

Assessment of Pollution Load Indices of Heavy Metals in Cassava Mill Effluents Contaminated Soil: a Case Study of Small-scale Processors in a Rural Community in the Niger Delta, Nigeria

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Abstract Cassava mill effluents are discharged into the environment by smallholder cassava processor in rural communities in the Niger Delta region of Nigeria. Cassava mill effluents are known to induce toxicity in some biodiversity such as livestock (sheep, goat), vegetation, microorganisms and fisheries. This study evaluated the pollution load indices of heavy metals in cassava mill effluents contaminated soil in rural community in the Niger Delta region of Nigeria. Secondary data from cassava mill effluents soil were used for the study. The data were classified based on seasons. The pollution load was calculated following standard protocol. Nine pollution indices were considered including Contamination factor (CF), Degree of contamination (CD), Pollution load index (PLI), Pollution index (PI), Sum of pollution index (SPI), Pollution index/ Contamination Index (PI/CI), Metal pollution Index (MPI), Average Pollution Index (API) and Nemerow integrated pollution index (NIPI). In few instance that some heavy metals was not detected, 50% of mean detected individual metals were considered for the location that the metals were not detected. Geometric (BGM) and median mean (BMM) were considered for the background scenarios except for API and PI/CI in which median mean was used. The pollution load resulting from these heavy metals viz: Fe, Cr, Zn, Cu, Co, Ni, Mn, Pb and Cd revealed that CF and CD had low to moderate contamination level in both seasons apart from Pb that had considerable pollution in one of the locations for wet season, PLI were within no pollution to moderate pollution, PI were also within no pollution to low pollution level and NIPI were within warning line of pollution to low level of pollution for dry season, and warning line of pollution to high pollution in wet season. MPI, PI/CI and API showed slight pollution. The findings of this study also showed that cassava processing by smallholder in rural communities in the Niger Delta is slightly contributing to heavy metals pollution is receiving soil which varies according to seasons. Furthermore, age and heavy metal content in the cassava tuber and quantity of cassava processed in each mill and other anthropogenic activities could account for difference in pollution among the various locations, while runoff resulting from rainfall could account for the seasonal influence.

Keywords Cassava mill effluents; Degree of contamination; Heavy metals; Pollution load

Background

Environmental sustainability is under threat mostly due to anthropogenic activities and to lesser extent natural effects. Industrial activities releases wide range of waste streams into the environment. For instance, artesian and automobile repairs workshops which comprises of auto mechanic, auto welding, auto electrician and auto painting units releases several waste streams such as used oil and fluids, dirty shop rags, used parts, asbestos from brake pads and waste from solvents used for cleaning different parts of their daily operations (Al-Anbari et al., 2015). Several other processing sectors such as food processing also release wastes into the environment. For instance, oil palm processing releases three wastes stream including gaseous emission (air pollutants), palm oil mill effluents (liquid wastes), oil palm processing chaff, fiber, empty fruit bunch and palm kernel shell (solid wastes) (Ohimain and Izah, 2013; Ohimain et al., 2013a,b; Izah et al., 2016a). Also the processing of cassava tuber into garri, fufu and or lafun releases three wastes stream including whey (cassava mill effluents-liquid wastes), gaseous emission (air pollutants) and solid wastes (peels and seivate) (Ohimain et al., 2013c; Izah, 2016; Izah et al., 2017a). Typically, the diversity and concentration of pollutants released into the environment have increased in the last few decades (El-Metwally et al., 2017).

Heavy metals enter into the soil through natural or anthropogenic sources (Hernandez et al., 2003; Wang et al., 2012; Rivera et al., 2015; Mazurek et al., 2017). Natural source of heavy metals in the environment is related to lithogenic and pedogenic processes (Kabata-Pendias, 2011; Mazurek et al., 2017). Anthropogenic (human) activities also contribute to heavy metals concentration in the environment.

Most industrial and agricultural activities lead to the release of toxic substances into the receiving environment including soil, air and water. One of the major pollutant releases into the environment from most industrial and processing outfit is heavy metals. According to Idris et al. (2013), Izah et al. (2016b; 2017b,c), heavy metals are metalloid with density higher than 5 cm³ or 5 times denser than the density of water. Wang et al. (2010) also described heavy metals as one of the major substance that causes global environmental pollution. The toxicity of heavy metals on the environment may be due to their ability to persistent and bioaccumulate (Ghazaryan et al., 2015; Hassaan et al., 2016; Izah and Angaye, 2016). Heavy metals in the environment (soil and water) are up-taken by some living things in the environment and stored faster than they can metabolize (Hassaan et al., 2016). For instance, in water/sediment, fisheries tend to bioaccumulate heavy metals in their body parts including muscle, bone, liver, kidney, blood etc (Izah and Angaye, 2016). As such, heavy metals could pose a significant threat to human health irrespective of the environment (water and soil) (Ghazaryan et al., 2015).

Heavy metals are typically classified into two major forms including essential and non-essential metals. Essential heavy metals have beneficial role in living things at certain concentration. Some of these important heavy metals include iron, manganese, copper, zinc, chromium among other. High concentration of essential metals in biological system could lead to toxicity on the exposed organisms. While other, such as lead, cadmium, mercury and arsenic have no known role on living organisms. As such they are highly lethal even at low concentration.

In recent time, an elevated concentration of heavy metals in soils in many regions of the world is a major source of concern especially in developing nations (Zhou et al., 2016). The worry of heavy metals in soil could be due to their ability to resist biodegradation, toxicity and accumulative characteristics (Mohseni-Bandpei et al., 2016). Studies on soil heavy metals are mainly focused on heavily urbanized areas including industrial areas and city agglomerations, as well as on the areas of constant and linear emitters, which include industrial plants, waste landfills and roads (Al-Anbari et al., 2015).

In Nigeria several studies have been carried out on the impact of wastes and other industrial activities on soil quality. Specifically, cassava mill effluents which account for about 16% of total weight cassava (Ohimain et al., 2013c) have been reported to have impact on soil quality including microbial (Nwaugo et al., 2007, 2008; Ehiagbonare et al., 2009; Okechi et al., 2012; Omotiyama et al., 2013; Ezeigbo et al., 2014; Ibe et al., 2014; Eze and Onyilide, 2015; Igbinsosa and Igiehon, 2015; Omomowo et al., 2015), physicochemical (Nwaugo et al., 2008; Eneje and Ifenkwe, 2012; Nwakaudu et al., 2012; Okechi et al., 2012; Osakwe, 2012; Chinyere et al., 2013; Izonfuo et al., 2013; Eze and Onyilide, 2015) and heavy metals characteristics (Nwakaudu et al., 2012; Osakwe, 2012; Igbinsosa, 2015; Igbinsosa and Igiehon, 2015).

Several pollution indices are available in literature for the assessment of environmental quality (Hakanson et al., 1980; Tomlinson et al., 1980; Liu et al., 2004; Cheng et al., 2007; Qingjie et al., 2008; Yang et al. 2011, 2013; Sarala and Sabitha, 2012; Guan et al., 2014; El-Metwally et al., 2017; Gasiorek et al., 2017) with regard to some environmental components (soil, water and sediment). According to Sarala and Sabitha (2012), the use of varying algorithms could lead to discrepancy on pollution evaluation in an environment (such as sediment and soil). As such, its essential to use appropriate and/ or best fit method to evaluate environmental components such as soil and sediment for effective decision making and spatial planning (Sarala and Sabitha, 2012). Specifically, pollution index and or/ contamination indices is an important tool for processing, analyzing, and conveying raw environmental information to decision makers, managers, technicians, environmentalist and the general public at large (Caeiro et al., 2005; Sarala and Sabitha, 2012).

Several authors have widely assessed pollution load and or/ contamination indices of heavy metals in an industrial environment viz: soil, water and sediment using different pollution load indices (Hakanson, 1980; Tomlinson et al.,

1980; Sutherland, 2000; Tijani et al., 2004; Yu et al., 2004; Qingjie et al., 2008; Wang et al., 2010, 2016; Liang et al., 2011; Suresh et al., 2011; Yang et al. 2011; Sarala and Sabitha, 2012; Zhu et al., 2012; Fiori et al., 2013; Swarnalatha et al., 2013; Elias et al., 2014; Jiang et al., 2014; Singovszka et al., 2014; Tang et al., 2014; Uriah and Shehu, 2014; Vowotor et al, 2014; Al-Anbari et al., 2015; Ghaleno et al., 2015; Ghazaryan et al., 2015; Karydas et al., 2015; Soliman et al., 2015; Hassaan et al., 2016; Mohseni-Bandpei et al., 2016; Todorova et al., 2016; Bhutiani et al., 2017). But information on pollution load of heavy metals resulting from the discharge of cassava mill effluents into the soil is scanty in literature. Therefore, this study is aimed at investigating the pollution load of heavy metals in cassava mill effluents contaminated soil in a rural community in the Niger Delta region of Nigeria. The study applied several pollution indices viz: contamination factor (CF), contamination degree (CD), pollution load index (PLI), pollution index (PI), Pollution index/ Contamination Index (PI/CI), Metal pollution Index (MPI), Sum of pollution index (SPI), Average Pollution Index (API) and Newmerow integrated pollution index (NIPI). The findings of this study may be useful to environmentalist and policy makers in Nigeria and other cassava processing countries of the world.

1 Methodology

1.1 Study area

Ndemili Umusadege, Utagba-Uno is one of the communities in Ndokwa-West local government area of Delta state. Ndemili lies between latitude N06°01' and longitude E006°17'. Like other regions of the Delta state, the average annual precipitation of the area is about 1900 mm (Orji and Egboka, 2015). The atmospheric temperature and relative humidity of the area is approximately $28 \pm 6^\circ\text{C}$ and 50 – 95% respectively all year round. Major economic activities in the area include farming. Some of the major crops farmed in the area are food crops such as cassava, yam, maize, oil palm etc (Izah et al., 2017d). The cassava cultivated in the study area are typically processed into gari (cassava flakes) and Akpu (a food made from slurry of fermented cassava tuber).

1.2 Data source

Secondary data was used for the determination of pollution load indices of heavy metals in cassava mill effluents contaminated soil. The background mean values (geometric and median mean) and concentration of heavy metals based on two seasons data from five locations previously reported by Izah et al. (2017d) (Table 1). The values were used to calculate the pollution load indices based on seasons (viz dry and wet) at the different locations.

1.3 Pollution load assessment model

Pollution by heavy metals has been widely studied using several indices including CF, CD, PLI, PI, PI/CI, MPI, API, SPI and NIPI. The basis of determining the pollution load is to quantify the extent of heavy metals pollution by cassava mills effluents in receiving soil in comparison to its natural background. Several mean data have been recommended/ suggested to be used as natural background reference value for the assessment of pollution load and ecological risk assessment. Some of these means include geometric mean (BGM) (Thambavani and Uma Mageswari, 2013; Bhutiani et al., 2017) and median mean (BMM) (Sarala and Sabitha, 2012; Monakhov et al., 2015; Bhutiani et al., 2017). According to Sarala and Sabitha (2012), the use measures of the central tendency such as median instead of an arithmetic mean shows the main trend in the index values for management purpose. Furthermore, BGM and BMM have been applied in determining pollution load in environmental components. Based on the values presented in Table 1, CF, CD, PLI, PI, PI/CI, MPI, API, SPI and NIPI were calculated and the resultant values was compared to the criteria presented in Table 2, Table 3a, Table 3b, and Table 4.

Table 1 Concentration of heavy metals among the various locations with their background values by in soil receiving cassava mill effluents from small-scale cassava processors in a rural community in the Niger Delta region of Nigeria

Locations& background values	Copper		Zinc		Manganese		Iron		Lead		Cadmium		Chromium		Nickel		Cobalt	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
BMM	6.06	3.87	43.45	40.31	39.19	39.69	3526.00	3309.04	5.27	1.89	0.11	0.23	2.12	1.59	2.66	1.38	10.31	0.039
BGM	5.94	4.07	32.47	35.47	32.47	35.82	3083.03	3384.44	4.84	2.22	0.11	0.30	1.62	1.84	2.85	1.77	8.13	0.051
Min	3.10	3.34	9.65	18.98	18.37	18.47	1405.77	2635.83	1.66	0.79	0.11	0.230	0.38	1.19	1.88	0.88	3.34	0.039
Max	10.41	4.84	49.75	49.65	55.29	53.87	5696.99	4171.09	10.63	8.21	0.11	0.479	3.90	4.50	4.21	4.87	11.28	0.083
LA	6.056	3.87	9.65	18.98	18.37	18.47	1405.79	3041.84	9.92	1.89	0.11	0.230	3.90	2.13	4.21	0.88	3.34	0.083
LB	8.83	4.83	38.09	49.65	20.91	53.87	1824.58	2635.83	10.63	8.21	0.11	0.479	0.38	1.18	1.88	2.94	10.31	0.039
LC	4.29	3.69	43.45	34.72	39.19	34.07	5696.99	4171.09	5.27	0.79	0.11	0.230	2.12	1.59	2.66	4.87	11.28	0.039
LD	10.41	3.34	45.41	40.33	43.03	43.83	5406.05	4012.61	2.88	1.89	0.11	0.230	1.54	1.19	4.20	1.38	10.86	0.039
LE	3.10	4.84	49.75	42.55	55.29	39.69	3525.99	3309.04	1.66	2.35	0.11	0.447	2.31	4.50	2.13	1.00	8.39	0.0711

Note: Izah et al. (2017d); BMM- Background Median Mean; BGM- Background Geometric Mean

Table 2 Degree of contamination and contamination factor used to assess environmental pollution

Indices	Low risk	Moderate risk	Considerable	•
Contamination factor (CF)	CF<1	1 ≤ CF<3	3 ≤ CF<6	CF ≥ 6
Contamination degree (CD)	CD<8	8 ≤ CD<16	16 ≤ CD<32	CD>32

Note: Hakanson (1980) and have been widely applied by Bhutiani et al. (2017), Singovszka et al. (2014), Soliman et al. (2015), Todorova et al. (2016), Fiori et al. (2013), Karydas et al. (2015), Zhu et al. (2012)

Table 3a Pollution load (PLI, NIPI and PI) used for assessing environmental pollution

Pollution load index	No pollution	-	Moderate pollution	Heavy pollution	Extremely heavy pollution	Tomlison et al., 1980; Bhutiani et al., 2017; Ghaleno et al., 2015
	PLI<1	-	1<PLI<2	2<PLI<3	3<PLI	
Nemerow integrated pollution index (NIPI)	No pollution	Warning line of pollution	Low level of pollution	Moderate level of pollution	High level of pollution	Yang et al., 2011; Jiang et al., 2014; Yu et al., 2004
	NIPI≤0.7	0.7<NIPI≤1	1<NIPI≤2	2<NIPI≤3	NIPI>3	
Pollution index (PI)	No pollution	Low pollution	Moderate pollution	High/strong pollution	Very high/strong pollution	Yang et al., 2011; Jiang et al., 2014; Yu et al., 2004
	PI≤1	1<PI≤2	2≤PI≤3	3PI<5	PI>5	

Table 3b Index performance evaluation criteria for some integrated pollution indices as applied for MPI

Criteria	MPI	Indices performance evaluation criteria:
Representativity	1	This is the capacity to provide a spatially representative picture of the environmental states and the associated impacts.
Comparability	1	This involves the existence of a target level or threshold against which to compare it so that users are able to evaluate the significance of the values associated with it.
Sensitivity and Robustness	1	This involves the responsiveness to change in the environment.
Credibility	2	This provides a good theoretical basis in technical and scientific terms
Acceptability	2	This gives information about an acceptable levels of uncertainty
Simplicity	3	This provides the ease of calculation and interpretation.

Note: Sarala and Sabitha (2012), Caeiro et al. (2005)

1.3.1 Contamination factor

Contamination factor (CF) is used to assess contamination level in relative to average concentration of the respective heavy metals in the environment i.e. soil to the measured background values from previous study with similar geological origin or uncontaminated soil (Sutherland, 2000; Tijani et al., 2004; Uriah and Shehu, 2014). CF is often expressed based on the formula previously described by Hakanson (1980) and have been applied by Bhutiani et al. (2017), Uriah and Shehu (2014), Singovszka et al. (2014), Soliman et al. (2015), Ghaleno et al. (2015), Todorova et al. (2016), Fiori et al. (2013), Karydas et al. (2015), Zhu et al. (2012), Elias et al. (2014), Mohseni-Bandpei et al. (2016), Swarnalatha et al. (2013), Hassaan et al. (2016), Vowotor et al. (2014), Ghazaryan et al. (2015), Odukoya et al. (2016).

$$\text{Contamination factor} = \frac{\text{Concentration of the respective metal in the contaminated soil (Cm)}}{\text{Background values from similar geological area (Bm)}} \quad (\text{Equal 1})$$

Cm is the mean concentration of each metal under study, while BM is the background concentration.

Table 4 Contamination factor of heavy metals concentration in cassava mills effluent contaminated soil

Location	Seasons	BMM									BGM								
		Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co	Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co
LA	Dry	1.00	0.22	0.47	0.40	1.88	1.00	1.83	1.58	0.32	1.02	0.30	0.57	0.46	2.05	1.00	2.40	1.48	0.41
	Wet	1.00	0.47	0.47	0.92	1.00	1.00	1.34	0.64	2.13	0.95	0.54	0.52	0.90	0.85	0.77	1.58	0.50	1.63
LB	Dry	1.46	0.88	0.53	0.52	2.02	1.00	0.18	0.71	1.00	1.49	1.17	0.64	0.59	2.20	1.00	0.23	0.66	1.27
	Wet	1.25	1.23	1.36	0.80	4.34	2.09	0.74	2.13	1.00	1.19	1.40	1.50	0.78	3.70	1.60	0.64	1.66	0.76
LC	Dry	0.71	1.00	1.00	1.62	1.00	1.00	1.00	1.00	1.09	0.72	1.34	1.21	1.85	1.09	1.00	1.31	0.93	1.39
	Wet	0.95	0.86	0.86	1.26	0.42	1.00	1.00	3.53	1.00	0.91	0.98	0.95	1.23	0.36	0.77	0.84	2.75	0.76
LD	Dry	1.72	1.05	1.10	1.53	0.55	1.00	0.73	1.57	1.05	1.75	1.40	1.33	1.75	0.60	1.00	0.95	1.47	1.34
	Wet	0.86	1.00	1.10	1.21	1.00	1.00	0.75	1.00	1.00	0.82	1.14	1.22	1.19	0.85	0.77	0.65	0.78	0.76
LE	Dry	0.51	1.14	1.41	1.00	0.31	1.00	1.09	0.80	0.81	0.52	1.53	1.70	1.14	0.34	1.00	1.43	0.75	1.03
	Wet	1.25	1.06	1.00	1.00	1.24	1.96	2.82	0.72	1.82	1.19	1.20	1.11	0.98	1.06	1.50	2.44	0.56	1.39

Note: $CF < 1$ (low contamination); $1 \leq CF < 3$ (moderate contamination); $3 \leq CF < 6$ (considerable contamination); $CF \geq 6$ (very high contamination)

1.3.2 Contamination degree

Contamination degree (CD) is sometimes known as degree of contamination. CD is the sum of all contamination factors, which provides information about total contamination in a particular sampling location (Singovszka et al., 2014; Bhutiani et al., 2017). Contamination degree is often expressed based on the formula previously described by Hakanson (1980) and have been applied by Bhutiani et al. (2017), Uriah and Shehu (2014), Singovszka et al. (2014), Soliman et al. (2015), Todorova et al. (2016), Ghaleno et al. (2015), Fiori et al. (2013), Karydas et al. (2015), Zhu et al. (2012), Elias et al. (2014), Mohseni-Bandpei et al. (2016), Swarnalatha et al. (2013), Hassaan et al. (2016), Vowotor et al. (2014), Ghazaryan et al. (2015), Qingjie et al. (2008), Odukoya et al. (2016).

$$CD = \sum CF_{Fe} + CF_{Mn} + CF_{Co} + CF_{Ni} + CF_{Cd} + CF_{Cr} + CF_{Zn} + CF_{Pb} + CF_{Cu} \quad (\text{Equal 2})$$

1.3.3 Pollution load index

Pollution load index (PLI) gives information about the toxicity of the metal in each respective sample locations (Tomlinson et al. 1980; Ghaleno et al., 2015; Bhutiani et al., 2017). PLI was computed based on the formula previously described by Tomlinson et al. (1980) and widely applied by Suresh et al. (2011), Wang et al. (2016), Ghaleno et al. (2015), Bhutiani et al. (2017), Tang et al. (2014), Hassaan et al. (2016), Ghazaryan et al. (2015), El-Metwally et al. (2017).

$$PLI = \sqrt[n]{CF_{Fe} \times CF_{Mn} \times CF_{Co} \times CF_{Ni} \times CF_{Cd} \times CF_{Cr} \times CF_{Zn} \times CF_{Pb} \times CF_{Cu}} \quad (\text{Equal 3})$$

CF is the contamination factor for the respective metals and n is the number of elements (n = 9).

1.3.4 Pollution index and Nemerow integrated pollution index

Pollution index (PI) and Nemerow integrated pollution index (NIPI) is another type of indices used to assess extent of pollution in an industrial area (Cheng et al., 2007; Sarala and Sabitha, 2012). NIPI considers the overall level of soil pollution, taking into account the concentration of the various heavy metals under consideration (Guan et al., 2014; Kowalska et al., 2016; Mazurek et al., 2017).

PI has the same formula with CF. But unlike CF, PI consider the mean concentration of heavy metals from at least five locations/stations. PI formula has been previously described by Yu et al. (2004), Yang et al. (2011) and has been widely applied by Jiang et al. (2014), Al-Anbari et al. (2015).

$$PI = \frac{\text{Concentration of individual metals}}{\text{Background value}} \quad (\text{Equal 4})$$

NIPI considers all the individual metals investigated from equation 4 (Al-Anbari et al., 2015). NIPI can be used to assess the quality of soil (Liang et al., 2011). NIPI have been widely employed by authors in assessing risk pollution potentials of heavy metals in the environmental especially soil (Liu et al., 2004; Yu et al., 2004; Cheng et al., 2007; Yang et al., 2011, 2013; Sarala and Sabitha, 2012; Jiang et al., 2014; Al-Anbari et al., 2015).

$$\text{Nemerow integrated pollution index (NIPI)} = \sqrt{\frac{PI_{\text{mean}}^2 + PI_{\text{Maximum}}^2}{2}} \quad (\text{Equal 5})$$

Where PI_{mean}^2 is the mean value of PI of individual heavy metals and PI_{Maximum}^2 is the maximum PI value of individual heavy metals.

1.3.5 Pollution index (contamination index)

Pollution index (contamination index) (PI/CI) is often used in identifying pollution in priority areas (locations) (Sarala and Sabitha, 2012). According to Sarala and Sabitha (2012), PI/CI requires several measurements in the same sampling site. PI/CI was developed by Johansson and Johnsson (1976) and Ott (1978) and has been applied by Sarala and Sabitha (2012).

$$PI/CI = \sum \frac{1}{w} \times C \quad (\text{Equal 6})$$

Where W= weight of median value for pollution variable; C = maximum concentration of pollution variable per location.

1.3.6 Average pollution index

Average pollution index (API) is one of the algorithm integrated indices used to assess pollution (Sarala and Sabitha, 2012). API has been defined by Qingjie et al. (2008), Sarala and Sabitha (2012), Yang et al. (2013) as summation of all single pollution index divided by the number of heavy metals under consideration.

$$API = \frac{1}{n} \sum PI (CI) \quad (\text{Equal 7})$$

Where PI (CI) = single pollution index of heavy metal; and n = number of heavy metals under consideration. Contamination based on API for median mean was determined by comparing the values to the contamination classes provide for integrated indices by Sarala and Sabitha (2012). This include class 1- unpolluted, class 2 – lowly polluted, class 3 – moderately polluted, class 4 – strongly polluted and class 5 – extremely polluted. Value of API > 1.0 is an indication of low contamination level of the soil (Qingjie et al., 2008).

1.3.7. Metal pollution index

Metal pollution index (MPI) is a simple approach used to describe the integrated effect of heavy metals contamination (El-Metwally et al., 2017). MPI was calculated based on the method previously described by El-Metwally et al. (2017), AMA (1992) and have been applied by Usero et al. (1996), Sarala and Sabitha (2012). Furthermore, Qingjie et al. (2008) have applied this equation in environmental risk assessment and called it root of the product of pollution index.

$$MPI = (MC_{Fe} \times MC_{Mn} \times MC_{Co} \times MC_{Ni} \times MC_{Cd} \times MC_{Cr} \times MC_{Zn} \times MC_{Pb} \times MC_{Cu})^{1/n} \quad (\text{Equal 8})$$

Where MC= Metal concentration; n= number of number of metals considered.

The resultant values were compared with index comparison for MPI previously described by Sarala and Sabitha (2012), Caeiro et al. (2005) (Table 3b).

1.3.8 Sum of pollution index

Sum of Pollution index (SPI) previously described by Qingjie et al. (2008) was used for the applied.

$$RPPI = Pi_{Fe} + Pi_{Mn} + Pi_{Co} + Pi_{Ni} + Pi_{Cd} + Pi_{Cr} + Pi_{Zn} + Pi_{Pb} + Pi_{Cu} \quad (\text{Equal 9})$$

Where Pi = single pollution index of heavy metals

2 Results and Discussion

Table 4 presents CF of heavy metals in cassava mill effluent contaminated soil in a rural community in Delta state, Nigeria. The results showed that heavy metals contamination ranged from low contamination (CF<1) to considerable contamination ($3 \leq CF < 6$). Contamination due to copper was moderate at LA and LB and Low at LC for both seasons. It also showed moderate contamination at dry and wet season for LD and LE respectively at BMM scenario. Furthermore, it was moderate and low for LB and LC respectively. It was also moderate in dry season of LA and LD and wet season of LE at BGM scenario.

For zinc, there was moderate contamination for LD and LE for both seasons. Also, there was moderate contamination in wet and dry season for LB and LC respectively (BMM scenario) and all were moderately contaminated apart from LA in both seasons and wet season for LC at BGM scenario. In BMM and BGM scenario, manganese was only moderately contaminated in wet and dry season for LB and LC respectively. However, in LD and LE moderate contamination exit for both seasons. Iron under BMM scenario showed moderate contamination at LC to LE at both seasons and LB in only wet season. While in BGM scenario, there was low contamination for LA and LB in both seasons and also low for LE in wet season. In both BMM and BGM scenario, lead contamination was considerably high in wet season for LB. Furthermore, it was moderate at 60% of the entire location (with both seasons of study inclusive) in BMM scenario and 40% moderate contamination across both

seasons of study in all the location which occurred mostly in the dry season. Cadmium showed moderately contamination in all location across both seasons under BMM scenario. While under BGM scenario, 30% including LA, LC and LD in wet season showed low contamination. Nickel in wet season for LC showed considerable contamination. While 40% of other locations comprising both seasons of study showed low contamination. Under BGM scenario, there was 50% low and moderate contamination comprising of both seasons.

Chromium showed moderate contamination for LA, LC and LE at both seasons of study under BMM consideration. Similar trend was observed under BGM consideration for LA and LE of both seasons and LC of only dry season showed moderate contamination. Under BMM consideration for copper, LB, LC and LD of both seasons and LA and LC of wet season showed moderate contamination. Whereas in BGM scenario, both seasons for LE, dry season for LB, LC and LD and wet season for LA showed moderate contamination. Among the various locations, contaminations indicate the effect of anthropogenic activities on soil heavy metals (Sekabira et al., 2010; Bhutiani et al., 2017).

Among the 9 heavy metals studied under both seasons in the 5 locations, 59 (representing 65.56%), 2 (representing 2.22%) and 29 (representing 32.22%) showed moderate contamination, considerably contamination and low contamination respectively under BMM scenario. While in BGM 49 (representing 54.45%), 1 (representing 1.11%) and 40 (representing 44.44%) showed moderate contamination, considerably contamination and low contamination respectively.

This study showed that contamination level differs depending on heavy metals. This could be due to variation in anthropogenic activities leading to heavy metal generation, difference source of cassava tuber processed as well as age of the cassava tuber. Quantity of cassava mill effluents discharged into the soil in the various locations could also account for variation among the contamination level in each of the location. Runoff resulting from rainfall during the dry season could also be potential source of variation in the contamination factor.

Based on seasons, wet season has higher contamination (moderate and considerably) level compared to dry season under BMM scenario. Furthermore, in BGM scenario, dry season has higher contamination (moderate and considerably) compared to wet season. Comparing the two different background scenarios, fluctuations in the values could be associated to variation in the mean data. The trend in this study has been reported by Bhutiani et al. (2017).

The degree of contamination of heavy metals concentration in cassava mill effluent contaminated soil is presented in Figure 1. Among all the locations and season, there was moderate risk level ($8 \leq CD < 16$). Though, there was slight variation between both background levels. This suggests that the soil is being contaminated by the prevailing activities in each location.

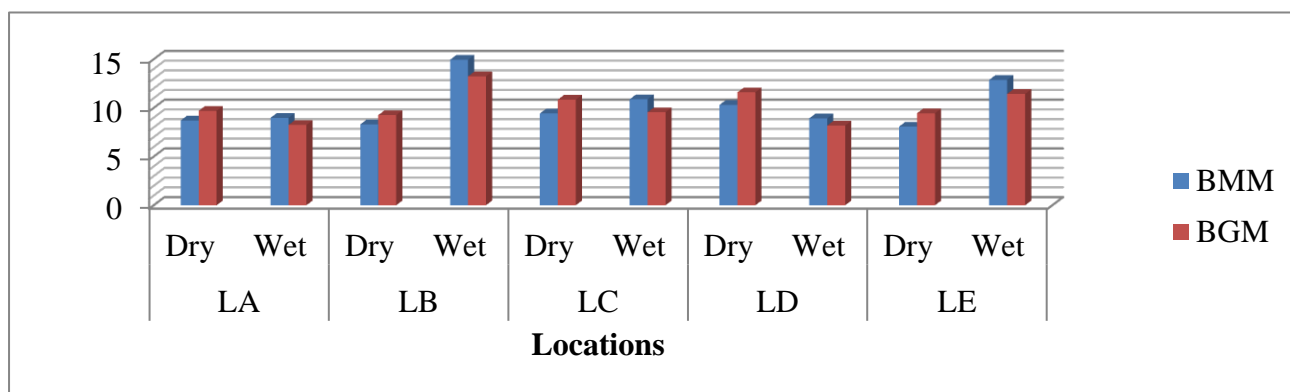


Figure 1 Degree of contamination of heavy metals concentration in cassava mill effluent contaminated soil

Note: $CD < 8$ (Low risk); $8 \leq CD < 16$ (Moderate risk); $16 \leq CD < 32$ (Considerable); $CD > 32$ (Very high)

BMM- Background Median Mean; BGM- Background Geometric Mean

Figure 2 presents the pollution load index of heavy metals concentration in cassava mill effluents contaminated soil. Pollution load index showed that LC in both seasons is moderately polluted, while wet season in LB and CE and dry season in LD showed moderate pollution under BMM consideration. While in BGM scenario, wet season in LB and LE and dry season of LC and LD also showed moderate pollution as well. The trend in both background level of this study is similar to findings of Bhutiani et al. (2017). This is also an indication that the level of pollution is affected by seasons as well as spatial distribution within the cassava mill effluents contaminated soil.

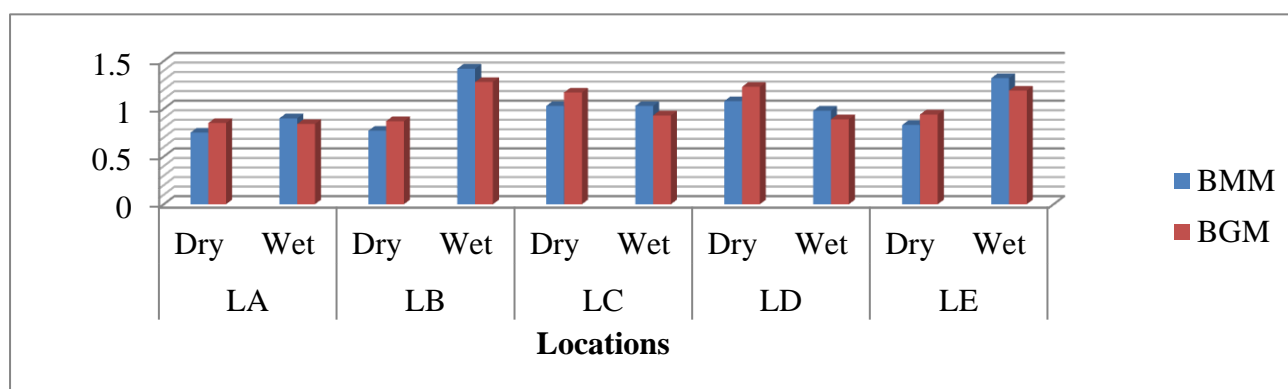


Figure 2 Pollution load index of heavy metals concentration in cassava mill effluent contaminated soil

Note: $PLI < 1$ (no pollution); $1 < PLI < 2$ (moderate pollution); $2 < PLI < 3$ (heavy pollution); $3 < PLI$ (extremely heavy pollution)

BMM- Background Median Mean; BGM- Background Geometric Mean

The statistical analysis of Pollution index of heavy metals concentration in cassava mill effluents contaminated soil is presented in Table 5. The mean value of all the heavy metals in both seasons under both background scenarios ranged from no pollution ($PI \leq 1$) to low pollution ($1 < PI \leq 2$). Under BMM scenario, copper, iron, lead, cadmium and chromium in both seasons, and nickel and cobalt in wet season showed low pollution, while the other heavy metals indicate no pollution. While in BGM consideration scenario, there was low pollution in all the metals under study across both seasons of study. This is an indication that pollution resulting from cassava mill effluent in small scale processing in rural community in the Niger Delta is low.

Table 5 Statistical analysis of pollution index of heavy metals concentration in cassava mill effluent contaminated soil

Parameters	Season	BMM			BGM		
		Min	Max	Mean	Min	Max	Mean
Cu	Dry	0.51	1.72	1.08	0.52	1.75	1.10
	Wet	0.86	1.25	1.06	0.82	1.19	1.01
Zn	Dry	0.22	1.14	0.86	0.30	1.53	1.15
	Wet	0.47	1.23	0.92	0.54	1.40	1.05
Mn	Dry	0.47	1.41	0.90	0.57	1.70	1.09
	Wet	0.47	1.36	0.96	0.52	1.50	1.06
Fe	Dry	0.40	1.62	1.01	0.46	1.85	1.16
	Wet	0.80	1.26	1.04	0.78	1.23	1.02
Pb	Dry	0.31	2.02	1.15	0.34	2.20	1.26
	Wet	0.42	4.34	1.60	0.36	3.70	1.36
Cd	Dry	1.00	1.00	1.00	1.00	1.00	1.00
	Wet	1.00	2.09	1.41	0.77	1.60	1.08
Cr	Dry	0.18	1.83	0.97	0.23	1.43	1.26
	Wet	0.74	2.82	1.33	0.64	2.44	1.23
Ni	Dry	0.71	1.58	1.13	0.75	1.48	1.06
	Wet	0.64	3.53	1.60	0.50	2.76	1.25
Co	Dry	0.32	1.09	0.85	0.41	1.39	1.09
	Wet	1.00	2.13	1.39	0.76	1.63	1.06

Note: $PI \leq 1$ (No pollution); $1 < PI \leq 2$ (Low pollution); $2 < PI \leq 3$ (Moderate pollution); $3 < PI \leq 5$ (High/strong pollution); $PI \geq 5$ (Very high/strong pollution); BMM- Background Median Mean; BGM- Background Geometric Mean

Table 6 presents the Nemerow integrated pollution index (NIPI) of heavy metals concentration in cassava mill effluents contaminated soil. NIPI ranged from warning line of pollution ($NIPI \leq 0.7$) to high level of pollution ($NIPI > 3$). Under BMM consideration, there was low level of pollution ($1 < NIPI \leq 2$) apart from cobalt in dry season. Variation exist under both scenarios in wet season, thus copper, zinc, manganese, iron, cadmium and cobalt showed low pollution, chromium and nickel showed moderate level of pollution while lead showed high level of pollution. Like dry season BMM consideration, dry season of BGM indicate low level of pollution in all the metals. While in wet season of BGM consideration, copper, zinc, manganese, iron, chromium and cobalt showed low pollution, lead and cadmium nickel showed moderate level of pollution while lead showed high level of pollution. The moderate/high pollution in lead is an evident of considerable contamination. While the moderate pollution in nickel and cadmium is an evident of moderate contamination. The slight variations that exist between both backgrounds suggest the differences in the mean value used in the study. In NIPI pollution categorization, it appears that dry season has lower pollution compared to wet season from the cassava mill effluents contaminated environment.

Table 6 Nemerow integrated pollution index of heavy metals concentration in cassava mill effluent contaminated soil

Parameters	BMM		BGM	
	Dry	Wet	Dry	Wet
Cu	1.44	1.16	1.46	1.10
Zn	1.01	1.09	1.35	1.24
Mn	1.18	1.18	1.43	1.30
Fe	1.35	1.16	1.54	1.13
Pb	1.64	3.27	1.79	2.79
Cd	1.00	1.78	1.00	2.36
Cr	1.46	2.20	1.35	1.93
Ni	1.37	2.74	1.29	2.14
Co	0.98	1.80	1.25	1.37

Note: $NIPI \leq 0.7$ (No pollution); $0.7 < NIPI \leq 1$ (Warning line of pollution); $1 < NIPI \leq 2$ (Low level of pollution); $2 < NIPI \leq 3$ (Moderate level of pollution); $NIPI > 3$ (High level of pollution); BMM- Background Median Mean; BGM- Background Geometric Mean

Table 7 presents the pollution index (contamination index) (PI/CI) of heavy metals concentration in cassava mill effluent contaminated soil in a rural community in Delta state, Nigeria. The PI/CI showed that the soil were between unpolluted to low polluted except for few instance viz: copper in dry season for LB, lead of wet and dry season for LC and CE, and wet season for LA and LE which were within low pollution to moderately polluted.

Table 7 Pollution index (contamination index) of heavy metals concentration in cassava mill effluent contaminated soil

Location	Seasons	BMM								
		Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co
LA	Dry	1.23	1.20	1.16	1.14	1.35	1.22	1.28	1.40	1.47
	Wet	1.04	1.09	1.15	1.13	1.12	1.22	1.30	1.66	2.53
LB	Dry	2.33	1.23	1.20	1.08	1.18	1.22	1.57	1.54	1.13
	Wet	1.04	1.13	1.40	1.05	1.39	1.12	1.64	1.22	0.00
LC	Dry	1.10	1.29	1.17	1.05	1.13	1.22	1.23	1.40	1.05
	Wet	1.11	1.17	1.25	1.07	2.25	1.22	1.64	1.10	0.00
LD	Dry	1.19	1.06	1.16	1.08	1.35	1.22	1.14	1.20	1.18
	Wet	1.09	1.03	1.10	1.09	1.12	1.22	1.62	1.32	0.00
LE	Dry	1.33	1.07	1.13	1.07	2.16	1.22	1.17	1.29	1.09
	Wet	1.05	1.13	1.10	1.08	1.32	1.46	1.16	1.45	2.07

Note: 1= unpolluted; 2= Low polluted; 3 = moderately polluted; 4 strongly polluted; 5; extremely polluted.

BMM- Background Median Mean; BGM- Background Geometric Mean

Figure 3 presents the average pollution index using median mean for heavy metals concentration in cassava mill effluent contaminated soil in a rural community in Delta state, Nigeria. The average index was greater than 1 in

both seasons (Figure 3). This is an indication of low level of pollution in soil associated with the discharge of cassava mill effluent into the soil.

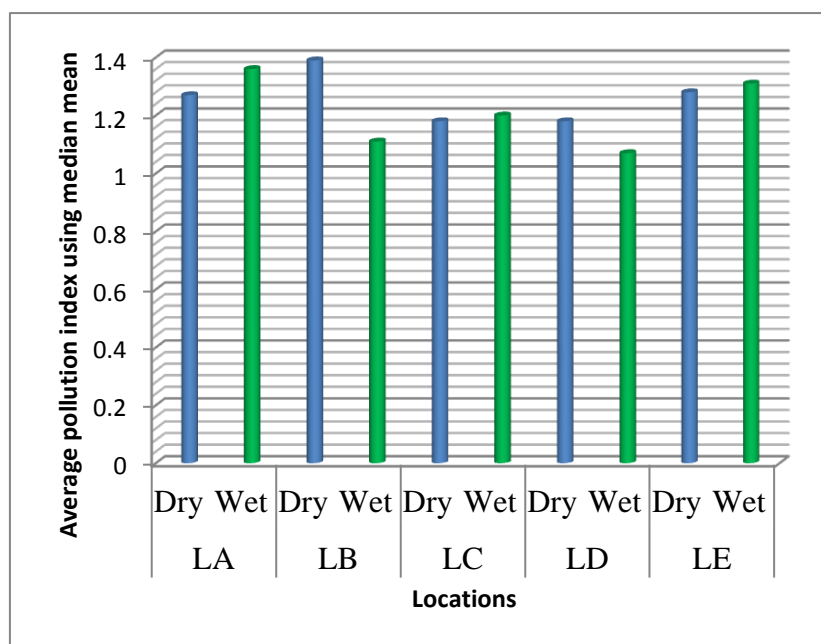


Figure 3 Average Pollution index using median mean of heavy metals concentration in cassava mill effluent contaminated soil
 Note: API > 1.0 is an indication of low contamination level of the soil

Figure 4 presents metal pollution index of heavy metals concentration in cassava mill effluents contaminated soil in a rural community in the Niger Delta region of Nigeria. The MPI was apparently higher in the dry season compared to the wet season, with the values ranging from 4.01 – 11.05. This could be due to dilution effects. The MPI was higher than 1 in all the locations. This is an indication of deterioration in the environment with regard to heavy metals concentration (El-Said and Youssef, 2013; El-Metwally et al., 2017). The values reported in this study had some similarity with the work of Sarala and Sabitha (2012) that reported MPI in the range of 5.63 – 7.98 in based on heavy metals in soil near sugar mill at varying depth of 0, 5 and 10cm. But higher than the value of 1.08 – 1.50 in sediment of red sea ports of Egypt reported by El-Metwally et al. (2017).

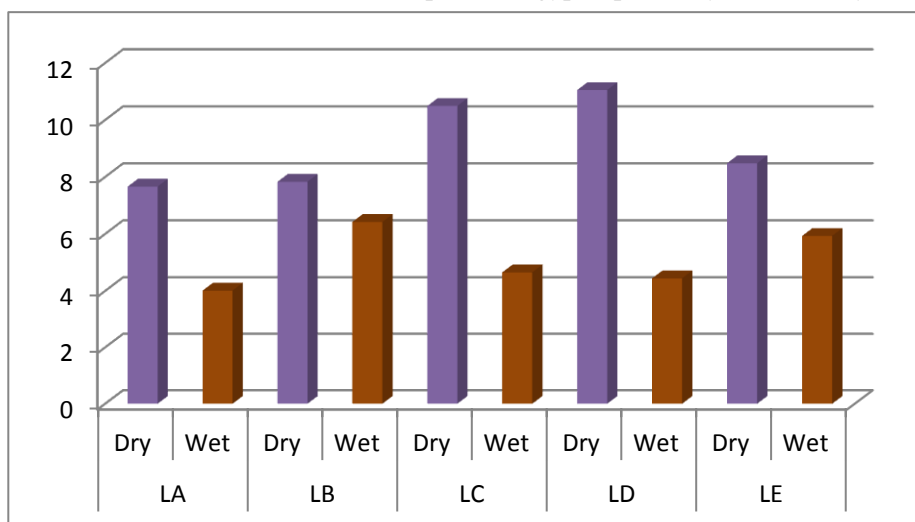


Figure 4 Metal Pollution index of heavy metal concentration in cassava mill effluent contaminated soil

Figure 5 present the sum of pollution index of heavy metals concentration in cassava mill effluent contaminated soil in a rural community in the Niger Delta region of Nigeria. The sum of pollution index ranged from 1461.35 – 5805.36 and 2757.03 – 4251.09 in dry and wet season respectively. Apart from location LE in both season, the

sum of pollution index showed wide range of disparity. This is an indication of seasonal influence. The variation among the different locations could be due to deviation in topography, making some of the areas more prone to runoff after rainfall. Furthermore, other anthropogenic activities could also account for variation in the various locations with regard to sum of pollution index.

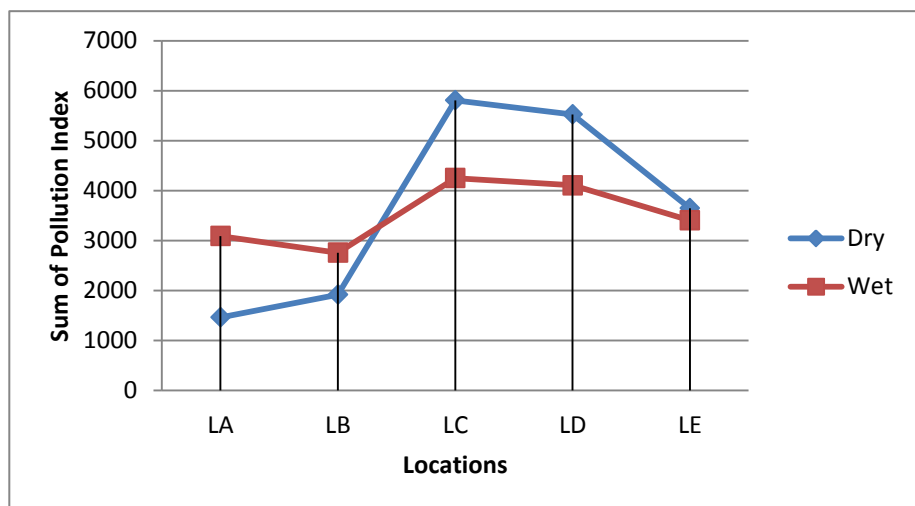


Figure 5 Sum of pollution index of heavy metals concentration in cassava mill effluent contaminated soil

From all pollution load indices consider, the study showed that cassava mill effluents in receiving soil are contributing to slight heavy metals pollution. According to Qiu (2010), heavy metals pollution from industrial setting typically originates from three sources including exhaust, human activities and secondary pollution. Based on the various pollution indices under study, the heavy metals resulting from cassava mill effluent is leading to low/slightly polluted to moderate pollution. This trend has been reported in soil near sugar mill when several integrated and contamination factors were applied in the assessment of pollution load (Sarala and Sabitha, 2012).

The pollution level based on the different indices used showed variation among the different mills in the study area. According to Mazurek et al. (2017), Hernandez et al. (2003), heavy metals pollution in soil varies according to its chemical and physical characteristics including texture, buffering ability and the capacity to neutralize contaminants. Mazurek et al. (2017), Pajak et al. (2015) also reported that the distribution/arrangement of soil heavy metals depends on landscape and or/ topography. This could account for minor variation among the various locations of study.

3 Conclusions

Nigeria is the world leading producer of cassava accounting for over 20% of global output. Cassava processing is majorly carried out by small-scale processors in the Niger Delta region of Nigeria. During cassava processing, effluent is produced from the dewatering zone which accounts for about 16% of total cassava tuber weight. This effluent is toxic to some living things. This study evaluated the pollution load of heavy metals in cassava mill effluents contaminated soil in rural community in the Niger Delta region of Nigeria. Secondary data from cassava mill effluents soil were used in this study. Pollution load were considered based on two background scenarios viz: BGM and BMM. The results revealed low to considerable contamination (CF, API, MPI), low to moderate contamination (CD, PI/CI), no pollution to moderate pollution (PLI), no pollution to low pollution (PI) and warning line of pollution to high pollution (NIPI). Therefore, cassava mill effluents from small-scale cassava processing in the Niger Delta are contributing to heavy metals pollution in the soil which tends to vary according to seasons.

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