Arsenic in agricultural soils and implications for sustainable agriculture

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Arsenic in agricultural soils and implications for sustainable agriculture

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Abstract: The concentration of arsenic in agricultural soils has become a global challenge. Arsenic sources in soils can be both anthropogenic and natural.Certain fertilizers can introduce arsenic into the agricultural soil. For this study, soil samples from a commercial farm in southwest Nigeria were analysed using Inductively Coupled Plasma Mass Spectrometry (ICPMS). This study indicates that arsenic concentration in the farm land is fairly normal, with some portion of the farm having higher concentration than the WHO recommended standard limits in agricultural soils. Thus, there is need for immediate intervention to reduce the arsenic concentration in the farm site as arsenic is toxic to both human and crops alike. Measures to reduce arsenic in agricultural soils have been highlighted.

Keywords: agricultural soils, arsenic, food security, management practices, soil pollution, southwest Nigeria

1. Introduction

Food security attainment has been one of the most important sustainable development goals in most developing nations. Agricultural soil serves as a storage reservoir for water and nutrients needed for plants growth. Therefore, heavy metals contaminationin agricultural soils can be harmful to normalplant's growth [1].Arsenic (As) as a toxic metalloid is mostly present in agricultural soils but have damaging effect on cells and tissues of humans when exposed at high concentration [2]. The concentration of arsenic in soils varieswith geographical regions, but the average total concentration of arsenic in soil is 5 mg/kg[3]. The common associates of arsenic are hydroxides of aluminium (Al), manganese (Mn), sulphides, oxides and iron (Fe) [4].

Several researchers have identified the major sources of arsenic in soils and this includes anthropogenic activities and natural processes [2, 5 - 7]. The anthropogenic activities that contaminate soils include unsystematic disposal of domestic and industrial wastes, massive use of pesticides,power plants that burn arsenic-rich coals,soil amendments, gold mines, cattle-dipping vats and chicken litter [2, 8, 9]. Other anthropogenic sources are sea salt sprays and volcanic eruptions[4]. Concentration of arsenic in groundwater of several nations of the world such as Argentina, Bangladesh, China, Cambodia, Netherlands and Thailandand very recently in Italy, has been reported to be on the increase[5, 10 - 13]. Agricultural soils can also be contaminated with arsenic through the use of contaminated water for crop irrigation purposes[14, 15].Table 1 shows the average concentration of arsenic in soils and water of some countries. Adverse health challenge arsenic (As) contamination has on the local population in several areas has been a major concern. This study aims at quantifying the concentration of arsenic in the soil of a commercial farm and suggests solutions to reducing the contamination effect of this element.

Table1: Soils and Groundwater Arsenic Concentration in Various Countries

Region	Types of Soil/Sediment (mg/kg)	Range	Mean	Concentration in groundwater (ug/l)
Argentina	All types	0.8 – 22.0	5	100 - 3810
Bangladesh	Sediment	9.0 – 28.0	22.1	< 10 - >1000
India	Sediment	10 – 196.0	-	0.003 - 3700
Japan	Paddy	1-2 – 38.2	9	-
Japan	All types	0.4 – 70.0	11	0.001 – 0.293
China	Al types	0.01 – 626.0	11.2	0.05 - 850
Germany	All types	2.5 – 4.6	3.5	-
France	All types	0.1 – 5.0	2	-
USA	All types	1.0 – 20.0	7.5	34 - 490

Source: Mandal and Suzuki (2002).

2. Geological Setting of the Study Area

The study area (Ota) as presented in Figure 1 is within the eastern Dahomey Basin of southwestern Nigeria. Dry season and rainy season are the two distinct climatic seasons that characterized the area. Occasional rainfall is also witnessed on the generally gently sloping study area. The rock types found in the area are Late Cretaceous to Early Tertiary [17].

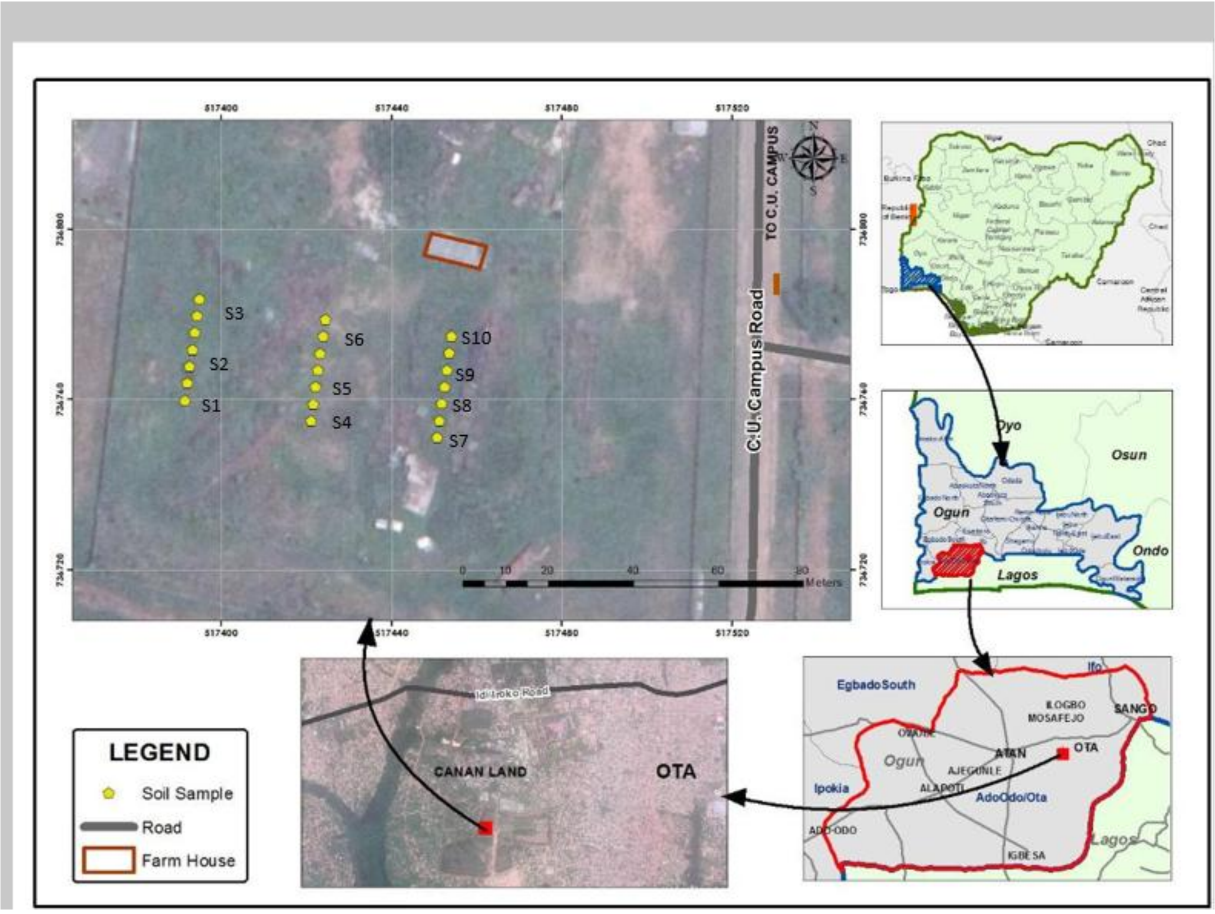

Figure1: The basemap of the study area.

3. Methodology

Ten (10) soil samples from the site at Covenant University farm werecollected at a depth of 50 cm between July and December,2018. The samples were subjected toelemental analysis at Bureau Veritas Mineral Laboratory (BVML, Vancouver, Canada). The laboratory is recognized for high-quality element content determination in different matrices [18, 19].MA250 pack of ICPMS was used for the analysis. Following the procedures of [18] the standard reference materials used for the soil analysis are STD OREAS25A-4A and STD OREAS45E. In this paper, only arsenic is presented and the measurement detection limit is 0.2 ppm. The protocol of the BVML quality assurance and control was observed as reported by [18, 19].

4. Results and Discussion

Table 2 presents the results of the analysed soil samples (S1-S10). The result indicatesthat arsenic concentration in the farm site ranges from 2.2–13.2 ppm.The measurement detection level (MDL) for arsenic using ICPMS is 0.2 ppm. The [20]standard limit for arsenic in water is 0.01 ug/l and 4.5 mg/kg (ppm)in soil based on the data of Dutch ecologist [21].All samples except S7 and S8 have values (4.6 – 13.2 mg/kg) higher than the standard limits in soil. This result indicates that arsenic concentration in the site is fairly high. Previous researchers have showed thatgroundwater in the farm site environs is free from arsenic toxicity [22]. The result of the geochemical analysis indicatesan uneven distribution of arsenic concentration in the farm site and suggests the source of arsenic concentration in the farm site as both geogenic (natural) and anthropogenic. However, anthropogenic sources include pesticides, fertilizers, soil amendments, chicken litter, cattle dipping vats and others as noted by [9].

Table 2: Results of the soil samples analysed at BVML, Canada

Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
MDL	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Soil	1	2	3	4	5	6	7	8	9	10
Values	9.3	11.6	13.2	6.5	8.1	7.4	2.3	2.2	4.6	8.9

Pesticides containing high amounts of arsenic are the major avenues for arsenic pollution in agricultural soils [23]. The dominant elements formed in soil are iron (Fe) - arsenic (As) and aluminium (Al) – arsenic complexes, butarsenic is more compatible with phosphate than Al oxides[14].

5. Implications for Sustainable Agriculture

High concentration of arsenic is toxic and therefore non-essential to plants. The damaging effects of plants root when exposed to arsenic ranged from inhibition of the root extensions to slowing the growth rate of plants [14]. Other devastating effects of arsenic include the disruption of plant's cells biochemical functions, loss of fertility in plants by reducing its reproductive capacity and reduction in the overall plant yield components [24, 25].Irrigation water contaminated with arsenic can increase arsenic concentrations in the soil, thereby reducing agricultural production, reducing crop quality and eventually leading to great economic loss. In extreme arsenic toxicity in agricultural soils, death of crops is a possible outcome as arsenic impedes the general metabolism processes of crops[26]. Several management methods for arsenic removal or reduction in agricultural soils and water have been proposed and adopted by several researchers.

6. Management Practices of Arsenic in Soils

The toxicity effects and carcinogenic tendencies of arsenic have become a worldwide concern. Therefore, management practices must be adopted in order to achieve sustainable agriculture. However, the solubility of arsenic has been linked to its toxicity in soils [27];hence, various immobilization materials have been proposed. Arsenide, arsenate and arsenite are some of the series of immobilization materials used for managing arsenic in wastewater laboratory experiments[27]. The iron donator used to investigate the immobilization and removal of arsenic is known as the ferrihydrite and the method posed efficient as about 99% of arsenic was totally removed from the waste water. However, [3, 28]have reported that intermittent flooding followed by intermittent irrigation on agricultural farmlands are promising management techniques to reduce arsenic levels and produce high yield grains on agricultural soils.

7. Conclusion and Recommendation

Arsenic contaminated groundwater used for irrigation may lead to arsenic concentration in the soil. The arsenic concentration in the soil in the site at Covenant University farm ranged from minimum to fairly high and the source is likely from pesticides and chicken litters used as part of the organic manure in the farmland. There is an urgent need to reduce the use of arsenic-based pesticides and probably adopt plant-derived organic materials in the farm to curb the spread of arsenic beyond the permissible limits in the soil of the farm area. Arsenic toxicity in agricultural soils is a global menace that needs urgent interventions. The significant damage of arsenic toxicity to human health in developing and developed nations is alarming, hence the need to curb the spreadin our soils.

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