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Geo-accumulation Index, Enrichment Factor and Quantification of Contamination of Heavy Metals in Soil Receiving Cassava Mill Effluents in A Rural Community in the Niger Delta Region of Nigeria

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Abstract This study investigated enrichment factor, geo-accumulation index and quantification of contamination of heavy metals in cassava mill effluents contaminated soil by smallholder cassava processors in a rural community in the Niger Delta region of Nigeria. Data used for the environmental risk assessment is from secondary sources. The assessment was carried out under two background scenarios viz: geometric (BGM) and median mean (BMM). 50% of mean detected individual metals was used as mean data for location that the metal was not detected. Assessment was carried out following well established protocol. Results showed that enrichment factor (EF), geo-accumulation index (Igeo), improved Nemerow Index (INI), Metal enrichment index (MEI) and quantification of contamination (QoC) in soil heavy metals (viz: Fe, Cr, Zn, Cu, Co, Ni, Mn, Pb and Cd) receiving cassava mill effluents in a rural community of the Niger Delta region of Nigeria revealed un-contamination to moderately contamination for Igeo, NMI, background rank to significant enrichment for EF, no enrichment to moderate enrichment for MEI, and positive values of quantification of contamination is an indication of pollution/contamination due to anthropogenic sources. The study further showed that cassava mill effluents are contributing to soil heavy metal contamination in study area.
Keywords Cassava mill effluents; Enrichment factor; Geo-accumulation factor; Heavy metals; Quantification of contamination

Background

Some waste disposal system is carried in unsustainable manner especially in developing countries. According to Swarnalatha et al. (2013), waste disposal system is carried out in unscientific and is ill-maintained approach due to unsuitable waste management and poor urban planning and implementation strategies. Most wastes stream end up in the environment (mostly in soil and surface water). These wastes stream mostly result from anthropogenic activities. According to Ghazaryan et al. (2015), human activities on natural landscapes affect both qualitative and quantitative characteristics of the environment (Ghazaryan et al., 2015).

The toxicity of any wastes depends on its composition and source. For instance, wastes emanating from cassava processing including solid (peels and sievate), liquid (cassava mill effluents or whey) and gaseous emission (pollutant gases) could have effect on the environmental components and its associated biota. The constituents of wastes from the cassava peel may depend on the age and species. The emissions also depend on the scale of processor and source. While cassava mill effluents generated during dewatering/pressing activity (Ohimain et al., 2013) is highly lethal to the environment and its associated biota. The characteristics of the effluent have been widely reported in literatures. The general physico-chemistry and heavy metals of cassava mill effluents have been reported by Orhue et al. (2014), Rim-Rukeh (2012), Adejumo and Ola (2011), Patrick et al. (2011), Olorunfemi and Lolodi (2011), Omomowo et al. (2015), Izah et al. (2017a-c). Furthermore, the microbial characteristics have also been documented by authors (Nwaugo et al., 2007; Rim-Rukeh, 2012; Omotioma et al., 2013; Omomowo et al., 2015).

Cassava mill effluents typically elevates the receiving soil heavy metal concentration (Nwakaudu et al., 2012; Osakwe, 2012; Igbinosa and Igiehon, 2015; Igbinosa, 2015). Heavy metals are highly lethal at high concentration for the essential metals as well as the non-essential ones even at low concentration (Izah et al., 2016; Izah and Angaye, 2016). Heavy metals have the ability to bioaccumulate within the different links of trophic chains (Ghazaryan et al., 2015).

Heavy metals contamination is one of the major problems facing environmental sustainability in both developed and developing countries (Singovszka et al., 2014). This could be due to the fact that they are toxic and recalcitrant to biodegradation (Singovszka et al., 2014; Mohseni-Bandpei et al., 2016). As such, their contamination level in soils is regarded as a potential hazard for food safety and public health (Karydas et al., 2015).

Typically, heavy metals in the soil could originate from natural pedogeochemical characteristics, anthropogenic sources and/ or mixture of both (Ghazaryan et al., 2015). The occurrence of heavy metals in the soil surfaces is harmful to soil ecosystem, citizens' health and can cause other environmental challenges (Mohseni-Bandpei et al., 2016). Therefore, there is the need to continually assess the characteristics of food processing wastes discharged into the environment at all scale of processing.

Several environmental risk indices have been used to assess and quantify extent of pollution in an environment. Some of these indices such as enrichment factor (EF), geo-accumulation factor (Igeo) and Quantification of contamination (QoC) have been applied by authors in assessing environmental risk assessment (Muller, 1969; Sutherland, 2000; Asaah et al., 2006; Elias et al., 2014; Tang et al., 2014; Vowotor et al., 2014; Ghaleno et al., 2015; Ghazaryan et al., 2015; Hassaan et al., 2016; Todorova et al., 2016; Wang et al., 2016; Bhutiani et al., 2017). Hence, this study aimed at assessing the Igeo, EF, QoC of heavy metals in soil receiving cassava mill effluents in a rural community of the Niger Delta region of Nigeria. This study could be used for to policy makers and environmentalists.

1 Methodology

1.1 Study area

Ndemili Umusadege is one of the quarters in Utagba-Uno in Ndokwa-West local government area of Delta state. Ndemili lies between latitude N06º01' and longitude E006º17'. The region is characterized by 28±6 ℃ and 50 – 95% of temperature and relative humidity respectively all year round. The average annual rainfall of 1900mm which is peculiar to other areas in Delta state (Orji and Egboka, 2015). Farming is a major source of livelihood to the indigenous people of the area. Some of the crops cultivated include cassava, yam, maize, oil palm etc.

1.2 Data source

The data used for the assessment is mainly from secondary source. Previous result from Izah et al. (2017c) was used for the assessment of metal enrichment index (MEI), QoC, Igeo and EF of the heavy metals in cassava mill effluents contaminated soil (Table 1), while Improved Nemerow Index (INI) was computed based on the value obtained from the Igeo. The assessment was carried out under two background scenarios viz: geometric and median mean. Authors have recommended the use of geometric mean (BGM) (Thambavani and Uma Mageswari, 2013; Bhutiani et al., 2017) and median mean (BMM) (Monakhov et al., 2015; Bhutiani et al., 2017) as background values in assessment of environmental risk. Geometric and median mean values are usually lower than the arithmetic values depending of the data distribution. Geometric mean is numerically lesser than the arithmetic mean due to reduction in the values of the sample group and therefore, it a useful indicator for background geochemical data (Thambavani and Uma Mageswari, 2013). Assessment was carried out based on two seasons (wet and dry) across 5 locations of soil receiving cassava mill effluents.

1.3 Enrichment factor, Geo-accumulation factor and identification of contamination source

MEI, EF, Igeo, INI and QoC of heavy metal in contaminated environment have been widely used to assess environmental risk of the activities leading to pollution. Several mean data have been recommended/suggested for the environment risk assessment. Some of these mean include geometric mean (Thambavani and Uma Mageswari, 2013; Bhutiani et al., 2017) and median mean (Monakhov et al., 2015; Bhutiani et al., 2017). Based on the values presented in Table 1, the resultant EF, INI, Igoe, QoC and MEI were calculated and the results was compared to the criteria presented in Table 2.

Table 1 Concentration of heavy metals among the various locations with their background values in cassava mill effluents contaminated soil

Metals	Seasons	BMM	BGM	Min	Max	LA	LB	LC	LD	LE
Cu	Dry	6.06	5.94	3.10	10.41	6.06	8.83	4.29	10.41	3.10
	Wet	3.87	4.07	3.34	4.84	3.87	4.83	3.69	3.34	4.84
Zn	Dry	43.45	32.47	9.65	49.75	9.65	38.09	43.45	45.41	49.75
	Wet	40.31	35.47	18.98	49.65	18.98	49.65	34.72	40.33	42.55
Mn	Dry	39.19	32.47	18.37	55.29	18.37	20.91	39.19	43.03	55.29
	Wet	39.69	35.82	18.47	53.87	18.47	53.87	34.07	43.83	39.69
Fe	Dry	3526.00	3083.03	1405.77	5696.99	1405.79	1824.58	5696.99	5406.05	3525.99
	Wet	3309.04	3384.44	2635.83	4171.09	3041.84	2635.83	4171.09	4012.61	3309.04
Pb	Dry	5.27	4.84	1.66	10.63	9.92	10.63	5.27	2.88	1.66
	Wet	1.89	2.22	0.79	8.21	1.89	8.21	0.79	1.89	2.35
Cd	Dry	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Wet	0.23	0.3	0.23	0.48	0.23	0.48	0.23	0.23	0.45
Cr	Dry	2.12	1.62	0.38	3.9	3.9	0.38	2.12	1.54	2.31
	Wet	1.59	1.84	1.19	4.50	2.13	1.18	1.59	1.19	4.50
Ni	Dry	2.66	2.85	1.88	4.21	4.21	1.88	2.66	4.20	2.13
	Wet	1.38	1.77	0.88	4.87	0.88	2.94	4.87	1.38	1.00
Co	Dry	10.31	8.13	3.34	11.28	3.34	10.31	11.28	10.86	8.39
	Wet	0.04	0.05	0.04	0.08	0.08	0.04	0.04	0.04	0.07

Note: Izah et al. (2017a); BMM- Background median mean, BGM- Background geometric mean, Min-Minimum, Max-Maximum

Table 2 Specification of Enrichment factor and Geo-accumulation index used in this study

Enrichment factor (EF)	Considered as background rank	Minimal enrichment	Moderate enrichment	Significant enrichment	Very high enrichment	Extremely high enrichment	-
	1	1 – 2	2 – 5	5 – 20	20 – 40	40	-
Geo-accumulation index (Igeo)	Uncontamination	Uncontaminated to moderately contamination	Moderate contamination	Moderate to heavy contamination	Heavy contamination	Heavy to extremely contamination	Extremely contaminated
	Igeo ≤ 0	0<Igeo ≤ 1	1<Igeo B≤2	2<Igeo ≤ 3	3<Igeo ≤ 4	4<Igeo ≤ 5	Igeo ≥ 5
Improved Nemerow Index (INI)	0< INI ≤0.5	0.5 < INI ≤1	1 < INI ≤2	2 < INI ≤3	3 < INI ≤4	4 < INI ≤5	INI > 5

Note: Geo-accumulation index is by Muller (1969) have been widely applied by Ghaleno et al. (2015), Bhutiani et al. (2017), Todorova et al. (2016), Improved Nemerow Index is by Forstner et al. (1990) and have been applied by Guan et al. (2014); while Enrichment factor is by Sutherland (2000) and have been applied by Bhutiani et al. (2017)

1.3.1 Quantification of contamination or anthropogenic metals

Quantification of contamination (QoC) represents the lithogenic metal (Asaah et al. 2006; Bhutiani et al., 2017) and was calculated by the formula presented by Bhutiani et al. (2017).

$$QoC\ (\%) = \frac{(C_n - B_n)}{C_n} x\ 100 \quad \text{(Equal 1)}$$

Where QoC is quantification of contamination, Cn is the concentration of metal in the sample and Bn is the background individual heavy metals concentrations.

1.3.2 Enrichment factor

Enrichment factor (EF) is an index used to assess the level of contamination of heavy metals from both natural and anthropogenic sources above uncontaminated background levels (Chen et al., 2007; Amin et al., 2009; Kowalska et al., 2016; Bhutiani et al., 2017; El-Metwally et al., 2017). Fe is the acceptable normalization element (Deely and Fergusson 1994; Elias and Gbadegesin, 2011; Elias et al., 2014; Kowalska et al., 2016; Bhutiani et al., 2017; Mazurek et al., 2017), hence it was used for the calculation of EF. Authors have variously reported that iron has the highest concentration among heavy metals in cassava mill effluents (Adejumo and Ola, 2011; Olorunfemi and Lolodi, 2011; Orhue et al., 2014; Omomowo et al., 2015). Typically, iron has a relatively high natural concentration and is therefore not expected to be substantially enriched from anthropogenic sources (Bhutiani et al., 2017). EF is mathematically expressed based on the method previously described and used by Bhutiani et al. (2017), Elias et al. (2014), Tang et al. (2014), El-Metwally et al. (2017), Gasiorek et al. (2017), Kowalska et al. (2016).

$$EF = \frac{\frac{HM\,(s)}{Fe(s)}}{\frac{HM(b)}{Fe(b)}} \quad \text{(Equal 2)}$$

Where HM (s) stands for concentration of heavy metals in sample, Fe(s) stands for concentration of Fe in sample, HM (b) stands for concentration of the heavy metals in the reference background value and Fe(b) is the concentration of Fe in the earth's crust or reference background value.

1.3.3 Metal enrichment index

Metal enrichment Index (MEI) has been applied in determining the extent of heavy metals associated with anthropogenic activities in an industrial area. In this study, metal enrichment index previously described by Riba et al. (2002) and have been applied by Sarala and Sabitha (2012) was used. MEI is sometimes called surface enrichment factor (Riba et al., 2002).

$$MEI = \frac{CA - CB}{CA} \quad \text{(Equal 3)}$$

Where, *CA* = total concentration of individual heavy metals; CB = Background level.

1.3.4 Geo-accumulation index

Geo-accumulation index (Igeo) is typically used to assess the degree of anthropogenic or geogenic accumulated pollutant loads (Bhutiani et al., 2017). According to Guan et al. (2014), geo-accumulation index is suitable for assessing heavy metals in soil contaminated by industrial activities. Geo-accumulation index by Muller (1969) and have been applied by El-Metwally et al. (2017), Bhutiani et al. (2017), Ghaleno et al. (2015), Todorova et al. (2016), Tang et al. (2014) Wang et al. (2016), Hassaan et al. (2016), Vowotor et al. (2014), Ghazaryan et al. (2015), Guan et al. (2014), Gasiorek et al. (2017), Kowalska et al. (2016).

$$Igeo = Log_2 \frac{HM(s)}{1.5 \times HM(b)} \quad \text{(Equal 4)}$$

Where HM(s) is the measured concentration of heavy metals in the sample, HM (b) is the background value for the heavy metals and the factor 1.5 is used because of possible variations of the background data due to lithological variations.

1.3.5 Improved nemerow index

Improved Nemerow Index (INI) is another index used in assessing pollution. It was improved by replacing the single factor index in geo-accumulation index (Guan et al., 2014). INI is calculated based on the formula previously described by Guan et al. (2014).

$$\text{Improved Nemerow Index} = \sqrt{\frac{Igeo_{mean}^2 + Igeo_{Maximum}^2}{2}} \quad \text{(Equal 5)}$$

Where $Igeo_{mean}^2$ the mean value of Igeo of the various locations for each of the heavy metals under consideration; and $Igeo_{Maximum}^2$ is the maximum value of geo-accumulation index of the various locations for each of the heavy metals under consideration. The resultant values were compared with the standard presented in in Table 2.

2 Results and Discussion

Table 3 presents Igeo of heavy metals in cassava mill effluents contaminated soil in a rural community in the Niger Delta, Nigeria. The Igeo ranged from un-contamination (Igeo≤0) to moderately contamination (1< Igeo ≤ 2). Copper were within un-contamination to moderately contamination at dry season of LD in both background scenarios (BMM and BGM). Zinc was within un-contamination to moderately contamination at dry season for LE in BGM background consideration, and uncontaminated level for BMM scenario. Like zinc in BMM consideration, manganese was uncontaminated in all the locations across both seasons of study. While under BGM consideration, it was within un-contamination to moderately contamination at dry season for LE. Iron was within un-contamination to moderately contamination at dry season for LC and LD under both scenarios and LE for wet season in BMM background consideration.

Lead showed moderate contamination in wet season of LB under both scenarios. Furthermore, LA for wet season in BMM background consideration was within un-contamination to moderately contamination. Cadmium showed un-contamination to moderately contamination in wet season for LB and LE. These levels of contamination were also peculiar in wet season of LB under BGM consideration. Chromium level at dry season for LA and wet season for LE under BMM scenario and wet season for LA and LE were within un-contaminated to moderate contamination. In nickel, wet season for LC were within moderate contamination. Furthermore, LA and LD for dry season and LB for wet season were within un-contamination to moderately contamination in BMM background consideration. While in BGM background scenario, nickel at LB and LC for wet season were within un-contamination to moderate contamination. Cobalt in wet season of LA and LE (under BMM consideration) and LA (under BGM scenario) were within un-contamination to moderately contamination. The findings of this study showed that only 17 (representing 18.89%) of all the metals under study in the different location across both seasons were contaminated under BMM background scenario. Under BGM background scenario, 11 (representing 13.33%) of all the metals under study in the different location across both seasons were also contaminated. Based on the statistical analysis the mean of all the location indicate un-contamination (Table 4). Furthermore, the trend of both background scenarios having different Igeo is in line with the trend previously reported by Bhutiani et al. (2017). Some of the contamination occurred in only one season is an indication of seasonal variations in cassava mill effluents contaminated soil by small-scale cassava processors in a rural area of the Niger Delta region of Nigeria. Based on the positive contamination factor reported by Izah et al. (2017d) and the negative geo-accumulation index, it suggests that instances of the heavy metals contamination in the processing mill are due to human activities. Oliveira et al. (2011), Bhutiani et al. (2017) attributed this to dilution by coarse nature of the environment as possible source of variation in Igeo of an industrial area. Furthermore, Abrahim and Parkers (2008) also reported that low level of contamination in some of the heavy metals could be due to background consideration value and lithological value of 1.5 in the Igeo equation. According to Guan et al. (2014), the 1.5 constant is used to compensate for the natural fluctuations of a given metal and for minor human impacts in the environment under investigation. Index of geo-accumulation approach focused on the comparative evaluation of the heavy metals in the study area (Fu et al., 2014; Todorova et al., 2016).

Typically, the accumulation of heavy metals in soil is related to the direct and indirect anthropogenic activities (Wei and Yang, 2010; Mmolawa et al., 2011; Zhao et al., 2013; Mazurek et al., 2017). According to Yisa et al. (2012), Mazurek et al. (2017), Zawadzka and Lukowski (2010), heavy metals resulting from human activities in the environment could have been transported via air and deposited into the topsoil which then penetrates into the soil profile. The penetration capacity is dependent on the soil characteristics with regard to texture and structure. This could also account for the variation in the Igeo among the contaminated sites/locations.

Table 3 Index of Geo-accumulation of heavy metals in cassava mill effluents contaminated soil

Location	Season	BMM									BGM								
		Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co	Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co
LA	Dry	-0.58	-2.74	-1.69	-1.89	0.32	-0.62	0.30	0.08	-2.18	-0.56	-2.32	-1.40	-1.74	0.45	-0.62	0.68	-0.03	-1.89
	Wet	-0.94	-1.69	-1.69	-0.71	-0.58	-0.60	-0.17	-1.22	0.50	-0.67	-1.47	-1.56	-0.74	-0.81	-0.97	0.82	-1.60	0.11
LB	Dry	-0.04	-0.79	-1.47	-1.56	0.42	-0.62	-3.06	-1.09	-0.58	-0.01	-0.36	-1.22	-1.36	0.55	-0.62	-2.64	-1.18	-0.23
	Wet	-0.64	-0.29	-0.15	-0.92	1.53	0.45	-1.03	0.51	-0.60	-0.34	-0.10	0.00	-0.94	2.47	0.10	-1.22	0.15	-0.97
LC	Dry	-1.09	-0.58	-0.58	0.11	-0.58	-0.62	-0.58	-0.58	-0.45	-1.06	-0.17	-0.32	0.30	-0.45	-0.62	-0.20	-1.00	-0.12
	Wet	-1.03	-0.81	-0.81	-0.25	-1.84	-0.60	-0.58	1.27	-0.60	-0.71	-0.62	-0.67	-0.27	-2.06	-0.97	-0.79	0.87	-0.97
LD	Dry	0.20	-0.51	-0.45	0.03	-1.47	-0.62	-1.06	0.07	-0.51	0.23	-0.10	-0.18	0.23	-1.32	-0.62	-0.67	-0.03	-0.17
	Wet	-1.15	-0.58	-0.43	-0.30	-0.58	-0.60	-1.00	-0.58	-0.60	-0.86	-0.40	-0.29	-0.30	-0.81	-0.97	-1.22	-0.94	-0.97
LE	Dry	-1.56	-0.40	-0.09	-0.58	-2.25	-0.62	-0.45	-0.92	-0.89	-1.35	0.03	0.19	-0.40	-2.12	-0.62	-0.07	-1.00	-0.54
	Wet	-0.62	-0.51	-0.58	0.58	-0.27	0.37	0.91	-1.06	0.26	-0.34	-0.32	-0.43	-0.60	-0.49	0.00	0.70	-1.40	-0.12

Note: Igeo ≤ 0 (uncontaminated), 0<Igeo ≤ 1 (uncontaminated to moderately contaminated), 1< Igeo ≤ 2 (moderately contaminated), 2 < Igeo < 3 (moderately to heavily contaminated), 3< Igeo < 4 (heavily contaminated), 4 < Igeo < 5 (heavily to extremely contaminated), Igeo ≥ 5 (extremely contaminated)

BMM- Background median mean, BGM- Background geometric mean

Table 4 Statistical Analysis of the Index of Geo-accumulation of heavy metals in cassava mill effluents contaminated soil

Background	Heavy metals	Dry season			Wet season		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
BMM	Cu	-1.56	0.20	-0.61	-1.15	-0.62	-0.88
	Zn	-2.74	-0.40	-1.00	-1.69	-0.29	-0.78
	Mn	-1.69	-0.09	-0.86	-1.69	-0.15	-0.73
	Fe	-1.89	0.11	-0.78	-0.92	0.58	-0.32
	Pb	-2.25	0.42	-0.71	-1.84	1.53	-0.35
	Cd	-0.62	-0.62	-0.62	-0.60	0.45	-0.20
	Cr	-3.06	0.30	-0.97	-1.03	0.91	-0.37
	Ni	-1.09	0.08	-0.49	-1.22	1.27	-0.22
	Co	-2.18	-0.45	-0.92	-0.60	0.50	-0.21
BGM	Cu	-1.35	0.23	-0.55	-0.86	-0.34	-0.5 8
	Zn	-2.32	0.03	-0.58	-1.47	-0.10	-0.58
	Mn	-1.40	0.19	-0.59	-1.56	0.00	-0.59
	Fe	-1.74	0.30	-0.59	-0.94	-0.27	-0.57
	Pb	-2.12	0.55	-0.58	-2.06	2.47	-0.34
	Cd	-0.62	-0.62	-0.62	-0.97	0.10	-0.56
	Cr	-2.64	0.68	-0.58	-1.22	0.82	-0.34
	Ni	-1.18	-0.03	-0.65	-1.60	0.87	-0.58
	Co	-1.89	-0.12	-0.59	-0.97	0.11	-0.58

Note: Igeo ≤ 0 (uncontaminated), 0<Igeo ≤ 1 (uncontaminated to moderately contaminated), 1< Igeo ≤ 2 (moderately contaminated), 2 < Igeo < 3 (moderately to heavily contaminated), 3< Igeo < 4 (heavily contaminated), 4 < Igeo < 5 (heavily to extremely contaminated), Igeo ≥ 5 (extremely contaminated); BMM- Background median mean, BGM- Background geometric mean

Table 5 presents the results of Improved Nemerow index (INI) of heavy metals concentration in cassava mill effluents contaminated soil. Under BMM consideration, all the heavy metals under study were within un-contaminated to moderate contamination apart from copper for dry season. While under BGM scenario all the heavy metals were uncontaminated except for lead, chromium and cadmium that were within un-contaminated to moderate contamination for dry season. In wet season, BMM scenario showed that cadmium and cobalt was un-contaminated, lead was moderately contaminated and copper, zinc, manganese, iron, chromium and nickel was within un-contaminated to moderately contamination in wet season. While in dry season the BGM were un-contaminated for copper, zinc, manganese, iron, cadmium and cobalt; moderately contaminated for lead and within un-contaminated to moderately contamination for nickel and chromium. This showed that different background data have effect on the assessment. But the overall analysis showed that cassava mill effluent is leading to no contamination to moderate contamination in the receiving soil and are influenced by seasons.

Table 5 Improved Nemerow index of heavy metals concentration in cassava mill effluent contaminated soil in a rural community in the Niger Delta region of Nigeria

Parameters	BMM		BGM	
	Dry	Wet	Dry	Wet
Cu	0.45	0.76	0.42	0.48
Zn	0.76	0.59	0.41	0.42
Mn	0.61	0.53	0.44	0.42
Fe	0.56	0.62	0.47	0.45
Pb	0.58	1.11	0.57	1.76
Cd	0.62	0.35	0.62	0.40
Cr	0.97	0.69	0.63	0.63
Ni	0.73	0.91	0.46	0.74
Co	0.72	0.38	0.43	0.42

Note: 0< INI ≤0.5 (Un-contamination); 0.5 < INI ≤1 (Uncontaminated to moderately contamination); 1 < INI ≤2 (Moderate contamination); 2 < INI ≤3 (Moderate to heavy contamination); 3 < INI ≤4 (Heavy contamination); 4 < INI ≤5 (Heavy to extremely contamination); INI > 5 (Extremely contaminated); BMM- Background median mean, BGM- Background geometric mean

Table 6 presents enrichment factor of heavy metals in cassava mill effluents contaminated soil in a rural community in the Niger Delta region of Nigeria. The EF ranged from background rank (EF ≤ 1) to significant enrichment (5< EF < 20). Copper in both background scenarios showed moderate enrichment at dry season for LA and LB and minimal enrichment at wet season for LB and LE and dry season for LD. Zinc minimal enrichment at both seasons for LB and LE under both scenarios. Like zinc, manganese showed minimal enrichment at both seasons for LB and LE, and dry season for LA under both scenarios. Lead showed significant enrichment at both seasons of LB and wet season for LA under both background consideration and wet season for LE at only BMM scenario. Cadmium at dry season for LA, wet season for LB and LE (under BMM consideration) and dry season for LA (under BGM scenario) were moderately enriched. Furthermore, LB for dry season of both background scenarios and only wet season for LA and LE at BMM consideration, and wet season for LE at BGM consideration also showed minimal enrichment.

Chromium showed minimal enrichment at wet season for LB and dry season for LE in both consideration scenarios. It also showed moderate enrichment at wet season for LE in both background scenarios and dry season for LA under only BMM consideration. Dry season of LA showed significant enrichment. Nickel showed moderate enrichment in both background level of dry season for LA, wet season for LB and LC and minimally enriched in dry season of LB. Furthermore, it also showed minimal enrichment in dry season for LD under BMM consideration. Cobalt under BMM consideration was minimally enriched in both seasons for LB and wet season for LE and showed moderate enrichment at wet season for LA. While under BGM consideration wet season for LA and LE were minimally enriched while dry season of LB was moderately enriched. EF in both background levels and seasons were highly similar. This trend is close to work of Bhutiani et al. (2017), which reported comparable enrichment factor in heavy metal associated to ground water in an industrial area. Anthropogenic activities are the major source of heavy metals enrichment into the environment. Specifically, Ghaleno et al. (2015) reported anthropogenic and agricultural source of cadmium could lead to relative enrichment in the receiving environment. According to Mazurek et al. (2017), Rivera et al. (2015), the distribution of the heavy metals in the soil depends on their geoavailability and pedochemical enrichment. This could also account for variation in the EF among the various locations and seasons.

Metal enrichment index (MEI) of heavy metal concentration in cassava mill effluents contaminated soil in a rural community in the Niger Delta region of Nigeria is presented in Table 7. The MEI showed that the soil had no enrichment to moderate enrichment. Under BMM consideration, manganese, lead, chromium and nickel showed enrichment, while manganese, lead and chromium showed enrichment under BGM scenario. Variation exists among the both seasons of study with regard to MEI.

The quantification of contamination (QoC) of heavy metals in cassava mill effluents contaminated soil in a rural community in Niger Delta region of Nigeria is presented in Table 8. Positive values were 34 (representing 37.78%) and 47 (representing 52.22%) in BMM and BGM background consideration respectively. Furthermore, negative values were 27 (representing 30.00%) and 5 (representing 5.56%) in the BMM and BGM background scenarios respectively. Each of the seasons under study had positive contamination quantification among the heavy metals under consideration. The positive values result suggests that pollution/contamination in the study locations are due to anthropogenic sources (Bhutiani et al., 2017) which is mainly by the activities of cassava processing. Among both scenarios, apparent differences exits which could be due to variation in the mean used for the background consideration. This trend has also been reported by Bhutiani et al. (2017).

Table 6 Enrichment factor of heavy metals in cassava mill effluents contaminated soil

Location	Season	BMM									BGM								
		Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co	Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co
LA	Dry	2.54	0.56	1.18	1.00	4.74	2.52	4.62	3.99	0.82	2.27	0.65	1.24	1.00	4.49	2.17	5.23	3.26	0.91
	Wet	1.16	0.55	0.54	1.00	1.15	1.16	1.56	0.74	2.49	0.98	0.54	0.52	1.00	0.86	0.78	1.17	0.51	1.61
LB	Dry	2.85	1.70	1.03	1.00	3.91	1.94	0.35	1.37	1.95	2.55	1.99	1.09	1.00	3.33	1.67	0.39	1.12	2.17
	Wet	1.67	1.65	1.81	1.00	5.77	2.80	0.99	2.86	1.35	1.41	1.63	1.76	1.00	4.33	0.19	0.75	2.02	0.87
LC	Dry	0.44	0.62	0.62	1.00	0.62	0.62	0.62	0.62	0.68	0.39	0.73	0.66	1.00	0.59	0.53	0.70	0.51	0.76
	Wet	0.81	0.73	0.72	1.00	0.35	0.85	0.85	2.99	0.85	0.68	0.72	0.70	1.00	0.26	0.57	0.64	2.05	0.55
LD	Dry	1.13	0.68	0.72	1.00	0.36	0.66	0.47	1.04	0.69	1.02	0.80	0.76	1.00	0.34	0.56	0.54	0.84	0.77
	Wet	0.75	0.88	0.97	1.00	0.87	0.88	0.66	0.88	0.88	0.63	0.88	0.94	1.00	0.15	0.59	0.50	0.60	0.57
LE	Dry	0.52	1.15	1.41	1.00	0.32	1.01	1.09	0.81	0.82	0.46	1.34	1.49	1.00	0.30	0.87	1.24	0.66	0.92
	Wet	1.33	1.06	1.06	1.00	1.32	2.19	3.02	0.77	1.95	1.12	1.05	1.03	1.00	0.99	1.44	2.27	0.53	1.26

Note: EF ≤ 1 (background rank), 1< EF < 2 (minimal enrichment), 2< EF <5 (moderate enrichment), 5< EF < 20 (significant enrichment), 20 < EF < 40 (very high enrichment), EF> 40 (extremely high enrichment); BMM- Background median mean, BGM- Background geometric mean

Table 7 Metal enrichment index (MEI) of heavy metals concentration in cassava mill effluent contaminated soil

Seasons	Locations	BMM								BGM							
		Cu	Zn	Mn	Pb	Cd	Cr	Ni	Co	Cu	Zn	Mn	Pb	Cd	Cr	Ni	Co
Dry	LA	0.00	-0.78	-0.53	0.88	0.00	0.84	0.58	-0.68	0.02	-0.70	-0.43	1.05	0.00	1.41	0.48	-0.59
	LB	0.46	-0.12	-0.47	1.02	0.00	-0.82	-0.29	0.00	0.49	0.17	-0.36	1.20	0.00	0.77	-0.34	0.25
	LC	-0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.09	-0.28	0.34	0.21	0.09	0.00	0.31	-0.07	0.39
	LD	0.72	0.05	0.10	-0.45	0.00	-0.27	0.58	0.05	0.75	0.40	0.33	-0.40	0.00	0.05	0.47	0.34
	LE	-0.49	0.14	0.41	-0.69	0.00	0.09	-0.20	-0.19	-0.48	0.53	0.70	0.66	0.00	0.43	0.25	0.03
Wet	LA	-0.53	-0.53	0.00	0.00	0.34	-0.36	1.00	0.00	-0.46	-0.48	-0.15	-0.23	0.16	-0.50	0.60	-0.05
	LB	0.23	0.36	3.34	1.09	-0.26	1.13	0.00	0.96	0.40	0.50	2.70	0.60	-0.36	0.66	-0.20	0.19
	LC	-0.14	-0.14	-0.58	0.00	0.00	2.53	0.00	-0.05	-0.02	-0.05	-0.64	-0.23	-0.14	1.75	-0.20	-0.09
	LD	0.00	0.10	0.00	0.00	-0.25	0.00	0.00	-0.14	0.14	0.22	-0.15	-0.23	-0.35	-0.22	-0.20	-0.18
	LE	-0.48	0.53	0.70	-0.66	0.00	0.43	0.25	0.03	0.20	0.11	-0.80	0.50	1.45	-0.14	0.40	0.19

Note: 1= no enrichment; 2= Low enrichment; 3 = moderate enrichment; 4 strongly enrichment; 5; extremely enrichment.

BMM- Background median mean, BGM- Background geometric mean

Table 8 Quantification of contamination (QoC) (%) values of heavy metals in cassava mill effluents contaminated soil

Location	Season	BMM									BGM								
		Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co	Cu	Zn	Mn	Fe	Pb	Cd	Cr	Ni	Co
LA	Dry	0.00	-350.26	-113.34	-150.82	46.88	0.00	46.15	36.82	-208.68	1.98	-236.77	-76.76	-119.31	51.21	0.00	58.46	32.30	-143.41
	Wet	0.00	-112.38	-114.89	-8.78	0.00	0.00	25.35	-56.82	-53.01	5.52	-86.88	-93.94	-11.26	-17.46	-30.43	13.62	-101.14	38.55
LB	Dry	31.37	-14.07	-87.42	-93.25	50.42	0.00	-457.89	-41.48	0.00	32.29	14.75	-55.28	-68.97	54.47	0.00	-326.32	-51.60	21.14
	Wet	19.88	18.81	26.32	-25.54	76.98	52.08	34.75	54.42	0.00	15.73	28.56	33.51	-28.40	72.96	37.50	-55.93	39.80	-30.77
LC	Dry	-27.27	0.00	0.00	38.11	0.00	0.00	0.00	0.00	8.60	-38.46	25.70	17.15	45.88	8.16	0.00	23.58	-7.14	27.93
	Wet	-4.59	-16.10	-16.50	20.67	-139.24	0.00	0.00	71.66	0.00	-10.00	-2.16	-5.14	18.86	-181.01	30.43	-15.72	59.55	-30.77
LD	Dry	41.79	-4.32	8.92	34.78	-84.72	0.00	-37.66	36.67	5.06	42.94	28.50	24.54	42.97	-68.06	0.00	-5.19	32.14	25.14
	Wet	-15.87	0.00	9.45	17.53	0.00	0.00	33.61	0.00	0.00	-21.86	-86.99	18.28	15.65	-17.46	30.43	-54.62	-28.26	-30.77
LE	Dry	-95.48	12.66	29.12	0.00	-21.75	0.00	8.23	-24.88	-22.88	-91.61	34.73	41.27	12.56	-191.57	0.00	29.87	-33.80	3.10
	Wet	19.88	5.26	0.00	0.00	19.57	48.89	64.67	-38.00	45.07	15.91	16.64	9.75	-2.28	5.53	33.33	59.11	-77.00	28.17

3 Conclusions

This study evaluated EF, Igeo, QoC, INI and MEI of heavy metals in cassava mill effluents contaminated soil in the Niger Delta region of Nigeria. Results showed un-contamination to moderately contamination for Igeo and INI; background rank to significant enrichment for EF, and some levels of pollution/contamination for QoC. The study showed that to large extent heavy metals concentration each of the locations is being influenced by cassava mill effluents.

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