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An Analysis of Heavy Metal Contamination in the Vicinity of Cassava processing mills in Aba, Abia State

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ABSTRACT: Cassava (Manihot esculenta) is a staple crop for peasant farmers in Nigeria and other tropical African countries. Cassava milling engines release heavy metals from dewatering machines, grates, and lubricating grease, contributing to environmental pollution. These metals persist in the soil and accumulate in living organisms. This study analyzed heavy metal contamination near cassava processing mills in Aba, Abia State, Nigeria. Fifteen samples, including cassava wastewater, wastewater-contaminated soil, and pristine soil, were collected from five locations in Aba. Heavy metal presence was determined using Atomic Absorption Spectrophotometer (AAS). Metal concentrations in wastewater followed the order: Fe > Mn > Ni > Cu > Zn > As > Pb > Cd. In contaminated soil, the order was: Fe > Mn > Zn > Cu > Pb > As > Ni > Cd, while in pristine soil, it was: Fe > Zn > Mn > As > Ni > Pb > Cu > Cd. Iron levels were highest in all samples, with manganese, nickel, copper, zinc, arsenic, and lead at lower levels, and cadmium being the least. Heavy metal levels in contaminated soil were significantly higher than in pristine soil, indicating anthropogenic pollution. This accumulation is concerning due to its negative impact on the environment and human health.

KEYWORDS: Aba, Abia State, Heavy metal, *Manihot esculenta,* Wastewater

1. INTRODUCTION

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. It has evolved through weathering processes driven by biological, climatic, geologic, and topographic influences (Encyclopaedia, 2023). According to Kolwzan et al. (2006), during the formation of soil weathering, geologic materials and microbial interactions are necessary (Kolwzan et al., 2006). The major recipient of different waste products from industrial and agricultural activities is the soil (Kolwzan et al., 2006).

Soil pollution by heavy metals represents a threat to the environment and food security due to the fast growth of industry and agriculture, and the disruption of natural ecosystems by anthropogenic pressure linked to the growth of human populations (Sarwar *et al*., 2017). Heavy metals naturally occur in the environment and are vital for survival, but they may become hazardous when they accumulate in the environment. A few of the most frequent heavy metals that contaminate the environment include mercury, cadmium, arsenic, chromium, nickel, copper, and lead (Hazrat et al., 2019). The toxic principles of heavy metals have been known for decades. It can become strongly toxic by mixing with different environmental elements, such as water, soil, and air, and humans and other living organisms can be exposed to them through the food chain (Saikat et al., 2022). Although heavy metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and its use, domestic and agricultural use of metals and metal-containing compounds contributes to their presence (He et al., 2025; Herawati et al., 2000; Shallari et al., 1998). Industrial sources include metal processing in refineries, coal burning in power plants, petroleum combustion, nuclear power stations and high tension lines, plastics, textiles, microelectronics, wood preservation, paper processing plants and cassava milling plants (Arruti et al., 2010; Sträte et al., 2010; Pacyna, 1998).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 (Hazrat et al., 2019). Heavy metal pollution is one of the challenges facing human beings and it can be toxic to life (Hazrat et al., 2019).

Nigeria is involved in growing and producing many food crops. One of such crops is cassava, a starchy staple food crop which has the ability to resist drought and diseases. Cassava (*Manihot esculenta*), is a major staple crop cultivated by most peasants and smallholder farmers at the family or village level within Nigeria and other tropical African countries (Oghenejoboh et al., 2021). It is a major source of carbohydrate in tropical Africa because of its resilience to drought and its ability to grow in almost all types of soil including marginal soils (Adams et al., 2009; Coker et al., 2015; Otekunrin and Sawicka, 2019). Cassava processing generates large quantity of solid as well as large volumes of liquid wastes. Wastes generated from cassava production and processing include the leaves, stems, peels, wastewater and starch bagasse (Oghenejoboh, 2015). In Nigeria, these generated wastes are usually disposed indiscriminately into water bodies, uncompleted buildings, undeveloped plots of land, farm lands and any available open spaces along major roads and streets by farmers despite the negative impact of these wastes on both the environment and general health of the people (Nweke, 1994; Omotioma et al.,2013; Oghenejoboh, 2015). This approach causes a serious threat to the environment and a health hazard to processors and communities (Omilani et al., 2015). However, there is limited information on the extent to which cassava processing activities in Aba contribute to the buildup of heavy metals in soil and wastewater.

During cassava processing, wastewater generated by the processed food are discharged into the soil through a drainage system, surface or groundwater and nearby pits (Adamu et al., 2021). These wastewaters basically are a pale-yellow turbid liquid with an earthly but inoffensive odour. It contains large floating or suspended solids and very small solids in colloidal suspension (Oboh, 2005). Wastewater usually contain a wide variety of chemicals, debris, various microorganisms and oil and grease from the lubricated parts of the grinding machine, in addition to its normal composition of carbohydrates and organic solids which are mostly emptied on soil or carried away through special underground pipes called sewers. Cassava processing into food, feed, starch and garri generates two liquid residues. The first results from washing and peeling cassava roots, and generally contains a larger amount of inert material with low Chemical Oxygen Demand (COD); the second results from draining the starch sedimentation tank, and have high contaminating load of COD and BOD. In view of the high BOD, COD and cyanide concentration, the effluent possess a serious threat to the environment and quality of life in rural areas where the processing unit are mainly located.

Report has shown that cassava effluent contains harmful cyanide, cooper, mercury, nickel which have the capacity of affecting native micro-biota (Aiyegoro et al., 2007). Pollution from such effluent could result to a serious imbalance in the living and non-living entities of the ecosystem (Lemke et al., 1997). Most previous studies on cassava effluent have focused on general pollution effects, but very few have assessed site-specific contamination levels in Aba, a city where cassava processing is both widespread and poorly regulated. This could lead to a reduction in soil fertility. Unlike toxigenic organic matters that are susceptible to degradation, the metals that are discharged into the soil have the tendency to persist indeterminately where they accumulate in the living organisms through the food chain (Cossica et al., 2002). This study is significant because Aba serves as a major cassava processing hub, and evidence of heavy metal accumulation will be valuable for guiding environmental management and public health policies.

This has led to this research which is aimed at analysing heavy metal contamination in the vicinity of cassava processing mills in Aba, Abia State, Nigeria.

2. MATERIALS AND METHODS

2.1. Study area

This study was carried out at five cassava processing sites in Aba, Abia State, in Southeast Nigeria. The study area is located between latitude 7°21'30"E and longitude 5°3'30"N. Sample locations includes Iheorji, Iheorji Avenue, Umnogele, 16 Dike Road and Owerri Aba Road respectively. The region is renowned for year-round cassava production, which is extensively processed into garri flour. The wastewater from these milling operations is typically discharged onto nearby farmlands adjacent to the processing sites.

2.2 Collection of Sample

Fifteen samples comprising of cassava wastewater, cassava wastewater contaminated soil and pristine soil were collected from these five locations, Iheorji, Iheorji Avenue, Umuogele, 16 Dike Road and Owerri Aba in Aba, Abia State. The cassava wastewater samples were collected directly from the discharge channel into a one liter rubber containers with screw caps. The soil samples were collected using a sterile soil auger into sterile screw cap containers at a depth of 15cm so as to avoid inclusion of roots and other accumulated organic material present on the soil surface while the pristine soil were collected 100m away from the milling site where there was no indication of effluent run-off. The samples were transported to the Chemistry Laboratory of Abia State, Polytechnic, Aba, and analyzed within 24 hours of collection.

2.3 Sample preparation

The soil samples were air dried at room temperature, crushed and sieved through 2 mm sieve to remove debris and kept in a labelled plastic containers until routine analysis. Raw cassava wastewater discharge were also collected sieved through a 2mm stainless steel sieve and stored in 1 litre-plastic containers. The presence of heavy metals such as iron, lead, cadmium, arsenic, zinc, copper, nickel was determined using Atomic Absorption Spectrophotometer (ASS).

2.4 Soil-water suspension preparation

Ten grams of each dried soil sample was introduced inside a 250ml beaker, 100ml of distilled water was added and the mixture was stirred for 30 minutes with glass rod. The soil suspension was allowed to stand for one hour so as to allow most of the suspended clay to settle out of the suspension.

2.5 Determination of Heavy Metals

The heavy metals such as iron, zinc, manganese, arsenic, lead, nickel, cadmium, sodium, and copper were determined using Atomic Absorption Spectrometry (AAS) according to American Public Health Association [25]. The wastewater water and soil-water suspension was thoroughly mixed by sharking and one hundred millilitres of it measured into a 250ml beaker. The samples were digested using concentrated Nitric acid and then filtered into sample bottle for Atomic absorption spectrometer analysis. The samples were aspirated into the oxidizing air-acetylene flame. When the aqueous samples were aspirated, the absorbance was read.

3. RESULTS

The heavy metals investigated in the cassava wastewater are presented in Table 1. The iron ranged between 151.8±0.113 and 245.8±0.119 mg/l; lead, 11.23±0.045 and 48.45±0.057mg/l; cadmium, 10.11±0.090 and 31.06±0.012mg/l; arsenic, 17.77±0.112 and 61.08±0.011mg/l; zinc, 41.33±0.023 and 72.88±0.011mg/l; copper, 45.12±0.136 and 73.67±0.091mg/l; nickel, 66.22±0.068 and 93.67±0.158mg/l and manganese, 80.09±0.019 and 140.7±0.340mg/l.

Table 1: Heavy metals investigated in the cassava mill wastewater

Heavy metals	Iheorji	Iheorji Avenue	Umuogele	16Dike Road	Owerri Aba
Iron (mg/l)	230.4±0.392	189.6±0.113	167.1±0.185	151.8±0.113	245.8±0.119
Lead (mg/l)	41.28±0.317	38.18±0.011	48.45±0.057	11.23±0.045	15.56±0.114
Cadmium (mg/l)	20.56±0.181	15.11±0.023	14.32±0.034	10.11±0.090	31.06±0.012
Arsenic (mg/l)	45.25±0.396	61.08±0.011	23.44±0.068	17.77±0.112	51.89±0.118
Zinc (mg/l)	52.56±0.170	41.33±0.023	72.88±0.011	66.01±0.328	42.55±0.509
Copper (mg/l)	73.67±0.091	52.28±0.011	45.12±0.136	60.23±0.181	61.11 ±0.464
Nickel (mg/l)	93.67±0.158	72.18±0.023	66.22±0.068	80.22±0.011	69.55±0.498
Manganese (mg/l)	82.57±0.011	110.80±0.11	80.09±0.019	98.23±0.023	140.70±0.34

The heavy metals investigated in the cassava wastewater-contaminated soil are presented in Table 2. The iron ranged between 28.19±0.226 and 44.2±0.238mg/g; lead, 3.01±0.023 and 11.13±0.158 mg/g; cadmium, 2.23±0.272 and 3.25±0.260mg/g; arsenic, 6.23±0.271 and 10.26±0.022 mg/g; zinc, 8.23±0.260 and 23.11±1.007 mg/g; copper, 6.23±0.339 and 18.42±0.019 mg/g; nickel, 4.01±0.091 and 8.45±0.498 mg/g and manganese, 9.11±1.132 and 28.06±0.174 mg/g.

Table 2: Heavy metals investigated in the cassava mill wastewater-contaminated soil

Heavy metals	Iheorji	Iheorji Avenue	Umuogele	16Dike Road	Owerri Aba
Iron (mg/l)	44.2±0.238	29.05±0.037	40.12±0.249	28.19±0.226	39.23±0.871
Lead (mg/l)	3.35±0.102	3.01±0.023	4.54±0.0566	11.13±0.158	3.26±1.143
Cadmium (mg/l)	3.05±0.023	2.56±0.158	3.01 ±0.0226	2.23±0.272	3.25±0.260
Arsenic (mg/l)	10.26±0.022	7.13±0.147	9.23±0.272	6.23±0.271	10.08±0.113
Zinc (mg/l)	18.05±0.045	23.11±1.007	12.15±0.181	8.23±0.260	20.11±0.136
Copper (mg/l)	18.42±0.019	9.15±0.057	8.17±0.204	6.23±0.339	10.08±0.102
Nickel (mg/l)	5.12±0.028	5.05±0.283	4.45±0.509	4.01±0.091	8.45±0.498
Manganese (mg/l)	23.14±0.037	28.06±0.174	11.25±0.294	9.11±1.132	18.23±0.272

The heavy metals investigated in the pristine soil are presented in Table 3. The iron ranged between 18.56±0.079 and 37.15±0.181mg/g; lead, 1.05±0.079 and 4.89±0.339mg/g; cadmium, 0.92±0.249 and 2.34±0.385mg/g; arsenic, 1.05±0.0792 and 7.58±0.226 mg/g; zinc, 11.11±0.136 and 20.41±0.430mg/g; copper, 1.49±0.124 and 3.01±0.0905 mg/g; nickel, 3.45±0.521 and 6.05±0.0679 mg/g and manganese, 4.25±0.294 and 11.23±0.260mg/g.

Table 3: Heavy metals investigated in the pristine soil

Heavy metals	Iheorji	Iheorji Avenue	Umuogele	16Dike Road	Owerri Aba
Iron (mg/l)	37.15±0.181	20.05±0.068	30.56±0.136	18.56±0.079	27.18±0.215
Lead (mg/l)	2.56±0.487	2.21±0.238	3.01±0.0226	4.89±0.339	1.05±0.079
Cadmium (mg/l)	0.92 ±0.249	1.15±0.170	2.34±0.385	1.22±0.249	1.97 ±0.023
Arsenic (mg/l)	7.58±0.226	4.14±0.0453	5.31±0.351	1.05±0.0792	3.56±0.226
Zinc (mg/l)	16.17±0.204	20.41±0.430	13.35±0.17	11.11±0.136	19.66±0.385
Copper (mg/l)	2.54±0.521	2.05±0.0679	2.23±0.147	1.49±0.124	3.01±0.091
Nickel (mg/l)	4.01±0.023	4.23±0.222	4.02±0.0339	3.45±0.521	6.05±0.068
Manganese (mg/l)	11.23±0.260	6.55±0.124	5.55±0.634	4.25±0.294	6.01±0.023

4. DISCUSSION

The results of the heavy metals analysis showed that the heavy metals concentrations were generally higher in the cassava mill wastewater and the cassava wastewater-contaminated soil than the pristine soil. This high level of metals in the wastewater contaminated soil is expected since the contaminated soil is the point of contact for the wastewater. The heavy metal levels for all the sites were significantly higher than the levels observed in the pristine soil. This can lead to pollution which is a potential source of hazards to humans and the entire ecosystem. It also implied that the pollution level of the cassava mill wastewater was anthropogenic visa-vis the discharge of the cassava mill effluent (Atulegwu and Nnamdi, 2011). This result agreed with the finding of Osakwe (Osakwe and Akpoveta, 2012), who reported that the heavy metal levels for all the sites were significantly higher than the levels observed in the control sites for the soil studied in Abraka and Environs, Detal State. This implied that the soils receiving cassava mill effluent had some levels of heavy metal enrichments (Osakwe and Akpoveta, 2012).

The iron (Fe) content of the cassava mill wastewater ranged from 115.80±0.113 – 245.80±0.119 mg/l while that of the cassava mill wastewater-contaminated soil ranged from 28.19±0.226 – 44.2±0.238 mg/g. The pristine soil contained iron that ranged from 18.56±0.079 – 37.15±0.181 mg/g (Tables 1 – 3). The raw cassava mill wastewater discharge and raw cassava mill wastewater-contaminated soil had higher iron than the pristine soil. It has been confirmed that natural soils contain significant concentration of iron (Aluko and Oluwande, 2003) and since the levels of iron in the wastewater-contaminated soil is higher than the levels in in the pristine soil, the cassava mill wastewater might have contributed to the increased levels of iron in the soils studied. This finding agreed with the work of Osakwe (Osakwe and Akpoveta, 2012), who reported that the levels of iron at the impacted point was at the range of 139.28 mg/kg and was higher than the level in control sites which was at the range of 85.20 mg/kg. High Fe concentrations can cause a toxic effect on some organs such as the skin and a trivial and hemosiderotic harmful effect on other organs as the liver can be affected (Jaishankar *et al*., 2014).

The lead (Pb) content of the cassava mill wastewater ranged from 11.23±0.045 – 48.45±0.057 mg/l. The cassava mill wastewater-contaminated soil had lead values that ranged from 3.01±0.023 – 11.13±0.158 mg/g while that of the pristine soil ranged from 1.05±0.079 – 4.89±0.339 mg/g (Tables 1-3). The raw cassava mill wastewater had higher lead than the cassava mill wastewater-contaminated soil and pristine soil. This result agreed with the work of Obueh and Odesiri-Eruteyan (2016) that reported lead at the range of 0.98±0.05 mg/l for effluent from waste pit, polluted soil at the range of 0.52 ± 0.01 mg/l and control soil at the range of 0.01 ± 0.00 mg/l. An investigation conducted by Oladele (2014) on the processing of cassava revealed that small scale cassava processor could be affected by environmental pollution by lead more than large scale processing because most milling sites grate and dewater their cassava in the processing sites and most pollution comes from graters and dewatering machines that are usually powered by diesel/petrol engines. Pb has a toxic effect on multiple body systems and is particularly harmful to young children (Sharma et al., 2016). High uptake of Pb is distributed to the brain, liver, kidney and bones. A higher concentration of Pb may cause a blood disorder anaemia in human by decreasing the time of reaction in human being (Ekeanyanwu et al., 2020). From an environmental perspective, Fe and Pb are the most common existing heavy metals in the soil and water of urban area (Rahman and Singh, 2019).

The cadmium level of the cassava mill wastewater ranged from 10.11±0.090 – 31.06±0.012 mg/l while the cassava mill wastewater-contaminated soil had cadmium levels that ranged from 2.23±0.272 – 3.25±0.260 mg/g and the pristine soil ranged from 0.92±0.249 – 2.34±0.385 mg/g (Tables 1-3). The cassava mill wastewater and the cassava mill wastewater-contaminated soil had a higher cadmium level than the pristine soil. This conformed to the work of Osakwe and Akpoveta (2012) that reported cadmium from the contaminated top soil at the range of 0.006 mg/kg and the control at the range of 0.001 mg/kg for the soils in Abraka and Environs, Delta State, Nigeria. Cadmium is a "modern metal" that has been used increasingly in corrosion prevention (Alloway, 2000). It is often used instead of zinc for galvanizing iron and steel (Osakwe and Akpoveta, 2012). Cadmium is released into the environment through natural activities such as volcanic eruptions, weathering, river transport and some human activities such as mining, smelting, tobacco smoking, incineration of municipal waste, and manufacture of fertilizers. It is highly toxic to the kidney and it accumulates in the proximal tubular cells in higher concentrations. Cadmium can cause bone mineralization either through bone damage or by renal dysfunction (Bernard, 2008).

Arsenic contaminations have occurred as a result of both natural geologic processes and the activities of man. Anthropogenic sources of arsenic include human activities such as mining and processing of ores. The smelting process, both the ancient and a recent one, can release arsenic to the air and soil (Matschullat, 2000).). Most of the paints, dyes, soaps, metals, semi-conductors and drugs contain arsenic. Certain pesticides, fertilizers and animal feeding operations also release arsenic to the environment in higher amounts. The inorganic forms of arsenic such as arsenite and arsenate are found to be more dangerous to human health. They are highly carcinogenic and can cause cancer of lungs, liver, bladder and skin.

Humans are exposed to arsenic by means of air, food and water. The arsenic content of the cassava mill wastewater ranged from 17.77±0.112 – 61.08±0.011 mg/l. The cassava mill wastewater-contaminated soil had arsenic values that ranged from 6.23±0.271 – 10.26±0.022 mg/g while that of the pristine soil ranged from 1.05±0.0792 – 7.58±0.226 mg/g (Tables 1-3). The cassava mill wastewater had higher arsenic level than cassava mill wastewater-contaminated soil and the pristine soil. Arsenic from this study was higher than the values (0.01 mg/kg) reported by Gabriel *et al*. (2014). Soil may get contaminated through improperly disposed arsenical chemicals, arsenical pesticides or by natural mineral deposits.

Arsenic toxicity can be either acute or chronic and chronic arsenic toxicity is termed as arsenicosis. Most of the reports of chronic arsenic toxicity in man focus on skin manifestations because of its specificity in diagnosis. Pigmentation and keratosis are the specific skin lesions that indicate chronic arsenic toxicity (Martin and Griswold, 2009). Lower levels of arsenic exposure can cause nausea and vomiting, reduced production of erythrocytes and leukocytes, abnormal heart beat, pricking sensation in hands and legs, and damage to blood vessels. Long-term exposure can lead to the formation of skin lesions, internal cancers, neurological problems, pulmonary disease, peripheral vascular disease, hypertension and cardiovascular disease and diabetes mellitus (Smith et al., 2000). Chronic arsenicosis results in many irreversible changes in the vital organs and the mortality rate is higher. In spite of the magnitude of this potentially lethal toxicity, there is no effective treatment for this disease (Mazumder, 2008).

The zinc level of the cassava mill wastewater ranged from 41.33±0.023 – 72.88±0.011 mg/l while that of the cassava mill wastewater-contaminated soil ranged from 8.23±0.260 – 23.11±1.007 mg/g. The pristine soil had zinc level that ranged from 11.11±0.136 – 20.41±0.430 mg/g (Tables 1-3). The cassava mill wastewater had higher zinc levels than the cassava mill wastewater-contaminated soil and the pristine soil. Presence of zinc could be attributed to corrosion of metal parts of the milling machine (Osakwe and Akpoveta, 2012). Zinc is also a component of crude oil and machine exhaust (Adrian, 2001). Izah *et al*. (2018), however reported zinc from cassava mill effluent at the range of 1.07 mg/l while Agbo *et al*. (2019) recorded zinc values for the cassava mill effluent at the range of 10.17±0.00 mg/l, impacted soil at 11.13±0.01 mg/g and un-impacted soil at 9.76±0.01 mg/l.

The copper level of the cassava mill wastewater ranged from 45.12±0.136 – 73.67±0.091 mg/l while that of the cassava mill wastewater-contaminated soil ranged from 6.23±0.339 – 18.42±0.019 mg/g. The copper level of the pristine soil ranged from 1.49±0.124 – 3.01±0.091 mg/g (Tables 1-3). The cassava mill wastewater had higher copper level than cassava mill wastewater-contaminated soil and the pristine soil. Izah *et al*. (2018) reported copper for cassava mill effluent at the range of 1.83 mg/l while Agbo *et al*. (2019), recorded copper values for the cassava mill effluent at the range of 29.34±0.01 mg/l, impacted soil at 14.73±0.01 mg/g and un-impacted soil at 8.40±0.01 mg/g .Variations in the findings of this study with previous works could be due to difference in geological formation as well as prevailing anthropogenic activities in the mills. Copper is a component of bronze and brass and is used as a corrosive resistant and decorating painting in machine (Osakwe and Akpoveta, 2012). It has been reported that high values of copper could result in chronic anemia (Iqbal et al., 2020).

The nickel (Ni) content of the cassava mill wastewater ranged from 66.22±0.068 – 93.67±0.158 mg/l. The cassava mill wastewater-contaminated soil had nickel content that ranged from 4.01±0.091 – 8.45±0.498 mg/g while that of the pristine soil ranged from 3.45±0.521 – 6.05±0.068 mg/g (Tables 1-3). The cassava mill wastewater and cassava mill wastewater-contaminate soil had higher nickel content than the pristine soil. This could have been influenced by soil (soil type and soil pH which has been made acidic by pollution). Agbo *et al*. (2019), recorded nickel values for the cassava mill effluent at the range of 1.75±0.00 mg/l, impacted soil at 0.68±0.00 mg/g and un-impacted soil at 0.66±0.0 mg/g. 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 (Jianbo et al., 2020).

Ni impacts the central nervous and digestive system at high concentrations (Khan et al., 2008). Even lower concentration of heavy metals are considered very toxic for living organisms (Human, animal, aquatic organisms, microorganisms etc.) because many metals slowly accumulate in human tissue. Intake of heavy metals either by food or water increased the concentration of metals and caused severe itching and irritation in the stomach and resulted in diarrhoea and vomiting (Khan et al., 2013).

The manganese values of the cassava mill wastewater ranged from 80.09±0.019 – 140.70±0.34 mg/l while those of the cassava mill wastewater-contaminated soil ranged from 9.11±1.132 – 28.06±0.174 mg/g. The pristine soil had manganese values that ranged from 4.25±0.294 – 11.23±0.260 mg/g (Tables 1-3). The cassava mill wastewater had higher manganese than the cassava mill wastewater-contaminated soil and pristine soil. This could be attributed to worn out of metals from the milling machine. Iwegbue *et al*. (2013), carried out an assessment of heavy metal contamination in soils around cassava processing mills in sub-urban areas of Delta and reported manganese within the range of 0.1 and 383.2 mg kg^{-1}. The abundance of manganese in the cassava mill effluent could also be attributed to wears and tears of the machinery part (Osakwe and Akpoveta, 2012). Manganese is a very essential trace heavy metal for plants and animals' growth. Its deficiency produces severe skeletal and reproductive abnormalities in mammals. High concentration of manganese (Mn) causes hazardous effects on lungs and brains of humans (Jarup, 2003). Manganese toxicity is a relatively common problem compared to other micronutrient toxicity. It normally is associated with soils of pH 5.5 or lower, but can occur whenever the soil pH is below 6.0 (Oladebeye, 2017). Manganese ions function as cofactors for a number of enzymes in higher organisms, where they are essential in detoxification of superoxide free radicals. It is also a required essential trace nutrient for all known living organisms. In larger amounts, it can cause a poisoning syndrome in man, with neurological damage which is sometimes irreversible (Law and Caudle, 2008). Human body (Emsley, 2001) contains about 10 mg of manganese, which is stored mainly in the liver and kidneys. In the human brain, the manganese is bound to manganese metalloproteins most notably glutamine synthetase in astrocytes (Encyclopedia, 2023).

Data analysis (Appendix 1) showed that the cassava effluent, effluent polluted soil and unpolluted soil had significant ($P < 0.05$) effects on the iron, lead, cadmium, arsenic, zinc, copper and manganese.

Heavy metals are considered toxic to humans and animals even at quite low concentration. Drinking water or eating foodstuff containing a high level of these metals can cause any number of health implications including severe stomach irritation, diarrhea and vomiting (Takeda, 2003). At higher doses, anemia can occur (Mahfooz et al., 2019). Even if heavy metal concentrations (Cd, Cr and Ni) are below the permissible limits for industrial effluents discharge, these toxins present both acute and chronic toxicity problems for humans (Afzal et al., 2014). Children are especially vulnerable to heavy metal poisoning due to the chronic/continued effects of long-term exposure.

Some of these heavy metals have the tendency to persist in the environment for a long time (Iqbal et al., 2011) as they have low degradation potential, 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 (Izah and Angaye, 2016). However, when in excess, these elements may become harmful to the environment and to organisms with associated neurological and cardiovascular impairments. Heavy metals pollution is of serious public health concern due to their persistence, toxicity and non-biodegradability in the environment (Nematshah et al., 2012). 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 (Adelekan and Sbegunde, 2011). 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. 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 (Shrivaster, 2011).

5. CONCLUSION

The comprehensive analysis of cassava mill wastewater and its impact on the environment in Aba, Abia State shows high levels of heavy metal pollution, particularly in the wastewater and contaminated soil. The concentrations of heavy metals such as iron, lead, cadmium, arsenic, zinc, copper, nickel, and manganese can pose threats to human health and the ecosystem.

The study highlights the anthropogenic origin of heavy metal pollution, primarily attributed to the discharge of cassava mill effluent. The high levels of heavy metals observed in the contaminated soil emphasizes its role as a direct recipient of wastewater runoff, exacerbating the pollution levels in the vicinity of cassava milling sites. Of particular concern are the toxic effects associated with heavy metal exposure, ranging from skin disorders to organ damage and systemic health issues. Lead, cadmium, arsenic, and nickel, in particular, pose significant risks to human health, with potential long-term implications such as anemia, neurological disorders, cardiovascular impairments, and even cancer.

Furthermore, the persistence of heavy metals in the environment exacerbates the problem, as they have low degradation potential and can accumulate over time, posing ongoing risks to soil and water quality. The findings of this study indicate the urgent need for effective environmental management strategies and regulatory measures to mitigate heavy metal pollution from cassava milling activities. Addressing this issue is crucial not only for safeguarding human health but also for preserving the integrity of the ecosystem in Aba, Abia State, and beyond.

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