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Research Article

ASSESSMENT OF SOME PHYSICOCHEMICAL PROPERTIES OF SOIL AND PLANTS ALONG DISCHARGED EFFLUENT DRAINAGE IN SHARADA INDUSTRIAL AREA, KANO, NIGERIA

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ABSTRACT

Objective: Soil is a vital resource of sustaining basic human needs, a quality food, food supply, and a liveable environment. Vegetables are vital to the human diet, and in particular, provide the well-known trace elements and heavy metals. Intake of heavy metal-contaminated vegetables may pose a risk to the human health.

Materials and Methods: Soil and plants (vegetables) samples were collected from the study sites (A, B, and C). They were subjected to heavy metals analysis which includes cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), and some physicochemical properties which include pH, electrical conductivity (EC), and cation exchange capacity (CEC) in the soil.

Results: The mean values of the heavy metals in soil were higher than the recommended value by United States Department of Agriculture (USDA) (2007), while the value recorded at the control site is found to be within the range. The values of Cd, Cr, and Pb were lower than the World Health Organization/Food and Agriculture Organization (1996) safe limit. However, the Cu levels found in vegetables were within safe limits in all samples. The pH and CEC of the three sites are within the range according to the USDA (2007). The CEC value of site A and B falls within the range. The EC value of site A is higher than site B while site C has the least.

Conclusion: These indicate that there is possible interference from the effluent discharged on the soil chemistry.

Keywords: Soil, Plants, Heavy metals, Physicochemistry, Determination.

INTRODUCTION

Soil serves as a vital resource for sustaining human basic needs, a typical quality food and supply with a liveable environment. Analysis of the chemical nature of soil is paramount for environmental monitoring and policymaking [1]. It provides information on nutrient availability, fertility status and the basis for recommendation of fertilizers as well as planning of a nutrient management program. Soil whether in agricultural or urban areas serves as a major sink of metals released into the environment from a variety of anthropogenic sources and activities [2].

Vegetables are important human diet, and in particular, provide the well-known trace elements and heavy metals. Minor or trace elements are essential for good health if they come from an organic or plant source. In contrast, if they come from an inorganic or metallic source, they become toxic. The processes of plant growth depend on the cycle of nutrients including trace elements, from soil to plant [3]. Vegetables, especially leafy vegetables, accumulate higher amounts of heavy metals because they absorb these metals in their leaves. Vegetables are rich sources of vitamins, minerals, and fibers and also have beneficial antioxidative effects. However, intake of heavy metal-contaminated vegetables may pose a risk to the human health. This is because heavy metals have the ability to accumulate in living organisms and at elevated levels they can be toxic. It has been reported that prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead (Pb) to the chronic accumulation of the metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney, and bone diseases [4,5]. The justification of the research is to derived out the need to study the quality of soil which determines its ability to support plant growth irrigated with effluent discharges into the Salanta river, and provide concrete information on the magnitude of the industrial liquid waste and help farmers and policymakers to take the necessary concrete measure on time. Furthermore, evaluate the ecological risk of heavy metal in the study area which has been reported that consumption of heavy metal through food may Pb to chronic accumulation of metal in kidney and liver, also disease in cardiovascular, neuron, and bone disease.

MATERIALS AND METHODS

Study area

This study was conducted in Sharada under Kano metropolis, which lies between latitude 11°57`34.0"N, longitude 8°30`39.9"E, and altitude of 485 m. It harbors many industries including tannery, textile, chemical, food, plastic and so on. The research was conducted at farmland along the bank stream of Sharada (Salanta river), where the stream water was mostly contaminated industries effluent from Sharada industrial area and all sample were collected from that area.

Site description

Site A: Farmland in Medile. Crops grown include Moringa, Okra, and Lettuce.

Site B: Farmland in Sabuwar Gandu. Crops grown include Spinach, Onion, and Tomato.

Site C: Farmland in Yahya Gusau (control). Crops grown include Bitter leaf, Lemongrass, and Cabbage.

Climate and agroecology

Kano falls under the dry-sub-humid agroecological zone of Nigeria with annual rainfall that lasts from late May or early June to September, with a mean range of about 600–726 mm [6]. Rainfall is, however, very variable just like humidity which is closely associated with it and potential evaporation is about 1700–1800 mm/annum. The mean annual temperature is about 28°C [6].

Sampling and sample preparation

Soil sampling

A soil sample from 2 to 15cm was collected manually using sterilized trowel, one sample was collected once per week where that each sample was collected at each 20 m distance which gives the total of five soil sample that was composited into one, it was then bagged in polythene bag and brought to the laboratory [7].

Plant sampling

A sample of the predominantly planted vegetable in the area irrigated with water containing industrial effluent was collected from the soil sampling site. The youngest fully matured plant is sampled; it was then parked into the envelope and brought to the laboratory [8].

Preparation of sample

Soil sample was air-dried, gently crushed and sieve with 2 mm sieve. Plant tissue was carefully washed with tap water and rinsed with distilled water, it then kept for, some hours and later oven dried at 70°C for 24 h and then grind it and sieve with 2 mm. Water sample collected in a plastic container was kept before analysis [9].

Duration of the sampling

All soil and plant samples were collected at the peak of irrigation activities between the 9 and August 30, 2016.

Plant analysis

Digestion of vegetable samples

About 5.0 g of the dry sample of each vegetable sample was ashed using muffle furnace that was set at 600°C until a constant weight was obtained. On cooling, the ash was transferred to a beaker and 10 ml of water was measured against 10 ml of HCl acid it was then stirred and filtered using No. 1 filter paper, 30 ml of distilled water were then added making 50 ml of the digested plant sample [10]. Concentration was then determined using atomic absorption spectrophotometer model 210VPG.

Soil analysis

Soil samples collected from the field were subjected to laboratory analysis using the following established procedure.

Determination of pH

The pH was determined using the 1:1 soil-water ratio using EL model 720 pH meter [7].

Determination of electrical conductivity (EC)

The EC of the samples were determined using 1:1 soil-water ratio used in pH determination with a Beckman Conductivity Bridge [7].

Determination of cation exchange capacity (CEC)

The CEC was determined using ammonium acetate saturation method as described by Jaiswal [9].

Determination of heavy metals in soil samples

About 5.0 g of each soil sample was weighed into an acid-washed glass beaker. 10 ml of distilled water was measured against 10 ml of HCl acid it was then mixed together against the soil sample and put inside the fume cupboard for some minute, then 10 ml of HCl acid was measured against 10 ml of distilled water it was then stirred and filtered using No. 1 filter paper [10]. It was then analyzed for heavy metals which include cadmium (Cd), chromium (Cr), copper (Cu), and Pb using atomic absorption spectrophotometer model 210VPG.

RESULTS

The mean of Cd concentration in the soil of the three sites is given in Table 1. Site B has a higher concentration of the metals than both Site A and C. All the mean values were higher than the recommended value by USDA [11], while the value recorded at the control site is found to be within the range. The major cause of the presence of Cd in the soils could be attributed to four factors as proposed by Wild [12] and World Bank Report [13]. These factors are (i) addition through phosphate fertilizers, (ii) its use in batteries, alloys, pigments, and plastics, (iii) its discharge through industrial sewage from tanneries, and (iv) geologic addition through rock weathering. Factors (i) and (iv) might be responsible for its detection in Site C (Yahya Gusau) while (ii) and (iii) might, respectively, be the reasons for its presence in Site A (Medile) and Site B (Sabuwar Gandu) as well as its declining trend down. All the soils tested by Fish and Johnson [14] have low but detectable amounts of Cd resulting from rapid releases from fertilizer during the first few hours of application which, however, slows down substantially after 24 h. Amounts detected by them ranged from as low as 5.7 µg/g to as high as 12.7 µg/g depending on fertilizer type and soil characteristics. Low Cd level even in areas prone to contamination is common as acknowledged by some studies [15]. In Tehran reported Cd values as low as 0.67 mg/kg in soils irrigated with waters of Firozabad River which is polluted by industrial effluents. The gradual build-up of metals due to their non-degradability as explained by Wild [12] might have accounted for the rapid buildup of this metal in Site C (Yahya Gusau) and may be the reason for the deviation from the earlier works.

The mean of Cr in the soil of the sampling sites was presented in Table 1. Based on the results, it indicates that the mean concentrations of all the sites are below the recommended standard in the soil. Cr is strongly associated with industrial effluents, especially the tanning industry as well as the textile and iron and steel industries at various levels [12]. This factor alone might have significantly contributed to the excessively high concentration at especially the Challawa basin which has the highest concentration of all the aforementioned industries, particularly the tanning and textile industries. World Bank Report [13] has reported that the largest chunk of Nigeria's tanning industries is located in Kano, especially at the Bompai and Challawa Industrial Estates. Bichi [16] indicated that Kano is a booming industrial center in Nigeria, with over 320 industrial establishments comprising of chemical industries, tanneries, textiles, and food processing factories which release wastewater into rivers, these, however, have stressed the reports of Maldonado *et al*. [17] and Mapanda *et al*. [18] of possible soil contamination over a long period of application of sewage sludge.

Cr could be attributed to the forms of the metal that is available in the soil. The predominant form is Cr (III) which is highly stable, but the less stable form of Cr (VI) is equally commonly encountered both in association with other metals especially Ca, K, Fe, and Na as chromates and hydrochromates. As explained by Zayed and Terry [19] with increasing pH, the chromates form to dominate the soil while with decreasing pH the hydrochromates dominate; and unless if in association with Zn and Pb; their solubility tends to increase in the reverse of the order mentioned above.

The mean concentrations of Cu in the soil of the sites are shown in Table 1. Site A has the highest and Site B the least. The highest value was observed closed to industrial waste. The concentrations were above the permissible limit in Table 2 by United States Department of Agriculture (USDA) >1.0 as toxicity level the Cu concentration in all the sites is attributable to the fact that Cu is a metal that is found in domestic sewage sludge as well as in industrial wastewater [12,13]. In general, Cu gets into soils through several means most importantly, geochemical and anthropogenic; and its variability in concentration is also acclaimed [17,20].

Cu is a metal that is predominantly adsorbed at the top soil by clay and/or organic matter, and for most of the metals, this adsorption increases with increasing pH [12]. Basta *et al*. [21] showed that the electronic properties of Cu and Pb result in a very strong affinity for soil organic matter and the formation of strong inner-sphere metal surface.

The mean concentration of Pb is shown in Table 1. Based on the results, the values found to be below the recommended level as suggested by USDA [11]. The Site A has recorded the higher value among the three sites. Pb is an element which is used in batteries and has very low solubility in acid and alkaline conditions [22]. Of greatest concern, as a source of contamination is, however, Pb added in petrol which is emitted through exhausts of machinery [12]. Deposition of Pb at one point could be transported to several kilometers away through the air or after conversion to Pb sulfate [12,23]. This, therefore, explains the concentration in this research is due to addition to exhaust discharges by motor\vehicles or water pumping machines being used by irrigators in the entire site to be making an appreciable contribution. The increasing concentration levels with proximity to municipal could be used to justify the contribution of vehicular exhaust discharges as in all cases higher concentrations tend to be found where motor vehicles are more. In the studies of Bada *et al*. [23] at two selected highways, they found that concentration of the metal was correspondingly decreasing from the roadside to distances away from the highway.

The mean concentration of heavy metals in the leaves of the plants grown was shown in Table 3. The Cd plant content is more in Site A (0.0364 mg/kg) followed by Site B and C which has the lowest concentration of the metal. The content of Cd in this study is generally lower than the [24] safe limit.

Cd content is found highest (0.0364 mg/kg) at a distance 15 m from the industrial site and the lowest at 25 m (0.0182 mg/kg) from the industrial area. This could infer that the level of Cd in the plant and soil has nothing to do with distance. There has been a report that Cd is a highly mobile metal, easily absorbed by the plants through root surface and moves to wood tissue and transfers to upper parts of plants [25]. Muhammad *et al*. [26] reported that there is a direct relation between the levels of presence of Cd in the root zone and its absorption by the plant. Thus in this study, soil Cd concentration is higher than plant Cd concentration.

The metal Cr was equally distributed in all plant organs with a mean value of 0.0154–0.0462 mg/kg. This value is lower than the [24] safe limit of 0.30 mg/kg. The soil content (1.0769 mg/kg) was found to be higher than plant content. Sharma *et al*. [27] studied the heavy metal contents in different vegetables grown in the lands irrigated by wastewater and noted the concentration of Cr to be within the safe limits. However, it was noted that Cr concentrations in all the cases were under permissible limits (0.30 mg/kg World Health Organization [WHO]).

Table 1: Mean concentration of some heavy metals in the soil (mg/kg)

SITE	Cd	Cr	Cu	Pb
Site A Medile	0.7273	1.0769	3.6364	0.0464
Site B Sabuwar Gandu	0.9091	0.9231	2.2727	0.0265
Site C Yahya Gusau (control)	0.5455	1.0769	3.1818	0.0397
USDA 2007	>0.5	0.3	>1.0	>1.0

USDA: United States Department of Agriculture, Cd: Cadmium, Cr: Chromium, Cu: Copper, Pb: Lead

Table 2: Mean concentration of some heavy metals in vegetables (mg/kg)

SITE	Cd	Cr	Cu	Pb
Site A Medile	0.0364	0.0462	0.2272	0.0265
Site B Sabuwar Gandu	0.0182	0.0154	0.1364	0.0132
Site C Yahya Gusau (control)	0.0182	0.0308	0.0909	0.0199
WHO/FAO (1996)	0.1	0.3	2.3	0.1

WHO/FAO: World Health Organization/Food and Agriculture Organization, Cd: Cadmium, Cr: Chromium, Cu: Copper, Pb: Lead

Table 3: Mean of some physicochemical properties of the Soil

SITE	pH	EC (μS/cm)	CEC (cM/kg)
Site A Medile	7.3	625	17.2
Site B Sabuwar Gandu	6.7	563	15.5
Site C Yahya Gusau (control)	6.5	527	13.7
USDA, 2007	6.8–7.2	–	>15

USDA: United States Department of Agriculture, EC: Electrical conductivity, CEC: Cation exchange capacity

Cr has not been classified as essential in plant nutrition and the only perspective to view its presence is in terms of tolerance based on which phytoremediation of contaminated soils is planned. As reported by Zayed and Terry [19], the use of biological remediation technologies such as bioremediation and phytoremediation for the cleanup of Cr-contaminated areas has received increasing interest from researchers worldwide. They further reported that Cr is readily immobilized in soils by adsorption, reduction, and precipitation processes, with only a fraction of the total Cr concentrations available for plant uptake. When taken up by plants, >99% of the absorbed Cr is retained in the roots where it is reduced to Cr (III) species in a short time. Phytotoxic levels of Cr in most plants seem to limit its accumulation in the food chain, because most plants have low Cr concentrations, even when grown on Cr rich soils, the food chain is well protected against Cr toxicity. These facts about it might have explained its low values in plants despite its higher values in the soils as shown in Table 3. Akinola and Ekiyoyo [28] were able to extract from washed samples as high 47 μg/g in roots and none in shoots of *Telfairia occidentalis* from a total concentration of 3647 μg/g in the soil. Plants, however, as suggested by Zayed and Terry [19] vary in their extractive abilities for Cr. This probably explains why [28] detected as much as 65.60 μg/g in leaves of *Talinum triangulare* from an industrial soil concentration no >12.80 μg/g while Akan *et al*. [30] reported concentrations in lettuce grown on the banks of Challawa river to as high as 1.54–2.43 μg/g claiming that vegetables accumulate a considerable amount of heavy metals especially Cr in roots and leaves.

The Cu plant concentration is highest in Site A Medile (0.2272 mg/kg) and lowest in site C Yahya Gusau (control) (0.0909 mg/kg). These values were less than the [24] safe limit. The Cu levels found in vegetables were within safe limits in all samples. Muhammad *et al*. [26] studied the response of three vegetables to Cu toxicity and found that Cu levels in both root and shoot increased, but root Cu concentration increased more sharply than shoot with increasing Cu levels in growth media. Cu mainly accumulated in roots while a small fraction (10%) of absorbed Cu was transported to shoot. Mohsen and Mohsen [15] found that Cu concentration in the shoots was significantly influenced by Cu concentration in soil and increased markedly with an increase in the soil Cu concentration. The possible deficiency in plant tops is due to its preferential accumulation in the roots [25]. Soil Cu concentration is higher than plant Cu concentration.

Cu is a micronutrient needed by plants and according to Tisdale *et al*. [31] its normal range is between 5 and 20 mg/kg and deficiency may be exhibited when concentrations fall <4 mg/kg. By this standard; therefore, the plants, here, are likely to exhibit deficiency symptoms. The results portray the effect of soil concentrations on the concentrations in plants as those areas with higher soil concentrations also have higher concentrations in their plant tissues.

This is in agreement with the findings of Mohsen and Mohsen [15] in which the high concentration of Cu detected in soil correspondingly reflects in plant tissues to as high as 25 mg/kg from a maximum soil concentration of 54 mg/kg. Several tissues of plants analyzed by Akan *et al*. [30] grown on the banks of Challawa River have revealed that Cu content in roots, leaves, and shoots of tomato and carrot ranged from as low as 2.5 mg/kg to as high as 12.3 mg/kg.

The level of Pb in this study is found highest in Site A (0.0265 mg/kg) and lowest in Site B (0.0132 mg/kg). All these values are small when compared to the WHO/Food and Agriculture Organization (FAO)

(1996) safe limit of 0.1 mg/kg as shown in Table 3. One likely source of the Pb contamination on the vegetables could be as a result of acid-Pb batteries as a waste dump in the drainage around the site which is subsequently used to irrigate the farmland. This may also be responsible for high level of Pb in the vegetable site.

Pb is a serious cumulative body poison which enters into the body system through air, water, and food and cannot be removed by washing fruits and vegetables [25]. The high levels of Pb in some plants may probably be attributed to pollutants in irrigation water, farm soil or due to pollution from the highway's traffic [32]. Pb pollution has been shown to be commensurate with population/vehicular density. One possible explanation for this situation is that the Pb uptake can be promoted by the pH of soil and the levels of organic matter. Pb is a toxic element that can be harmful to plants, although plants usually show the ability to accumulate large amounts of Pb without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed several 100 times the threshold of maximum level permissible for human consumption [26]. The introduction of Pb into the food chain may affect human health, and thus, studies concerning Pb accumulation in vegetables have increasing importance. The study shows that the soil Pb content is more than the plant Pb content.

The salinity related properties of the three sites were shown in Table 4. The pH of the respective sites is within the range of slightly acidic as in Site B and C (6.7 and 6.5) to slightly neutral as in Site A (7.3). This shows that the pH of the three sites is within the range according to USDA [11].

The EC values of Site A (Medile) is higher than that of Site B (Sabuwar Gandu), much higher value was recorded at that site compared with control Site C (Yahya Gusau).

The CEC value of the study site was presented in Table 4. Only the value in Site C (Yahya Gusau) has lower value compared to Site A (Medile) and Site B (Sabuwar Gandu). The CEC value of the three areas falls within the ranges classified as a medium when the ranking [33] of 6 cmol/kg, 15 cmol/kg, and 30 cmol/kg as low, medium, and high, respectively, is used. Esu [34], however, classified values >15 cmol/kg as high. The effects of organic matter content in the soil in relation to CEC are markedly expressed here. The sites with higher organic matter content have significantly higher CEC values than the sites that have lower contents. Brady and Weil [35] are of the opinion that the contribution of organic matter to the total CEC of the soil is much higher than that of clay.

The values obtained across these sites are fairly in disagreement with many works across soils of many basins of tropical rivers. The work of Mustapha [36] has found mean CEC as low as 4.35 cmol/kg in the basins of some rivers in Bauchi. Similar low values were obtained [37].

CONCLUSION

Based on the result from Tables 1 and 3, it shows that the concentration of Cd, Cr, and Cu in soil was all above the permissible limit with the exception of Pb which found to be within the limit according to USDA (2007). Meanwhile, the concentrations of Cd, Cr, Cu, and Pb in plants samples were all below the permissible limit according to the WHO/FAO (1996). The values of pH in all sites are within the standard values of USDA (2007). EC values of Site A and B has proven to be higher than the control. CEC values of Site A and B were higher than the standard limit of USDA (2007) while that of Site C is less. These indicate that there is possible interference from the effluent discharged on the soil chemistry. This is a source of concern due to the elevation of such toxic metals and their role in environmental pollution.

RECOMMENDATIONS

- To avoid entrance of metals into the food chain, municipal or industrial wastes should not be drained into rivers and farmlands without prior treatment.
- Farmers should avoid direct use of the contaminated water for watering directly or using sludge as manure.
- Tube wells and hand dug wells should be used as a source of irrigation water to avoid use of contaminated water.
- There is a need for further studies to establish more environmental, health, economic, and other impacts of these wastes to the receiving communities.

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