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Assessing the Health Risks of Heavy Metal Contamination in Water Sources Utilized for Palm Oil Production in Selected Local Industries in Ondo State, Nigeria

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***Abstract* - This study investigates into the adverse impacts of heavy metal concentration on human health, particularly when present in water used in palm oil production in selected industries in Ondo State, Nigeria. Through wet-digestive analysis, the levels of heavy metals including Copper (Cu), Lead (Pb), Manganese (Mn), Zinc (Zn), and Cadmium (Cd) were assessed in both water samples and palm oil products. The results revealed concentrations of heavy metals in water samples and control ranging from Copper (0.167 – 0.297 and 0.143 mg/L), Lead (0.047 – 0.100 mg/L), Manganese (0.250 – 0.327 mg/L), and Zinc (0.0417 – 0.547 mg/L), while palm oil concentrations ranged from Cu (0.327 - 0.100 mg/L), Ni (0.045 - 0.010 mg/L), Pb (0.207 – 0.100 mg/L), Mn (0.390 - 0.183 mg/L), and Zn (0.697 – 0.453 mg/L). Comparison with World Health Organization (WHO) standards indicated that Pb concentrations in water exceeded permissible limits, suggesting potential contamination in palm oil samples. Additionally, a significant positive correlation ($p<0.05$) was observed between Pb levels in water and palm oil samples, indicating the transfer of lead contaminants into the palm oil during production. These findings underscore the importance of monitoring and regulating heavy metal concentrations in water sources used in palm oil production to safeguard public health.**

Keywords: Heavy metals, WHO, Spectrophotometer.

I. INTRODUCTION

The effects of heavy metal exposure can vary depending on the specific metal, duration of exposure, and individual susceptibility. However, common effects can include various health problems such as neurological disorders, kidney damage, respiratory issues, cardiovascular diseases, and even cancer. Some heavy metals like lead, mercury, and cadmium can cause neurotoxicity, leading to cognitive and behavioral impairments, developmental delays in children, and in severe cases, paralysis or coma (Adepoju-Bello *et al.*, 2012). Renal Damage, like cadmium and mercury are known to accumulate in the kidneys, causing damage over time and potentially leading to kidney failure. Metals such as arsenic and nickel can irritate the respiratory system, causing symptoms like coughing, wheezing, and in severe cases, lung cancer. Heavy metal exposure has been linked to an increased risk of cardiovascular diseases such as hypertension, heart attacks, and stroke. Certain heavy metals, including lead and mercury, can affect reproductive health in both men and women, leading to infertility, miscarriages, or birth defects. Heavy metals can also have detrimental effects on the environment, contaminating soil, water, and air, and disrupting ecosystems. In general, the effects of heavy metal exposure underscore the importance of minimizing exposure through regulatory measures, industrial controls, and public health interventions.

No doubt there is presence of heavy metal in the processing of palm oil that required quantities of water in mills where oil is extracted from the palm fruits. Palm oil is an edible vegetable oil derived from the mesocarp (reddish pulp) of the oil palm tree (*Elaiesguineesis*). It has been reported that contamination of diets including red palm oil with heavy metals could result from different sources such as drinking water, high ambient air concentration industrial waste, acidic rain breaking down soils and food chains (Singh *et al.*, 2007). Contamination of the food chain with heavy metals could pose potential health risk to humans and animals because these heavy metals have the ability to bio accumulates. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time compared to the chemical concentration in the environment.

Nigeria is currently the fifth world's leading producer of palm oil (Nnorom, 2012). The palm oil industry is a major agro-based enterprise in Nigeria, especially in the southern part where palm oil trees are found both in the wild and in plantation (Nwaugo *et al.*, 2008). Red palm oil is rich in antioxidant, vitamins, trace elements and supplies fatty acid

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essential for proper growth, development and for general wellbeing (Sunday *et al.*, 2015).

Figure 1: Ripe palm Kernel

Although red palm oil remains vital in human nutrition, it however could be contaminated by toxic elements and other contaminants. The presence of these toxic metals may appear harmless in minute quantities, however their accumulation over time poses potential health risk to human who regularly consume palm oil contaminated with toxic metals (Azab *et al.*, 2010).

II. MATERIALS AND METHODS

2.1 Study Area

Ondo state was created in 1976 out of the former Western State. The state lies between latitudes 5 4'S and 7 52'N and longitude 4 20'W and 6 03'E. The state occupies a land area of about 15, 000 square kilometers with a population of 3, 441, 924 people according to 2006 census. The state has eighteen (18) Local Government Areas and three (3) Senatorial Districts (Ondo North, Ondo Central and Ondo South) with Akure as the capital city. Agriculture is the mainstay of the people of Ondo State. The study area randomly selected from four major town, comprises Imoru, Owo (Ondo North) and Owena, Bolorunduro (Ondo Central) Senatorial Districts of Ondo State.

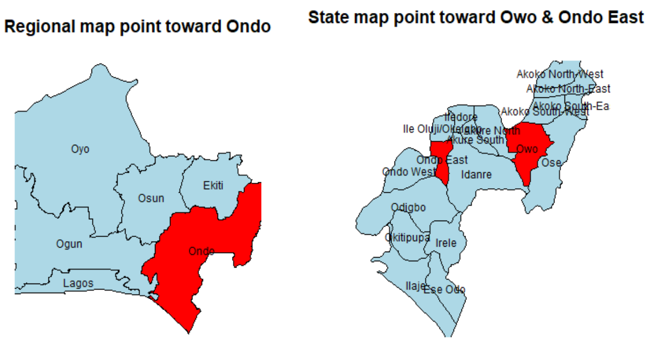

Figure 2: Map of Ondo State indicating the sampling sites

Key: ★ Owo Local Government

★Ondo East Local Government

2.2 Sampling techniques

Fresh palm oil *Elaesisguineensis* samples were obtained in August, 2023 from production mills situated along high way roads in four (4) major towns (Imoru, Owo, Owena and Bolorunduro) of Ondo state (Figure 1). Duplicate samples were collected from each point to make a representative sample. The Palm oil and water used in the oil palm production were collected in a pre-cleaned polyethylene bottles, labeled and kept in the refrigerator prior to analysis.

2.3 Reagents and Materials

All the reagents used for the analysis are of high purity analytical grade by Merck, Darmstodt, Germany. All the plastic and glassware were cleaned by soaking overnight in a 10% nitric acid solution and then rinsed with double deionized water. The element standard solutions used for calibration were supplied by Sigma Chemical Co (St Louis, MO).

2.4 Determination of Heavy Metal Content in Palm Oil Sample

The heavy metals (Cu, Cd, Ni, Pb, Mn and Zn) of the palm oil samples were extracted by digestion of palm oil sample. Exactly 1g of each sample of palm oil was weighed and transferred into a 250 mL conical flask and thereafter digested with 10 mL of the digested acid mixture of perchloric, nitric and sulphuric acids (1:2:2). The mixtures were heated on a hot plate in a fume cupboard until evolution of white fumes. The digest was allowed to cool and 20 mL of distilled water was added to bring the metal into solution and filtered using ashlesswhatman filter paper into a 50 mL calibrated volumetric flask and made up to mark with distilled water. (Durali *et al.*, 2009). A blank sample was also carried out following the same procedure in the absence of the sample. The digest was analysed for metals using Atomic Absorption Spectrometer (AAS) manufactured by Buck Scientific Model 210VGP, USA.

2.5 Determination of Heavy Metal Content in Water Samples

The heavy metals (Cu, Cd, Ni, Pb, Mn and Zn) of the water samples were determined by digestion of water samples. Exactly 100mL of water samples was measured and transferred into 250mL conical flask. A 10 mL of the digested acid mixture (ratio 1:2:2 of perchloric, nitric and sulphuric acids) was added and the mixture was heated on a hot plate in a fume cupboard until evolution of white fumes. The digest was allowed to cool and 20 mL of distilled water was added to bring the metal into solution and filtered using ashlesswhatman filter paper into a 50 mL calibrated volumetric flask and made up to mark with distilled water.

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(Ideriah et al., 2007). A blank sample was carried out following the same procedure in the absence of the sample. The digest was analysed for metals using Atomic Absorption Spectrometer (AAS)(BUCK 211 VGP).

2.6 Quality Control

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. During the experiments, all glassware and equipment were carefully cleaned starting with 2% HNO3 and ending with repeated rinsing with distilled deionized water to prevent contamination. Reagent blank determination was used to correct the instrument readings. The accuracy and precision of the analytical method was calculated by analyzing the certified reference material NIST SRM 1577b ACCU Standard, USA). Spike recovery studies were also conducted on some of the samples.

2.7 Statistical Analysis

Statistical evaluation of the data was performed using SPSS software version 17.0 statistical package. A one-way analysis of variance (ANOVA) was carried out at $\alpha = 0.05$, and Tukey Multiple Comparison test was used to discern the source of the observed differences.

Table 1: Instrument Condition for AAS Determination of the studied metals

Metal	Wavelength (Nm)	Slit (nm)	Lamp Current (MA)
Cu	324.8	0.7	6
Cd	228.9	0.7	15
Ni	232.0	0.2	4
Pb	283.3	0.7	4
Mn	279.5	0.7	8
Zn	213.9	0.7	10

III. RESULTS AND DISCUSSION

Table 2: Heavy metal Concentration in palm oil samples

	Cu (mg/L)	**Cd** (mg/L)	**Ni** (mg/L)	**Pb**(mg/L)	**Mn**(mg/L)	**Zn** (mg/L)
Control	$0.162^{e}\pm0.01$	BDL	$0.010^{b}\pm0.01$	BDL	$0.128^{d}\pm0.01$	$0.324^{e}\pm0.15$
Imoru	$0.157^{c}\pm0.01$	BDL	$0.047^{a}\pm0.02$	$0.147^{b}\pm0.01$	$0.247^{b}\pm0.02$	$0.563^{c}\pm0.01$
Owo	$0.100^{d}\pm0.00$	BDL	$0.040^{a}\pm0.01$	$0.100^{d}\pm0.00$	$0.183^{c}\pm0.01$	$0.453^{d}\pm0.01$
Owena	$0.327^{a}\pm0.01$	BDL	$0.047^{a}\pm0.01$	$0.207^{a}\pm0.12$	$0.363^{a}\pm0.01$	$0.653^{b}\pm0.01$
Bolorunduro	$0.294^{b}\pm0.01$	BDL	$0.010^{b}\pm0.01$	$0.127^{c}\pm0.01$	$0.390^{a}\pm0.01$	$0.697^{a}\pm0.15$
STANDARDS:						
WHO	2.00	0.003	0.07	0.01	0.40	3.00
SON	-	-	0.02	0.01	0.20	3.00
Remark	BPL	BPL	BPL	APL	BPL	BPL

Data are presented as Mean ± S.E (n=3). Values with the same superscript letter (s) along the same column are not significantly different ($P \leq 0.05$).

BDL= below detection limit, APL= above permissible limit; BPL= below permissible limit, SON= Standard Organization of Nigeria, WHO=World Health Organization

3.1 Result of heavy metals in palm oil samples

Average concentration values along with standard deviation and range of the elements analysed (Cu, Cd, Ni, Pb, Mn and Zn) are given in Table 3.1.1. Metal concentrations in edible palm oils were found to be between; Cu (0.32 - 0.10), Ni (0.05 - 0.01), Pb (0.21 -0.10), Mn (0.39 - 0.18) and Zn (0.70 - 0.56) mg/L respectively. Cadmium was found to be below detection limit in all the samples. However, the concentrations of heavy metals in each town were not significantly different ($P < 0.05$) in all the samples.

Levels of metals like Cu, Zn, Fe, Mn and Ni are known to increase the rate of oil oxidation while other elements such as Cd and Pb are very important on account of their toxicity and metabolic role (Anthemidis *et al.*, 2005). The lowest and highest metal concentrations were observed in nickel and zinc in all the samples. The zinc concentrations in the samples ranged from 0.70 mg/L to 0.45 mg/L. Bolorunduro palm oil had the highest zinc concentration whereas Owena palm oil had the lowest zinc concentration. Zinc is known to be involved in most metabolic pathways in humans and is regarded as cofactor for many enzymes. Zinc deficiency can lead to growth retardation and immunological abnormalities (Anthemidis *et al.*, 2005). The zinc concentrations in the oil

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samples were lower than those reported by (Nnorom *et al.*, 2014) (3.6 - 14.6 mg/L) which is higher than the result of this study.

Copper is essential for human body but very high intake can cause adverse health problems. Long term exposure to copper can cause irritation of the nose, mouth and eyes and it causes headaches, stomachache, dizziness, vomiting and diarrhea (Ikem and Egicbor, 2005). Chronic copper poisoning results in Wilson's disease, characterized by a hepatic cirrhosis, brain damage, demyclination, renal disease, and copper deposition in the cornea. Copper deficiency leads to hypochromic anemia, leuopenia and osteoporosis in children (Kanumakala *et al.*, 2002).The values of copper in palm oil samples investigated were 0.10 and 0.32 mg/L in Owena and Owo oil palm mill production sites. In the literature copper levels in edible oils samples have been reported in the range of 0.021-0.265 mg/L (Zhu *et al.*, 2011). The copper values in the investigated oil samples were in agreement with the value reported by Nnorom *et al* (0.101-0.298 mg/L) (Nnorom *et al.*, 2014).

Manganese content was observed to have a minimum value of 0.18 mg/L in Owo while the highest value 0.39 mg/L was found in Bolorunduro palm oil mill sample. (Zhu *et al.*, 2011) have identified that the deficiency of manganese can result in severe skeletal and reproductive abnormalities in mammals while high doses of manganese produce adverse effects primarily on the lungs and on the brain (Zhu *et al.*, 2011). The Mn concentrations range 0.18-0.39 mg/L in this study were below the values (6.55-12.05 mg/L) reported by (Nnorom *et al.*, 2014).

The concentration of Cd in the oil samples investigated was below detection limit. Cadmium is a highly toxic metal with a natural occurrence in soil, but it is also spread in the environment due to human activities.

The concentration of lead in palm oil samples were 0.147, 0.100, 0.207, and 0.127 mg/L in Imoru, Owo, Owena, and Bolorunduro respectively. The minimum levels of lead 0.100 mg/L was observed in the sample from Owo while the highest value 0.207 mg/L was found in the oil sample from Owena. The values of Pb in the present study were above the values reported by (Nnorom *et al*, 2014) (0.024 - 0.067 mg/L).

The value of Lead is significantly different ($P < 0.05$) in all the palm oil samples. Lead serves no useful purpose in the human body, but its presence in the body can lead to toxic effects, regardless of exposure pathway. Some researchers have suggested that lead continues to contribute significantly to socio-behavioral problems such as juvenile deligency and violent crime (Zhu *et al.*, 2011). Lead absorption may constitute a serious risk to public health. Lead has harmful health effects even at lower levels and there is no known safe exposure level. This means that even at low concentration, the presence of lead in the vegetable oil may be harmful if the oil samples are consumed over long period of time since lead can show an accumulated harmful effect (Geller *et al.*, 2006). Lead can inhibit cognitive development and intellectual performance in children, and increase blood pressure and cardiovascular disease in adult (Suppin *et al.*, 2006). Exposure to Lead has been associated with slow growth, hyperactivity, anti-social behaviors and impaired learning and hearing (Dahiya *et al.*, 2005). The lead values in all investigated palm oils were found to be higher than the WHO recommended legal limits of 0.01 mg/L for edible oils. The highest concentration of lead in this study could probably be due to the contamination of the water used for the palm oil processing and other anthropogenic sources. Lead in trace amounts level was detected in water samples used in the Palm oil processing above the recommended standards for good drinking water (0.01 mg/L), while it was not detected in the control sample. The observed values for Pb in the water used for the palm oil processing could have occurred from palm oil milling operations and may have been enhanced from other contaminants around the river, local runoffs from nearby surface soils, interactions between the water and sediments and animal remains at the bottom of the rivers, equipment used in the palm oil extraction process, laundry activities of surrounding residents and runoff of household effluents.

Trace amounts of nickel may be beneficial as an activator of some enzyme systems, but its toxicity at higher levels is more prominent. The minimum and maximum levels of Niwere observed to be 0.01 mg/L in Bolorunduro and 0.05 mg/L in Imoru and Owena town respectively. Adepoju *et al.*, (2012) reported a Ni concentration of (0.044 – 0.068) mg/L which compare well with the results of this study, but the values were lower than the values 0.15 – 0.81 mg/L) reported by Nnorom *et al.*,(2014).

Table 3: Concentration (mg/L) of Heavy Metals in water sample used for palm oil processing

	P^H	Cu	Cd	Ni	Pb	Mn	Zn
Control	6.70	$0.143^c \pm 0.01$	BDL	BDL	BDL	$0.060^d \pm 0.01$	$0.113^c \pm 0.15$
Imoru	6.89	$0.223^c \pm 0.01$	BDL	BDL	$0.047^b \pm$	0.277b±0.01	$0.517^b \pm 0.01$
Owo	7.21	$0.297^a \pm 0.01$	BDL	BDL	$0.093^a \pm$	0.297b±0.02	$0.477^c \pm 0.01$
Owena	7.68	$0.263^b \pm 0.01$	BDL	BDL	$0.100^a \pm$	0.327a±0.01	$0.547^a \pm 0.01$

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Bolorunduro	6.84	0.167^{d}±0.01	BDL	BDL	0.060^{b}±	0.250c±0.01	0.417^{d}±0.01
STANDARDS:							
WHO		2.00	0.003	0.07	0.01	0.40	3.00
SON		-	-	0.02	0.01	0.20	3.00
Remark		BPL	BPL	BPL	APL	BPL	BPL

Data are presented as Mean ± S.E (n=3). Values with the same superscript letter (s) along the same column are not significantly different (P ≤ 0.05).

BDL= below detection limit, APL= above permissible limit; BPL= below permissible limit, SON= Standard Organization of Nigeria, WHO=World Health Organization

3.2 Trace metals below permissible limit (Cu, Cd, Ni, Mn and Zn)

The heavy metal parameters of water used for palm oil production in the study areas are presented in Table 3. The pH was found in the range of 6.70 – 7.68 which are within the maximum permissible level for standard drinking water (WHO, 2006). The lowest pH was observed in Imoru at all the four towns.

The concentration of heavy metals in the water samples collected at the palm oil production site were found in the following range; Copper (0.167 – 0.297 mg/L), lead (0.047 – 0.100 mg/L), manganese (0.250 – 0.327 mg/L) and zinc (0.417 – 0.547 mg/L). Cadmium and Nickel metal were not detected in all the water samples analyzed.

Copper which has been considered one of the essential elements to human body was found in relatively low concentration in all the water samples. The concentration of Cu in the water sources were in the range of 0.167 – 0.297 mg/L respectively. These values are far below the maximum permissible limits of 2.00 mg/L (JMP, 2012) respectively as shown in Table 4.3. Contamination of drinking water with high level of copper may lead to chronic anemia (Ruqia *et al.*, 2015). Copper toxicity is a fundamental cause of Wilson's disease.

Manganese (Mn) and Zinc (Zn): Manganese and zinc, which are considered as essential elements to the human body, were also found in relatively low concentrations in all the samples. Nevertheless, higher concentrations of zinc can be toxic to the organism. Zinc plays an important role in protein synthesis and is a metal which shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources. The concentration of Mn and Zn in the water sample was in the range of 0.250 – 0.327 mg/L and 0.417 – 0.547 mg/L respectively. The permissible limit of manganese and zinc in water according to WHO standards are 0.40 mg/L and 3.0 mg/L respectively. In all the collected water samples, concentration of manganese and zinc were recorded below permissible limit set by WHO (JMP, 2012).

Cadmium (Cd) and Nickel (Ni): Cadmium and Nickel metal were not detected in all the water sample analyzed. Even though nickel is regarded as an essential trace metal it is equally toxic at elevated concentration. Hair loss, lung fibrosis, skin allergies, outbreak of eczema and variable degrees of kidney and cardiovascular system poisoning have been associated with humans exposed to high level of nickel (Azab *et al.*, 2010). In addition, it has the tendency of substituting for iron and zinc in the body, thus interfering in the normal biochemistry (Shanker, 2008).

Also on comparing with similar study, investigating the chemical characteristics of these metals in surface water from Osun State, it was also seen that the concentrations of Mn, Cu, and Zn in all the samples were below the regulatory desirable level for the metals in the various water sources (Oluyemi *et al.*, 2010). Based on the result from the various water sources in the study area it can be implied that these trace metals do not import undesirable contaminants to the water nor pose possible health threat to consumers.

3.3 Trace metals above permissible limit (Pb)

According to WHO and SON standards permissible limit of lead in water is 0.01 mg/L. Concentration of lead in all the water samples ranged between 0.047 – 0.100 mg/L. The minimum and maximum levels of lead were observed to be 0.047 mg/L in Imoru and 0.100 mg/L in Owena town respectively. In all the collected water samples concentration of Pb was above the permissible limit set by WHO (2006) and SON (2007). This could have resulted to the high levels of Pb observed in palm oil sample. Lead serves no useful purpose in the human body but its presence in the body can lead to toxic effects regardless of exposure pathway. It accumulates with age in bones aorta and kidney, liver and spleen. It can enter the human body through uptake of food. The possible sources of lead in these samples could be attributed more to anthropogenic activities such as car wash operators, house paint, automobile repair workshops located in the area and accumulation of Pb in ground water from the study locations. Amongst the six metals, significant degree of pollution was seen in lead. This confirms the result on trace metal of lead above permissible limit in the palm oil samples obtained at Imoru, Owo, Owena and Bolorunduro in Ondo State (Table 3).

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3.4 Correlation study

Table 4: Correlation Study between Metals in Water and the Oil Palm Sample

	Cu-W	Cd-W	Ni W	Pb-W	Mn-W	Zn-W	Cu-O	Cd-O	Ni-O	Pb-O	Mn-O	Zn-O
Cu-W	1											
Cd-W	a	a										
Ni-W	a	a	a									
Pb-W	**.847***	a	a	1								
Mn-W	**.794***	a	a	**.911***	1							
Zn-W	**.762***	a	a	**.848***	**.982***	1						
Cu-O	-.115	a	a	-.058	-.539	**-.837***	1					
Cd-O	a	a	a	a	a	a	a	a				
Ni-O	**.775***	a	a	.283	**.606***	**.744***	-.340	a	1			
Pb-O	.455	a	a	**.864***	-.098	-.258	**.695***	a	.399	1		
Mn-O	-.334	a	a	-.221	**-.690***	**-.934***	**.970***	a	-.502	.553	1	
Zn-O	-.424	a	a	-.349	**-.777***	**-.921***	**.931***	a	-.477	.542	**.971***	1

A correlation study was made for the elements in water and their corresponding oil sample (Table 4). The result showed that there was a significant correlation ($p<0.05$) between Cu and other metals such as Pb, Mn, and Zn in the water sample, and the Ni in the oil sample.

A positive correlation ($p<0.05$) was observed between Pb in the water and oil sample. This implies that the metal might be from the similar source. As it was reported earlier, the high levels of Pb observed in the oil sample could have been resulted from the contaminated water used for processing of the oil sample.

Similarly, a positive correlation ($p<0.05$) was found to exist between Ni in the oil sample and Mn and Zn in water sample. A negative correlation ($p<0.05$) was however, observed between the metals Mn, Zn in water sample and the metals Mn, Zn and Cu in the oil sample. This relationship implies that, the presence of Mn and Zn in water sample reduces the presence of Mn, Cu and Zn in the oil sample. A positive correlation ($p<0.05$) was also found to exist between the metals Cu, Mn, Pb and Zn in the oil sample. This implies that the metals might be of the similar source.

IV. CONCLUSION

The study was aimed at assessing the levels of heavy metals (Cu, Cd, Ni, Pb,Mn and Zn) concentration in water used in production of palm oil in four selected local oil palm production industries in Ondo State. From the result obtained, the heavy metals content in the palm oil sample were within maximum allowable limit as set by WHO (2006) and SON (2007) except for Pb which was observed to be higher than the stipulated standard in both palm oil and water sample. The results of this study show that the locally produced palm oil samples are safe for consumption. However, there is a need for provision of clean potable water for palm oil production as it was observed from the present study that the water was the major source of contaminants in the palm oil samples.

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