Effects of Water Pollution on Soil Physical and Hydrological Properties of a Valley Bottom in University of Ibadan, Nigeria

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Abstract: ***The cultivation of valley bottoms has been one of the means of coping with recent unpredictable rainfall pattern and climate change. These valleys are often prone to pollution from adjacent plains due to their lower elevation which might have significant impacts on soil physical and hydrological properties. The effects of water pollution on soil physical and hydrological properties of a valley bottom was evaluated during 2010 dry season at a site within the University of Ibadan, Nigeria. Geo-referenced ground and surface water samples were collected from the field and analyzed for their physical and chemical properties. Bulk soil and plant samples were collected for analysis. River soil sediment samples were collected 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 WHO and 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. 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 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 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 the valley bottom were suggested.***

Keywords: Water pollution, Valley bottom, Soil physical and Hydrological properties

1. Introduction

Water pollution is a major problem in the global context. It has been suggested as the leading worldwide cause of deaths and diseases and that it accounts for the deaths of more than 14,000 people daily [6], [12]. In addition to the acute problems of water pollution in developing countries, industrialized countries continue to struggle with pollution problems as well. In a recent national report on water quality in the United States, 45 percent of assessed stream miles, 47 percent of assessed lake acres, and 32 percent of assessed bay and estuarine square miles were classified as polluted). Water body contaminations have also been reported in Nigeria at Ogun River, where industrial effluents from Lagos and Abeokuta is discharged [13]. The river was reported to have high level of turbidity, faecal coliform, iron, oil and grease [13]. The valleys which convey this water are also prone to pollution from human activities such as road/bridge constructions which are major yardsticks for good governance in Nigeria.

With the recent trends of unpredictable rainfall patterns and climate change, these polluted water bodies and valleys are often used in augmenting inland agricultural production (the cultivation of valley bottom called *Fadama*). 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 [1]. 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 30 December 1988 [11]. The FEPA has statutory responsibility of ensuring the protection of the environment. The World Health Organization (WHO), defines water quality as its fitness for beneficial uses, which it has provided for drinking by man and animals, the support of marine life, irrigation, industry, recreation and aesthetic purposes [19]. This study is 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.

2. Materials and Methods

A. Study area

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^{0} 26'850" to N07^{0} 27'087" and latitude

E003^{0}53'899" to 003^{0}53'552 with elevation ranging from 205m-227m above sea level. The area lays in the sub humid tropics (Fig 1). 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 i.e *Amaranthus spp*, *Celosia spp*, and *Abelmoschus esculentus*.

B. Sampling

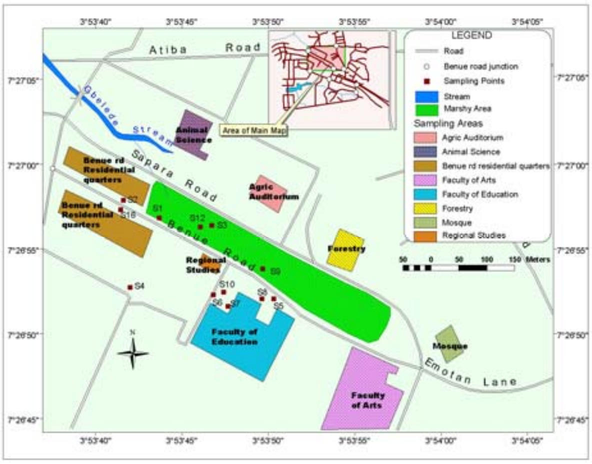

Fig. 1: Map of University of Ibadan Showing Study Area and Sampling Points

C. Soil and Water Analysis

Soil bulk density, gravimetric moisture and particle size was determined as described by Hilel (1982). Volumetric moisture and Total porosity were calculated from bulk density and as described by Hilel (1982). 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 [7]. pH, Temperature, Total Suspended solids (TSS), Total Dissolved Solids (TDS), Turbidity, Biological oxygen demand (BOD)., Dissolved oxygen (DO), Acidity, Alkalinity, Chloride, Sulphate, Sodium concentration, Carbonate, Bicarbonate, calcium, magnesium,

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

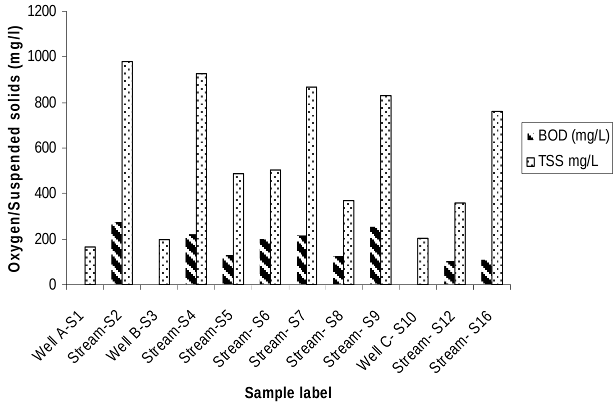

Fig. 2: Relationship between Biological Oxygen Demand and Total Suspended Solids

Iron, lead, cadmium, copper, cobalt and total hardness. Sodium Absorption Ratio was determined as described by FAO [10]. The values obtained are compared with the drinking and irrigation water quality standards of FAO [10], FEPA [11], WHO [19], and SON [17]. They were also subjected to statistical technique of dispersion and central tendencies while parameters that are 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.

3. Results and Discussion

A. Physical properties of water

In surface water, most parameters observed are above the WHO, FEPA and SON Standards for drinking water (Table 2). However in the ground water, most of the observed physical parameters are within permissible limits (Table 1). 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 [8]. Treatment methods that may likely ameliorate these are: coagulation, biological clarification, aerobic oxidation, anaerobic oxidation, autolysis and nitration [14]. 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) [18]. 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.

B. Chemical properties of water

Among 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 of the surface water samples show high value of Na (over 3000mg/l) (Fig. 3).

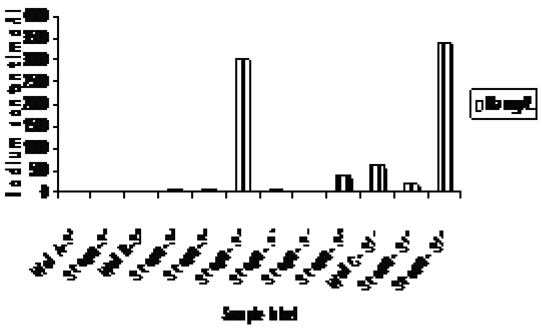

Fig.3. Sodium concentration in water samples

This could be derived from drainage/sewage water from hostels which harbors thousands of students on campus. This water is channeled directly into the surface water. 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 are polluted with respect to iron since their iron content in is above 0.3mg/l [17]. The process of iron coagulation is recommended. The heavy metals analyzed (Lead, Chromium, Cobalt and Cupper) were absent which implies there is no heavy metal pollution in the water bodies. The quality of water for irrigation was assessed by comparing with FAO irrigation water quality standards [10]. 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 [10]. Therefore, surface water may not be suitable for irrigation. Van de Graaff and Patterson reported that high sodicity causes excessive swelling of clay mineral [16]. This 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 is causes extensive leaf burn, defoliation and loss of yield [2]. In the ground water, SAR is still within the normal range for irrigation.

***C.* 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 who worked on a simmmilar valley in south western Nigeria [15]. 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).

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 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

[10],[11],[19],[17]

TABLE 2: 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	Nill	20	Nill
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

[10],[11],[19],[17]

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

[10],[11],[19],[17].

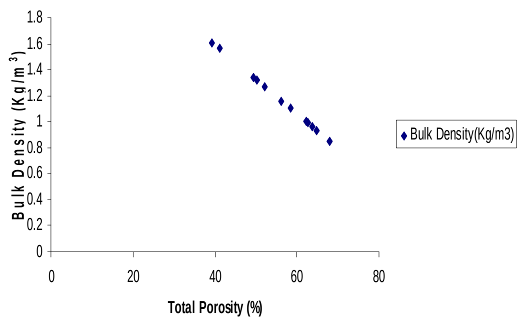

Fig. 4. Relationship between total porosity and bulk density

It implies the lower the bulk density the higher the total porosity which 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, there should be a perfect positive correlation between these parameters [5].

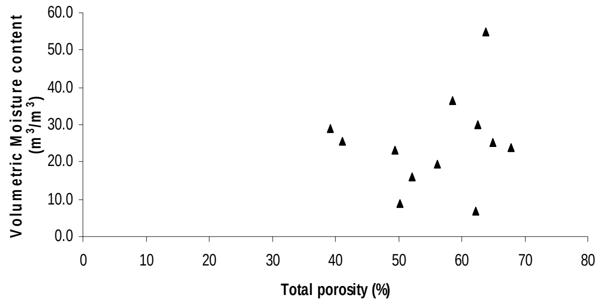

Fig. 5. Relationship between Volumetric Moisture and Total Porosity

This implies blockage of pores as a result of soil dispersive capacity of sodium. According to Hudson (1994), high sodicity in soil may reduce the soil available water by reducing the permanent wilting point and also adding to osmotic potential which later cause wilting of crops on field [3]. 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 [4].

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

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 much for fresh water. This can be attributed to the reasons stated above. This gives us how the soil might look like after continuous irrigation with the sodic water.

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

[10],[11],[19],[17].

4. Conclusions

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 newly constructed roads and bridges. The high BOD and turbidity in surface water indicate that there is microbial explosion and it is dangerous to human, animal, plants and soil. The high SAR may cause low soil infiltration and high soil dispersion. The ground water shows no sign of pollution. There are no significant heavy metal contaminations in all the analyzed water, vegetable and soil samples.

It is thus recommended that 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 water around the area to make it safe for human and animal consumption and the environment. There should be proper water quality assessment at the onset of every season.

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