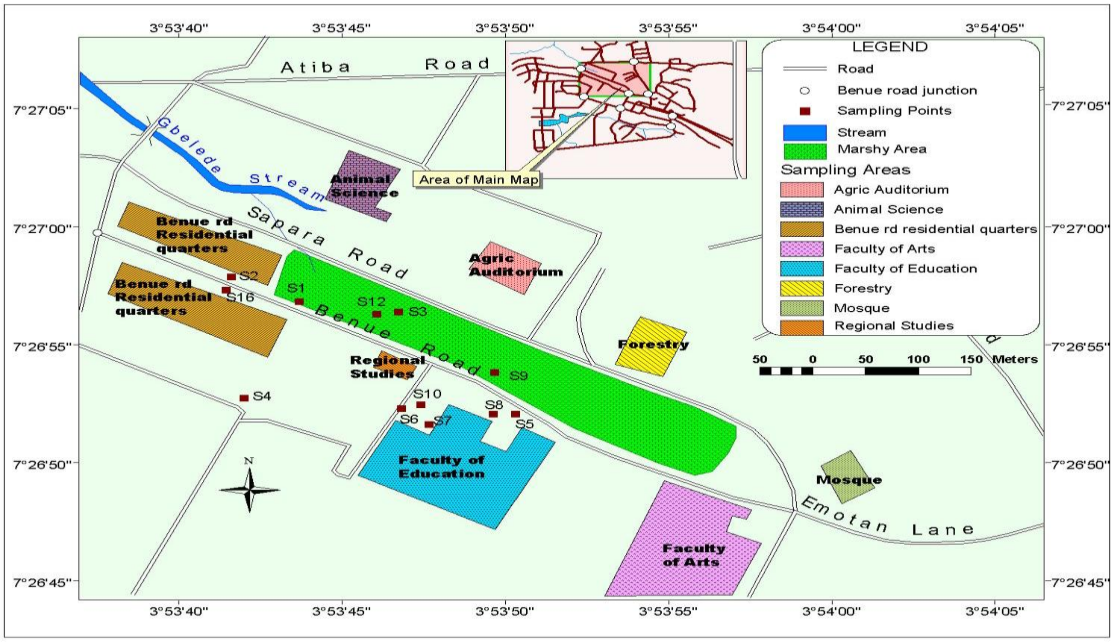

Fig. 1: Map of University of Ibadan Showing Study Area and Sampling Points

RESULTS AND DISCUSSION

Physical properties of water: In surface water, most parameters observed are above the WHO, FEPA and SON Standards for drinking water (Table 1). However in the ground water, most of the observed physical parameters are within permissible limits (Table 2). The unacceptable Appearance, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and Turbidity of surface water might be due to high bitumen/asphalt pollution from adjacent recently constructed roads and parking lots. This pollution may have encouraged the growth of phytoplankton and algae as described by EPA (2004). Treatment methods that may likely ameliorate these are: coagulation, biological clarification, aerobic oxidation, anaerobic oxidation, autolysis and nitration as recommended by Eddy and Udoh (2006). Biological Oxygen Demand (BOD) increases with Total Suspended Solids (Fig 2). Large quantity of Suspended solids encourages the growth of microorganisms which decomposes them. The quantity of oxygen used by these organisms is called Biological Oxygen Demand (BOD) (Schueler, 2000). Most of the surface water samples have high BOD which is directly related to the quantity of suspended solids. This may lead to low dissolved oxygen (DO) which might reduce the survival of fish and other aquatic organisms.

Chemical properties of water*:* Among the cations, sodium is the most abundant element. It varies from 29 to 3400 mg/l in the surface water with mean of 800.8mg/l and 605 to 38.2mg/l in the ground water with a mean concentration of 321.6mg/l (Tables 3 and 4). Some surface water samples showed high value of Na (over 3000mg/l) (Fig. 3). This could be derived from drainage/sewage water from hostels which habours thousands of students on campus, which is channeled directly into the surface water. The open drainage water from the university Junior Staff quarters at Abadina area is also drained into this valley bottom and used for irrigating vegetables during dry season and must have also contributed to the high surface water Na values observed. The iron content of the water samples ranged from 0.24 – 1.99 mg/l (mean = 0.82mg/l) and 0.13-1.27mg/l (mean = 0.42mg/l) in the surface water and ground water respectively. Therefore the water samples were polluted with respect to iron since their iron content is above the critical level of 0.3mg/l (SON, 2007). The process of iron coagulation is recommended to ameliorate the possible pollution effects of iron in domestic water. The absence of heavy metals (Lead, Chromium, Cobalt and Cupper) in analyzed water samples implies that there is no heavy metal pollution in the water bodies. In terms of SAR, the quality of water was assessed for irrigation by comparing with FAO (1985) irrigation water quality standards. The surface and ground water shows mean SAR values of 26.28meq/l and 6.87meq/l respectively. SAR in surface water is greater than the recommended value of 9meq/l (FAO, 1985) while in ground water SAR ranged from 5.16meq/l to 6.87meq/l; below 9.0meq/l critical level in irrigation water (FAO, 1985). Therefore, surface water may not be suitable for irrigation. Van de Graaff and Patterson (2001) reported that high sodicity causes excessive swelling of clay mineral which weakens the aggregates in the soil, causing structural collapse and closing-off of soil pores. Consequently, water and air movement through sodic soils are severely restricted. The effect of highly sodic water on plant will lead to extensive leaf burn, defoliation and loss of yield (Savva *et al.*, 1981). In the ground water, SAR is still within the permissive limit for irrigation water (Table 1).

Table 1: Physical Parameters of Ground Water and Standards

Parameters	**Minimum**	**Maximum**	**Mean**	**Coefficient of variability (%)**	**FAO Irrigation**	**WHO Drinking**	**FEPA drinking**	**NISS (SON) Drink**
Appearance	Clear	Clear	Clear	Nil	Nil	Clear	Clear	Clear
Temperature (^{0}C)	28	29	28.33	2.04	Nil	27-28	<40	Ambient
Turbidity(mg/l)	1.10	1.60	1.33	18.87	Nil	5	5	5
TSS (mg/l)	165.30	201.30	188.10	10.55	Nil	Nil	20	Nil
TDS(mg/l)	142.50	178.40	163.10	11.37	2000	500	500	Nil
BOD(mg/l)	4.60	6.20	5.46	14.79	Nil	1-2	4	Nil
DO(mg/l)	9.48	10.24	9.93	4.14	Nil	Nil	Nil	Nil
TOTAL HARDNESS (mg/l)	37.98	41.45	34.6	4.78	Nil	500	50	150
Sodium Adsorption Ratio (meq/l)	5.16	7.16	6.87	23.42	9	Nil	Nil	Nil

Sources: FAO 1985: FEPA, 1991: WHO, 1993: SON, 2007

Table 1: Physical Parameters of Surface Water and Standards

Parameters	Minimum	Maximum	Mean	Coefficient of variability (%)	FAO Irrigation	WHO Drinking	FEPA drinking	NISS (SON) Drink
Appearance	Cloudy	Cloudy	Cloudy	Nil	Nil	Clear	Clear	Clear
Temperature (^{0}C)	21	29	27.67	9.39	Nil	27-28	<40	Ambient
Turbidity(mg/l)	2.20	44.80	17.68	86.39	Nil	5	5	5
TSS (mg/l)	357.60	978.50	675.9	36.30	Nil	Nil	20	Nil
TDS(mg/l)	266.70	438.60	36.67	18.34	2000	500	500	Nil
BOD(mg/l)	105.20	279.20	185.68	35.80	Nil	1-2	4	Nil
DO(mg/l)	3.44	7.64	5.82	24.83	Nil	Nil	Nil	Nil
Total Hardness (mg/l)	9.55	43.94	29.89	46.36	Nil	500	50	150
Sodium Adsorption Ratio (meq/L)	5.24	439.84	26.28	252.60	9	Nil	Nil	Nil

Sources: FAO 1985: FEPA, 1991: WHO, 1993: SON, 2007

TABLE 3: Chemical Properties of Ground Water and Standards

Chemical Parameters	Minimum	Maximum	Mean	Coefficient of variability (%)	FAO Irrigation	WHO drinking	FEPA Drinking	NISS (SON) Drinking
pH	6.6	6.9	6.7	2.6	6.0-8.5	6.5-8.5	6-9	6.5-8.5
Sodium(mg/l)	38.2	605	321.6	158	920	200	Nil	200
Chloride(mg/l)	28.40	63.90	45.56	39.02	1065	250	0.3	250
Calcium(mg/l)	14.30	23.90	17.87	29.4	400	1.0	Nil	100
Magnesium(mg/l)	81.10	95.20	88.23	8.00	60	0.01	Nil	0.2
Bicarbonate(mg/l)	42.7	61	59.5	18.20	610	Nil	Nil	Nil
Sulphate(mg/l)	41.15	51.16	48.01	17.18	960	400	200	100
Iron(mg/l)	0.13	0.97	0.42	111.93	Nil	0.03	200	0.3
Carbonate(mg/l)	0.00	0.00	0.00	0.00	30	Nil	Nil	Nil
Acidity(mg/l)	5.40	10.60	8.06	32.26	Nil	Nil	Nil	Nil
Alkanity(mg/l)	1..20	1.60	1.37	15.23	Nil	500	50	Nil
Potassium(mg/l)	1.06	7.84	3.94	88.91	78	200	Nil	Nil

Sources: FAO 1985: FEPA, 1991: WHO, 1993: SON, 2007

Soil physical properties**:** Bulk density varies from 0.85-1.61Mg/m^3 with an average of 1.17Mg/m^3 (Table 5). The soil is fine textured with very high organic matter which agrees with the findings of Ogban and Babalola (2003). Volumetric moisture ranges from 6.79-54.85 m^3/m^3.Total porosity ranges from 67.9-39.2%. The total porosity has a perfect negative correlation with the bulk density with a correlation co-efficient r= -1(Fig 4). The implication of this suggests that the lower the bulk density, the higher the total porosity as is expected for normal soil. From Fig 5, Volumetric moisture content shows no correlation with total porosity, with correlation coefficient r= 0.17. In normal soil, a perfect positive correlation is expected between these parameters (Hilel, 2003).

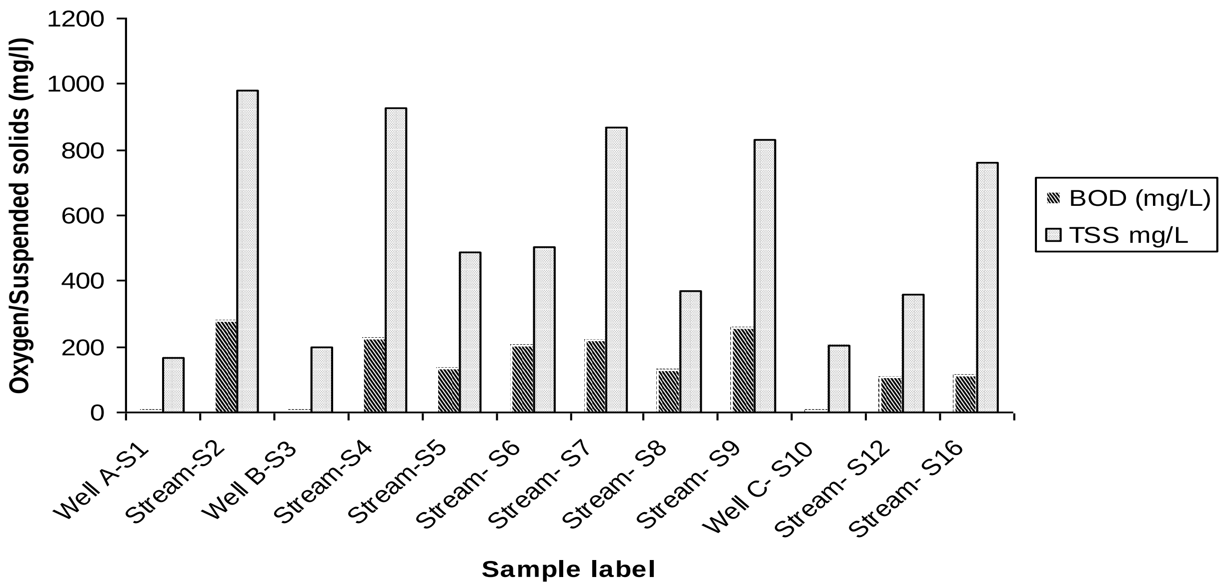

Fig. 2: Relationship between Biological Oxygen Demand and Total Suspended Solids

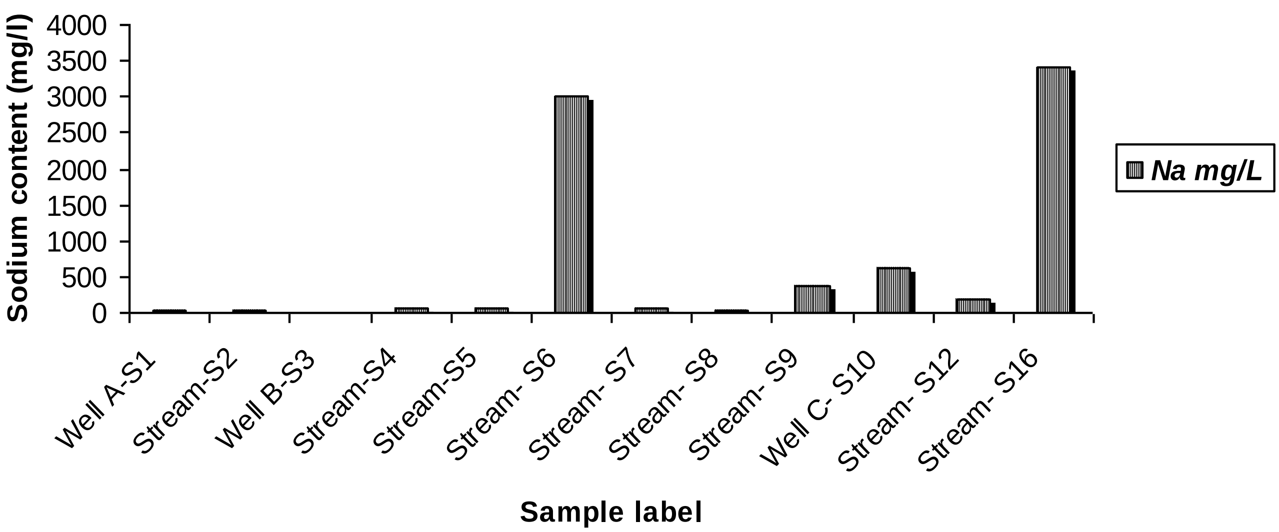

Fig.3. Sodium concentration in water samples

TABLE 4: Chemical Properties of Surface Water and Standards

Chemical Parameters	Minimum	Maximum	Mean	Coefficient of variability (%)	FAO Irrigation	WHO drinking	FEPA Drinking	NISS (SON) Drinking
pH	6.4	7.5	6.9	4.9	6.0-8.5	6.5-8.5	6-9	6.5-8.5
Sodium(mg/l)	29.00	3400.00	800.8	171.46	920	200	Nil	200
Chloride(mg/l)	35.50	60.35	48.91	17.03	1065	250	0.3	250
Calcium(mg/l)	13.40	33.40	23.40	28.83	400	1.0	Nil	100
Magnesium(mg/l)	10.26	94.50	58.86	64.28	60	0.01	Nil	0.2
Bicarbonate(mg/l)	24.00	103.70	69.09	33.76	610	Nil	Nil	Nil
Sulphate(mg/l)	3.43	91.45	33.15	88.40	960	400	200	100
Iron(mg/l)	0.24	1.99	0.82	75.43	Nil	0.03	200	0.3
Carbonate(mg/l)	0.00	9.91	9..91	Nil	30	Nil	Nil	Nil
Acidity(mg/l)	1.00	18.20	10.33	62.45	Nil	Nil	Nil	Nil
Alkalinity(mg/l)	0.80	1.90	1.32	26.41	Nil	500	50	Nil
Potassium(mg/l)	4.17	9.05	7.06	26.93	78	200	Nil	Nil

Sources: FAO 1985: FEPA, 1991: WHO, 1993: SON, 2007

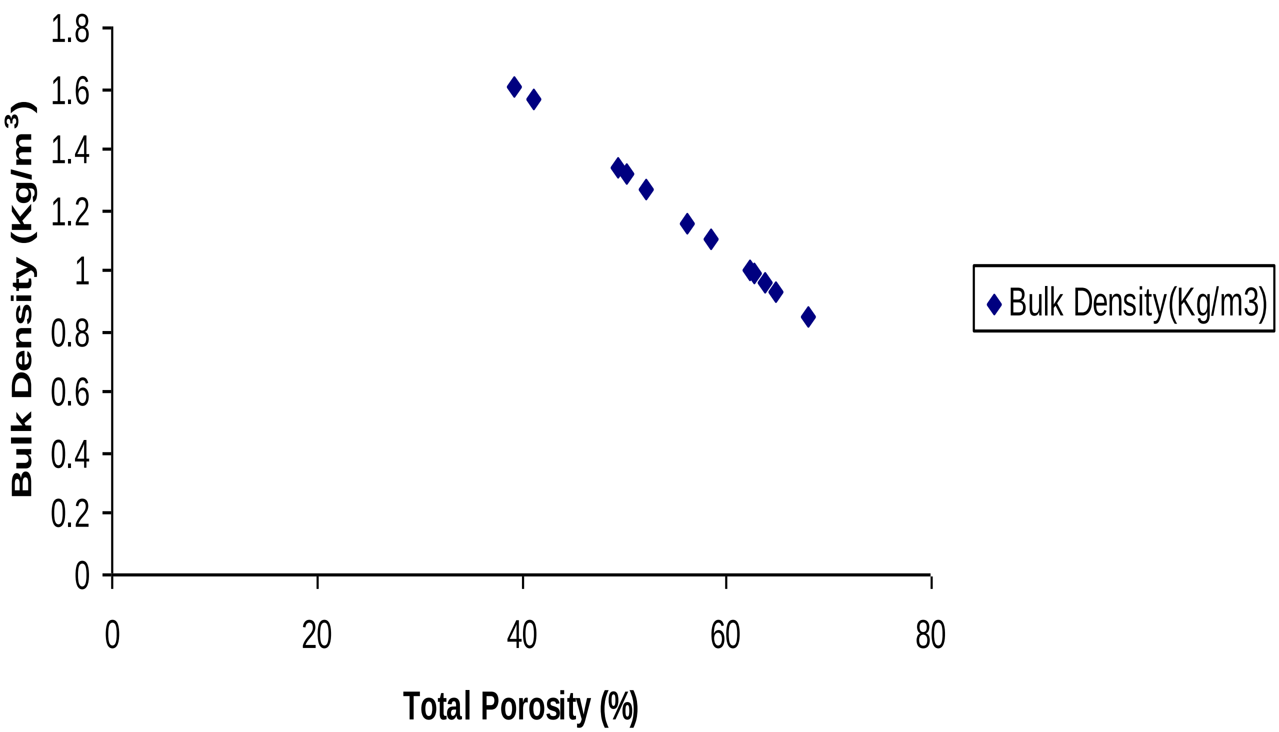

Fig. 4. Relationship between total porosity and bulk density

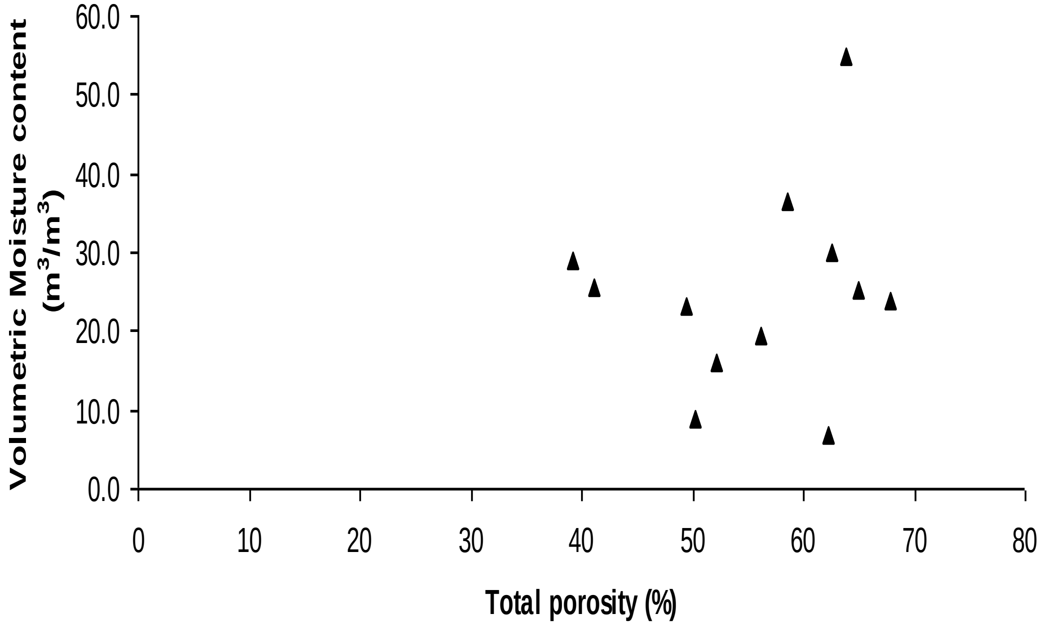

Fig. 5. Relationship between Volumetric Moisture and Total Porosity

Hence, the observed relationship implies blockage of pores as a result of soil dispersive capacity of sodium in surface water. According to Hudson (1994), high sodicity in soil may reduce the soil available water to plants by reducing the permanent wilting point and also adding to osmotic potential which may later cause crops on the field to wilt.

From the particle size analysis (Table 6), all the soils are totally sandy with a minimum sand fraction of 860g/Kg. Kamaruzzaman *et al*. (2002), considers rivers sediments as important sinks for contaminants derived from inland sources. They reported a minimum sand fraction of 700g/Kg on particle size of estuarine (mixture of salt and fresh water) in Malaysia. Comparing the two studies, the observed sand fraction may be too high for fresh water irrigation site. This can be attributed to the reasons stated above and gives an indication of the physical state of the soils in the valley bottom under the influence of continuous irrigation with the sodic water over time.

Table 5: Soil Physical and Hydrological Properties

Sample	Bulk Density (Mg/m^3)	Volumetric Moisture m^3/m^3	Total Porosity (%)
Well A-S1	1.10	36.51	58.5
Stream-S2	1.27	15.90	52.1
Well B-S3	1.00	6.79	62.3
Stream-S4	0.99	30.14	62.6
Stream-S5	1.56	25.65	41.1
Stream-S6	0.96	54.85	63.8
Stream-S7	0.93	25.11	64.9
Stream-S8	0.85	23.75	67.9
Stream-S9	1.61	28.93	39.2
Well C-S10	1.16	19.55	56.2
Stream-S12	1.34	23.09	49.4
Stream-S16	1.32	8.83	50.2

Table 6: Particle Size Distribution of Stream Sediment (g/Kg)

Sample	Sand	Silt	Clay	Textural Class (USDA)
Well A-S1	960	40	0	Sand
Stream-S2	940	40	20	Sand
Well B-S3	960	20	20	Sand
Stream-S4	940	40	20	Sand
Stream-S5	940	40	20	Sand
Stream-S6	960	20	20	Sand
Stream-S7	940	40	20	Sand
Stream-S8	900	60	40	Sand
Stream-S9	980	20	0	Sand
Well C-S10	860	100	40	Loamy-Sand
Stream-S12	960	20	20	Sand
Stream-S16	900	80	20	sand

CONCLUSION

The surface water is polluted with respect to BOD, Turbidity, Sodium and SAR. The pollution in surface water is from sewage channels and erosion from adjacent residential settlements, newly constructed roads and bridges. The high BOD and turbidity in surface water indicate the possibility of microbial explosion and this makes it dangerous to human, animal, plants and the soil. The high SAR may cause low soil infiltration and high soil dispersion with consequent decline in soil quality and reduced capability for sustainable vegetable production. There are no significant heavy metal contaminations in all the analyzed water samples from the ground water, vegetable and soil samples, hence the ground water did not show signs of pollution.

In order to ameliorate the possible effects of pollution from vegetable produced from this valet bottom soils, more emphasis should be placed on the use of ground water for irrigation rather than surface water which is prone to pollution. Water treatment should be done for all surface waters within the University of Ibadan campus to make them save for human and animal consumption and the environment. The comprehensive water quality assessment of water bodies on campus at the onset of every rainy season is also recommended. There is also an urgent need for the Nigerian standards for irrigation water quality.

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