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Heavy Metals on Cassava Processing and the Environmental Effects in Central Nigeria

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Research Article

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Abstract

Cassava (Manihot esculenta) has been considered one of the major sources of carbohydrate in the world. Cassava can be processed into flakes (garri), chips and Akpu. Locations and machines for the processing of cassava are also responsible for the pollution of the environment due to the constant release of heavy metals from graters, dewatering machines and automobiles. These heavy metals are capable of affecting humans, animals and ecosystems. This research was carried out in some selected cassava processing local governments namely; Lafia, Obi, Keana and Wamba in Nasarawa state, Central Nigeria. The results of this research show that heavy metals concentrations are present in the cassava processing environment. Lead was identified to be in all the local government, which is above the WHO and US standards. Nickel, copper, Cadmium, Zinc and Manganese were also identified in a traceable quantity. If this is not remediated, its accumulation could be harmful to the soil thereby affecting the entire environments. The mineral contents of Magnesium, Sodium and Potassium are significantly lower in all the local governments due to high cyanide concentration. The hydrogen cyanide concentration reduces the mineral contents and increases the acidity, which is detrimental to the soil. Heavy metal pollution is of very serious public health concern due to its persistence, toxicity and non-biodegradability in the environment. This calls for an increasing public health concern and monitoring to avert the harmful effects on plants, animals and humans which share the same food chain by detoxifying the affected environment, using Phyto-remediation methods.

Keywords: Heavy metals, Cassava processing, Environmental effects, Central Nigeria

Introduction

The presence of heavy metals in water bodies, air, soil and food has become a problem due to their harmful effects on human health even at low concentration in the environment [1]. Heavy metal pollution is one of the challenges facing human beings and it can be toxic to life [1]. The soil is described as a special habitat for plants and living things. According to Fantahu, 2013, the soil is the foremost constituent of the environment [2]. The soil also plays an economic, social and ecological role in life. Since soil is an important part of the ecosystem, it directly or indirectly affects the quality of the environment [3]. Several human activities also take place in the soil, as such, it's a fundamental asset needed for human existence [3]. More so, the soil is a land component upon which structures and buildings are erected; also for plant cultivation and supports vegetation growth. Soil is classified as an integral part of landscape due to its unique characteristics that result from the transformation of a layer of unconsolidated solid material covering the bedrock of a planet [4]. According to Kolwzan *et al*., 2006, during the formation of soil weathering, geologic materials and microbial interactions are necessary [5]. The major recipient of different waste products from industrial and agricultural activities in the soil [5]. For instance, during processing, effluents generated by the processed food are discharged into the soil through a drainage system, surface or groundwater and nearby pits. Sylvester. *et al*.,2017 reported that during the processing of oil palm, it generates effluents that drain to the soil which are capable of changing or altering the properties of the soil [6]. According to Okwute and Isu, 2007, soil already contaminated with palm oil mill effluents becomes dark brown, odiferous, damp, hummus and contains debris from the processing of palm fruit to oil [7]. Nigeria is rated as the highest, in the production of cassava in the world. In July 2018, it was reported that Nigeria produced about 53 million metric tons which is three times the production of Brazil and double the production of Indonesia and Thailand [8]. Other cassava producing countries in Africa are the Democratic Republic of Congo, Ghana, Madagascar, Mozambique, Tanzania and Uganda which appears small in comparison to Nigeria's substantial output [9]. In the classification of food, Cassava (*Manihot esculenta*) is considered as one of the major sources of carbohydrate in the world and a common and popular food processing outfit that generates several waste streams. The effluents are hardly treated, especially in a developing country like Nigeria [10]. During processing, three major streams of waste are generated including solid (peels, cassava cake), liquid (whey or cassava mill effluents) and air emission (gaseous emissions) [10]. The liquid waste known as cassava mill effluents is generated during grating and dewatering. Microbial characteristics of the soil receiving cassava effluents are always altered with regards to the soil particle size, bulk density, physicochemical properties, density, microbial diversity and porosity [11]. The potential of cassava mill effluents to impact soil characteristics could be associated with the fact that it contains cyanide which is highly lethal, fairly mobile in soil and damages microorganisms [10]. Plants growth are adversely affected as a result of Cassava mill effluents contamination on the soil [10]. The native microbiota of the soil has a high tendency to be affected by the high concentration of heavy metals, especially non-essential metals [1]. The concentration of heavy metals on the soil receiving cassava mill effluents often exceeds the regulatory advisory limits recommended by the Federal Environmental Protection Agency (FEPA) World Health Organization (WHO) and the United State Standards for all categories of effluents to be discharged into the environment (i.e. soil, surface or groundwater) [11]. Heavy metal accumulation in the soil can be remediated depending upon its concentration at different levels [13]. Phytoremediation is an aspect of bioremediation that uses plants for the treatment of polluted soils [14]. Phytoremediation of heavy metal polluted soils can be achieved via different mechanisms by using the natural ability of certain plants called hyper-accumulators to bioaccumulate, degrade, or render harmless contaminants in soils, water, or air. These mechanisms to remediate it includes phytoextraction, phytostabilization, and phytovolatilization [14]. Like the microbial and physicochemical characteristics of the soil, heavy metals concentration in cassava mill effluents has been reported in several locations in Nigeria. For instance, Igbinosa-Etinosa *et al*., 2015 reported heavy metals in cassava mill effluent contaminated soil in South-south, Nigeria [15]. Nwakaudu *et al*., 2012, reported heavy metals in cassava mill effluent contaminated soil in the part of the South Eastern state of the country [16]. This research is focused on studying the concentration and remediation of heavy metals in the soil affected by cassava processing mills effluents in Nasarawa State, Central Nigeria.

Materials and Methods

Location

Nasarawa State is centrally located in the middle belt region of Nigeria as shown in figure 1. The state lies between latitude 7o 45' and 9o 25' N of the equator and between longitude 7o and 9o 37' E of the Greenwich meridian [8]. It shares boundary with Kaduna state in the North, Plateau state in the East, Taraba and Benue state in the south while Kogi and Federal capital Territory flanks it in the West [8]. It has thirteen Local Government Areas namely Akwanga, Awe, Doma, Karu, Keana, Keffi, Kokona, Lafia, Nasarawa, Nasarawa Eggon, Obi, Toto and Wamba [8].

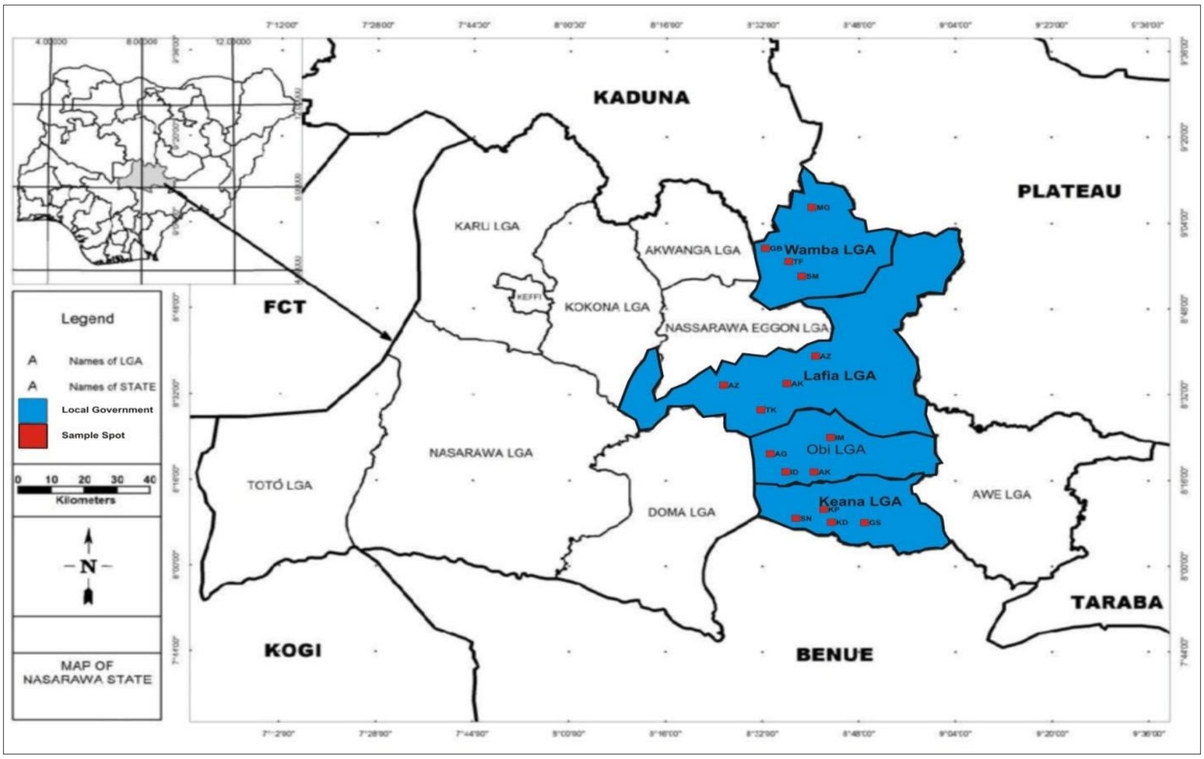

Figure 1: Map of Nasarawa State Showing the Location of the Study Area

Plate 1: A Stream connecting one of the Milling Sites.

Plate 2: Cassava Processing Milling Site

Samples Collection

Soil samples were collected from busy and popular milling sites of the state. Soil 1 and soil 2 were collected 20meters apart. Controlled samples were collected 120m from the milling sites at Lafia, Wamba, Obi and Keana Local government areas of Nasarawa State as illustrated in figure 1. In Lafia Local government, samples were collected at Angwan Nungu (AN), Tudun Kauri (TK), Azuba Bashayi (AZ) and Akurba (AK) In Wamba Local government, samples were gotten from Gbata (GB), Maraban Gongon (MG), Traffic Junction (TF) and Small London (SL) , In Obi Local Government, samples were collected at Agyaragu (AG), Akanga (AK), Imough (IM) and Idevi (ID), In Keana Local Government, samples were collected at Sarkin Noma (SN), Gidan Kpalev (GK), Gidan Sule (GS) and Kadarko (KD). A total of 3 samples of soil (soil1, soil 2 and control) were collected at each site totaling 48, and sealed using a nylon bag and was taken to the Chemistry laboratory of Benue State University, Makurdi.

Physiochemical Analyses

The analyses of heavy metals; Lead (Pb), Nickel (Ni), Copper (Cu), Cadmium (Cd), Zinc (Zn) and Manganese (Mn) were determined using the AAS (Atomic Absorption Spectrometer) by the procedure of AOAC, Sodium (Na), Magnesium(Mg) and Potassium(K) contents were determined by a flame photometer, while the cyanide concentration of soil 1, soil 2 and their control were determined using the standard addition method [17-19].

Heavy Metals	Locations			
	Lafia	Obi	Keana	Wamba
Pb	0.19875^{c}	0.47225^{ab}	0.31950^{b}	0.52410^{a}
Ni	0.10130^{c}	0.76077^{a}	0.27710^{b}	0.003575^{c}
Cu	-0.00118^{d}	0.48075^{a}	-0.02325^{b}	-0.01455^{c}
Cd	0.04125^{c}	0.40051^{a}	0.08525^{b}	0.01591^{d}
Zn	1.46025^{ab}	1.92725^{a}	1.05513^{b}	0.29197^{c}
Na	31.09025^{ab}	27.09751^{b}	33.45510^{a}	33.72120^{a}
Mg	7.77510^{b}	7.51410^{b}	9.56975^{b}	10.67051^{a}
K	1.11525^{b}	1.43175^{a}	1.46612^{a}	1.43625^{a}
Mn	0.40953^{b}	0.54825^{a}	0.45275^{b}	0.19151^{c}

Table 1: Mean Values of Heavy Metals in mg/kg or ppm in the Soil Samples of the Cassava Farms

Means bearing different superscript along the same row are significantly not different at the 5% level of Probability (P> 0.05) Level of Significance.

Cyanide	mg/kg	Control	Soil 1	Soil 2
		2.651201b	18.56131a	17.45112ab

Table 2: Mean Value of Cyanide Concentration in mg/kg in the Soil Samples

Means bearing different superscript along the same row are Significant at a 5% level of Probability (P> 0.05) Level of Significance.

Discussion

From table 1 above, the mean concentration of lead is significantly different in all the local governments with 0.19875mg/kg, 0.47225mg/kg,0.31950mg/kg and 0.52410mg/kg in Lafia, Obi, Keana and Wamba Local government cassava milling sites respectively. In all these Sites, the concentration of lead is higher than the World Health Organization (WHO) standard, where it says that the permissible concentration of lead in the soil should be 0.1mg/kg [19]. Bach et al., 1986 stated that Lead emission migrated from the combustion of leaded gasoline and Alkyl gas compound are usually used as fuel additives in large vehicles or machines to control engine knocking [20]. When lead is emitted enough into the atmosphere or the environment, it can cause lead poising. Automobile exhaust is also a potential source of lead; the environment can be highly polluted with lead when machines or mechanic activities are taking place or have taken place [21]. An investigation conducted by Kolawole in 2014 on the processing of cassava revealed that small scale cassava processor could be affected by environmental pollution by lead more than large scale processor because most milling sites grates and dewatered their cassava in the processing sites and most pollution comes from graters and dewatering machines that are usually powered by diesel/petrol engines [22]. This could be why all the milling sites in all the sampled local governments were found to have lead concentration above the standard. According to the Centre for radiation, Chemical and environmental hazard in 2011 said Lead can be found in rocky areas and can be injected into the environment through emission from mining, smelting, recycling and waste incineration [23]. The investigation has shown that Wamba local government is ranked top in the state in igneous rocks where it consists of Pegmatite [24]. This claim was observed in Wamba where it recorded the highest concentration of Lead of 0.52410mg/kg. This could be that most milling and cassava processing sites are situated on the rocky environment that releases some concentration of Lead.

Machines or vehicular components which include wires, tires, alloys, oil and brake pads release some metals like cadmium, zinc, lead, iron and copper into roadside soil and plants. There is an increasing concentration of heavy metals in urban roadside soils and plant samples due to higher traffic [25]. Though some heavy metals like Cu, Mn, and Zn are essentially required in minute quantities by organisms for normal metabolic activities. For instance, Cu and Zn are known cofactors or activators of some enzymes [26]. However, when in excess, these elements may become harmful to the environment and to organisms with associated neurological and cardiovascular impairments. Zinc and Cu as observed in Obi with 1.92725mg/kg and Lafia Local government with 1.46025mg/kg concentration of zinc in Obi Most milling or processing sites are situated by the roadsides for easy access to customers. From table 1. Cu was recorded as the highest with a value of 0.48075mg/kg in Obi; this could be due to the siting of the processing mills by the roadside in other to have easy access to buyers and the operation of dewatering and graters surrounding the cassava milling sites. In the case of Manganese, Obi has the highest value of Manganese, followed by Lafia and Keana. The maximum permissible concentration range of heavy metals according to the World Health organization for Zn, Cu, and Mn is 3mg/kg,1.5-3.0mg/Kg, 2.0-5.0mg/kg and the US recommended standards are 10-40mg/kg, 4-10mg/kg and 2.0-5.0mg/kg respectively. Comparing both WHO and US Standard, It was observed that the emissions were still below the regulatory advisory limits, but the accumulation of these metals may be deleterious to the environment with time. Nickel and Cadmium can be emitted or released into the environment due to the combustion of fossil fuels, municipal incineration and the production of iron and steel, especially non -ferrous metals [27]. With the concentration of Cadmium recorded to be 0.40051mg/kg, 0.08525mg/kg, 0.04125 and 0.01591mg/kg, Nickel concentrations to be 0.760775mg/kg, 0.27710mg/kg, 0.10130mg/kg and 0.003575mg/kg in Obi, Keana, Lafia and Wamba Local government respectively. WHO and the US recommended standards for Cadmium are 3mg/kg, and 0.01mg/kg respectively. The result shows that traceable cadmium was found to be present in the soil, if this is not remediated, its accumulation could be harmful to the soil and thereby affecting the entire environment. The standards for both WHO and US for nickel are 1.03mg/kg and 0.70mg/kg. From table 1 above, traces of nickel were found in the soil samples in all the local government and it was found to be dominant in Obi local government and some traces in the rest of the local governments and this could be dangerous to the environment. Heavy metals pollution is of serious public health concern due to their persistence, toxicity and non-biodegradability in the environment [28]. These heavy metals may be found in the atmosphere in particulate form and can be transferred to land or water surfaces by wind or precipitation [29]. These traces would definitely be harmful to the soil or water with accumulation and spread due to the transient movement of water in the soil within the region with time. The presence of high heavy metals could be a result of the high concentration of cyanide effluents in the soil as shown in Table 2. Studies have indicated the increasing presence of harmful levels of heavy metals such as lead, zinc, manganese and copper in cassava and its associated products [30]. This calls for an increasing public health concern and monitoring to avert the harmful effects on plants, animals and humans which share the same food chain.

The mineral contents Mg, Na and K in table 1 were significantly lower with concentrations of Mg to be 7.77510mg/kg, 7.51410mg/kg, 9.56975mg/kg and 10.67051mg/kg. Na with 31.09025mg/kg 27.09751mg/kg 33.45510mg/kg, and 33.72120mg/kg. K having 1.11525mg/kg,1.43175mg/kg 1.46612mg/kg and 1.43625mg/kg in all the local governments under study. As shown in table 2, cyanide concentration is high in soil 1 and 2 at a concentration level of 18.56131mg/kg 17.45112mg/kg respectively. The Canadian Council of Ministry of Environment reported in 2018 that the maximum permissible ranges of Mg, Na and K in the soil are 80-100mg/kg, 80-200mg/kg and 80-250mg/kg [31]. The hydrogen cyanide dissolves in the soil and remains there. When it dissolves in the soil, cyanogenic glycosides remain without conversion by microorganisms because of the presence of few enzymes which are not enough to complete the conversion process. The lowering in these mineral contents is detrimental to soil health and plant growth, thereby decreasing the PH of the soil and increasing the acidity of the soil. Continual application of cassava effluents may lead to changes in the physicochemical properties of the soil within the environment and the quality of water both on the surface and underground could be contaminated due to transient movement, seepage or infiltration of cyanic effluents within and around the milling site [32].

Remedy

It is advisable for strategic well-built Structures (Cassava Processing Plant) to be made available to all the cassava processing workers in Nasarawa state and Nigeria, to avoid open processing of cassava flakes. The environment should be detoxified by Phytoremediation. Phytoremediation is an aspect of bioremediation that uses plants for the treatment of polluted soils. It refers to the natural ability of certain plants called hyper-accumulators to bio accumulate, degrade, or render harmless contaminants in soils, water, or air. These can be achieved via different mechanisms which include phytoextraction, phytostabilization, and phytovolatilization. Planting of the hyper-accumulators plants do not have special planting procedures, they are planted with the normal agronomic practices unique to each plant. For heavy metals, Amaranthus (black and white seeds), pumpkin (Ugu) and Sunflower are well-known plants that can be used for the remediation of polluted soil (Hyper-accumulate). For cyanide, Bean plant (Phaseolus vulgaris) and Plantains also known as fleawort (Plantago major) may be used as plants to detoxify the concentration of cyanide in the environment. This method may be applied in all the study areas to clean up the concentration of toxic heavy metals and cyanide thereby retaining the micronutrient of the soil and also detoxifying the environment. The phytoremediation method is efficient, cost-effective, eco-friendly, and an attractive alternative to the conventional physical and chemical processes.

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