



Concentration level of arsenic in agricultural soil and surface water used for irrigation in Bukuru, JOS-south LGA of plateau state, Nigeria

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Abstract

Arsenic concentration of agricultural soil and surface water used for irrigation were surveyed in two abandoned mining sites of Jos South Local Government Area. DB-Zang and Dorowa total dissolved solid, total hardness, electrical conductivity, temperature and pH of the agricultural soil and surface water were determined according to standard procedure. Result indicates that Total dissolve solids in W1 was 156 ± 2.00 mg/L and for W2 (160 ± 2.00 mg/L), total hardness W1 (35.20 ± 4.70 mg/L) and W2 (44.67 ± 4.70 mg/L), electrical conductivity for W1 was 0.240 ± 0.189 μ S/cm and W2 was 0.120 ± 0.189 μ S/cm, electrical conductivity for S1 (0.49 ± 0.16 μ S/cm), S2 (0.17 ± 0.16 μ S/cm), temperature for both water was 28.00 ± 0.00 °C for soil are 18.00 ± 0.00 °C, pH for W1 (7.10 ± 0.05) and W2 (7.20 ± 0.05), pH for S1 (6.90 ± 0.15) S2 (6.60 ± 0.15). The concentration of Arsenic in soil L2 is 14.00 ± 0.70 μ g/kg which is in agreement with WHO recommended level of Arsenic in soil and for L1 257.00 ± 120.00 μ g/kg which is not in agreement with the WHO recommended level of arsenic, while in water for L1 was 3.00 ± 0.50 μ g/L which is not in agreement with the WHO recommended level of arsenic and L2 was 48.00 ± 0.70 μ g/L which is not in agreement with the WHO recommended level of arsenic. The cultivation of food crops in those areas are not recommended.

Keywords: Agricultural Soil; Arsenic; Concentration; Physicochemical Properties; Surface Water.

1. Introduction

Arsenic is an abundant component of the earth's crust. As a result, the potential for human exposure to arsenic is very high. This potential is even higher for people living in regions with particularly high arsenic concentrations, whether occurring naturally or as a result of industrial activities (Walter 2015). Arsenic is a well-known poisonous substance and classed as being carcinogenic to humans. Epidemiological studies have indicated that arsenic is able to increase risk of cancers of lung, liver, bladder, and skin in human, and more than a million people are suffering from arsenic-contaminated ion in drinking water worldwide (WHO 2018).

1.1. Physical and chemical properties of arsenic

Arsenic is a silver-grey brittle, crystalline (hexagonal, rhombic), metallic-looking substance which exists in three allotropic forms (yellow, black, and grey). It is odorless and nearly tasteless. It is soluble in nitric acid, cold hydrochloric, and sulfuric acids. It is insoluble in water and nonoxidizing acids. Pure arsenic can be heated to burn in air, giving off an odour of garlic and white fumes of arsenic trioxide

Arsenic is odourless and is usually combined with one or more other elements such as oxygen, chlorine and Sulphur. Pure arsenic is not soluble in water or organic solvents, but can be dissolved by strong acids. Arsenic trioxide is sparingly soluble in water.

Soil is biologically active, porous medium that has developed in the uppermost layer of Earth's crust. Soil is one of the principal substrata of life on Earth, serving as a reservoir of water and nutrients, as a medium for the filtration and breakdown of injurious wastes, and as a participant in the cycling of carbon and other elements through the global ecosystem. It has evolved through weathering processes driven by biological, climatic, geologic, and topographic influences.

1.2. Arsenic in water

Lubyanka & Vladana (2018) determined arsenic in water depending on the physical, chemical and biogeochemical processes and condition of the environment, various arsenic species can be present in water. Water soluble arsenic species existing in natural water are inorganic arsenic and organic arsenic species. All acidic species, according to the chemical equilibrium, have well-recognized molecular and ionic forms in water. The distribution of species is a function of pH value of water are found in groundwater, lakes, rivers and ocean. The WHO provisional guideline value for arsenic in drinking water is 10μ g L⁻¹. The most selective and sensitive methods for determination of total



use the water (dam) for irrigation farming for the vegetables and tubers planted on the farmland which include spinach, lettuce, sweet and Irish potatoes, cabbage, spring onions and so on.

2.2.2. Water sample

The water samples were collected in 1litre capacity polythene bottles previously cleaned with metal free detergent, rinsed with distilled water from the two locations which are DB-Zang and Dorowa. The samples were label W(A) and W(B) in triplicate respectively.

2.3. Sample preparation

2.3.1. Soil sample

The soil samples were collected different polythene bags, properly labelled and immediately taken to the laboratory where they were properly dried for one week (7days) at room temperature. There were then crushed with a mortar and pestle and sieved with 2mm mesh and then oven dried for 72hrs before stored in a sample bottle for analysis.

2.3.2. Water sample

After sample collection, the samples were labeled and taken to the laboratory for preservation by treating with concentrated nitric acid (HNO₃) and kept in refrigerator with the temperature maintained below 60°C throughout the period before the analysis.

2.4. Determination of temperature

The temperature of the water sample was determined by dipping the thermometer into the water to get the current temperature of the water on the location.

2.5. Determination of soil pH

1.0g of dried soil samples from each site were mixed with 20ml of deionized water in a 50ml beaker and stirred with a glass rod. The pH was measured by introducing a glass probe of the pH into the soil solution and read out.

2.6. Determination of total dissolve solid (TDS)

A clean evaporating dish was heated in a drying oven at temperature of 105°C for about 30minutes. It was then cool in desiccator for about 10minutes. Then the dish was weighted carefully on a balance, with the weight recorded and the weight was labelled as A. About 100ml of water was added and evaporated to dryness and then transferred to oven at 105°C and dried for about 1-2hours. The dish was allowed to cool in air, which was later placed in a desiccator while still warm to complete the cooling process. The dish was weighted as soon as it cooled and recorded as B.

Calculation

$$\text{Total solid in mg/L} = \frac{B - A \times 100}{\text{ml of sample}}$$

Where B = weight of residue and dish

A = weight of the dish alone

2.7. Determination of electrical conductivity

The conductivity meter with a reference electrode was rinsed with distilled water, and immersed in the water sample to be analyzed. It was allowed to stand for few seconds after which the results were displayed for successive samples.

2.8. Determination of total hardness

50ml of water sample is pipette into 100ml conical flask followed by 2ml of ammonium chloride buffer. A little pinch of Erichrome T black powder was added. The solution was then titrated immediately with 0.01M EDTA and mixed continuously until the colour changed to clear blue. The volume of EDTA used was noted at end point.

Calculation

$$\text{Total hardness} = \frac{\text{ml of EDTA} \times 1000}{\text{ml of sample}}$$

2.8.1. Digestion of soil sample

To different samples in the beakers, 20ml of concentrated nitric acid (HNO₃) was added to 2g of soil samples, they were left overnight; The samples were shaken mechanically for 30 minutes then heated on a heating mantle under the fume cupboard at about 95°C for 10minutes it was brought down from the heating mantle and were allowed to cool then filtered into 100ml of volumetric flask using Whatman filter paper (No.1). It was made up to 100mls with distilled water. The filtrates were then analyzed for Arsenic (As) using Atomic Absorption Spectroscopy (AAS) AA990.

2.8.2. Digestion of water sample

To the different samples in the beakers, 20ml of nitric acid (HNO₃) was added to 5ml of water sample and left to stay overnight; the samples were shaken mechanically for 30 minutes and then heated on a heating mantle under the fume cupboard at 95°C for 10 minutes. They were brought down from the heating mantle and were allowed to cool, filtered into 100ml of volumetric flask using Whatman filter paper (No.1)

and funnel. It was made up to 100mls with distilled water. The filtrates were then analyzed for Arsenic (As) using Atomic Absorption Spectroscopy (AAS) AA990.

2.9. Determination of the concentration of arsenic in surface water (used for irrigation) and agricultural soil

Based on beer-lambert theory Atomic Absorption Spectroscopy light beam is directed towards a monochromator through the flame and unto detector that measures the amount of absorbed light. The vapour of an element which contains free atoms absorbs light having wavelength equal to that which the atoms of the element are capable of emitting. When light of this wavelength passes through a flame containing a cloud of free atoms of the respective element, the intensity of the ray is reduced due to absorption. The measured decreased intensity of the light is proportional to the concentration of atoms in the solution.

3. Results

The results for the determination of physicochemical properties of the soil and water samples are presented in Table 1 and 2 respectively while Table 3 reveals the concentration of arsenic in both water and soil at the two sample locations.

Table 1: Determination of Temperature, Ph, Electrical Conductivity, Total Hardness and Total Dissolved Solid for Water Sample

LOCATION	pH	TEMPERATURE °C	TOTAL HARDNESS mg/l	ELECTRICAL CONDUCTIVITY ms/cm	TOTAL DISSOLVE SOLID mg/l
W ₁ (DB-ZANG)	7.10±0.05	28.00±0.00	35.20±4.70	0.240±0.189	156±2.00
W ₂ (DOROWA)	7.20±0.05	28.00±0.00	44.67±4.70	0.120±0.189	160±2.00
WHO STAND-ARD	6.50-8.50	27.00-30.00	500	0.00-19.90	500.00

Table 2: Determination of the Temperature, Ph and Electrical Conductivity for Agricultural Soil in Location A (DB-Zang) and Location B (Dorowa)

LOCATION	pH	TEMPERATURE °C	ELECTRICAL CONDUCTIVITY ms/cm
S ₁ (DB-ZANG)	6.90 ±0.15	18.00±0.00	0.49±0.16
S ₂ (DOROWA)	6.60±0.15	18.00 ±0.00	0.17±0.16
WHO STANDARD	6.50-8.50	27.00-30.00	19.90

Table 3: Mean Concentration of Arsenic in Soil and Water Obtained from Location A and B (DB-Zang and Dorowa)

LOCATION	CONCENTRATION	WHO Standard
W ₁ DB-ZANG	3.00 ± 0.50µg/l	10.00µg/l
W ₂ DOROWA	48.00± 0.70µg/l	10.00µg/l
S ₁ DB-ZANG	257.00 ± 120.00µg/kg	10.00µg/l
S ₂ DOROWA	14.00 ± 7.00µg/kg	40.00µg/kg



Fig. 2: Bar Chart Showing Concentration of Arsenic Soil and Water from Sampling Sites.

4. Discussion

pH is the measure of alkalinity or acidity of water. The World Health Organization (WHO) standard pH for drinking water is within the range of 6.5-8.5. (WHO, 2018). The results obtained for water at DB Zang was 3.00±0.5 and Dorowa was 48.00±0.7 shows that the water is safe for domestic usage as the respective values falls within the range of WHO quality standard. The values of the pH ranges from 7.1 - 7.2 which indicate that the surface water samples are basic and are in agreement with what was reported by other researchers which are within the range of 6.5-8.9 in similar study (Edimeh *et al* 2011, Aremu *et al* 2011).

The average temperature of water samples of the study area was 28 °C for both location and in the range of 28–29 °C. Temperature in this study was found within permissible limit of WHO (30 °C). Ezeribe (2012) reports similar result (29 °C) of well water in Nigeria.

Water has the ability to dissolve a wide range of inorganic and some organic minerals and salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulphates etc. These minerals produce unwanted taste and diluted colour in appearance of water.

Standard limit for TDS is 500mg/L (WHO 2018). The TDS in drinking water value was in the range of 156 and 160 mg/L. The mean total dissolved solids at DB-ZANG were found to be 156 mg/l, DOROWA IS 160mg/l and it is within the limit of WHO standards. Water containing high solid may cause laxative or constipation effects. According to Sasikaran *et al.* (2012).

Hardness is defined as the concentration of calcium and magnesium ions expressed in terms of calcium carbonate. The presence of carbonates/ bicarbonates may cause poor lather formation and scales on boilers (Durrance 1986). Soap reacts with these minerals to form "soap scum" when hard water is boiled using home heater, it forms solid deposit of calcium carbonate, this scale can reduce the life of equipment, raise the cost of heating the water, lower the efficiency of electric water heaters and clog pipes. But hard water has some benefits too and based on the classification of hard water by WHO, sample W1 and W2 are low. The total hardness of the both waters are low compared to the WHO standard.

Pure water is not a good conductor of electric current rather a good insulator. Increase in ion concentration enhances the electrical conductivity of water. Generally, the number of dissolved solids in water determines the electrical conductivity. Electrical conductivity (EC) actually measures the ionic process of a solution that enables it to transmit current. According to WHO standards, EC value should not exceed 400 $\mu\text{S}/\text{cm}$.

The physicochemical properties of the agricultural soil and surface water which are pH., Total Dissolved Solid, Temperature, Total Hardness and Electrical Conductivity has no effect on the agricultural soil and surface water according to the result obtained in Tables 3 and 4.

Arsenic is present in surface water in Site (A) which is DB-Zang, the mean concentration is $3.0 \pm 0.5 \mu\text{g}/\text{l}$ and in a minute quantity.

Arsenic is present in agricultural soil in location (A) which is DB-Zang and in higher quantity the mean concentration is $257 \pm 120 \mu\text{g}/\text{kg}$ which is higher than the permissible limit of $40 \mu\text{g}/\text{kg}$ World Health Organization (WHO 2018).

Arsenic is present in agricultural soil in location (B) which is Dorowa the mean concentration is $14 \pm 0.7 \mu\text{g}/\text{kg}$ its lower than the permissible limit $40 \mu\text{g}/\text{kg}$ of WHO standard.

Arsenic is present in surface water in location (A) which is DOROWA the mean concentration is $48 \pm 0.7 \mu\text{g}/\text{l}$ the concentration level is higher than the permissible limit $10 \mu\text{g}/\text{l}$ of WHO standard.

5. Conclusion

This research work is based on determination of arsenic concentration in agricultural soil and surface water used for irrigation. The study revealed the presence of arsenic in soil and water to be above the permissible limit of WHO (2018). Therefore, the sites are not fit for cultivation.

Following adequate and careful comparison of results of the various analyses with the standards for World Health Organization (WHO), the following recommendations are made.

Mining and industrial activities should be discouraged in these areas because such activities expose the people around those areas to pollution i.e., the toxic metals underground to the surface and therefore serves as a source of pollution of the soil and water used for agricultural purposes.

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