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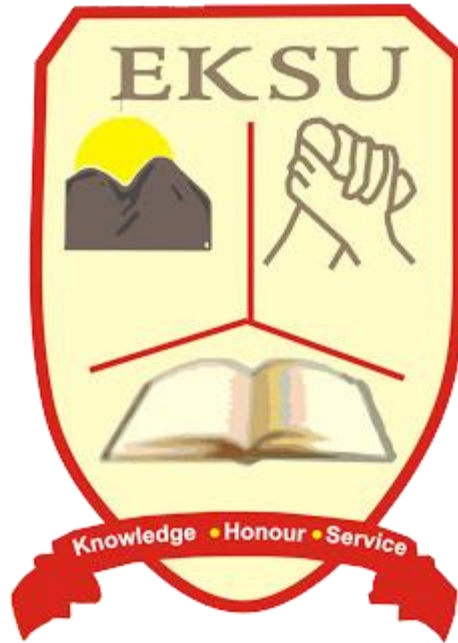
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Heavy Metal contents of Cocoa (*Theobroma cacao* L.) Beans and Plantation Soils in Ondo State, Nigeria

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Abstract

The use of pesticides to increase and stabilize cocoa production has become a global concern because portions applied to the foliage and pods end in the plantation litter and soils for uptake by the crop. The resultant heavy metal contamination of the soils has implications for product quality and food safety. This study assesses the heavy metal contents of surface layer (0-15 cm) and subsoil (15-30 cm) samples of soils in plantations and the parts of cocoa beans in Ondo State, Nigeria. The samples were collected from nine villages across three Local Government Areas and analyzed for the heavy metals using standard laboratory procedures. 90 copies of type 1 questionnaire were administered on 10 randomly selected farmers per village and 10 copies of type 2 questionnaire administered on 3 or 4 store keepers. Descriptive statistics of frequency counts, percentage, means and standard deviation were used to analyze the responses while data of heavy metals were subjected to analysis of variance. The average age, farm size and family size were 52 ± 14 years, 9 ± 13 acres and 6 ± 2 persons, respectively. The farmers were males (87.8%) with formal education (91.5%), had used seeds harvested from plantations for planting (74.4%) and adopted 1111 seedlings ha⁻¹ (90.3%). Only 47.6% used fertilizers and the main products were NPK 15-15-15 and NPK 20-10-10 mainly at 2 bags acre⁻¹. The heavy metal contents of the soils were higher at 0-15 cm than 15-30 cm and the values significantly differed ($p < 0.05$) among the locations. The order of abundance was Cu > Pb > Cd with Cu and Cd (detected in one location) above the permissible limits of 140 and 3 mg kg⁻¹ respectively. The whole bean, testa and kernel were contaminated with Pb in all locations while Cu contamination of the whole bean and testa was in 3 and 2 locations respectively. The threat posed to market demand by quality and food safety concerns means that farmers should adhere to the recommended types and doses of pesticides to reduce heavy metal contamination while all stakeholders should monitor the cocoa from production through processing to packaging for the market.

Keywords: Cocoa beans, cocoa kernel, cocoa testa, heavy metals, Ondo State

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Introduction

The squash-like pods (fruits) of the cocoa tree (*Theobroma cacao* L.) that grow proximal to the trunk and thicker branches contain the beans (seeds)

which are extracted, fermented and sun-dried. The beans constitute an important agricultural commodity and key raw material in the food industry, mainly for the production of chocolates

(UNCTAD, 2006) and in the manufacture of pharmaceutical and cosmetic products (McShea et al., 2008; Fowler, 2009). Cocoa powder is used in confectioneries, production of cocoa wine and spirits (liqueur), and as flavour in biscuits, ice cream, and dairy drinks while cocoa butter is used in the manufacture of soaps and cosmetics. The nutritional value relates to the richness in energy and amino acids, high levels of mineral and vitamins while the flavonoids (polyphenols) account for the health benefits, especially in the suppression of cardio-vascular diseases, cancer and several age-related degenerative diseases (Cooper, 2008; Afoakwa, 2008).

Cocoa is crucial to the Nigerian economy as the leading non-oil (agricultural) export commodity and for poverty alleviation (Ibiremo et al., 2014). The estimated annual production was 420,000 tons (t) in the 1960s but with the advent of crude petroleum as highest source of government revenue, the cocoa output progressively declined to 170,000 t in 1999. Several initiatives and policies meant to address the problems of low agricultural expenditure and output, import substitution and adoption of modern best farm practices stimulated cocoa output which attained 485,000 t in 2006 but declined to 238,000 t in 2012/2013, 236,521 t in 2016 and 240,000 t in 2017/2018 as the 5th world producer (FAOSTAT, 2017; factfish, 2018).

The producers are estimated 300,000 dispersed small-scale farmers who own <2 ha holdings (farms or plantations) in the 14 cocoa-producing states but with two-thirds living in Ondo, Ogun, Ekiti, Oshun and Oyo States and accounting for 60% of national output (Adelodun, 2017). The yield is below 500 kg ha⁻¹ of raw beans year⁻¹ and the output declined progressively due to erratic rainfall from climate change, fire outbreaks, soil fertility depletion, ageing trees and farmers, labour scarcity and cost, poor adoption of improved plantation management strategies and pests and diseases (Cadoni, 2013). Phytophthora pod rot or black pod disease, caused by the fungus *Phytophthora palmivora*, is the most widely-distributed disease of cocoa in plantations established in wet humid areas which, if uncontrolled, can cause up to 75% yield loss (Akrofi et al., 2003). The major insect pests of cocoa are the mirids (capsids): brown mirid (*Sahlbergella singularis*) and black mirid (*Distantiella theobroma*) and cocoa mosquito (*Helopeltis bergrothi*) which feed on pods, chupons and fresh shoots with the

feeding injury acting as entry points to die-back fungus (*Calonectria rigidiuscula*) that causes the death of shoots from the tips (Opeke, 2003). The other insects are *Earias biplaga* whose caterpillars burrow into and destroy buds or eat some of the leaves during the rainy season and cocoa mealy bugs- *Planococcoides njalensis*, *Planococcus citri* and *Ferrisia virgata* – which are vectors of the virus that cause cocoa swollen shoot disease. The commonest black pod disease control strategy among farmers in Nigeria is the monthly spray of copper-based fungicides (lime-bordeaux mixture, carbide-bordeaux mixture, cuprous oxide etc) and various insecticides whose amounts used have increased progressively since the 1950s (CRIN, 2003, Aikpokpodion et al., 2013). Asogwa and Dongo (2009) observed that the various pesticides used in cocoa production accounted for 31% of the total agrochemical market in Nigeria and this consisted of insecticides and fungicides at 35 and 65% respectively.

The use of pesticides to increase and stabilize crop production has become a global concern because of the issues related to sustainable environmental and food safety. A substantial portion of the foliar applied pesticides, enters the soil through spray drift and as wash-off from leaves and pods by rain and dew such that only 15% stays in the crop and taken up by the plant cells while the rest ends in the plantation litter and soils (Mabbett, 1984). The eventual accumulation of heavy metal impurities have impacts on the crop, animals and man through the food chain. The heavy metals are non-biodegradable and persistent environmental pollutants but at low concentrations, some- copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) - are essential for normal biochemical and physiological processes. Others- arsenic (As), cadmium (Cd), cobalt (Co), chromium (Cr), lead (Pb) etc- play no essential roles in plants and animals (Benavides et al., 2005) but can bio-accumulate to toxic levels. Reis et al. (2015) noted that stress from Pb toxicity led to structural changes of the mesophyll, cell membrane disorganization, unfavourable chloroplast development, changes in the mitochondria and outbreak of the nuclear membrane in root cells of cocoa plant. The heavy metals can accumulate in different human organs to produce deleterious/toxic effects. Exposure to excess Pb can cause hematic, renal and gastrointestinal damages while effects on the nervous

system include headache, poor attention, spasm, irritability, dullness and memory loss (CDC, 2001). Cu poisoning symptoms include abdominal pain, nausea and non-persistent vomiting (ATSDR, 2008) while Cd can produce renal tubular dysfunction, formation of kidney stones, disturbance of calcium metabolism, and skeletal, endocrine, reproductive and respiratory defects (Järup and Åkesson, 2009; WHO, 2010). The toxic effects of heavy metals on human health have attracted global attention. The European Commission set maximum tolerance/permissible levels for contaminants and Cd in foodstuffs and a pronouncement to implement regulations governing chocolate and cocoa products that contain excessive Cd levels from 1st January 2019 (EU, 2014). The Codex Alimentarius Commission of the Joint FAO/WHO Standards Programme has a proposed draft on the maximum levels for Cd in chocolate and cocoa derived products which will have significant economic and social consequences on the cocoa producing and exporting countries.

The demand of the global community for cocoa products from Nigeria, reputed for the aroma is threatened by quality problems, especially the presence of heavy metals at elevated levels in the cocoa beans. There are continued efforts to raise the farmers' awareness in appropriate use of

pesticides as part of improved farm practices, fermentation and drying, preparation and packaging which affect the flavour. Ondo State is the largest producer of cocoa in Nigeria with annual output of about 90,000 t (Cadoni, 2013) from plantations on which substantial amounts of pesticides are used to raise cocoa output for poverty alleviation. This study was conducted to evaluate the level of compliance of cocoa farmers and store keepers to the recommended pesticide dosages and the levels of heavy metals in the plantation soils and different parts of the cocoa bean in Ondo State, Nigeria.

Materials and Methods

Sample Sites

This study was carried out in three of the aforementioned Local Government Areas (LGAs) of Ondo State (Fig. 1); Akure South, Idanre and Ile-Oluji/Oke-igbo based on their high cocoa output. Three cocoa plantations were selected in each LGA namely: Akure South (Iwoye 7° 12' N 5° 6' E), (Ago Akure 7° 13' N 5° 6' E) and (Ago Store 7° 13' N 5° 2' E); Idanre (Owena - CRIN 7° 11' N 5° 5' E), (Oke Maye 7° 10' N 5° 2' E) and (Ola'nika 7° 10' N 5° 2' E); Ile-oluji/Oke-igbo (Oke'risa 7° 20' N 4° 55' E), (Agric. Farm Settlement 7° 17' N 4° 56' E) and (Eyin'gun 7° 16' N 5° 0' E).

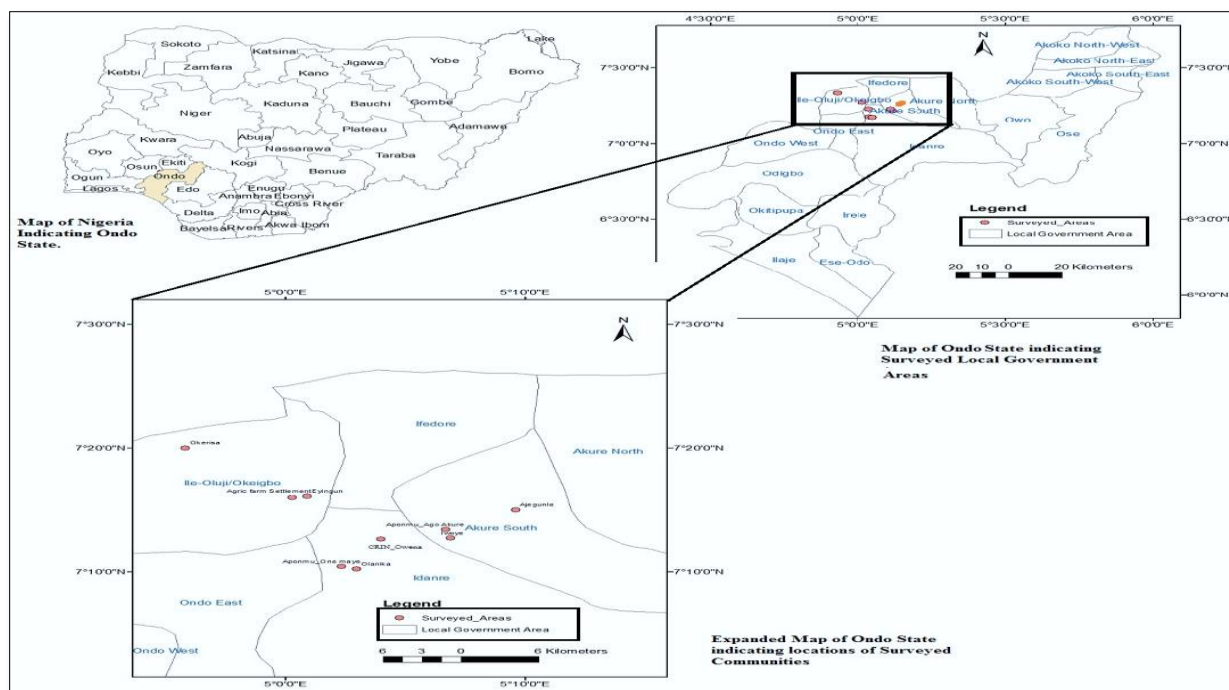


Fig. 1: Map of Ondo State indicating the surveyed Local Government Areas.

Data collection method

Two sets of well-structured and validated questionnaire were prepared for the study. The first set was administered on 90 randomly-selected farmers (10 per farming village or study site) to determine the attitude and perception towards pesticides usage and the level of compliance with the types and doses recommended by Cocoa research Institute of Nigeria (CRIN). The second type was administered on 10 store keepers at 3 per study site (except Ile-Oluji with 4). Out of the 100 copies only 82 were retrieved.

Collection of cocoa bean samples

Sun-dried cocoa beans were collected from 9 cocoa-growing villages. The cocoa bean heap from each farm was divided into three equal parts and three samples were collected from the top, middle and top portions, and bulked to form a 500 g composite sample from each of the 9 sites. The cocoa beans were further air-dried to constant weight at 84% relative humidity and stored in well-labeled sample bags.

Collection of soil samples from cocoa plantations
Soil samples were collected randomly less than 1 m away from cocoa trees at 0-15 and 15-30 cm depths in three points on each plantation using a calibrated Dutch auger. The samples were bulked to form a composite for each depth and from which 2 kg sub-sample was taken and kept in well-labeled sample bag. The soil samples were air-dried and stored for laboratory analysis.

Soil pH was determined with a glass electrode pH meter in 1: 4 soil: water paste.

Heavy metal determination in soil and

Results and Discussion

Table 1 shows the demographic features of the respondents. The >53 years age bracket made up 50% of the respondents while the mean age was 52 ± 14 years. This means that the respondents were beyond the active and productive ages in agreement with the ageing farmer population identified as one of the constraints of the cocoa industry (Nwachukwu et al., 2010; Cadoni, 2013). The mean age obtained in this study agrees with 51 years reported by Tijani (2006) as the age of cocoa farmers in Ondo State. Ayinde et al. (2013) noted that 58% of the cocoa producers in Obafemi Owode LGA, Ogun State aged between 61 and 70 years. The farmers were mostly male (87.8%) which agrees

cocoa bean samples

The soil samples were passed through 0.5 mm sieve and 1 g portion was weighed into 50 ml flask, digested in 20 ml of nitric acid and perchloric acid (3: 1 mixture) by boiling gently on a hot plate and 20 ml de-ionized water added followed by boiling again. The digest was cooled, filtered and make up to mark in a 25 ml standard flask with de-ionized water. The Cd, Cu and Pb were determined on Atomic Absorption Spectrophotometer.

Air-dried cocoa bean samples (whole bean, kernel and testa) were milled and homogenized, and 0.5 g samples were weighed into 30 ml porcelain crucibles and placed in muffle furnace set at 450-500°C for 6-8 h. the ashed samples were cooled and 5 ml of 1N HNO₃ added followed by evaporation to dryness on a hot plate at low heat. The samples were returned to the furnace and heated at 400°C for 10-15 minutes until perfectly white or greyish ash was obtained. The samples were cooled and 10 ml of 1N HCl added to dissolve the ash, and followed by filtration into 25 ml volumetric flask. The crucible and filter paper were washed with portions of 0.1N HCl to make up to mark. The Cd, Cu and Pb were determined on the Atomic Absorption Spectrophotometer.

Statistical analysis

The questionnaire responses were analyzed for descriptive statistics of means, frequencies, percentages and standard deviation using IBM SPSS Statistical 20.0 Package. The data of heavy metals were subjected to Analysis of Variance (ANOVA) using DSAASTAT and the means were separated with Duncan's Multiple Range Test (DMRT).

with dominance of males in cocoa production observed in Ogun, Osun, Edo, Kwara and Ondo States at 75.0, 97.5, 96.7, 83.3 and 88.0% respectively (Ogunjimi and Farinde, 2012; Mokwunye et al., 2012, Tijani, 2006). The farm size was mainly 1-13 acres (85.4%) and averaged 9 ± 13 acres which confirm the small scale nature of cocoa production carried out at on atomistic farms (Tijani, 2006; Adelodun 2017) average farm size at 9 ± 13 acres confirms that reports cocoa production is still largely on a small scale and carried out at the initiative of atomistic producers (Tijani, 2006; Adelodun 2017). The household size of 6-7 persons (46.7%) and average at 6 ± 2 persons are low compared to household size of in Obafemi Owode

LGA, Ogun State. Almost all the respondents had formal education (91.5%) with 39% each at the primary and secondary levels. Tijani (2006) noted that cocoa farmers in Ondo State were literates with

majority able to read and write in Yoruba language whereas Mokwunye et al. (2012) found low literacy levels among most cocoa farmers in Ogun, Osun and Kwara States.

Table 1: Demographic information of the respondents

Variables	Categories	Frequency	Percentage	Mean	SD
Age	25-38	13	15.9	52	14
	39-52	28	34.1		
	53 and above	41	50.0		
Sex	Male	72	87.8	9	13
	Female	10	12.2		
Farm size (acres)	1-13	70	85.4	6	2
	14-26	11	13.4		
	27-39	0	0.0		
	40 and above	1	1.2		
Family size	2-3	5	6.1	6	2
	4-5	30	36.6		
	6-7	35	42.7		
	8-9	6	7.3		
	10 and above	6	7.3		
Educational background	No formal education	7	8.5	39.0	39.0
	Primary education	32	39.0		
	Secondary education	32	39.0		
	Tertiary education	11	13.5		

Source: Field survey, 2019

Table 2 shows that 42.7% of the respondents had cultivated cocoa for 10-20 years, 54.9% cultivated the Amazon variety, 74.4% planted previously harvested seeds and 90.3% planted at the recommended 1,111 plants ha⁻¹ population. Tijani (2006) noted that 58% of farmers in Ondo State had over 20 years of experience and Ayinde et al. (2013) reported 48 years of experience. These are in conformity with the average age of the farmers in each study. Most of the farms still contained the Amazon unlike in Ogun State where 78% cultivated the hybrid varieties which were attributed to farmers' attendance of agricultural extension and enlightenment programmes. More than half (52.4%) of the respondents did not use fertilizer. The most used fertilizers were NPK 15-15-15 and NPK 20-10-10 by 51.3 and 30.8% of those who applied fertilizers while manure and compost were not popular. Fertilizers were used mainly by 33.3 and 30.8% of respondents at 2 and 0.5 bags acre⁻¹ respectively while only 2.6% used 4 and 10 bags

Table 3 shows that 80.5% of the respondents used manual weed control method, identified termites as the major pests (65.9%) and black pod was the main disease of cocoa (93.9%). Most respondents adopted chemical control for insects (85.4%) and other pests (98.8%). The fungicides used were ultimax plus (63.4%) and red force (45.1%) at 1 sachet in 15 l of water (70.7%) while the dominant insecticide was cypermethrin (68.3%) applied at 1 insecticide cap in 15 l of water (56.1%). Most of the fungicides are in the CRIN recommended list and doses. The ultimax plus used by most respondents is also approved by the Standards Organization of Nigeria whereas red force, a popular brand is not listed and should be screened for effectiveness by CRIN with a view to approving its adoption. Natural pesticides (bio-pesticides) are being developed and promoted because they do not leave deleterious residues in soils and plants or negative impacts on food and the environment (Asogwa and Dongo, 2009; Fayinminnu et al., 2017).

Table 2: Enterprise characteristics of respondents

Variables		Frequency	Percentage
Period of cultivation cocoa	< 10 years	7	8.5
	10-20 years	35	42.7
	20-30 years	15	18.3
	30-40 years	11	13.4
	> 40 years	14	17.1
Variety of cocoa cultivated*	Amelonado	25	30.5
	Amazon	45	54.9
	Hybrib	35	42.7
Sources of cocoa seeds*	Previously harvested seeds	61	74.4
	Local seed retailers	12	14.6
	Imported seed	2	2.4
	CRIN	5	6.1
	ADP	3	3.7
Number of cocoa seedlings planted	< 1000	1	4.8
	1000	3	3.7
	1111	74	90.3
	1500	1	1.2
Fertilizer application	Yes	39	47.6
	No	43	52.4
Type of fertilizer*	NPK 15-15-15	20	24.4
	NPK 20-10-10	12	14.6
	Compost	2	2.4
	Farm yard manure	5	6.1
	One quarter bag	5	6.1
Quantity of fertilizer applied	Half bag	12	14.6
	1 bag	5	6.1
	2 bags	13	16.0
	3bags	2	2.4
	4bags	1	1.2
	10bags	1	1.2

Source: Field survey 2019

Table 4 shows the heavy metal contents at different soil depths in the cocoa plantations. The Pb and Cu were higher in the 0-15 cm depth except Pb at Eyin'gun while Cd was only detected 0-15 cm depth in Iwoye. Renan (1994) had reported higher values of Pb and Cu in the 0-15 cm than 15-30 cm depth which suggests the source of exposure to be anthropogenic. Savithri et al. (2003) noted that the build-up of Cu is more in the agricultural surface soil (0-15 cm) without evidence of its accumulation at depths below 25 cm within the profile. The Pb and Cu contents in the soils varied significantly ($p < 0.05$) among the plantation sites. The 0-15 cm soil depth at Iwoye contained the highest Cu (363.55 mg kg⁻¹) which differed significantly from Ago Akure (339.75 mg kg⁻¹) and the highest Pb (79.31 mg kg⁻¹) that was significantly higher than Owena (29.25 mg kg⁻¹) and Ola'nika (29.00 mg kg⁻¹). Ago Akure

contained the highest Cu (122.40 mg kg⁻¹) in the 15-30 cm depth, which differed from Iwoye (106.60 mg kg⁻¹) while the highest Pb at Eyin'gun (33.55 mg kg⁻¹) differed significantly from Owena (25.40 mg kg⁻¹). The least Pb values in both soil depths were in Agric Farm Settlement and Cu in Oke'risa. The order of abundance at Cu > Pb > Cd is consistent with the copious foliar spray of Cu-based fungicides in the plantations which get deposited in the soil through rainfall and dew (Aikpokpodion et al., 2010). The soil Cu levels in Ago Akure, Ago Store, Iwoye, Okemaye and Owena are higher than the permissible level at 140 mg kg⁻¹ and the Pb levels in all the plantations below the permissible level at 300 mg kg⁻¹ while Cd at Iwoye exceeded the 3.0 mg kg⁻¹ limit (EU, 2014).

Table 3: Types and level of pesticide use

Variables		Frequency	Percentage
Method of weed control	Weeding	66	80.5
	Chemical application	16	19.5
Associated pest affecting cocoa production*	Termites	54	65.9
	Rodents	30	36.6
	Fungi	21	25.6
Type of disease encountered*	Cocoa black pod	77	93.9
	Cocoa mired (capsid)	16	19.5
	Farm sanitation	2	2.4
Method of insect control	Trap setting	10	12.2
	Chemical method	70	85.4
Method of controlling other pest	Chemical method	81	98.8
	Gamalin	1	1.2
	Glyphosate/touchdown/round up/clear weed	8	9.8
Type of herbicides used*	Paraquat	13	15.9
	Atrazine	3	3.7
	None	59	72.0
	Half milk tin	1	1.2
Concentration of herbicides used	1 milk tin	8	9.8
	2 milk tin	1	1.2
	Half pesticide cap	1	1.2
	1 pesticide cap	10	12.2
	2 pesticide caps	2	2.4
	Ridomil gold plus	29	35.4
Type of fungicides used*	Red force	37	45.1
	Mackecknie gold	6	7.3
	Champ DP	2	2.4
	Kocide 2000	1	1.2
	Ultimax plus	52	63.4
	None	2	2.4
Concentration of fungicide applied per 15L of water	Half sachet	19	23.2
	1 sachet	58	70.7
	2 sachets	3	3.7
	Actara 25 WG	22	26.8
	Proteus 170	1	1.2
Type of insecticides used*	Cypermethrin	56	68.3
	Chlorpyrifos	3	3.7
	Gamalin	1	1.2
	None	3	3.7
	12g	1	1.2
	1 milk tin	9	11.0
Concentration of insecticides used	2 milk tin	2	2.4
	1 pesticide cap	46	56.1
	2 pesticide caps	4	4.9
	One sachet	16	19.5
	2 sachets	1	1.2

Table 4: Levels of heavy metals at different soil depths on cocoa farms from nine study areas in Ondo State

Heavy metals	Pb (mg/kg)		Cu (mg/kg)		Cd (mg/kg)	
Depth	15 cm	30 cm	15 cm	30 cm	15 cm	30 cm
Ago Akure	18.00d	17.70c	339.75b	122.40a	ND	ND
Ago store	26.20c	16.50c	174.30c	31.90f	ND	ND
Agric Farm S.	5.90f	5.35d	42.75g	30.90f	ND	ND
Eyingun	18.75d	33.55a	25.35h	19.35g	ND	ND
Iwoye	79.31a	16.65c	363.55a	106.60b	8.63	ND
Okemaye	12.30e	7.75d	154.65d	86.80d	ND	ND
Okerisa	12.80e	6.15d	18.45i	15.50h	ND	ND
Olanika	29.00b	16.30c	120.60h	95.10c	ND	ND
Owena	29.25b	25.40b	145.55e	69.05e	ND	ND
*EU STD	300	300	140	140	3	3

Values with the same letter within a column are not significantly different at $p < 0.05$, *EU STD (2001) = European Union Standard, ND = Not Detected

Table 5 shows the Pb, Cu and Cd contents of the cocoa bean parts. The Pb content differed significantly among the plantations and the cocoa bean parts. The highest Pb values in the whole beans were obtained from plantations in Ola'nika (142.80 mg kg⁻¹) and Owena (142.60 mg kg⁻¹) which did not differ while Okemaye was below detectable level. The kernel Pb content was highest at Eyin'gun (72.85 mg kg⁻¹) followed by Oke'maye (63.95 mg kg⁻¹). The testa Pb was highest at Eyin'gun (465.70 mg kg⁻¹) followed by the similar values at Agric Farm Settlement (342.35 mg kg⁻¹) and Ago Store (342.20 mg kg⁻¹). The testa contained the highest Pb in all locations except at Ago Akure, Ola'nika and Owena whose whole bean samples had the highest values. The concentrations of Pb in the whole bean, kernel and testa across the locations were higher than allowable maximum residue limit of 2.0 mg kg⁻¹ (WHO/FAO, 2012). The source of contamination could have been through the soil, bioaccumulation on the farm and vehicular emission as sun-drying took place near high traffic roads (Rankin et al., 2005). The highest whole bean Cu was in Agric Farm Settlement (121.30 mg kg⁻¹) which differed significantly from Ola'nika (105.00 mg kg⁻¹) and other plantations. The kernel Cu was highest in Eyin'gun (26.85 mg kg⁻¹) and followed by Agric Farm Settlement (21.30 mg kg⁻¹) while Oke'risa contained the highest testa Cu. The bean contained highest Cu in Ago Akure, Agric Farm Settlement, Eyin'gun, Iwoye and Ola'nika while the testa contained the highest Cu in

the rest location while the kernel Cu content was least across the locations. Cu was lower than the maximum residue limit of 30 mg kg⁻¹ (WHO/FAO, 2012) in the kernel, higher in the whole bean from Agric Farm Settlement, Ola'nika and Eyingun, and higher in the testa at Oke'risa, and Ago Store. Cd was detected in the whole beans at Ola'nika (0.60 mg kg⁻¹) and kernel from Ago Akure (0.65 mg kg⁻¹) only and these are lower than 1.0 mg kg⁻¹ maximum allowable limit (WHO/FAO, 2012). The order of abundance was Pb > Cu > Cd, similar to report by Naser et al. (2011) that plants contain higher levels of Pb than Cu.

The desire of farmers to maximize productivity in the cocoa plantations necessitated adhering to recommended farm practices which emphasize the use of fertilizer and pesticides. These activities have been indicted for heavy metal contamination in soils but the levels in the soils of the study sites were below the maximum allowable limits. The elevated Pb and Cu levels in the soils were reflected in the higher concentrations of the whole beans, testa and kernels of cocoa which exceeded the maximum allowable limits. The quality and safety concerns would pose threats to market acceptability of the products and eventually dampen local production. Therefore, farmers should adhere to the recommended dosages and types of agrochemical inputs while the concerned stakeholders should monitor the cocoa from on-farm through processing methods and packaging.

Table 5: Levels of heavy metals in cocoa beans from nine study areas in Ondo State

Location	Pb (mg/kg)			Cu (mg/kg)			Cd (mg/kg)		
	Bean	Kernel	Testa	Bean	Kernel	Testa	Bean	Kernel	Testa
Ago Akure	72.35c	15.50g	49.00f	23.70e	12.70g	14.95g	ND	0.65	ND
Ago store	76.15b	36.55e	342.20b	26.80d	17.85d	31.65b	ND	ND	ND
Agric Farm S.	25.60f	57.85c	342.35b	121.30a	21.30b	24.80e	ND	ND	ND
Eyingun	50.10d	72.85a	465.70a	30.45c	26.85a	24.15e	ND	ND	ND
Iwoye	41.25e	13.65h	54.80e	23.25e	12.90g	22.50f	ND	ND	ND
Okemaye	ND	63.95b	115.00c	16.35f	18.90c	24.70e	ND	ND	ND
Okerisa	7.95g	11.40i	58.40d	30.20c	13.60f	63.65a	ND	ND	ND
Olanika	142.80a	20.40f	34.90g	105.00b	14.90e	26.00c	0.60	ND	ND
Owena	142.60a	54.30d	6.80h	10.80g	12.55g	25.40d	ND	ND	ND
*WHO/FAO		2			30			1	

Values with the same letter within a column are not significantly different at $p < 0.05$

*WHO/FAO, (2012) = Maximum Residue Limit for Heavy metals in food

Conclusion and Recommendation

Surface soils and cocoa beans from cocoa plantations are mostly contaminated with Cu but cocoa kernels were not, while Pb heavy metal was a major contaminant in cocoa beans (whole, kernel and testa) in Ondo State. This study and that of Aikpokpodion (2010) reported the high level of Cu contamination on cocoa plantation soils in Ondo State, Nigeria. This may be due to continuous application of Cu-based fungicides to control blackpod disease of cocoa and sun-drying of cocoa beans closer to the major roads thereby contaminated with tetra-ethyl lead additive in gasoline. The results indicated that concentrations of Cu and Pb in cacao beans were above tolerance limits, while the concentrations of Pb in plantation soils were below the permissible limits. Cadmium heavy metal however, was mostly not detected in plantation soils and cocoa beans. High levels of Cu and Pb in cocoa beans may hereby have implications on the quality and safety of this valuable crop and may pose a threat to cocoa

production in Ondo State. It is therefore recommended that pesticides (especially fungicides) and fertilizers should be avoided and if they were to be used, farmers should adhere/comply strictly to their recommended usage. Planting selected cocoa varieties with low accumulation levels of contaminants. The concerned Cocoa Board/Agency should also monitor cocoa crop from on-farms through processing methods.

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References

- Adelodun, A. 2017. Cocoa Production in Nigeria: A Literature Review. In: Analysis, Food and Agribusiness. Centre for Public Policy Alternatives. ccparesearch.org
- Afoakwa, E.O. (2008). Cocoa and chocolate consumption are there aphrodisiac and other benefits for human health. S. Afr. J. Clin. Nutr. 21 (3), 107113.
- Agency for Toxic Substances and Disease Registry (ATSDR) 2008. Draft Toxicological Profile for Cadmium. Atlanta, GA.
- Aikpokpodion P.E, Lajide, L. and Aiyesanmi, A. (2013). Impacts of Cu-Based Fungicide on Copper Residue and Mineral Elements Distribution in Cocoa Beans and Pods. World Journal of Agricultural Sciences 9 (1):10-16
- Aikpokpodion P.E. (2010). Assessment of heavy metals pollution in fungicide treated Cocoa plantations in Ondo state, Nigeria. Journal of Applied Biosciences 33: 2037 2046.

ISSN 19975902

- Akrofi, A.Y., Appiah, A.A. and Opoku, I.Y. (2003). Management of Phytophthora palmivora rot disease on cocoa farms in Ghana. *Crop Protection* 22(3): 469-477.
- Asogwa, E.U and Dongo, L.N. (2009). Problems associated with pesticides usage and application in Nigeria cocoa production: A review. *African Journal of Agricultural Research*.4 (8) pp. 675-683
- Ayinde, I., Kareem, R. Thomas, F. and Bakare, H.(2013). Analysis of pesticide use in cocoa production in Obafemi Owode Local Government Area of Ogun State, Nigeria. *Journal of Biology, Agriculture and Healthcare*, Vol.3 (6) 1-9
- Benavides, M.P., Gallego, S.M. and Tomaro, M.L. (2005). Cadmium toxicity in plants. *Braz. J. Plant Physiol.* 17 (1):2134.<http://dx.doi.org/10.1590/S1677-04202005000100003>.
- Cadoni, P. 2013. Analysis of incentives and disincentives for cocoa in Nigeria. *Technical Notes Series*,
- Centers for Disease Control and Prevention (CDC, 2001). Managing Elevated Blood Lead Levels Among Young Children: Recommendations from the Advisory Committee on Childhood Lead Poisoning Prevention. Atlanta.
- Cocoa Research Institutes of Nigeria (CRIN) (2003): Information Booklet. page 10
- Cooper, A.K., Donovan, J.L. Waterhouse, A.L. Williamson, G. (2008). Cocoa and health: a decade of research. *Br. J. Nutr.* 99: 111.
- European Union (EU, 2014). Commission Regulation (EU) No 488/2014 amending regulation (EC) No1881/2006 as regards maximum levels of cadmium in foodstuffs. *Off. J. Eur. Union* 138: 75.
- Factfish, 2018. Nigeria: Cocoa Beans, Production Quantity (tons). www.factfish.com/statistic-country/nigeria/cocoa+beans+production+quantity. Accessed on 26/12/2018
- Fayinminnu, OO, Adeniyi, OO, Alabi, OY, and Omobusuyi, DO. 2017. Potentials of aqueous extract of pod husk *Parkia biglobosa* (Jacq.) benth as a biopesticide in okra (*Abelmoschus esculentus* (L.) Moench) production. *Journal of Agriculture and Ecology Research International*. 12(1): 1-12
- Ibiremo, O.S., Akanbi O.S.O., Oloyede, A.A. and Adewale, B.D. (2014). Comparative evaluation of NPK fertilizer sources on the growth and yield of cocoa in Ibadan, Nigeria. *World Journal of Biology and Biological Sciences* 2(3): 062-066
- Järup, L. and Åkesson, A. (2009). Current status of cadmium as an environmental health problem. *Toxicol. Appl. Pharmacol.* 238 (3): 201-208.
- Mabbett, T. (1984). *World crop*, 36 (3): 86-103
- Mokwunye I. U., Babalola F. D. Ndagi I. Idrisu M. Mokwunye F.C. and Asogwa, E. U. (2012). Farmers' compliance with the use of approved cocoa pesticides in cocoa producing states of Nigeria. *Journal of Agriculture and Social Research (JASR)* Vol. 12(2)
- Ogunjimi S. I. and Farinde A. J. (2012). Farmers' knowledge level of precautionary measures in agro-chemicals usage on cocoa production in Osun and Edo States, Nigeria. *International Journal of Agriculture and Forestry* Vol 2(4): 186-194 DOI: 10.5923/j.ijaf.20120204.10
- Rankin, C.W., Nriagu, J. O., Aggarwal, J. K., Arowolo, T. A., Adebayo, K., Flegal, A. R. (2005). Lead contamination in cocoa and cocoa products: Isotopic evidence of global contamination. *Environmental Health Perspectives*, 113 (10), 1344-1348. DOI: 10.1289/ehp.8009.
- Tijani A. A. (2006). Pesticide use practices and safety issues: The case of cocoa farmers in Ondo State, Nigeria. *J. Hum. Ecol.*, 19(3) 183-190. Retrieved from <http://krepublishers.com/02-Journals/JHE/JHE-19-0-000-000-2006-Web/JHE-19-3-000-000-2006-Abstract-PDF/JHE-19-3-183-190-2006-1343->

- Tijani-A-A/JHE-19-3-183-190-2006-1343-Tijani-A-A-Text.pdf
- Tripathi, R.D., Srivastava, S., Mishra, S., Singh, N., Tuli, R., Gupta, D.K., Maathuis, F.J.M., (2007). Arsenic hazards: strategies for tolerance and remediation by plants. Trends Biotechnol. 25, 158165.
- UNCTAD (2006). <http://r0.unctad.org/infocomm/anglais/cocoa/market.htm#cot>
- WHO, (World Health Organisation) (2010). Exposure to Cadmium a Major Health Concern. WHO Document Production Services, Geneva, Switzerland.