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ORIGINAL RESEARCH ARTICLE

Determination of Heavy Metals Concentrations in Soil and Tomato Plant (*Solanum lycopersicom*) from Ajiwa *Fadama* farms, Katsina State.

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ABSTRACT
The study aimed to determine heavy metals Cu, Zn, Ni, and Pb concentration from soil and tomato plants (root stem and fruits) produced from Ajiwa Fadama farm. Tomato (*Solanum lycopersicum* L.) is a vegetable cultivated in Ajiwa fadama sites and is also commonly consumed in Katsina and Nigeria at large. Heavy metal concentrations from soil and tomato plants were determined using Atomic Absorption Spectroscopy (AAS). The results of heavy metal revealed that lead (Pb) has the highest concentration, followed by Zn, Cu and Ni as the lowest in both soil and plant parts. However, the concentration of all examined heavy metals in the soils and tomato plants was lower than the permissible values approved by FAO/WHO except for lead (Pb), which has a higher concentration above the permissible limits of 0.3 ppm. The findings of this study indicate possible exposure to lead by the consumers in the sampling area. Further studies are recommended to analyze the heavy metals of irrigation water and organic and inorganic fertilizers used.

INTRODUCTION

In many parts of the world, agricultural soils and irrigation water contain toxic heavy metals like zinc (Zn^{2+}), nickel (Ni^{2+}), cadmium (Cd^{2+}), copper (Cu^{2+}), cobalt (Co^{2+}), lead (Pb^{2+}), mercury (Hg^{2+}), arsenic (As^{2+}), and chromium (Cr^{2+}). Agricultural irrigation practices, phosphate fertilizers, applications of sewage sludge, and industrial effluent might cause this. The accumulation of harmful heavy metals in soils and agricultural products may be significantly impacted by using city wastewater for irrigation in agriculture. The accumulation of heavy metals in soils and agricultural products may be significantly impacted by using urban wastewater for irrigation (Singh *et al*., 2010; Naaz and Pandey, 2010). Because the root system has direct contact with contaminants, absorption frequently occurs in the root system, where toxins are directly transferred and absorbed into plant tissues. Animals and people are exposed to toxic heavy metals that damage plants. Above a certain threshold, toxic heavy metals become poisons that harm natural microbial populations and obstruct crucial ecological processes (Salem *et al*., 2016). It has been investigated in many research (Cu, 2015; Nazar *et al*., 2012; Aydinalp and Marinova, 2009; Mahmood *et al*., 2007; Fayiga *et al*., 2004; Rout and Das, 2003; Baccouch *et al*., 1998; Coppola *et al*., 1988) how dangerous heavy metals affect the growth of plants and microbes. Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) were used to identify toxic heavy metals in plant tissues (Psaras and Manetas, 2001; Qi *et al*., 2003; Arru *et al*., 2004; Yashvanth *et al*., 2013; Galvez *et al*., 2015).

The tomato, or *Solanum lycopersicum* L., is a fruit widely cultivated worldwide (Agrios, 2005). It originated in South America (Nonneoke, 1989), but Portuguese traders and formerly enslaved people from the West Indies brought it to West Africa (Tindall, 1988). According to John *et al.* (2010) and Bugel (2003), tomatoes are a good source of vitamins, minerals, and lycopene, a powerful antioxidant that lowers the incidence of breast and prostate cancer (Giovannucci, 1999). A total of 3,170.000 ha are used for approximately 89.8 million metric tons of output worldwide (Samuel *et al*., 2011). An annual total of one million hectares of land are utilized for tomato growing in Nigeria, Africa's second-largest producer of tomatoes (Erinle, 1989; Bodunde *et al*., 1993). According to Olayide *et al.* (2002), tomatoes comprise around 18% of Nigeria's average daily vegetable consumption. Tomatoes can be made into pastes or purses used in cooking and creating fruit drinks (Babalola *et al.* 2010).

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Plants' Heavy metal absorption varies depending on plant species and variety, soil chemical composition, heavy metal concentration, and soil pH. Plants do not readily take significant levels of heavy metals. Consuming vegetables regularly is an important human exposure pathway for heavy metal poisoning. Various chronic illnesses may develop as a result of heavy metal ingestion from contaminated vegetables. The biotoxicity of heavy metals is influenced by their content, oxidation state, source, and deposition process. Emphysema, bronchiolitis, and alveolitis are pulmonary effects of cadmium exposure (Fernandes and Henriques, 1991).

According to Gardea-Torresdey *et al.* (1996), lead intoxication results in decreased hemoglobin synthesis, dysfunction of the kidney, joint, reproductive, and cardiovascular systems, as well as long-lasting harm to the peripheral nervous system. Although some heavy metals are essential micronutrients for plants in low quantities, they can impair most plant species' growth at higher concentrations (Goyer, 1997). The toxicity of heavy metals in various crops might vary significantly (Komarek *et al.*, 2008). According to studies, some plant species that are native to soils rich in metalliferous elements may be able to withstand greater than usual concentrations of heavy metals or other toxic compounds. According to Leon *et al.* (2002), heavy metal toxicity results in the inactivation of biomolecules by either obstructing vital functional groups or displacing important metal ions.

The accumulation of toxic metals at hazardous levels in aquatic environments has become a problem of increasing concern. Excessive population of surface water could lead to health hazards in men either through drinking water or consumption of vegetables. The increasing importance of tomatoes as a source of food and the interest in understanding the accumulation of heavy metals at the tropic level of the food chain extends the focus toward the determination of heavy metals in tomato produce in Ajiwa Fadama. Heavy metals cause damage to the brain and the central nervous systems. It also causes kidney and liver damage and damage to circulatory and nerve tissues Ndinwa *et al.*, (2014). Therefore, this study aimed to determine the levels of heavy metals in various sections of tomato (*S. lycopersicum*) plant and soil collected from the Ajiwa Fadama Dam site with the following specific objectives:

(i) To determine the heavy metals in the soil from Ajiwa Fadama and

(ii) To determine the level of heavy metals in tomato root, stem, and fruits.

MATERIALS AND METHODS

Study Area

Ajiwa Fadama Dam is located in Katsina State near Batagarawa L. G. A on latitude and longitude 12°54'69" - 12°57'58" N and 7°42'53" - 7°47'50" E. It is located in Nigeria's Sudan savannah zone, which has two seasons (wet and dry). The dry season lasts from November to April, and the wet season typically lasts from May to October. The populations of Katsina, Batagarawa, Mashi, and Mani local government regions use the reservoir mostly for irrigation and water supplies. 1973 saw the reservoir's filling, and 1975 saw its opening. The Tagwai River is its main source. Its height was originally 12 meters, but following restoration in 1998, it is now 14.7 meters. The reservoir's crest length was 880 meters at the time of construction; after rehabilitation, it has grown to 1491.8 meters. Additionally, its surface area is 607.0 acres. 22.73 million cubic meters of water can be stored, according to Parkman and Haskoning (1996). The reservoir provides water to adjacent communities such as Ajiwa, Masabo, Tsagero, Kwatami, Maje, and Gajeren giwa (Usman and Yerima 2017).

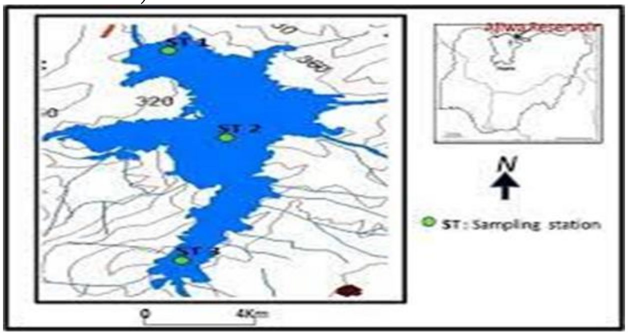

Figure 1: Map of Ajiwa Fadama showing the irrigation and sample collection site

Sample Collection

Topsoil (0-15 cm) and tomato root, stem, and fruit were collected from Ajiwa Fadama farms between August to September 2023. The samples were taken at the three random replicated plots in three different quarters. Both soil and plant samples were stored in polyethylene bags and taken to the Microbiology Laboratory of Umaru Musa Yar'adua University Katsina for further analysis. The wet soil samples were allowed to dry under sunlight and later kept at room temperature of 25^{o}C, free from moisture. The tomato root, stem, and leaves were air-dried, grinded, and sieved (Salem *et al.*, 2016).

Plant and Soil Analysis

To remove any outside heavy metals, the tomato samples were submerged in a 0.01 M HCl solution for a minute before being rinsed with deionized water. The plants were then divided into fruit, stem, and roots. They were then dried in an oven at 100 °C for 10 minutes, then at 70 °C until they were totally dry. The plants and soil samples were digested with a solution of 3:1 HNO_3:$HCLO_4$ (v/v). The concentration of heavy metals was determined using an Atomic Absorption Spectrophotometer (Agilent Technologies Model Product No: G8430A).

Determination of Metal in Soil Sample

The loamy sand texture was 99% sand and 1% silt and clay. 20g of soil were weighed into acid washed platinum crucible. 20 mL of concentrated HNO_3 was added and left for 20 minutes. 2mL each of $HClO_4$ and HCl in the ratio of 10:1 was added and left for about 10 minutes. Sample were heated in the crucible hot plate from 135–180°C and evaporated the content almost to dryness. 10mL of deionized water was added and boil gently to dissolve the residue. Cool and filter through No. 42 wattman filter paper into a 100mL volumetric flask and make to mark with deionized water. The soil extracts and the standard solutions were aspirated into the air-acetylene flame of Varian 220 (*fast sequential*) Atomic Absorption Spectrometer. A blank sample was prepared and analyzed along with the sample (Adefemi and Eyitayo 2013).

Determination of Heavy Metals in Tomato Root, Stem, and Fruits Samples

The roots stem, and fruits of two tomato plants weighed 20 grams each and were placed into two acid-washed platinum crucibles. Before adding perchloric acid, 20mL of pure HNO_3 was poured into each container, and they were instructed to sit for 20 minutes. Failure to do so could result in an explosion. 2mL of HClO4 and HCl in a 10:1 ratio were added, and the mixture was allowed to sit for around 10 minutes. The samples were heated in a crucible hot plate between 135 and 180 °C to completely evaporate the contents. 10 mL of deionized water was added and gently boiled to dissolve the residue. Cool and filter through No. 42 Wattman filter paper into a 100mL volumetric flask and make to mark with deionized water. The extract of the tomato root, stem, leaves, and standard solutions were aspirated into the air-acetylene flame of a Varian 220 (*fast sequential*) Atomic Absorption Spectrometer. A blank sample was prepared and analyzed along with the sample (Salem *et al.*, 2016).

RESULTS AND DISCUSSION

The results of four heavy metal concentrations in tomato plants and soil from Ajiwa Fadama are presented in Figure 2. The highest heavy metal concentration recorded is the lead Pb, followed by Zn, Cu, and Ni as the lowest concentration of the heavy metals analyzed. The results of heavy metals presented have shown that the concentration of all tested heavy metals in tomato fruits was below the maximum permissible value of heavy metals in food crops reported by FAO/WHO (2001). Accordingly, the maximum permissible value for Ni is 4 ppm, Cu 40 ppm, and Zn 100 ppm. The lead concentration has exceeded the maximum permissible value of Pb 0.3ppm for agricultural soil and consumption.

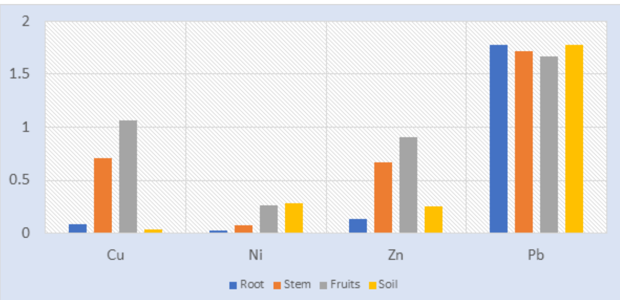

Figure 2: Concentration of heavy metal in tomato parts and soil

DISCUSSION

Through the consumption of food crops grown on these soils, heavy metal contamination of Fadama soil caused by extensive long-term fertilizer and pesticide use in food crop production has a negative impact on human health (Liu et al., 2014). Because of this, it is crucial to minimize heavy metal pollution of our farmlands. To do this, certain industrialized nations have passed laws establishing tolerance limits for heavy metal inputs (such as fertilizers and biopesticides). Farmland soil is deemed heavy metal-polluted and unsuitable for agriculture if its concentration of Cu, Ni, Zn, and Pb exceeds the limit value.

This analysis revealed that the total Pb concentration was higher than the FAO/WHO (2001) rules' limit for agricultural soil. The results back up the idea that the soil under study is polluted. The outcomes of examining heavy metals in tomato fruits stems, and roots confirm this. In particular, tomato fruits had average Cu, Ni, and Zn values of 1.06 ppm, 0.26 ppm, and 0.91 ppm, respectively. According to FAO/WHO (2001), these values are substantially lower than the maximum permitted value for food crops.

The findings of this study also demonstrated the soil and roots of a plant accumulated more of the Pb heavy metals under investigation than did the fruit. These findings align with those of Murtic *et al.* (2018), who carried out research along these lines on the distribution of heavy metals throughout the tomato plant (*Lycopersicum esculentum* Mill.) and their uptake by the plant.

According to Gomes *et al.* (2017), plants have a range of defense mechanisms to combat the negative impacts of heavy metals. By complexing metals with the organic compounds produced and released by the roots, one of the initial strategies is to stop them from taking nutrients from the soil. To stop the transmission of harmful heavy metals from the root to other sections of the plant, plants may activate various tolerance mechanisms, such as metal compartmentalization in distinct intracellular compartments or production and accumulation of numerous chemicals aiming at metal complexation. The plant's genetic makeup and growth environment are the primary determinants of strategy choice.

The findings of this study, which are related to the levels of heavy metals in the soil and how much of them accumulate in tomato plants, support the theories outlined above. The study's intriguing result was that the root of tomato plants has higher quantities of the dangerous heavy metal Pb than other plant sections.

CONCLUSION

Atomic absorption spectroscopy (AAS) was used in this work to find harmful heavy metals (Cu, Ni, Zn, and Pb) in tomato soil, roots, stems, and fruits. Pb, the most dangerous toxic heavy metal, was discovered to be the only metal that could collect in tomato roots and spread to stems and fruit. Fruits of tomato could not be found to contain any hazardous heavy metal. The findings also suggest that additional research be done to examine the harmful heavy metals present in irrigation water, including cadmium (Cd^{2+}), copper (Cu^{2+}), cobalt (Co^{2+}), mercury (Hg^{2+}), arsenic (As^{2+}), and chromium (Cr^{2+}, Cr^{2+}), as well as the usage of both organic and inorganic fertilizers.

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