Assessment Of Environmental Degradation Due To Processing Of Cassava Into Garri Flakes

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Abstract

The processing of cassava into garri is a multi-staged process that generates a large amount of effluent. This study was aimed at determining the impact of cassava processing into garri on the environment in Nsukka Metropolis. The soil, wastewater and sludge samples were collected from four different locations and subjected to physico-chemical analysis. The results obtained were subjected to descriptive statistical analysis and estimation of various measures of pollution indices. A detailed sanitary study of the processing plants was undertaken to ascertain their immediate and remote environmental impacts. The concentrations of hydrogen cyanide, total suspended solids and electrical conductivity were above the FEPA permissible limit and ranged from 8.6-42.8, 11900-40800 mg/l and 4006-5240 $\mu\text{S}/\text{cm}$ respectively. Arsenic and mercury were above the FEPA permissible limit while the remaining heavy metals were within the permissible limits. Identified impacts from garri processing are: soil loss, litter generation, air pollution, water pollution, greenhouse gas emission, water demand and energy demand. The average pollution load index of the recipient soils ranged from moderately polluted (2.48) to highly polluted (4.56). Nemerow's pollution index (NPI) indicated that soil samples from three of the locations were severely polluted (>3.0), while one was moderately polluted ($2 < \text{PI} < 3$). The geoaccumulation indices ranged from -0.03 (uncontaminated) to 2.59 (heavy contamination). The values of E_r ranged from 5.63 to 91.8 for all metals investigated. The order of ecological risk of various metals based on their average values was: $\text{As} > \text{Cd} > \text{Cu} > \text{Cr} > \text{Pb} > \text{Ni}$ with corresponding ecological risk values of 50.63 (moderate risk), 34.43 (low risk), 15.93 (low risk), 10.51 (low risk), 8.93 (low risk) and 5.63 (low risk).

Introduction

The wide range of climate variation in Nigeria enables the production of various food and cash crops such as maize, cassava, guinea corn, yam etc. Cassava (*Manihot esculenta*), known to be a major source of carbohydrate is one of the main staple crops cultivated in Nigeria. It is mostly cultivated by small scale or peasant farmers in tropical African countries and readily available for the poor. Its readily availability is due the resilient characteristics it poses during drought season and the capacity to have a favorable growth in most kinds of soil including marginal soils (Otekunrin, et al., 2019; Coker, et al., 2015). In the year 2018, cassava production hit 278 million tonnes globally as Nigeria emerged 21% of the world data as the largest producer of cassava (Olaoye, et al., 2020). Cassava can be further processed into flakes (garri), fermented cooked paste (fufu), kpokpo-garri flakes (tapioca) etc that are of high calorific values (Coker, et al., 2015). However, garri accounts for about 70% of cassava consumption in Nigeria and millions of persons in West Africa, being a staple food eaten by the rich and poor alike (Ezeh, et al., 2012). Garri can be produced at subsistence level using manual methods or on a commercial scale by a fully mechanized process. Regardless of the method of production or level of mechanization, garri production some significant environmental impact at the during and post- processing.

Garri production results in the emission of gaseous, liquid and solid substances that cause environmental degradation. Wastes such as leaves, peels, wastewater and sludge are majorly generated during the production and processing of cassava (Oghenejoboh, 2015) These generated wastes are uncontrollably

deposited in open areas and undeveloped plot of land by farmers notwithstanding the negative impact they may have on public health and the environment (Omotioma, et al., 2013; Oghenejoboh, 2015). Its uncontrollable deposition also causes serious menace to the aquatic lives (Olaoye, et al., 2020). The knowledge gap on the impact of cassava waste to the environment by smallholders' farmers and also with ineffective waste management policies in Nigeria has made cassava waste management difficult (FAO, 2020). Studies have shown that the idea of sensitizing peasant farmers whose sole objective is to cater food and income for the family on effective cassava waste management is quite overwhelming and above their capability (Omalani, et al., 2019).

However, the capability of sustaining proper waste management system has been a major concern. While developed countries inch closer and closer to sustainable environmental sanitation through cleaner production and strategic waste management, many developing countries are gradually being turned into refuse dumps. For instance, in Nigeria, it is common to see heaps of waste dumped in an open space or a plot of land yet to be developed (Oghenejoboh, et al., 2017; Ideriah, et al., 2010). Poor solid waste management has severe implications for water resources and other aspects of the environment. Specifically, various kinds of cassava wastewater have been indicted for surface water pollution in some rural parts of Nigeria. Environmental pollution from cassava wastewater deserves some serious attention because of the high level of toxicity associated with cassava effluents. The risk posed by this hazard to the environment can be due to the release of various highly toxic substances such as heavy metals and high cyanide into the immediate environment during processing. (Olaoye, et al., 2018; Gomes, et al., 2016).

The processing of cassava into garri is done in the study area using a semi-mechanical method which entails manual peeling, sieving and frying; and mechanical crushing and dewatering. The unit operations are standalone, disconnected stages that do not allow for integrated management of waste fractions generated in the process. As a result of this, waste fractions from the various unit operations escape into the surrounding environment, thereby causing adverse impacts. Further to this, effluent wastewater streams are deliberately discharged into the surrounding environment without any form of treatment. Given that these plants are located in sub-urban sections of the municipality where drains are not available, the operators of these plants conveniently discharge the effluents on adjoining bushes and farmlands. The cumulative and long term impact of this practice constitutes a source of concern and therefore deserves scientific scrutiny.

Materials And Methods

Sample Collection and Laboratory Analyses

Four cassava processing plants were selected for this study based on the high amount of generated and disposal of cassava waste. The plants are located at Ogurugu road Nuskka (A), Justina Eze street Nuskka (B), Agbami Nuskka-Onitsha road (C) and Nguru Road Nkpnnano, Nuskka (D) (Table 1). Wastewater and sludge samples were collected for investigation of major pollutants present in them,

while soil samples were collected to investigate the impact of cassava processing effluents on the receiving environment. Soil samples were collected with hand trowel and then put in well labeled and tightly covered 100ml containers. The sample collection was done at depth between 0-0.40 m (surface). Subsequently, the samples were transported to the National Center for Energy Development (NCED), University of Nigeria Nsukka for physic-chemical analyses.

Table 1. Details of Cassava processing plants investigated

At the laboratory the pH of the different samples were measured using Jenway pH meter with model 3510. Buffer solution of pH 7 was used in the standardization of the pH meter. Conductivity meter (model LF.90) was used to determine the conductivity of the wastewater which was standardized using 0.01M KCl solution. Meanwhile, the determination of total solids was achieved using Meynell (Meynell, 1982) technique by oven-drying 5g of the sample for 5 hours at 105°C. This was then followed by the cooling of the dried sample in a dessicator and then weighed. On the other hand, the total suspended solids (TSS) was determined by weighing about 20 ml of sample and filtered after weighing the filter paper. The filter paper is then weighed after being oven dried and cooled in a dessicator. The processes were continued until a constant weight was achieved. Heavy metals concentrations (Pb, Cu, Cd, As, Hg, Cr and Ni) in the soil, wastewater and sludge samples was determined using de-ionized water, 3 M HNO₃, distilled water (double), Atomic Adsorption Spectrometer model (AA-7000 Shimadzu, Japan ROM version 1.01, S/N A30664700709) following standard methods.

Assessment of Environmental Impact

In order to unveil the environmental impact of cassava processing and resultant discharge of effluents in the study area, soil samples from the immediate vicinity of the processing plants were collected and sent to the laboratory for determination of heavy metals contents. The samples were collected from the soil at a depth between 0 and 40cm. Heavy metal contents of the soil samples were extracted with ammonium acetate buffer solution and then analysed using atomic absorption spectrophotometer (AA-7000 Shimadzu, Japan ROM version 1.01, S/N A30664700709). The results of heavy metal analysis were subjected to descriptive statistical analysis and analyses of contamination status using standard pollution measures such as pollution index, modified degree of contamination, pollution load index, geo-accumulation index, ecological risk and Nemerow pollution index as described in Table 2.

Table 2: Summary of measures of pollution employed

C_i = concentration of individual metal at a selected site; C_{ib} = background concentration of individual metals in the study area; n = number of metals investigated; T_i = Hakanson’s toxicity factor for individual metal. T_i = 10 for As, 2 for Cr, 5 for Cu, 1 for Mn, 5 for Ni, 5 for Pb, 1 for Zn, 30 for Cd and 10 for Hg.

Results And Discussions

The Physico-Chemical Status of Impacted Environment

One of the most important indicators of the chemical disposition of wastewater and its potential to cause environmental damage is the pH. The pH of cassava wastewater, cassava sludge and impacted soils ranged from 6.6 – 6.9, 6.6 – 6.7 and 8.0 – 11.9 respectively (Table 2). The determined pH values are not within the FEPA permissible limit of effluent discharge ((FEPA), 1991). The pH of cassava of freshly collected cassava wastewater from the study area ranged from 3.8 to 4.3 which indicate a very acidic condition induced by the presence of hydrogen cyanide a conjugate acid released by the decomposition of cyanogenic glycosides - linamarin and lotaustralin (Priya, et al., 2011). The low pH of cassava wastewater will cause damage to plants and other flora and fauna when disposed on land without appropriate treatment to conform to effluent standards. This does not agree with the optimal range of soil pH stated between 6.5 and 7.5 (Anon, 2004b). Acidic condition can also interfere with treatment processes hence the need for adjustment of pH using strong alkaline such as NaOH in order to render it amenable to biochemical treatment. It has been reported that optimal adsorption of cyanide from cassava wastewater occurs at a pH of 10 (Akpan, et al., 2019). It has been reported that hydrogen cyanide inhibits the activities of methanogens and that three days of acclimatization might be required for cyanide concentration up to 10mg/L (Glapracha, et al., 2018). When left to stand for one month, the pH of cassava wastewater obtained from two plants increased steadily from 3.79 and 4.29 to 9.24 and 9.72 respectively. Samples from the other two plants increased only slightly from 3.8 and 4.0 to 4.0 and 4.36 respectively. The increase in pH over time can partly be attributed to the escape of hydrogen cyanide from cassava wastewater when exposed to the atmosphere. Microorganisms such as *Fusarium Solani* and *Pseudomonas Fluoresens* that use ferrocyanide as a source of nitrogen and carbon can also decompose hydrogen cyanide. Therefore, maintaining proper pH of the soil is essential since it tends to determine the nutrient uptake in the soil. The acidic properties of the soil can also be linked to the presence of high hydrocarbon cyanide content. In forest and savannah region, the pH range that favours the growth of plant and microorganisms is 5.70-6.50 (Banjoko, et al., 1994). However, low soil pH less than 6.0 enables and raises the exchangeability of aluminum which is highly toxic to crops.

Figure 1.pH of wastewater at four different locations.

The hydrogen cyanide content in the collected cassava wastewater sample from different locations ranged from 8.6 to 42.8mg/L. Report has been made that 85% to 90% of cyanide are lost during the process of oven drying at 65°C and there is about 56% of cyanide loss from sun drying (Cooke, et al., 1978). Therefore, the amount of cyanide in cassava is unusually high when compared with the concentrations of total cyanoglucosides in cassava wastewater which ranged between 10.4 to 274mg/L (Balagopalan, et al., 1998).

Table 3. Descriptive statistics of the monitored physicochemical parameters and heavy metals

The electrical conductivity of cassava wastewater in the sample areas ranged from 4006µS/cm to 5240µS/cm. This is within the range reported in literature. The total suspended solid (TSS) ranged from 11900 mg/l to 40800 mg/l. This is above the FEPA permissible limit for TSS. According to Ehiagbonare et al. (Ehiagbonare, et al., 2009), TSS increases the absorption of heat from the sun in the wastewater

thereby increasing its temperature. It also influences the turbidity of wastewater which prevents the penetration of sunlight when discharged in a given water body, thus impacting negatively on the aquatic lives in the water.

The concentration of heavy metals in samples generally exceeded the effluent discharge guidelines for the heavy metals investigated except copper. The concentration of copper in the different samples (sludge, wastewater and soil) ranged from 0 to 0.194 ppm across the various locations which are less than the permissible limit for effluent discharge. Among the samples, sludge has the least concentration of copper. In this study, the concentration of copper in the contaminated soil displayed slight deviation from the values reported by other authors. This study shows that the concentration of copper in the soil ranged from 0.1293 to 0.194 ppm. Concentrations of copper reported by other researchers ranged from 0.146 to 2.90 ppm (Nwakaudu, 2012; Osakwe, 2012; Igbinosa, et al., 2015). Cadmium concentration in the different samples of this study ranged from 0 to 0.1429 ppm. The concentration of cadmium in the sludge was found to be higher than the concentration in wastewater and soil. The low level of contamination of cadmium in the soil has been found to be of similar range with previous studies. Cadmium values of 0.012 ppm and 0.006-0.04 ppm have been reported (Osakwe, 2012; Nwaugo VO et al., 2008). Notably, cadmium as well as other heavy metals is one of the additives in lubricating oil used for lubricating processing machine parts. The level of concentration of chromium in the samples ranged from 0 to 0.233 ppm. Cassava wastewater has higher chromium concentration than sludge and Chromium concentration in the soil exhibits some level of disparity with previous works (Osakwe, 2012; Nwaugo VO et al., 2008).

The concentration of Nickel in the samples ranged from 0 to 0.8205 ppm at various locations. Sludge has the maximum concentration of nickel followed by soil with 0.8205 ppm and 0.5128 ppm respectively. Mercury is a naturally occurring metal which has a silver white, odourless liquid but becomes colourless and odourless gas when heated. Mercury concentration of the different samples in this study ranges from 0 to 6.0 ppm which is associated with the degree of anthropogenic activities. This range is way high above the permissible limit of 0.001 ppm for effluent discharge into the environment. The Arsenic concentration in the different samples of this study ranged from 0.9032 to 8.5806 ppm which is above the 0.1 permissible limit of effluent discharge. This implies that the effluent and soil in the various locations are highly polluted with arsenic. The concentration of arsenic was found to be the highest in the sludge sample and lowest in the wastewater with 8.5806 ppm and 0.9032 ppm respectively. This implies that the samples are all above the permissible limit of effluent discharge for arsenic concentration. At low concentration, arsenic has a high adverse effect on the environment and that of public health. The fermentation period and human anthropogenic activities tend to affect the arsenic concentration in the various locations.

Impact Assessment Of Cassava Processing Into Garri In The Environment

The processing of cassava into garri involves the following operations; peeling, washing, grating, dewatering /pressing, fermentation, sieving and roasting/frying. The process material sequence is shown

in Figure 2. The first stage in the processing of cassava into garri after harvesting involves peeling to remove the outer brown skin and inner thick cream layer. This process generates large amounts of solid waste whose management constitute a problem to the environment (Figure 3). Considering that about 20 – 35% of cassava tube consists of peels (Oghenejoboh, et al., 2021), the dimensions of the problem it creates can better be envisaged. This situation introduces a complicating dynamics to the already overwhelming burden of solid waste management in Nigeria. On an annual basis, between 11 and 20 million metric tons of cassava peels are generated from about 59.5 million metric tons of cassava produced annually. Added to this is the potential of leaching of toxic substances such as heavy metals and cyanide from the cassava peels into surrounding soils and water bodies. After peeling, the cassava tubers are then washed to remove stains and dirt, and then crushed/grated to reduce the particle size to smaller particles for ease of dewatering and further processing. This process can be achieved manually or mechanically. The crushing of the cassava tubers causes rupture of cells and releases some of cyanogenic glucosides into the liquid phase. The moisture-laden cassava pulp is then subjected to dewatering in a filter press. Cassava roots are high in moisture content (60 – 70% on wet basis) most of which (40 – 50%) are lost during dewatering (Dahdou, et al., 2020). It has been reported that 90% of the total cyanogens present in cassava tubers were removed during fermentation and that one-third of the original linamarin were found in the water (Montagnac, et al., 2009). In most cases, the wastewater effluent from the dewatering process is freely discharged into the environment without any form of treatment, thus negatively impacting on soil and water resources. An estimated 20 million tons of cassava wastewater is produced annually in Nigeria, which translates into about 20,000 m³ of cassava wastewater per annum or a daily stream of 57m³/day.

Subsequently, the mashed cassava is then packed, tied and secured in a jute bags. The mashed cassava in the bags are then pressed/dewatered using a metallic presser or heavy stone in order to dewater and remove the starchy juice. The fermentation process is the final process of cyanide removal for it to be good for consumption. At this point, they are left for at least two days for fermentation based on the consumer tastes and preferences. The fermented pressed cassava is then sun-dried and rubbed over a sieve tray to take out the roughages. The sieved grains are then roasted over fire using a cast iron made frying pan which can be sieved further to remove lumps where necessary. Lumps found after roasting can be due to water not properly removed during pressing. While roasting, red palm oil can be added to prevent the garri from getting burnt. Finally, the roasted cassava is air dried and allowed to cool before storing or packaging for sale.

Figure 2. Material cycle in garri processing

Figure 3. Waste generation from Garri processing unit operation

Each of these processing stages generates some level of environmental impacts starting from cassava harvesting to the closure of the process as demonstrated in Figure 4. The harvesting of cassava involves pulling the roots and tubers out of the soil, thus dislodging some soil particles. Sumithra et al (2013) estimated that about 80.7 g/root of soil is lost during harvesting of cassava; and the crop-specific soil

loss is 7.64 kg/ha (Sumithra, et al., 2013). The environment is also impacted due to generation of litters during peeling, sieving and frying. The litters can be in the form of large particles such as those generated during peeling or particulate matter such as those generated during sieving and frying which contribute to air pollution. The major contributor to air pollution in garri processing hinge on burning of fossil fuel due to transportation, grinding and frying. The severity of this comes to the fore considering the fact that most of the vehicles used for transportation of agricultural products are very old and spit out excessive amounts of combustion by-products, including carbon soot. The diesel generators used to drive the grinding machines are no better. Ai et al (2012) reported that NO_x and PM from agricultural machineries are equivalent to 17% and 22% of the total on-road traffic emissions in Anhui, China (Ai, et al., 2012). Aged vehicles emit significantly higher amounts and more toxic pollutants than newer ones due to changes in the properties of emissions such as hygroscopicity, particle size distribution, phase partitioning, morphology and chemical constitution (Liu, et al., 2019). The issue is further worsened by the overloading of these worn out trucks that transport agricultural produce from farm clusters in rural areas to the cities. Garri processing is a semi-mechanized process which is energy intensive. Almost every stage of the process exerts significant amount of energy demand. Energy is required at the following stages: transportation, peeling, grinding, pressing, sieving and frying. Jekayinfa and Olajide (2007) estimated a total energy demand of 327.17 MJ per tonne of fresh cassava tuber processed (Jekayinfa, et al., 2007).

Figure 4. Environmental impact matrix for Garri processing

Water demand kicks in when washing peeled cassava tubers to remove soil particles and stains smeared during peeling. Water is also required for cooling the diesel engines used for driving the grinding machines. The wash water forms the first phase of liquid effluent from the process. Cassava Large amount of effluent are generated from cassava processing mills which contains highly toxic substances that affect biodiversity, water and soil physicochemical characteristics (Kolawole, 2014; Izah, et al., 2017; Omomowo, et al., 2015). Generally, cassava effluents are discharged directly into the soil and surface water which tends to pollute the receiving environment due to high cyanogenic contents, total suspended solid, total colour, heavy metals, chemical demand oxygen (COD) etc. This alters the suitability of the receiving surface water from drinking and washing. Ehiagbonare et al. (Ehiagbonare, et al., 2009) reported that cassava effluent has negative impacts on plants, air, domestic animals, soil and water. If cassava wastewater is not properly treated before disposal, it causes serious pollution by percolating into the soil or contaminating the runoff that drains inside the stream or nearby water bodies. Ogundola and Liasu (Ogundola, et al., 2007) reported that cyanide stays in the soil at a negligible level when it is added to soil but becomes toxic to soil microorganism at high concentrations.

None of the processing plants investigated in this study has a treatment unit for any of the effluent categories before discharge into the environment. In all cases, the effluents are discharged directly into the immediate environment of the setup. This continuous input of pollutants into the environment through unregulated effluent discharge leads to a build-up of contaminants in the environment. Besides, the processing of cassava into garri involves partial fermentation of the crushed tubers which usually

generates foul smell due to the production of volatile acids. This odour can be perceived as far as 90.3m to 102.3m from the source (Ehiagbonare, et al., 2009). The unpleasant sensation of odour from cassava effluent may induce adverse physiological and olfactory reaction. This effluent could actually breed insects that may later cause disease infection in humans. Some side-effects caused by cassava odour pollution include loss of appetite, coughing, breathing difficulty and nose irritation. It is quite unfortunate that environmental agencies in developing countries like Nigeria are yet to adopt practical measures to mitigate the adverse impacts of cassava processing in the country. Apart from odour from fermentation, other forms of air pollutants, notably greenhouse gases are emitted during transportation of the raw or processed product, grinding and frying. Most of the grinding machines examined in the area were diesel powered engine with either automated starter or manual starter (Table 3). Diesel engines are considered as one of the largest source of environmental pollution in the form of carbon monoxide (CO), hydrocarbons (HC), particulate matter and nitrogen oxides – NO_x (Reşitoğlu, 2015). Diesel emissions contribute to the development of cancer; cardiovascular and respiratory health effects; pollution of air, water, and soil; soiling; reductions in visibility; and global climate change (Lloyd, 1995). These processing plants are located in close proximity to people's houses, thus making them direct recipients of the adverse impacts.

Table 4. Common types of power engines for cassava processing (grinding)

The average pollution load index of the recipient soils ranged from moderately polluted (2.48) to highly polluted (4.56) with an average value of 3.05. This signifies a significant adverse shift from the background concentration. The values of pollution index were highest for chromium in two of the locations and for arsenic at another location with values greater than 5 (very highly polluted). Arsenic exhibited high pollution index ($PI > 3$) in two locations and moderate pollution index ($2 < PI < 3$) in two locations. Chromium exhibited high pollution index in two locations and moderate pollution index in one. Copper exhibited high pollution index at one location and moderate pollution index at three locations, while nickel and lead generally exhibited only slight level of pollution. Based on the average values of pollution indices, two locations were highly polluted, while the other two were moderately polluted. Nemerow's pollution index (NPI) indicated that soil samples from three of the locations were severely polluted (> 3.0), while one was moderately polluted ($2 < PI < 3$). Based on the modified degree of contamination assessment, soil samples from three of the locations were moderately contaminated with heavy metals ($2 < mCD < 4$), while one location had a high degree of contamination. The geoaccumulation indices ranged as follows: 0.58 (slight contamination) to 2.59 (heavy contamination) for arsenic; 1.0 (slight contamination) to 2.59 (heavy contamination) for chromium; 0.58 (slight contamination) to 1.58 (moderate contamination) for copper; -0.03 (uncontaminated) to 0.32 (slight contamination) for nickel; 0.03 (slight contamination) to 1.03 (moderate contamination) for cadmium. It is obvious that the soils in the immediate vicinity of garri processing plants are being adversely impacted due to poor waste management and uncontrolled effluent discharge. Arsenic and chromium are ranked the highest with respect to pollution indices. Arsenic and chromium have a lot in common: they are both known carcinogens with high level of toxicity; widespread environmental contaminants; commonly present in air,

soil and water; and readily intrude into the human body via the major routes of inhalation, ingestion and skin absorption (Vimercati, et al.). Once in contact with the soil, heavy metals are quickly absorbed and re-distributed in the soil by mineral precipitation, ion exchange, adsorption, aqueous complexation, biological mobilization/immobilization and plant uptake (Wuana, et al., 2011). This combination and sequence of processes make the contaminants readily available to plant uptake, leading to bioaccumulation and bio-magnification up the food chain. It is difficult to attribute the presence of these heavy metals in the soil within the vicinity of garri processing plants to any specific source. It would, however, appear that the major source are the cassava tubers themselves which had absorbed the contaminants from their native soils during the growing season. Atafar et al (2010) reported an overall increase in the concentrations of Cd, Pb and As in soil due to fertilizer application (Atafar, et al., 2010). It has also been reported that the concentrations of Cd, Cr and Pb in cassava leaves are above the WHO limits of 0.20mg/kg, 0.05mg/kg and 0.30mg/kg respectively (Ajiwe, et al.). Hence, the cassava tubers serve as a medium of heavy metal, recycling, transport and redistribution. While this is not desirable, it has an intrinsic advantage in that the heavy metals which would have been directly ingested by humans while eating the cassava tubers have been screened out through cassava processing. Other sources of heavy metals input to the environment include: wearing of the metallic moving parts of the grinding machine and filter press, spillage of diesel and condemned engine oil as well as exhaust carbon soot from diesel power engines.

The environmental risks associated with the input and build up of heavy metals in the soil within the immediate environment of the garri processing plants were assessed using the ecological risk factors (Er) and the potential ecological risk index (RI). The values of Er ranged from 5.63 to 91.8 for all metals investigated. The order of ecological risk of various metals based on their average values was: As>Cd>Cu>Cr>Pb>Ni with corresponding ecological risk values of 50.63 (moderate risk), 34.43 (low risk), 15.93 (low risk), 10.51 (low risk), 8.93 (low risk) and 5.63 (low risk). Based on individual metal assessment per location, cadmium and arsenic posed the highest risk with Er values of 91.8 and 90.0 respectively. Overall, low ecological risk was recorded 83.3% of the times, which indicates that despite the gradual build up of heavy metals in the immediate environment of the processing plants, the ecological risk posed remains low. However, a red flag exists with respect to certain heavy metals whose concentrations at some spots present a reasonable probability of high ecological risk. A preponderance of heavy metal concentration in the soil has the potential to affect soil native microorganisms and most heavy metals have low tendency to be degraded with high tenacity to exist in the environment for a long period of time (Aiyegoro, et al., 2007; Izah, et al., 2016). The presence of these heavy metals in the soil has immediate and remote adverse consequences which include phyto-toxicity, reduces soil productivity, water pollution, illnesses associated with intake of contaminants either through ingestion of impacted water or plant. For instance, exposure to arsenic even at low concentrations can lead to vomiting and reduction in the production of red and white blood cell while ingestion of high concentration can cause death. Nickel and Copper can be associated with the following side effect on human like kidney failure, diarrhea, headaches, allergy, cardiovascular, lung and nasal cancer. Cadmium, Chromium, Mercury and Lead are potential human carcinogens that affect human organs such as lungs, kidney etc.

Conclusion

From this study, it is clear that effluent from cassava processing into garri can be a source of environmental degradation if not properly managed. The soil, wastewater and sludge from around cassava processing mill in Nsukka, Nigeria were characterized by high concentrations of hydrogen cyanide, acidic pH and elevated heavy metal content. Pollution indices indicate that the soils in the vicinity of garri processing plants have been significantly contaminated with heavy metals, especially arsenic and chromium. The adverse environmental impacts identified for garri production are: air pollution, GHG emission, water pollution, soil loss, soil pollution, energy demand and impairment of physical environmental aesthetics through generation of litters.

Declarations

Compliance with ethical standards

Availability of data and materials (data transparency): The datasets generated during and analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest: The authors declare no conflicts of interest associated to this research.

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Authors' contribution: **Chidozie Charles Nnaji**: Conceptualization, Methodology and Review. .
Chukwuebuka Chigozie Akanno: Writing –original draft, Methodology, Review and Editing

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Tables

Tables 1-4 are available in the Supplemental Files section.

Figures

Figure 1

pH of wastewater at four different locations.

Figure 2

Material cycle in garri processing

Figure 3

Waste generation from Garri processing unit operation

Stages of Processing	Environmental Impacts								
	Soil loss	Litter	Air pollution	Water pollution	Release of Heavy metals	Soil pollution	GHG Emission	Water demand	Energy Demand
Harvesting									
Transportation									
Peeling									
Washing									
Grinding									
Dewatering/ Fermentation									
Sieving									
Frying									
Sieving									

Figure 4

Environmental impact matrix for Garri processing

Supplementary Files

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- [Table1.docx](#)