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Environmental Heavy Metal Contamination in Some Selected Cocoa Plantations in Oyo State, Nigeria

G. A. Adewoye[1*] and N. A. Amusa[2]

[1]Soil and Plant Nutrition Section, Cocoa Research Institute of Nigeria, Ibadan, Nigeria.
[2]Department of Plant Science and Applied Zoology, Olabisi Onabanjo University, Ago Iwoye, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author GAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author NAA managed the analyses of the study, the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The frequent use of copper-based pesticides for the control of cocoa pests and diseases by farmers in Oyo State, Nigeria has necessitated the determination of heavy metal contamination in soil samples obtained from randomly selected cocoa plantations in Longe, Abaagbo, Sikiti, Idi-Ope, Alaagba, and Idi-Ogun in the State. Presence and quantities of copper, chromium, cadmium, manganese, lead and zinc were assayed in the collected samples. Levels of contamination of each of the soil samples were also assessed using contamination factor, degree of contamination, index of geo-accumulation and pollution load index (PLI). Results obtained from the study revealed a gradual deterioration of the analyzed cocoa soils. The PLI values also gave an indication of pollution. Cocoa farmers in the State therefore need to be properly enlightened on the use of synthetic pesticides, and be encouraged to adopt integrated pest management practices that place less emphasis on the use of chemicals.

Keywords: Cocoa; heavy metal; geo-accumulation; contamination factor; pollution load index.

**Corresponding author: E-mail: baogoa@yahoo.com;*

1. INTRODUCTION

Cocoa production is important to the economy of Nigeria. Cocoa is the leading agricultural export of the country and Nigeria is currently one of the world's largest producers of cocoa, after Ivory Coast, Indonesia, Ghana, and Cameroun [1] and the third largest exporter, after Ivory Coast and Ghana [2]. The crop was a major foreign exchange earner for Nigeria in the 1950s and 1960s and in 1970, the country was the second largest producer in the world. However, following investments in the oil sector in the 1970s and 1980s, Nigeria's share of world output declined. In 2010, cocoa production accounted for only 0.3% of agricultural GDP [1]. Average cocoa beans production in Nigeria between 2000 and 2010 was 389,272 tonnes per year [1], rising from 170,000 tonnes produced in 1999 (IITA)

Nigerian cocoa farmers make use of copper based fungicides which is believed to be the fastest and most reliable means of tackling the menace of black pod disease which is caused by *Phytophthora palmivora* and *P. megakarya*. The major economic loss is from the infection of the pods which in turn affect the quality of the beans within the pods. The incidence of black pod disease is an annual occurrence and the degree of prevalence depends on the rate of precipitation and humidity. This naturally calls for annual application of copper based fungicide if the farmers must make harvest of cocoa pods at the end of the year. In other words, average Nigerian cocoa framers apply copper based fungicide at least eight times in a year. The implication of this act is the accumulation of copper which is a heavy metal in the soil [3].

Heavy metals are of high ecological significance since they are not removed from soil as a result of self purification, but accumulate in reservoirs and enter the food chain [4]. There is increased awareness that heavy metals present in soil may have negative consequences on human health and on the environment [5]. From the environmental point of view, all heavy metals are largely immobile in the soil system, so they tend to accumulate and persist in agricultural soils for a long time. The most frequently reported heavy metals with potential hazards in soils are cadmium, chromium, lead, zinc and copper [6]. The concentrations of these toxic elements in soils may increase from various sources including anthropogenic pollution, weathering of natural high background rocks and metal deposits [7]. At present, relatively little data is available on the extent of environmental pollution as a consequence of using heavy metal-based fungicides on cocoa.

Oyo State is one of the cocoa producing areas in Nigeria and most of the farmers use copper based fungicides for the control of black pod disease [3]. It is therefore necessary to assess heavy metal contamination levels in soils under cocoa plantations due to their potentially harmful effects on human health and also to ascertain whether the heavy metals present are from anthropogenic or geogenic source.

2. MATERIALS AND METHODS

2.1 Sample Collection

Soil samples were collected from cocoa plantations in three selected Local Government Areas, LGAs (Oluyole, Ibarapa East, and Ona-Ara) of Oyo State (Fig. 1). From each of the selected LGAs, two villages were selected, while three farms and adjacent forests from each of the villages were sample. Nine samples were collected from each farm and three from the adjacent forest at 0-15 cm depth using a soil auger. A total of one hundred and eighty samples were collected, composite samples were made from the sample collected. The soil samples were labeled, air dried and sieved.

2.2 Heavy Metals Determination

Some 3 g of dry soil samples were digested in about 15 ml of aqua regia (HCl: HNO_3= 3:1) for approximately 4-5 hours using a hot plate maintaining a heating temperature of approximately 110^{o}C.The samples were next put in a 100 ml Pyrex glass beaker and diluted with distilled water up to 50 ml. The solution was filtered and filtrates were analyzed for heavy metals: manganese, copper, lead, cadmium, chromium and zinc using PG. 990 Atomic Absorption spectrophotometer [8].

2.3 Determination of Environmental Indices

2.3.1 Contamination factor (CF) and degree of contamination

The assessment of soil contamination was carried-out using contamination factor (CF) and the degree of contamination (C_d). The CF is the concentration of each metal in the soil divided by the background concentration of the metal (concentration in unpolluted soil), the sum of contamination factors for all elements examined represents the C_d of the environment and all classes are recognised [9].

Table 1 shows the different contamination factor classes and levels.

$$CF = \frac{C\ heavy\ metal}{C\ background}$$

$$C\ deg = \sum \left(\frac{Cm}{Bm}\right)i$$

Where:

i represent the respective metals (i.e Zn, Pb, Cu, Cd, Mn, Cr) Cm is the measured concentration in soil while Bm is the background (adjacent forest) concentration value of metal (m) within the area of study

2.3.2 Geochemical index (Igeo)

As proposed by [10] has also been widely used to evaluate the degree of metal contamination in terrestrial, aquatic as well as marine environments [11,12,13]. It is expressed as

$$Igeo = Log_2 \frac{C_n}{1.5B_n}$$

Where:

C_n is the measured concentration of the element 'n' in the soil and Bn is the geochemical background value of element 'n' in the background or control within the study area .The constant 1.5 is a factor which allow us to analyze natural fluctuations in the contents of small anthropogenic influences.

Muller [14] has distinguished six classes of the geo-accumulation index.

However, an Igeo of 6 is said to be indicative of 100-fold of a metal with respect to the background value [15].

2.3.3 Pollution Load Index (PLI)

Pollution load index for a particular site, has been evaluated following the method proposed by Tomilson et al. [16]. This parameter is expressed as.

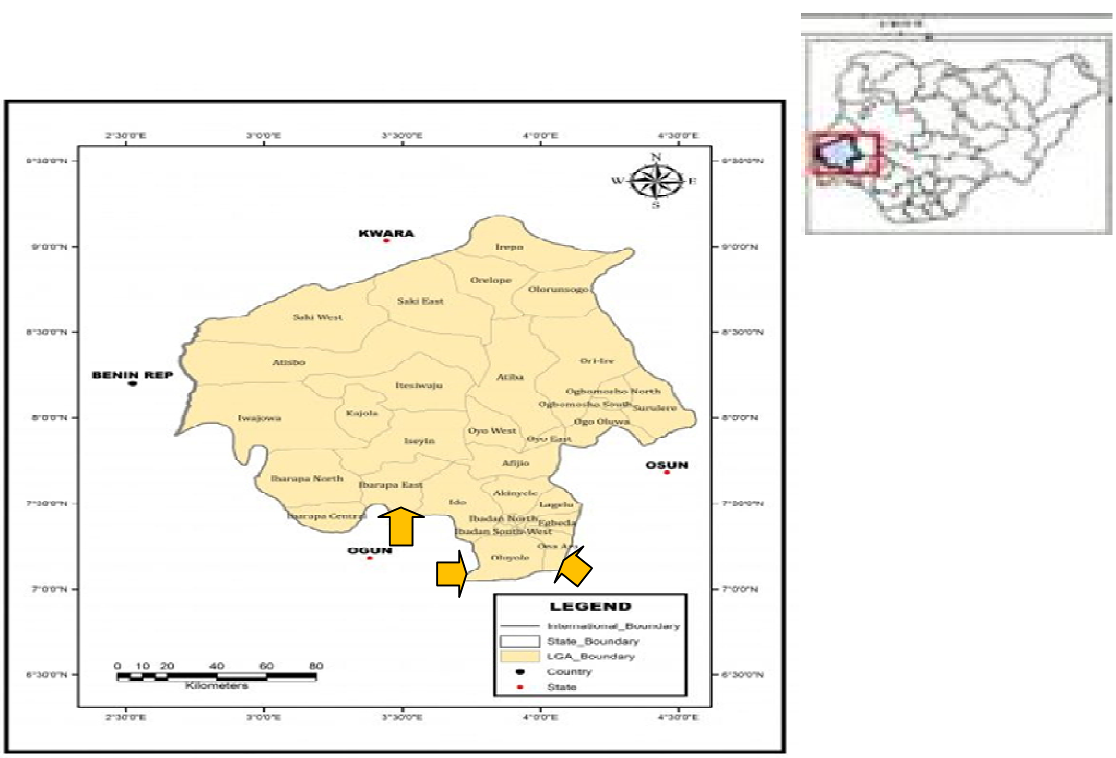

Fig. 1. Map of Oyo State, Nigeria showing the study areas

$PLI = (CF_1 \times CF_2 \times CF_3 \ldots\ldots\ldots CF_n)^{i/n}$

Where:

N is the number of metals and CF is the contamination factor. The contamination factor can be calculated from the following relation.

$$CF = \frac{\text{Metal concentration in soil}}{\text{Background value of the metal}}$$

3. RESULTS AND DISCUSSION

Results of contamination factor of the studied soils are presented in Table 3. Contamination factor of zinc ranged between 0.90 and 1.93 with a mean factor of 1.17. Contamination factor of lead ranged from 1.36 to 2.19 with a mean factor of 1.79. Also, the contamination factor of copper ranged from 1.57 to 2.57 with a mean value of 2.01. Contamination factor of cadmium ranged between 1.07 and 1.68 with a mean value of 1.43.

The contamination factor of manganese ranged from 0.90 to 3.18 with a mean value of 1.47, while chromium contamination factor ranges between 1.11 and 1.98 with a mean value of 1.53. According to the contamination factor of Hankanson [9], the soils studied showed low degree of contamination with zinc, lead, cadmium, manganese, chromium and copper.

The results of geo-accumulation index (I_{geo}) are as presented in Table 4. Geo-accumulation index of zinc ranged from -0.74 to 0.36 with a mean value of -0.42, cadmium, manganese and chromium values ranged between -0.49 and 0.16, -0.74 and 1.08, and -0.43 and 0.39 respectively, with mean values of -0.08, -0.18 and -0.003. The I_{geo} being negative showed that the cocoa farm soils studied were practically uncontaminated with zinc, cadmium, manganese and chromium according to Muller (1981). This implies that the zinc, cadmium, manganese and chromium were not from anthropogenic sources; they were rather from natural sources.

I_{geo} for lead in the studied soils ranged from -0.14 to 0.55 with a mean value of 0.24. By the classification of Muller (1981), it then infers that the lead contents in cocoa plantations studied in this work is solely from natural sources.

I_{geo} of copper ranged from -0.58 to 0.78 with a mean value of 0.25. This I_{geo} mean value is lower than the value reported by Aikpokpodion [17]. The intake of copper by plants is proportional to the content of its soluble forms in soil which increases at low pH (Kabata-Pendias and Pendias,1999 [18]. Moreover, copper compounds from anthropogenic sources are more available to plants than the ones from natural sources.

Results of pollution load index (PLI) which is the nth root of the multiplication of all the contamination factors for all the examined heavy metals are presented in Table 5.

Table 1. Different Contamination Factors (CF) for Soil [5]

Cf Value	Contamination Factor level
Cf<1	Low contamination factor indicating low contamination
1<Cf<3	Moderate contamination factor
3<Cf<6	Considerable contamination factor
6<Cf	Very high contamination factor

Table 2. Classes of geo-accumulation index

Class	Implication
Igeo =0	Practically 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

Table 3. Contamination factor of heavy metals in the selected cocoa farms

Plot	Zn	Pb	Cu	Cd	Mn	Cr
Longe	1.17	1.36	2.57	1.48	3.18	1.28
Abaagbo	1.93	1.63	2.15	1.68	1.26	1.52
Idi-Ope	0.90	1.88	2.22	1.40	1.00	1.68
Sikiti	1.08	1.58	1.57	1.49	0.90	1.98
Alaagba	1.01	2.11	1.67	1.07	1.14	1.58
Idi-Ogun	0.92	2.19	1.90	1.48	1.35	1.41
Min	0.90	1.36	1.57	1.07	0.90	1.28
Max	1.93	2.19	2.57	1.68	3.18	1.98
Mean	1.17	1.79	2.01	1.43	1.47	1.53

Table 4. Index of geo accumulation of heavy metals in the selected cocoa farms

Plot	Zn	Pb	Cu	Cd	Mn	Cr
Longe	-0.35	-0.14	0.78	-0.02	1.08	-0.23
Abaagbo	0.36	0.12	0.52	0.16	-0.26	0.02
Idi-Ope	-0.74	0.32	0.57	-0.11	-0.60	0.16
Sikiti	-0.47	0.07	0.07	-0.01	-0.74	0.39
Alaagba	-0.58	0.49	0.15	-0.49	-0.39	0.07
Idi-Ogun	-0.71	0.55	-0.58	-0.02	-0.15	-0.43
Min	-0.74	-0.14	-0.58	-0.49	-0.74	-0.43
Max	0.36	0.55	0.78	0.16	1.08	0.39
Mean	-0.42	0.24	0.25	0.08	0.18	0.003

Table 5. Pollution load index of heavy metals in the selected cocoa farms

Farm	Pollution load index
Longe	4.11
Abaagbo	3.63
Idi-Ope	1.47
Sikiti	1.19
Alaagba	1.14
Idi-Ogun	1.41
Min	1.14
Max	4.11
Mean	2.16

According to Tomlinson et al.[12] (0.0) indicates perfection, a value of (1.0) indicates only baseline level of pollutants present and values above one (>1.00) would indicate progressive deterioration of the site. Pollution load index (PLI) of the studied cocoa plantation soils ranged from 1.14 to 4.11. This confirmed that the studied cocoa farms are polluted. The PLI can provide some understanding to the cocoa farmers in Oyo State and all other cocoa growing states in Nigeria who use synthetic pesticides in combating the menace of black pod and other associated diseases about the quality of soil which is a component of their environment. It also provide valuable information and advice for policy and decision makers on the pollution levels of cocoa soil in Oyo State and the whole of Nigeria.

4. CONCLUSION

Results of the environmental factors used (contamination factor, geo accumulation index and pollution load index) showed that all the cocoa plantations under study were polluted with heavy metals. The pollution load index values showed clearly that the soil was deteriorating, and so, farmers should be cautioned on the use of synthetic pesticides, but should be encouraged to adopt the use of botanicals or other natural control strategies including integrated crop and pest management that places less emphasis on the use of chemicals.

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