

Trend of heavy metal contamination: A case study on the soil of Amassoma community, Bayelsa state of Nigeria

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Abstract

Presence of heavy metal contamination in agricultural lands, even at low levels is not desirable for human and animal health. Six soil samples were taken from three locations in Amassoma community in Bayelsa state in the months of April from the year 2019 to 2021. These samples were taken from the rhizosphere of pawpaw tree and scent leaf from the depth of 0-30 cm. Samples were prepared by wet-ashing in line with the method defined by Smith 1972 and subjected to Atomic Absorption Spectrophotometry (AAS) and readings analysed with SPSS V.23 and IBM InStat GraphPad Prism V.3. Unpaired t test and trend analysis (graph, moving averages and slope) was used to ascertain significant difference between the yearly means and WHO limit at $P < 0.05$, and trends of heavy metal contamination over the study period respectively. Increase in contamination of Lead (Pb), Cadmium (Cd), and Nickel (Ni) from 2019 to 2021 was revealed as $0.050 \text{ mg/kg}^{-1} \text{ year}^{-1}$, $0.005 \text{ mg/kg}^{-1} \text{ year}^{-1}$, and $0.063 \text{ mg/kg}^{-1} \text{ year}^{-1}$ respectively. There was no reported increase in Zinc contamination ($0.00 \text{ mg/kg}^{-1} \text{ year}^{-1}$). Yearly analysis revealed statistically significant differences in observed heavy metal concentrations to that of the WHO limit ($p < 0.05$). The 2-tailed p-value between the means of heavy metals studied and that of the WHO limits were all significantly different. Recommendations are that more researches be conducted to determine heavy metal accumulations in soils in Amassoma and other communities in Bayelsa state Nigeria. Government effort is required to initiate concerted remediation processes of the reported heavy metals to curb future health dangers.

Keywords: Heavy metals; Heavy metal concentration; Contamination; Soil; Amassoma community; Toxicity

1. Introduction

Heavy metals are naturally occurring elements with atomic weight and density above 5 times that of water. They are widely used in industry, homes, agriculture, medicine and technology [1,2] and thus a wide distribution in the environment [3]. Their occurrence is reported to depend on the soil type; a decreasing sequence of $\text{Cd} > \text{Cu} > \text{Zn} > \text{Pb}$

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on light soils and trend of $Cd > Zn > Pb > Cu$ on medium soils [4]. The presence of heavy metals in the soil, even at low concentrations, due to natural processes and anthropogenic activities [1,2] has been reported to impart functional disorders of soils, retarded plant growth and even harm the health of humans through contamination of food chain [5]. Contaminants in aquatic systems, including heavy metals, have been reported to stimulate the production of Reactive Oxygen Species (ROS) that can damage fishes and other aquatic organisms [6]. These heavy metals in the soil are not biodegradable and thus can potentially lead to the uptake and accumulation of these metals in the medicinal plants' parts [7,8]. These are a good source of possible health risk to plants and animal partly because they have the capacity to form concentrates in the normal ecological food chain, and the kidneys excrete such heavy metals only slowly, most times resulting into a consequent deleterious health effect [9,10]. These deleterious effects may be in the form of decrease in immunological defenses, cardiac dysfunction, fatal malformation, impaired psychosocial and neurological behaviors, gastrointestinal cancer, and many others [11]. High concentrations of some heavy metals have been implicated in metabolic disturbances and growth inhibition of some plants [12]. Other studies have demonstrated that the uptake of Nickel and Cadmium can damage the integrity of cell membrane in certain plants [13], for example excess concentrations of Cd, Cu, Pb, and Zn has been reported to significantly affect the plant water status of sunflowers causing water deficit and subsequent changes in plant [14]. The WHO has recommended allowable limits of commonly used heavy metals on plants which when taken will have no or minimal effect on human health [15,16]. Other studies have also reported high levels of EC, pH and heavy metals in the tissues and supporting soil in the sampled plots in Port Harcourt in Rivers State, Nigeria concerning pawpaw (*Carica papaya linn* but in decreasing order of $Pb > Cu > Hg > Zn > Cd$). The use of the soil and its produce for food and medicine is also common in Nigeria [17,18]. Plants of common use include scent leaf and the pawpaw fruit with various ascribed medicinal uses [12].

There is a reported need for immobilization, soil washing and phytoremediation techniques to reduce the associated risks, make the land resource available for agricultural production, enhance food security and scale down land tenure problems arising from changes in the land use pattern [19]. The widely practiced forms are those of the integrated processes, involving the combination of two different methods to achieve a synergy in removing heavy metals [20, 21]. An increasing trend for Cd ($p < 0.05$; $0.0081 \text{ mg kg}^{-1} \text{ year}^{-1}$), a decreasing trend for Cu ($p < 0.05$; $-0.80 \text{ mg kg}^{-1} \text{ year}^{-1}$), and no significant trend for Pb ($p = 0.155$), Zn ($p = 0.746$), and Ni ($p = 0.305$) was reported in farmlands in China in the year 2014 [22]. Drastic shoot up of heavy metals has also been reported in surface waters in Nigeria from a study carried out from 2007 to 2009 [23]. The need for investigating the level of contamination of some heavy metals such as Zinc, Nickel, Lead and Cadmium in soils and comparing their levels with prescribed benchmark values of WHO in Amassoma community, Bayelsa State, Nigeria is thus necessary.

2. Material and methods

2.1. Field Studies

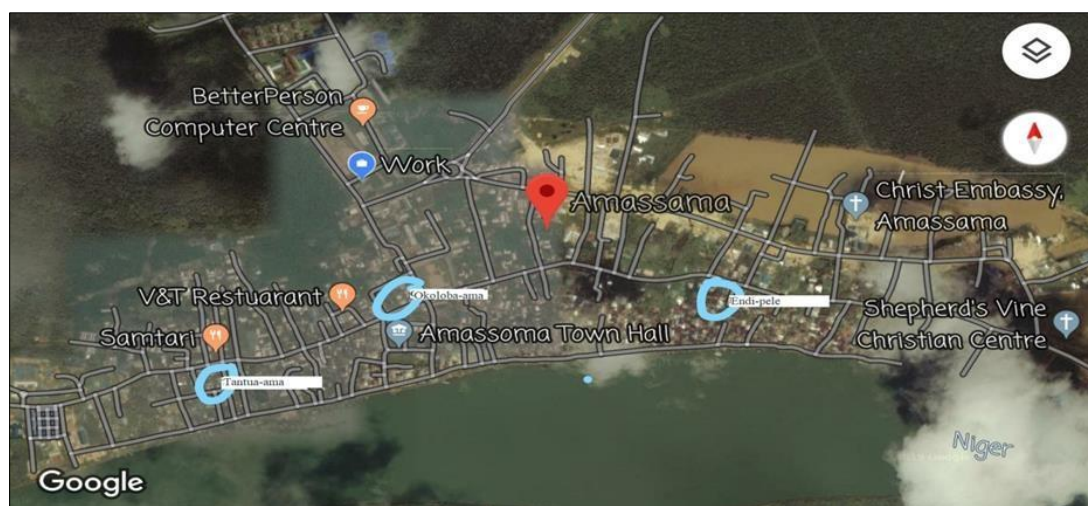


Figure 1 Geographical location of the study environment

Amassoma community in Southern Ijaw LGA, Bayelsa State of Nigeria was selected for sampling. Sampling was done at random from three different locations (Endi-pele latitude 4.93625833 and longitude 6.33791167, Okoloba-ama latitude 4.93613167 and longitude 6.33823 and Tantua-ama latitude 4.93625833 and longitude 6.33791167) within Amassoma

metropolis. These locations were selected at random to centralize the sample stations within the community (Sample location) as shown in Figure 1. Geographically, sample area has land mass of 2,682 km² and a population of 319413 at the 2006 census. The study location has been reported to have a loose soil type. The people are predominantly farmers, fishermen, business men and civil servants. It is the fastest growing community in Bayelsa State for reasons of the presence of the first state owned university (Niger Delta University) and its increasing commercial bustles.

2.2. Soil Sampling, Preparation and Laboratory Studies

Six samples of soil were taken from the rhizosphere of pawpaw tree and scent leaf at the depth of 0-30 cm on the soil of Amassoma community in the year 2019. The samples were prepared by wet-ashing in line with the method defined by Smith 1972 [24]. The soil samples were air-dried and crushed into dust in order to provide for proper analysis. Then 1g of each blended samples were weighed and wet-digested with conc. HNO_3/H_2SO_4 in the ratio of 1:3 on the hot-plate in a fume-hood. This was heated till the solution became clear. 20 ml of distilled water was introduced to the digest and filtered in 100 ml volume flask and was made up to the mark with distilled water. The samples filtered were then transferred into 100 ml plastic bottles before it was taken for analysis. Then the Atomic Absorption Spectrophotometer (AAS) was switched on and the various lamps were set up, and appropriate lamp currents were also set up. The concentrations of Cadmium (Cd), Nickel (Ni), Lead (Pb), and Zinc (Zn), were analyzed and the concentrations in the soil were recorded as mg/kg of sample and this was compared with the WHO allowable limits for heavy metals in soil. This process was repeated again in the year 2020 and 2021 and concentrations of heavy metals recorded for comparison to the previous readings to ascertain possible trends of level of contamination.



Figure 2 Atomic absorption spectrophotometer



Figure 3 Laboratory work

2.3. Statistical Analysis

The samples of this study were analysed using the Statistical Programme for Social Sciences (SPSS) and IBM Instat GraphPad Prism V.3. Anunpaired t-test was used to determine the significant difference between the means of the various samples, using $P < 0.05$ level of significance. Trends of concentration of heavy metal contamination was ascertained with trend analysis (graph, moving averages and slope).

3. Results and discussion

3.1. Observed general contamination trends of Lead, Cadmium, Nickel and Zinc

The study carried out from 2019 to 2021 on the soil of Amassoma community in Bayelsa state of Nigeria revealed a general increasing trend of heavy metal contamination. This is depicted by the increasing average concentrations of heavy metals over the years, and the slope values as shown in table 1 and figure 4 to figure 7 below. There was a revealed increasing trend of contamination of Lead (Pb), Cadmium (Cd), and Nickel (Ni) from 2019 to 2021 as 0.050 mg/kg⁻¹year⁻¹, 0.005 mg/kg⁻¹year⁻¹, and 0.063 mg/kg⁻¹year⁻¹ respectively but not for Zinc contamination (0.00 mg/kg⁻¹year⁻¹). Shao et al 2016 [22] reported a decreasing trend of Cu ($p < 0.05$; -0.80 mg kg⁻¹ year⁻¹), increasing trend for Cd ($p < 0.05$; 0.0081 mg kg⁻¹ year⁻¹) and no significant increasing trend for Pb ($p = 0.155$), Zn ($p = 0.746$), and Ni ($p = 0.305$) from

2000 to the year 2014 on farmlands of Yangtze River Delta (YRD), China. Nubi, Oyediran and Nubi 2011 [23] also reported an inter-annual trends of 2009 > 2008 > 2007 for Fe, Zn, Cu, Cr, Pb in Nigerian soils. These studies are also in consonance with the likelihood of general increase in heavy metal contaminations in farmlands.

Analysis at the individual years in the year 2019 revealed similarity between the samples collected for the study (depicted by small standard deviations) and statistically significant differences in the concentration of observed level of heavy metals to that of the maximum contamination level as prescribed by the WHO. The 2-tailed p-value between the mean observed concentration of all the heavy metals studied and that of the WHO recommended targets were all significantly different in observations. This is also evident with the large mean differences (MD) of the observed means from the expected WHO means and their respective t-scores. This is as shown in table 2. Similar observations were made with the 2020 and 2021 samples of the study. This is as contained in table 3 and table 4.

Table 1 Concentration of heavy metals (Pb, Cd, Ni and Zn) from the year 2019 to 2021 in the soils of Amassoma community, Bayelsa state, Nigeria

Concentration of heavy metals (Pb, Cd, Ni and Zn) from the year 2019 to 2021 in the soils of Amassoma community, Bayelsa state, Nigeria					
Heavy metal		Pb	Cd	Ni	Zn
Samples (mg/kg) 2019	2019A	1.34	0.239	8.103	3.169
	2019B	1.094	0.24	5.347	1.242
	2019C	1.42	0.289	0.67	2.425
	2019D	1.235	0.256	7.133	1.691
	2019E	1.216	0.246	0.614	3.394
	2019F	1.855	0.258	7.523	1.398
Mean Conc. (mg/kg)		1.36	0.255	4.898	2.219
Samples (mg/kg) 2020	2020A	1.36	0.338	8.203	3.179
	2020B	1.113	0.311	6.337	1.222
	2020C	1.532	0.291	1.733	2.335
	2020D	1.443	0.276	7.733	1.722
	2020E	1.226	0.266	3.644	3.401
	2020F	1.877	0.299	7.666	1.418
Mean Conc. (mg/kg)		1.425	0.297	5.886	2.213
Samples (mg/kg) 2021	2021A	1.47	0.318	8.403	3.271
	2021B	1.223	0.339	6.17	1.276
	2021C	1.953	0.421	1.788	2.531
	2021D	1.899	0.266	7.798	1.777
	2021E	1.726	0.276	3.944	3.54
	2021F	2.811	0.355	7.933	1.648
Mean Conc. (mg/kg)		1.847	0.329	6.006	2.341
WHO Limit (mg/kg)		85	0.8	35	50
R ²		0.4	0.332	0.014	1.00E-05

Table 2 Concentration of heavy metals (Pb, Cd, Ni and Zn) in the year 2019 in the soils of Amassoma community, Bayelsa state, Nigeria

Concentration of heavy metals (Pb, Cd, Ni and Zn) in the year 2019 in the soils of Amassoma community, Bayelsa state, Nigeria					
Heavy metal		Pb	Cd	Ni	Zn
Samples (mg/kg)	2019A	1.34	0.239	8.103	3.169
	2019B	1.094	0.24	5.347	1.242
	2019C	1.42	0.289	0.67	2.425
	2019D	1.235	0.256	7.133	1.691
	2019E	1.216	0.246	0.614	3.394
	2019F	1.855	0.258	7.523	1.398
Mean Conc. (mg/kg)		1.36	0.255	4.898	2.219
T-score		12.482	-33.562	3.505	5.91
Sig.(2-tailed)		< 0.0001	< 0.0001	0.0172	0.002
Std. Dev		0.2669	0.0289	3.7566	0.9737
SEM		0.109	0.0076	1.397	0.3756
Confidence interval (CI)		1.080-1.640	0.235-0.274	1.305-8.491	1.254-3.186
WHO Limit (mg/kg)		85	0.8	35	50
Mean Difference		-83.64	-0.5453	-30.102	-47.78

Table 3 Concentration of heavy metals (Pb, Cd, Ni and Zn) in the year 2020 in the soils of Amassoma community, Bayelsa state, Nigeria

Concentration of heavy metals (Pb, Cd, Ni and Zn) in the year 2020 in the soils of Amassoma community, Bayelsa state, Nigeria					
Heavy metal		Pb	Cd	Ni	Zn
Samples (mg/kg)	2020A	1.36	0.338	8.203	3.179
	2020B	1.113	0.311	6.337	1.222
	2020C	1.532	0.291	1.733	2.335
	2020D	1.443	0.276	7.733	1.722
	2020E	1.226	0.266	3.644	3.401
	2020F	1.877	0.299	7.666	1.418
Mean Conc. (mg/kg)		1.425	0.2968	5.886	2.213
T-score		13.06	28.222	5.495	5.904
Sig.(2-tailed)		< 0.0001	< 0.0001	0.0027	0.002
Std. Dev		0.2673	0.02576	2.624	0.9181
SEM		0.1091	0.01052	1.071	0.3748
Confidence interval (CI)		1.145-1.706	0.269-0.324	3.132-8.640	1.249-3.176
WHO Limit (mg/kg)		85	0.8	35	50
Mean Difference		-83.575	-0.5032	-29.114	-47.787

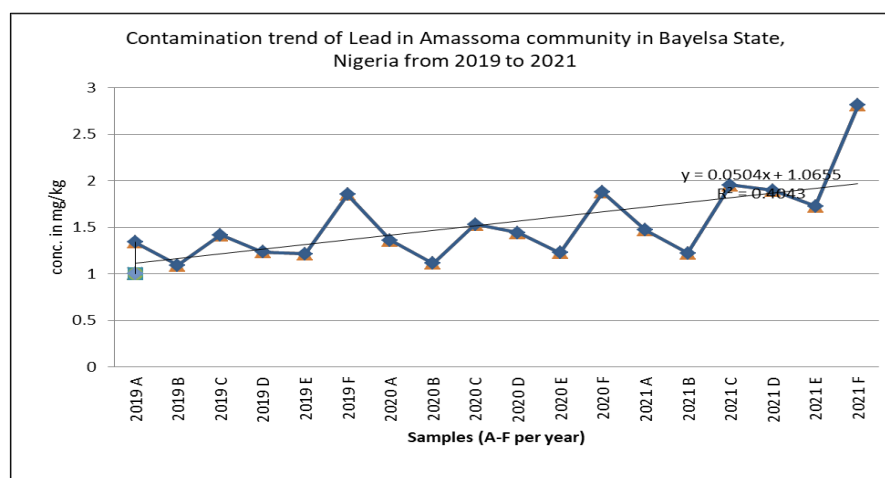
Table 4 Concentration of heavy metals (Pb, Cd, Ni and Zn) in the year 2021 in the soils of Amassoma community, Bayelsa state, Nigeria

Concentration of heavy metals (Pb, Cd, Ni and Zn) in the year 2021 in the soils of Amassoma community, Bayelsa state, Nigeria					
Heavy metal		Pb	Cd	Ni	Zn
Samples (mg/kg)	2021A	1.47	0.318	8.403	3.271
	2021B	1.223	0.339	6.17	1.276
	2021C	1.953	0.421	1.788	2.531
	2021D	1.899	0.266	7.798	1.777
	2021E	1.726	0.276	3.944	3.54
	2021F	2.811	0.355	7.933	1.648
Mean Conc. (mg/kg)		1.847	0.3292	6.006	2.341
T-score		8.289	14.192	5.581	6.203
Sig.(2-tailed)		0.0004	< 0.0001	0.0025	0.0016
Std. Deviation		0.5458	0.05681	2.636	0.9242
SEM		0.2228	0.02319	1.076	0.3773
Confidence interval (CI)		1.274-2.420	0.269-0.389	3.239-8.773	1.370-3.311
WHO Limit (mg/kg)		85	0.8	35	50
Mean Difference		-83.153	-0.4708	-28.994	-47.659

3.2. Observed individual contamination trends of Lead, Cadmium, Nickel and Zinc

3.2.1. Trend of Lead (Pb)

The individual heavy metals revealed differences in their rate of increase or otherwise of the level of contamination the studied soils. A moving average of the six samples taken yearly depicts the differences in the trends. The rate of increase in contamination of Lead (Pb) from the year 2019 to 2021 was revealed by the average concentrations as 1.36 mg/kg, 1.425 mg/kg and 1.847 mg/kg respectively, giving a prediction of $0.050 \text{ mg/kg}^{-1} \text{ year}^{-1}$ increasing trend as was predicted by the slope of the graph. The equation on the linear line of the graph suggests a backward prediction that the contamination of the soil of Amassoma with lead started some 21.3 years before the year 2021. This is as shown in table 1 and fig. 4.

**Figure 4** Observed contamination trend of Lead from 2019 to 2021

The increase in lead concentration could be attributable to indiscriminate disposal of storage batteries and ammunition, incineration and recycling, and mobilization of previously buried lead as is a common practice in the study environment. The above prediction makes sense to coincide with the advent of full scale commercial activities in the community that was brought by the sitting of the state university in the community by the year 2000. Similar trends have been reported by Mañay, Cousillas, Alvarez, & Heller, 2008 [25]; Deborah, 2013 [26], and Erin, 2017 [27]. Persistence of lead in soils and sediments of industrial and urban areas has been linked with inhibitory effects on photosynthesis and plant growth and survival as reported by the United Nations Environmental Programmes, 2010 [28]. Organ toxicity has also been reported in animals by Assi, Hezmee, & Haron, 2016 [29] and in fish by the UK Marine SACs project, 1999 [30].

3.2.2. Trend of Cadmium

Cadmium (Cd) also revealed a $0.005 \text{ mg/kg}^{-1}\text{year}^{-1}$ increase as was depicted by the slope of the graph. The moving averages were 0.332 mg/kg, 1.425 mg/kg and 0.3292 mg/kg for the year 2019, 2020 and 2021 respectively. Depictions from the linear equation of the graph traced a 49 years backward accumulation period of this heavy metal. This is illustrated in table 1 and figure 5. Presence of this metal has also been reported with minimal adverse effects on humans and plant. It is reported to be potentially released from power station heating systems, metal working industries and urban traffic into the environment as opined by Roy & Mehta, 2005 [31]; Mohan & Pittman, 2007 [32]; Hasegawa, Rahman, Matsuda, Kitahara, Maki, & Ueda, 2009 [33]. It is possible that social life and the use of electricity was seen in the community as from such periods.

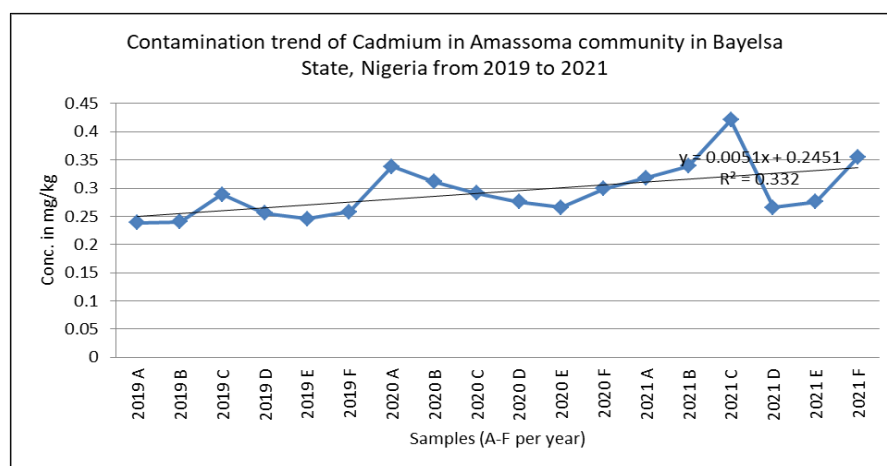


Figure 5 Observed contamination trend of Cadmium from 2019 to 2021

3.2.3. Trend of Nickel (Ni)

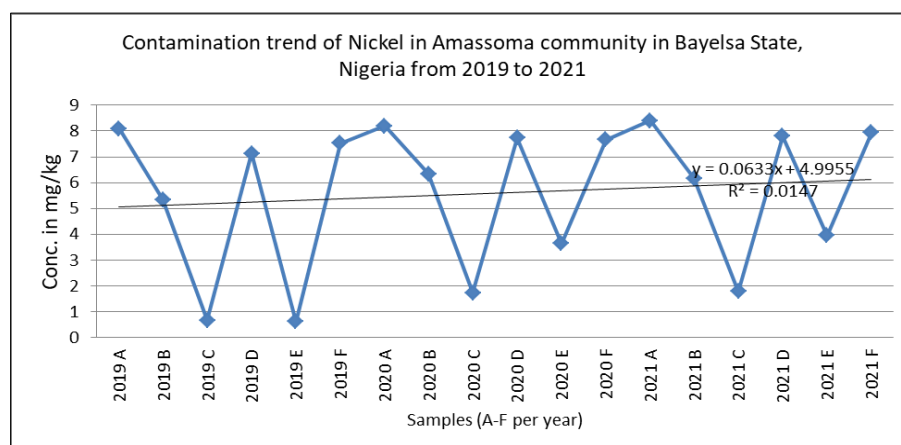


Figure 6 Observed contamination trend of Nickel from 2019 to 2021

The study revealed an increase of $0.063 \text{ mg/kg}^{-1}\text{year}^{-1}$ in levels of contamination of Nickel. There was a reported 4.8983 mg/kg, 5.886 mg/kg and 6.006 mg/kg moving averages with the passing of time. A 79.3 years initiation and

accumulation period was also predicted backward by the linear equation on the trend graph. This is shown in table 1 and figure 6.

Daily Nickel skin contact, inhalation, or ingestion above 1 mg/kg has been reported to be toxic by McGrath & Smith, 1990 [34]. It is reported to be mainly sourced from nickel and nickel alloy production plants, welding plants, electroplating environments, and in areas where grinding and cutting operations are carried out. Also nickel refining, nickel salts production, and stainless-steel companies are other reported by Kasprzak, *et al.*, 2003, and Seilkop & Oller, 2003 [35,36] as sources of nickel contaminations. The frequency of allergy to nickel is reported by Sivulka, 2005 [37] to be on the increase and that it cannot be fully explained by its medical applications.

3.2.4. Trend of Zinc (Zn)

2.219 mg/kg, 2.213 mg/kg and 2.341 mg/kg moving average of Zinc metal was reported in the year 2019, 2020 and 2021 respectively. The trend depicted no yearly Zinc metal concentration increase over the years of study. This is contained in table 1 and figure 7.

Zinc is used in the making of denture creams in the concentrations of 17 and 38mg of zinc per gram. Toxicities to the lives of plants and animals are reported by Zhang, 1996 [38]. According to Tampa Bay Times, 2010 [39], Zinc in the excess amount of 50 ppm in soil can interfere with the plants absorption ability to iron and manganese.

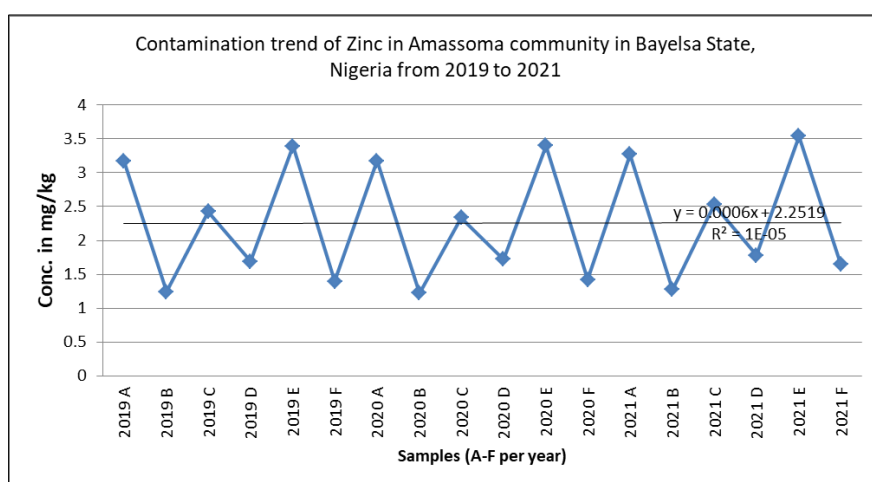


Figure 7 Observed contamination trend of Zinc from 2019 to 2021

4. Conclusion

Presence of heavy metal contamination even at low levels is mostly not desirable for human and animal health. The longitudinal study conducted at the busy town, Amassoma community in Bayelsa state of Nigeria from the year 2019 to 2021 revealed a general increasing trend of heavy metal contamination, depicted by the increasing moving averages of concentrations of heavy metals over the years, and the slope of trend graphs in the order of $Zn < Pb < Cd < Ni$. The 2-tailed p-value between the mean observed concentration of all the individual heavy metals studied and that of the WHO recommended targets were all significantly different in observations as evident with the large differences of the mean of the observed means and the expected WHO means and their respective t-scores. The rate of increase in contamination of Lead (Pb), Cadmium (Cd), Nickel (Ni) and Zinc (Zn) from the year 2019 to 2021 were reported as 0.050 mg/Kg, 0.005 mg/Kg, 0.063 mg/kg and 0.00 mg/kg yearly respectively. This increase in heavy metal contamination in the study environment is a cause for alarm.

It is recommended that communities should be cautious on the use of heavy equipment or sources of exposure route to heavy metals and the use of agrochemicals and pesticides like DDT (dichlorodiphenyltrichloroethane) which are various sources of the observed heavy metal pollution in the environment that have the propensity to greatly impact both plants and animal's health. Similar researches are recommended to be conducted from time to time to determine the levels of heavy metal accumulation in plants of medicinal values in Amassoma and other local communities where these plants are used frequently for nutrition and medicinal purposes. Due to urbanization, modern agricultural activities, and industrial activities taking place in communities, monitoring the safety levels of such heavy metals should become very necessary to avoid poisoning of any sort. Caution is also recommended when such plants are to be used as alternative

to conventional medicine as excess of it could pose the risk of bioaccumulation and possible health effects in human. Government effort is required to initiate concerted remediation processes of the heavy metals to curb future health dangers.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest is associated with this work.

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