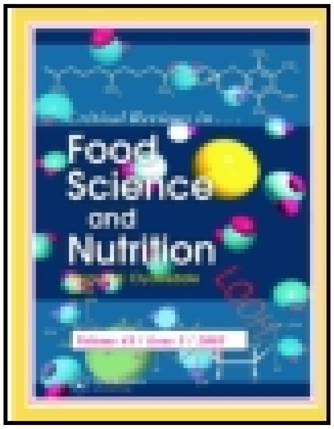

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Trace Elements and Radionuclides in Palm Oil, Soil, Water and Leaves from Oil Palm Plantations: A Review

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TRACE ELEMENTS AND RADIONUCLIDES IN PALM OIL, SOIL, WATER AND LEAVES FROM OIL PALM PLANTATIONS: A REVIEW

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ABSTRACT

Oil palm (*Elaeisguineensis*) is one of the most productive oil producing plant in the world. Crude palm oil is composed of triglycerides supplying the worldôs need of edible oils and fats.Palm oil also provides essential elements and antioxidants that are potential mediators of cellular functions. Experimental studies have demonstrated the toxicity of the accumulation of significant amounts of non-essential trace elements and radionuclides in palm oil that affects the health of consumers. It has been reported that uptake of trace elements and radionuclides from the oil palm tree may be from water and soil on the palm plantations. In the present review, an attempt was made to revise and access knowledge on the presence of some selected trace elements and radionuclides in palm oil, soil, water and leaves from oil palm plantations based on the available facts and data.Existing reports show that the presence of non-essential trace elements and radionuclides in palm oil may be from natural or anthropogenic sources in the environment. However, the available literature is limited and further research need to be channelled to the investigation of trace elements and radionuclides in soil, water, leaves and palm oil from oil palm plantations around the globe.

Key words: Oil palm, trace elements, radionuclides, antioxidants, toxicity

1.0 INTRODUCTION

Palm oil is the world second most essential vegetable oil after olive oil (Ong and Goh, 2002). It is agood choice for manufacturers of fooddue of its nutritional resourcefulness. The oxidative stability andprofitability is incomparableamongoils, which are free of cholesterol.These values extend to blends of polyunsaturated oils to provide a longer storage life for the oil.Currently, there is a supply of genetic-modification-free palm oil, whichis a cheap perennial crop with unparalleled productivity (Ong and Goh, 2002). Virgin palm oil also provides carotenes, tocotrienols and tocopherols.These are potent antioxidants and facilitators of cellular functions. Edible oils such as palm oil contain trace elements and radionuclides that are known for their toxicities and affect the health of consumers (Arogunlo, 2007). The concentrations of radionuclides and trace elements affects oil qualities as regards to its freshness, storage, stability and influence on human nutrition and health (Don Pedro *et al.,* 2004).Manǒs activities have increased the baseline for these elements in the environment. However, baseline radionuclides and trace elements burden is not sufficient to explain the level of contamination of palm oil from various natural and antropogenic sources (Arogunlo, 2007 & UNSCEAR, 1988).

Metals and radionuclides occur naturally in soil in minute amounts and life has evolved to cope with only small exposures to these elements. Many industrial processes concentrate metalsthat later end up in soils and water bodies (Hendershot, 2005). The naturally occurring trace metals are supplemented by releases from anthropogenic sources, which for some metals exceed natural inputs.Hazardous effects to human health could arise when they enter the food chain (Manahan, 1991; Ayodele&Oluyomi, 2011;Omaka*et al.*, 2011).

Radionuclides can be dissolved in solution or complexed with soil organics. Radiosensitive elements can undergo transformation or sorption reaction that alters mobility and relative toxicity (Igwe*et al*., 2005). Radionuclides and trace elements are toxic to living organisms at excessive concentrations but some trace elements are essential for normal healthy growth and reproduction by plants and animals at low but critical concentrations and some radionuclidesare used as tracers of some micronutrients (Alloway, 1995; Anyakora*et al.*, 2011). Trace elements and radionuclides studies on palm oil has not been extensivelyinvestigated, yet about 80% of palm oil production is destined for human consumption with the other percentage going to animal feed and various industries.

Trace elements may come from various industrial sources and may have a significant contribution to environmental pollution because of anthropogenic activities. Some trace elements are essential or beneficial micronutrients for plants and animals butothers have no known biological or physiological function. All trace elements at high concentrations have toxic effects and are an environmental threat (Igwe*et al*., 2005). Traceelements in palm oilsare due to palm oil trees beinggrownin highly acidic soils where trace elements are potentially more bio available for root uptake.Trace element contents of palm oil may have both beneficial and adverse effects onhuman health. The regular consumption of palm oil can contribute to the daily dietary requirements of some of these elements. Owing to the importance of trace elements and radionuclides, many studies were carried out to determine their levels in palm oil, palm fruit oil, leaves, water and soils. In view of the growing awareness and concerns about trace elements and radionuclides,an attempt was made to review recent scientific findings on the concentration levels of some trace elements and radionuclides on red palm oil, fruit, leaves, water and soil on palm oil plantationsbased on the availableliteratures.

1.1 The Oil Palm Tree

The African oil palm (*Elaeisguineensis*) is indigenous to West and South West Africa andgrown in countries suchas Angola, Nigeria and the Gambia.Specie is the American oil palm *Elaeisoleifera*that is grown in Malaysia, Central and South America. It is a tropical tree with a stem and at maturity reaches a height of about 20m. The fruit of the oil palm tree is a fleshy mesocarp with a kernel from which oil can be extracted(Reeves and Welhrauch, 1979).

Biofuel can be produced from palm oil, which has increased the overdependence on the oil causing acontroversy on whether the oil should be used for food or fuel. Developed countries and researchers now seek for alternative energy by using waste from the oil palm tree such as the fronds, husks,etc as a form of renewable energy, biogas and plastics.(Hilary Chiew, 2008). Consumption of palm oil is associated with the reduction of serum cholesterol, low-density lipoprotein, decreased risk of cardiovascular disease and cancer (Oguntibeju*et al.,* 2010; Oluba*et al*., 2011). Red palm oil is rich in vitamins, antioxidants, and phytonutrients responsible for good health and growth.

1.2 Trace Elements

Trace elements are dischargedfrom industries, farmlands, municipal urban runoffs into surface waters causing contamination. The pollution of the ecosystem presents serious concern. Trace elements are non-degradable and incessant in the ecosystem.Advancement in technology,

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population growth and anthropogenic activities has led to high levels of industrialization causing discharge of effluent bearing heavy metals into our environment(Igwe*et al*, 2005; Jimoh and Mahmud, 2012;). The sources of trace elements on oil palm plantations whichare generally from natural and anthropogenic sourcesmay have significant contribution to environmental pollution. Many sources of chemical contaminants such as lead, nickel and boron are gasoline additives that are released into the atmosphere and carried to the soil through rain.

Trace elements in palm oils are due to palm oil trees grown in highly acidic soils where trace elements are potentially more bioavailable for root uptake. Several stages of processing in the extraction of palm oil from fresh fruits bunch are as follows, sterilization, bunch stripping, digestion, oil extraction and finally clarification and purification; each unit has its unique operations (Igwe and Onyegbado, 2007). Trace element contents of palm oil may have both beneficial and adverse effects on human health. The regular consumption of palm oil can contribute to the daily dietary requirements of some of these elements. The accumulation of aluminium in palm oil is associated with Alzheimerߴs disease (Judith, 2011). In a similar way, other trace elements, arsenic, cadmium, chromium, lead, manganese, and nickel contents have been investigated in many South Asian and African countries where palm oil is used as stable oil in food (Pais&O'Neill, 1990; Jones, 1997; Njoku*et al.*, 2010;Asemave*et al.,* 2011).

1.3 Radionuclides

Radionuclides occur naturally and can be produced artificially (Petrucci*et al*., 2002). Radionuclides are important inindustry. They are hazardous to animal and human health. There are many radionuclides but only a few are encountered during routine testing in medicine, military and industry (USEPA, 2007). Naturally, occurring radionuclides can be classified as primordial, secondary, and cosmogenic radionuclides.Secondary radionuclides are mostly derived from the decay of primordial radionuclides but have shorter half-lives to their predecessors. Cosmogenic isotopes, such as carbon-14, are present because they are created in the atmosphere due to cosmic rays (Petrucci*et al.,* 2002). Nuclides of any element that have atomic number greater than bismuth-83 are unstable and therefore radioactive (Brandy, 1974). Americium-241, caesium-137, cobalt-60, iodine129 are some radionuclides that occur naturally; caesium for example, is an alkali metal like potassium and resembles it metabolically (Mster, 1996). Whereas potassium is an essential element for man, there is no evidence, that caesium is also an essential trace element. Stable caesium-133 is rare in the biosphere (Brandy, 1974). The radioactive isotope caesium-137 is produced in nuclear fission and is one of the most significant products (Brandy & Weil, 1999). Artificial radionuclides are produced from nuclear reactors, radionuclide generators and weapon testing (Petrucci*et al*., 2002).The extent of this widespread but generally diffused contamination has caused concern about its possible hazards on plants, animals and human beings. Nuclear fission in connection with atomic weapons testing and power generation provides some of the sources of soil contamination (Holmgen*et al.*, 1993; Nyle&Ray, 1996). These normal soil levels of the fissionof radionuclides are not high enough to be hazardous. Evenduring the peak periods of weapons testing, soils did not contribute significantly to the level of these nuclides in plants. Atmospheric fallout on vegetation was the primary source of radionuclides in the food chain (Holmgen*et al,* 1993;Meiwether*et al*., 1988).Considerable research has been accomplished on the behaviour of radionuclides in the soil and plants (Meiwether*et al.,* 1988; Osibote*et al*., 1999; Petrucci*et al*., 2002; Awodugba&Tchokossa,

2008).In addition to radionuclides added to soil becauseof weapons testing and accidents such as that which occurred at Chernobyl, Ukraine,soil may interact with low-level radioactive waste materials that have been buried for disposal (Iskauder, 1992; Knox *et al*., 2000;). Radionuclides buried in landfillsmay be dissolvedin soil (Brandy &Weil, 1999). Plutonium, uranium, americium, neptunium, curium and caesium are among the elements whose nuclides occur in radioactive wastesand organic matter content (Wiler 1965;Nyle& Ray, 1996). Fruits and seeds have generally much lower of these nuclides than are leaves, suggesting that grains may be less contaminated by nuclides than forage crops and leafy vegetables (Knox *et al.*, 2000).

2.0 TRACE ELEMENTS IN OIL PALM

2.1 Arsenic (As)

Arsenic is a deadly poison, which is persistent in the environment and capable of causing mutations, cancer infertility and tumours (WHO, 2003).A compound of arsenic known as arsenic trioxide was used to treat some forms of cancer; especially promyelocytic leukaemia in the past. It has a long history of use as a homicidal agent, pesticide and a constituent of consumer product. Due to the toxicity of arsenic, its use in agriculture has drastically declined. Occupational arsenic poisoning is common among miners and smelters mining arsenic and farmers working in farms where arsenic fertilizers have been used(Pais& Jones, 1997).

2.1.1 Arsenic in soils from oil palm plantations

Sources of atmospheric arsenic may be from microorganisms or volcanoes.Anthropogenic activities such as the burning of fossil contribute to about 80% of atmospheric arsenic pollution. Arsenicphytotoxicity in soil depends on factors such as pH and soil texture and increases especially at low pH and in sandy soils(O'Neil, 1995).The oil palm plantation is an economic crop and the waste such as the fibers and shells can be used as a source of fuel. Hamzah*et al.,* (2012), investigated the effect of the use of fiber and shell as a source of fuel on soil of an oil palm plantation. The study was carried out to determine the effect of anthropogenic activities such as fertilizer application and agronomical practices such as burning of fuel on the soil of the oil palm plantation. The soil and palm fronds of the oil palm tree were analyzed for As, Cu, Ni, Co,V, Hg, Zn and Mn using Energy Dispersive X-ray Fluorescence (EDXRF) Technique. The concentration of elements such as Arsenic in the soil and palm fronds (leaves) wasattributed to the fly ash, fertilizer and pesticide application. The plot distribution pattern of elements on the soils of the oil palm tree was established to determine hot spots for such metals (Hamzah*et al.,* 2012).Ben & John (2006) undertook an overview of toxic herbicides and pesticides examination at the Higaturu Oil Palm Plantation Limited (HOPPL) in Popondetta, Oro, Northern Papua, New Guinea. An initial environmental examination of the impacts of palm oil activities on the soil of the 20-year-old plantation were sampled at 150-350 mm depth. Pilot assessment of soil fertility and contaminants in the plantation were investigated. The key objective was to provide scientific evidence to support claims for compensation by villages on the effect of environmental degradation due to activities of the palm oil plantation. The site recorded significant levels of arsenic (<1 mg/kg).The researchers inferred that arsenic contamination of the palm oil plantation

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soil could be due to leakages from copper chrome arsenate preservative which was used to preserve timber from a nearby local timber mill (Ben & John, 2006).

2.1.2 Arsenic in water from oil palm plantations

Significant amounts of toxic inorganic arsenicsin water can cause some form of mutations in aquaculture, which poses healthrisks.Symptoms of chronic contamination are seen as diarrhea, skin cancer, abdominal pain and neurological defects.Sarmani and colleagues (1992) investigated the inventory of heavy metals and organic micro pollutants in an urban water catchment basin in oil palm plantations. The Linggi River drainage basin in Negeri Sembilan Malaysia is the major source of potable water for townships of Seremban and Port Dickson in Malaysia. Water quality was threatened by industrial and commercial activities of the oil palm plantations in the basin. The study investigated the concentrations and distribution of organic micro-pollutants and heavy metals within the catchment. Arsenic, copper, cadmium, lead, mercury, and zinc were determined in water and sediment samples. The heavy metal concentrations were increased down the basin; arsenic and copper concentration in particular were elevated probably due to flow of arsenical herbicides from the oil palm plantations (Sarmani*et al.,* 1992)

A lot of research has been conducted on arsenic in water and effluents (Wals*et al*., 1980; Hughes *et al*., 2011; Kumar *et al*., 2011; Chengbei*et al*., 2013; Tyson, 2013). Data on the studies of arsenic in water from oil palm plantation is limited.

2.1.3 Arsenic in plants from oil palm plantations

Plants absorb arsenic easily, so high concentrations of arsenic may be present in food. Arsenic is known to alter and disturb uptake and transport of nutrients in plants (Paivokeand Simola, 2001). Disturbance of plant mineral nutrition is the main cause of decrease in yield. Visual symptoms of phytotoxicity include leaf wilting, retardation in root and shoot growth, root discoloration, and leaf necrosis (Wool son *et al*., 1971). The phytotoxicity of arsenic is attributed to its ability to substitute for phosphate in enzyme-catalyzed, phosphorylation reactions and thus interfere with the energy status of the plant. Plant is the major uptake of arsenic to animals and humans. Determination of arsenic in seeds, fruits and some researchers ,Kukier*et al*., 1994; Jurgen*et al*., 2000., Melendez *et al.,* 2011., Ramirez-Andreotta*et al*., 2013; have studied stem of various plants.The determination of arsenic in water from oil palm plantation is sparse.

2.1.4 Arsenic in palm oil

In addition to food, edible oils like palm oil may act as an important potential dietary ingestion source of toxic elements in daily life. The regular consumption of palm oil may contribute to the daily dietary requirements of several elements. Nevertheless, at the same time, some toxic elements like arsenic may also be ingested into the body (Han *et al*., 2005).The oil palm tree especially fruits can accumulate trace elements from soil and soil solution from the application of fertilizers and herbicides containing arsenic. Recently, this practice is gradually fading.Hammid*et al*., (2012), determined the concentration of arsenic in by products of palm oil using the microwave digestion technique and the graphite furnace atomic absorption spectrometry method. The mean recovery of arsenic showed that the method was suitable in the determination of palm oil and palm kernel oil. Evaluation of the concentration of some toxic

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metals in dietary palm oil was investigated by Adepoju-Bello *et al*(2012).The purity and safety of palm oil which is regarded as a dietary and medicinal component was investigated. Concentrations of cadmium, chromium, mercury, lead, nickel and arsenic in twenty-five samples of palm oil bought randomly in different markets in Lagos state, Nigeria was analysed using Atomic Absorption Spectroscopy. The Oral Component Limit for cadmium, chromium, mercury, lead, arsenic and nickel were 0.5µg/g, 25µg/g, 1.5µg/g, 1µg/g and 25µg/g respectively. The results show that palm oil samples analyzed were safe for human consumption (Adepoju-Bello *et al*., 2012). Studies on distribution and uptake of trace elements in red palm oil have not been done exclusively so far. Most analysis is performed on edible oils bought from markets in which palm oil is inclusive. Chen *et al*. (2001) developed a method for the development of arsenic in edible fat and oils by acid digestion in a microwave digester using atomic fluorescence spectrometer (AFS). The recovery studies were performed at 0.05, 0.10, and 0.20-ppm spike levels in palm oil, olive oil, and lard. The samples were analyzed to contain 0.005~0.027 ppm of arsenic. Chen & colleagues (2001) also reported a direct method of arsenic content in salad oil, fish oil, palm oil, and lard with graphite furnace atomic absorption spectrophotometer. The edible oils were diluted with n-hexane followed by the determination of arsenic with Zeeman furnace atomic absorption spectrophotometer and transverse heated graphite atomizer. Results showed that optimal ashing and atomizing temperatures were 1200°C and 2300°C respectively. The detection limit was 0.010 ppm and the percentage recovery for the spike of 0.05, 0.10 and 0.20 ppm arsenic to salad oil, fish oil, palm oil and lard were 91.2~94.3%, 94.7~95.9%, 94.2~96.7% and 93.3~94.1% respectively. Arsenic contents were found to be below detection limits.

2.2 Cadmium (Cd)

Cadmium is mainly found in the earth crust and anthropogenically in industrial work places. Naturally, 25,000 tonnes of cadmium is released into the environment every year mostly in rivers through weathering of rocks, fires and volcanoes(Waalkes, 2000).Cadmium mostly occurs in combination with zinc. Hence, where zinc is suspected to be a major pollutant, the possibility of cadmium cannot be ruled out. It is the byproduct after the smelting of lead, copper and zinc in the miningindustry.Overexposuresoccurs where trace quantities of cadmium are foundbecause of its low permissible exposure limit. Industrial methods such as electroplating andspray-painting of materials constitute occupational hazards to workers.Cadmium is one of the most deleterious toxictrace metals to plants and to animals.It is designated as a human and a potent multi-tissue animal carcinogen (Johri*et al*., 2010). In humans, cadmium accumulates mainly in the kidney with a biological half-life of about 20 years, which can lead to pulmonary emphysema and renal tubular damage. Extreme cases of chronictoxicity results in osteomalacia and bone fractures, as characterized by the disease calledItai-Itai in Japan in the 1950s and 60s.This happened when populations of Japanese were exposed to cadmium-contaminatedfood crops, principally rice. Other health effects caused by cadmium in human are infertility, mental and immune system disorders, cancer and DNA damage.

2.2.1 Cadmium in soils from oil palm plantations

Soil analysis, has the advantage that it can measure the level of immediately available nutrients in the soil (nutrient intensity) and the soil ability to continue the supply of nutrients throughout crop growth. Interpretation of soil analysis allows for assessing fertilizer needs but it does not allow an evaluation of the efficiency or sufficiency of nutrient uptake to ensure optimal growth and productivity of the crop. With the development of modern industry and agriculture, cadmium has become one of the most harmful widespread pollutants in agricultural soils, mainly due to industrial emission, application of cadmium- sewage, phosphate fertilizers and metropolitan waste disposal (Gupta & Gupta 1998).It is an impurity in phosphate fertilizers pathway into the environment, which is mainly through soil, manures and pesticides. Acidification of soils enhances the mobilization of cadmium from soils into surface and ground waters.Phosphate fertilizer application is a significant contributor of trace elements, especially for cadmium accumulation in cropped soils. Repeated application of phosphate fertilizers may lead to a gradual buildup of cadmium in agricultural soils over time. The continuous application of phosphate rock fertilizer caused a lot of concern about the increasing accumulation of Cd and Zn in soils. Aini*et al*.,(2010) investigated two oil palm plantations in Malaysia. Trace metal concentrations were investigated on the plantations aged 10, 15 and 20 years. Cd and Zn isotherms were used to report the findings from the study. The results of the investigation indicated no accumulation of Cd but Zn, indicating that Cd adsorption can be suppressed by the presence of the zinc metal (Aini*et al.,* 2010). Cadmium concentrations in soils in palm oil plantations have not been reported frequently. Asante &Ntow (2009) recorded Cadmium contamination in soils and sediments in Tarkwa, Ghana where a small-scale palm kernel oil plantation and mill was sited. Analysis was performed using an Atomic Absorption Spectrophotometer. From the results of the investigation, it was observed that cadmium levels were generally higher than the WHO (1993) recommended level of 2.0mgkg^{-1}.Cadmium mean levels in the soil ranged between 1.23~4.63mgkg^{-1} in Tarkwa and its environs. Cadmium pollution in the soil may be attributed to a gold smelting company located near the plantation. Frequent routine analysis of trace elements was recommended in Tarkwa and her environs in order to control trace element pollution in the area (Asante &Ntow, 2009).

2.2.2 Cadmium in water from oil palm plantations

Cadmium exposure can cause adverse health effects over long periods. It is a trace element that isnon-biodegradable. Cadmium may be found in soil or water near industrial areas or hazardous waste sites. High levels of cadmium in surface waters usually result from cadmium particles settling from the air. Cadmium in water tends to sink and accumulate in bottom sediments. Oil palm agriculture and palm oil processing has the potential to pollute surface water through cadmium containing fertilizer run off and Palm Oil Mill Effluent (POME). Physicochemical and heavy metal parameters were investigated in a palm oil mill effluent selected randomly in palm oil milling sites in River state, Nigeria. Heavy metals found in the samples were Cd, Cr, Cu and Fe. Cu, Cr and Fe were significantly different while Cd had no significant difference. It was recommended that it is preferably to recycle POME rather than discharge into water bodies due to the concentration of trace elements (Ohimain*et al*., 2012). Ling et al. (2011) analyzed the oil palm plantation near the Sampadiriver close to an oil palm plantation in Malaysia with the objective to determine the water and sediment quality of the river. Results show that the river water had high concentrations of cadmium with the mean values of cadmium ranging between 0.05±0.02 to 0.66±0.05 (Ling *et al*., 2011).

2.2.3 Cadmium in plants from oil palm plantations

Trace element ions are reported as priority pollutants due to their mobility in natural ecosystems and their toxicity. Trace element uptake by plant can be useful in phytoremediation whereby plants clean up soils. The phytotoxicity of cadmium is also well known due to disruptions in plant ion. Increase soil cadmium content results in an enhanced uptake of cadmium by plant that is the pathway of human exposure through agricultural crops.Many studies had been conducted in order to identify plant species capable of accumulating undesirable toxic compound such as heavy/trace metals uptake by the roots and leaves of the plants (Adriano, 1986; Alloway, 1990; Cunningham &Ow, 1996). *Elaeisguineensis*was identified to remove heavy metals from soils. Monitoring of the content of heavy metals compounds in leaves/plants is necessary because of the toxicity of these metals.*Elaeisguineensis*was identified to remove heavy metals from soils. Monitoring of the content of heavy metals compounds in leaves/plants is necessary because of the toxicity of these metals. Soils have been contaminated with heavy metals because of industrial activities such as mining, automobile battery production, vehicle emission, and land filling of industrial waste. A study was conducted on the analysis of heavy metals (cadmium, chromium, copper, zinc, and lead) in the soil and sediments, roots and leaves of *Elaeisguineensis* using Atomic Absorption Spectrophotometer. Analysis of Variance Test conducted on *Elaeisguineensis*showed significant difference ($p<0.05$) for cadmium and lead trace elements uptake only while the other trace elements have no significant difference in uptake. The research showed that *Elaeisguineensis* could absorb heavy metals from different parts of tree plants (Anklam*et al*., 2001).

Aini and colleagues further investigated soils of a Malaysian oil palm plantation aged between 10, 15 and 20 years. Leave fronds of the oil palm plantation were analysed for the presence of cadmium. A correlation study revealed that that cadmium in soil and soil solutions possibly contributed to the concentration of cadmium in oil palm fruit and leaf fronds. They reported that these may influence the uptake of Cd by the oil palm tree. Adsorption isotherms also revealed that the concentration of Cd was also suppressed by the presence of zinc (Aini*et al.,* 2012).

2.2.4 Cadmium in palm oil

Food is a major route for cadmium exposure in plants and animals. Plants may only contain small or moderate amounts in non-industrial areas, but high levels are found in plants cultivated on contaminated soils.Oil palm trees grown on soils contaminated with trace elements such as cadmium may influence the uptake of Cd to the fruit. A correlation study conducted by Aini*et al.,* (2012) revealed that that cadmium in soil and soil solutions possibly contributed to the concentration of cadmium in oil palm fruit. Processed oil may be contaminated by trace metal from soils and soil solutions andcontamination from oil processing.Asemave and colleagues collected palm oil samples from two major markets in Markurdi, Nigeria. The oil samples were analysed for Cd, Cu, Fe, Cr, Al and Pb. The concentrations of the trace elements were within the safe limits and safe for consumption. The physicochemical properties of the oil such as viscosity, saponification and acid value were also investigated.

2.3 Zinc (Zn)

Zinc is an essential mineral that is naturally present in some foods, added to others, and available as a dietary supplementandtakes part in numerous aspects of cellular metabolism. It is required for the catalytic activity of about 100 enzymes and actively takes part in immune function, protein metabolism, foetus development and the healing of wounds. It is a micronutrient thathas been recognized as an essential trace element for normal healthy growth of animals and plants (Hartley, 1988). The average human body contains about 3 grams of zinc and a deficiency of this essential element results inoxidative stress, dysfunction of several enzyme systems ofvariousmetabolic activities. Zinc is involved in over one hundred different reactions in the body such as the growth and repair of DNA, tissues and systems. It has high antioxidant properties protecting the body from the action of free radicals. It is the active site for metalloenzymesrequired for nucleic acid synthesis. Zinc deficiency may lead tohair loss, mental apathy, reproductive,and growth disorders. Although zinc is an essential trace element, an excess in the human diet can lead to copper deficiency, immune system disorders, fatigue, and nausea (Hajo&Lothar, 2009).

2.3.1 Zinc in soils from oil palm plantations

A study on Zinc as it relates to crop nutrition was extensively studied by Alloway (1990).This appreciably provides an enhanced perception of zinc complexes in soil and plants. The causes and occurrence of zinc deficiency in crops growing on different types of soil in most agricultural regions of the world are reasonably well understood. Scientific methods are available to diagnose crop problems revealed by visible symptoms that identify soils of marginal or deficient zinc supply capacity. Therefore, the problem of wide spread zinc deficiencies can be solved if farmers are made aware of zinc deficient conditions and how to treat it. Zinc deficiency is not just a problem in developing countries; it also occurs in most developed nations. The difference in the situation is the existence of an extension agronomy service and rapid access to analytical facilities in developed countries, thus helping to reduce loss in yield brought about by zinc deficiency. Sandy, calcareous, and saline soils are usually prone to zinc deficiency. The problem of zinc deficiency is global and the most commonly encountered deficient trace element to plants.Soil analysis has the advantage that it can measure the level of immediate availability of nutrients in soil that is the soil nutrient intensity, and the soilǿs ability to continue the supply of such nutrients throughout crop growth. Interpretation of soil analysis allows for assessing fertilizer needs, but it does not allow evaluation of the efficiency or/of nutrient uptake to ensure optimal growth productivity of the plant.Levels of zinc in surplus of 500ppm in soil hinder the ability of plants to absorb other essential elements especially iron and manganese.Aweto and Enaruvbe (2010) evaluated the effect of variation of soil properties on a 30year old oil palm plantation in south west Nigeria. Five soil samples were selected, 0-20cm depth, segmented into upper and lower slopes and evaluated for exchangeable calcium and cation exchange capacity. Trace elements such as Zn, Cu, and Iron were significantly higher in the lower slopes. The significance of the study was to manage parts of the oil palm plantations on different topographic levels considering the variation in soil properties such as pH.Aini and colleagues (2010) investigated cadmium and zinc accumulation in soil in Malaysia`s oil palm plantation caused by continuous application of phosphate rock fertilizer on soils aged between 10~20 years. Oil palm plantations from coastal and inland areas in Malaysia were selected. Samples of soils from Jawa, Selangor and Sedu regions were collected to represent coastal areas while Munchong, Rengam and Segamat samples were collected to represent inland areas. To support the findings of the field study, zinc and cadmium adsorption isotherms were investigated using the same soil series. The pH effect on zinc adsorption and competitive adsorption between zinc and cadmium were investigated. In the study soil trace element mean concentrations were compared between three different ages of oil palm (10, 15 and 20 years). Results indicated no accumulation of cadmium in all soils but zinc accumulations were observed for Selangor and Segamat series. Of all the soil series studied, the Segamat series exhibited the highest amount of cadmium and zinc adsorption. Adsorption of cadmium was very low in Selangor and Segamat regions due to the presence of zinc. The increasing soil pH and age of the oil palm trees in Selagnor region also favoured the adsorption of zinc (Aini*et al*, 2010). Soil analysis has the advantage that it can measure the level of immediate availability of nutrients in soil which is the soil nutrient intensity, and the soilôs ability to continue the supply of such nutrients throughout crop growth. Interpretation of soil analysis allows for assessing fertilizer needs, but it does not allow evaluation of the efficiency or/of nutrient uptake to ensure optimal growth productivity of the plant.Soils contaminated with zinc through the mining of zinc-containing ores, refining, or where zinc-containing sludge is used as fertilizer, can contain several grams of zinc per kilogram of dry soil. Levels of zinc in excess of 500ppm in soil interfere with the ability of plants to absorb other essential metals, such as iron and manganese (Sawada, 2010).

2.3.2 Zinc in water from oil palm plantations

Zinc is concerned withseveral aspects of cell metabolism. It is essential for the catalytic functioningof about 100 enzymes and it plays a significant role in immune function, protein synthesis, wound healing, growth and foetus development. The indiscriminate dumping of waste and mining operations leach significant amounts of zinc and cadmium into the water and sediments of the Geul River due to the production of zinc ores. About 1.1 million tonnes of metallic zinc and 130 thousand tonnes of lead were mined and smelted in the towns of Belgian of La Calamine and Plombieresbetween the year 1806 and 1882. Smelter slag and other residues of the process also contain significant amounts of trace elements hence polluting the Geul River (Kucha*et al*., 1996). Some research has been conducted on the determination of zinc metal in different types of water (Yilmaz,*et al.,* 2009; Arancibia,*et al.,*2010; Braga,*et al*., 2012; Kiran, 2012).Information on the studies of zinc in water from oil palm plantation is sparse

2.3.3 Zinc in plants from oil palm plantations

The importance of zinc to plants was scientifically established about 70 years ago.The latest innovation of prevalent zinc deficiency problems in plants is linked to the intensification of farming in many emerging nations. This has involved a revolution from conventional agricultural practices to the use of recent agricultural chemicals. Many of the modern crop varieties are much more prone to zinc deficiency than the traditional crops and the increased use of macronutrient fertilizers, particularly phosphorus, can intensify the deficiency of zinc in crops. The yieldof

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many other crops can drasticallydecline due to zinc deficiency (Kauser*et al.,*2001). Providentially, the sources and occurrence of zinc deficiency in many crops growing on different types of soil in agricultural regions of the world are reasonably well understood because tools are available to diagnose crop problems revealed by visible signs and symptoms. The importance of fertilizer in the production and maintenance of large and sustainable yields of palm oil fruit bunches cannot be overemphasized. Considerable efforts have been made to develop methods providing a scientific basis for estimating fertilizer requirements of oil palm and oil palm products.However, although soil and leaf test analysis may provide basis for decisions on fertilizer use, the success of the final crop is the result of the interaction of so many different factors such as plant growth factors and nutrient relationships. The normal range of zinc in most plants is between 20 to 100 ppm. Zinc is not a very mobile element in plants, and deficiency symptoms occur in newly emerging leaves. Stunted growth is a common symptom linked with zinc deficiency and concentration in leaves remains constant with a rapid increase at the end of the growth cycle (Kauser*et al.,*2001).

2.3.4 Zinc in palm oil

Excessive absorption of zinc in the diet from foods such as palm kernel oil can suppress copper and iron adsorption into the blood stream. The free zinc ion in solution is highly toxic to humans, plants, and animals. Micro molar amounts of the free ion can be lethal.There is evidence of copper deficiencies at low intakes of 100-300mg Zn.Possible symptoms of chronic toxicity of zinc have been reported as lethargy, ataxia, haemolytic anaemia, liver and kidney damage,

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vomiting and diarrhoea (Fosmire, 1990).Zinc has been determined in various vegetable oil using different instrumental methods (Sun, et al.,1999; Huang and Shih, 2001; Anwar,*et al.,* 2004; Pehlivan, 2008.Atasie and colleagues (2009) studied the extraction, composition and physicochemical characteristics of palm kernel oil. The elemental composition of the palm kernel oil (mg/kg) of Na, K, Ca, Fe, P and Zn were between 3.4±0.00 and 39.51±0.22mg/kg with zinc in the palm oil having a value of 2.82±0.30mg/kg. The physicochemical properties of the oil such as saponification value, refractive index, iodine value, acid value and peroxide value were also determined (Atasie*et al*.; 2009).

2.4 Aluminum(Al)

Humans and plants are exposed to high aluminiumlevels in the environment. These exposuresoriginated from water in drinks and food preparation, cooking utensils as well as antacid preparation. Aluminium is the risk factor of Alzheimer's disease,dementia, osteomalacia and encephalopathy (Chen *et al.,* 2011). Toxicity of aluminiumis tracedto deposition in bones and the central nervous system in patients with reduced renal function. Aluminium competes with calcium for absorption in the bone marrows, thereby contributing to the reduced skeletal mineralization observed in infants with growth retardation (Ma *et al*., 2001). In high doses, aluminium causesneurotoxicity, and is associated with altered blood function. Other symptoms of high doses of aluminium in humans are dermatitis, digestive disorders, and vomiting. Studies have also shown that aluminium increases the incidences of breast cancer in humans.Although the use of aluminium cookware has not shown to lead to aluminium toxicity, excessive consumption of antacids and the use of cosmetics containing aluminium compounds provide significant exposure levels (Chen *et al*., 2011).

2.4.1 Aluminium in soils from oil palm plantations

Aluminium is a primary factor that reduces plant growth on acid soils but generally harmless to plant growth in pH-neutral soils. Acid soils are usually saturated with aluminium instead of hydrogen ions. Theacidity of the soil is consequently due to the hydrolysis of aluminium compounds. Aluminumis a major constituent of most soils but it can only be useful to plants in acidic soils in the form of Al^{3+}. Exchangeable aluminum (Al^{3+}) values may be high in soils with pH below 5.5 but may occur at pH values as high as 6.0 in heavy textured soils (Brown & Johnston, 1982). The critical soil pH, at which aluminum becomes exchangeable in toxic concentrations depends on many factors including the predominant clay minerals, organic matter level and concentrations of other cations, anions and total salts as well as the species of the plant(Brown & Johnston, 1982).Acosta &Munevar(2003)observeda strong relationship between high aluminum saturation in soils and the occurrence of bud rot disease of mature oil palm tree. Further investigation was that the addition of soil amendments could improve aluminum toxicity and enhance soil pH and fertility status.Addition of soil amendments could possibly alleviate aluminum toxicity, increase soil pH and improve soil fertility status. Generally, these factors are of interest to oil palm growers because of low cost. Alvaro *et al*. (2009) evaluated the effects of selected amendments (ground magnesium limestone, magnesium carbonate, gypsum and kieserite) used in oil palm cultivation with the objective to improve soil fertility. Four acid Malaysian soils were selected representing high aluminum concentrations in acidic soils. These samples were taken from a five-year-old oil palm estate located in Negeri, Sembilan and the pH, exchangeable cation, phosphorus and aluminum concentrations in the soil were determined. The amendments showed variable effects on acid soil parameters. The ground magnesium limestone gave the best agronomic and economic efficiency in neutralizing soil acidity. Therefore, a combination of different amendments must be used to obtain an adequate balance of the nutrients that assures greater efficiency of nutrient availability to the plants (Alvaro *et al.,* 2009). Yeboua&Ballo, (2000), compared the physical and chemical properties and organic matter content of soil in an oil palm plantation 40 years after forest clearing in an unclear forest plantation in Cote d'Ivoire, West Africa. The clay content of the topsoil layer (0-20 cm) in the oil palm plantation was 35 % less than that of the soil in the forest areas, while the exchangeable aluminium content and pH were similar and the aluminium toxicity risk was higher in the oil palm plantation. Phosphorus, nitrogen and total carbon levels were markedly lower in the oil palm plantation as compared to the forest. Organic matter was the main factor determining the unfavourable change in soil properties, leading to a marked deficiency in most nutrients (Yeboua&Ballo, 2000).

2.4.2 Aluminium in water from oil palm plantations

Aluminium is the most abundant element and occurs naturally on earth in the form of silicates, oxides, and hydroxides (Farizwana, 2011). Excessive addition of Aluminium salts as coagulants in water treatment processes might produce elevated concentrations of aluminium in processed water. Aluminium salts reduce organic matter, colour, and turbidity and microorganism levels in polluted water. To acknowledge the limited knowledge of aluminium exposure among consumers and the fact that high concentration of aluminium in water is detrimental to health;researchers performed several studies(Farizwana*et al.*, 2011;Warmate*et al.*, 2010).Farizwana*et al.,* (2011) investigated the concentration of Aluminium and the physicochemical parameters of different water in selected estates in Kota, Tinggi, Johor using the Inductively Coupled Plasma Mass Spectrometer. The estates were situated in the oil palm plantation with public and private water supplies. The water supplies were within the safe water limits except for the private water supply which hard poor turbidity values. The study was conducted to determine if trace elements from various agronomical practices leached into the drinking water supply.

2.4.3 Aluminium in plants from oil palm plantations

Aluminum is the key element in the soil which complexes with oxygen and silicate.At low pH, aluminum becomes solubilized in soil and easily available for plant uptake, which immediately prevents root growth. Aluminum toxicity limitsglobal cropproduction because half of the global lands have pH below five and aluminium is solubilized easily at such pH.Thus, much research has been conducted to understand the mechanism of aluminium toxicity and resistance thatis important for stable food production in the future (Nosco*et al.*, 1988). Aluminumresistance isacceleratedby exclusion from the root andby methods that make the plants capable of tolerating aluminum. Many characteristics of aluminiumtoxicity remainambiguous and difficult to detect. In plants, the foliar symptoms are similar to those of phosphorousdeficiency that presents itself asstunted growth, late maturity, leaf discoloration and reduction in root growth(Poschenrieder*et* *al*., 2008).Findings on the determination of aluminium in plants is sparse and more research needs to be focused in that area.

2.4.4 Aluminum in palm oil

Until recently, aluminium was considered harmless for the human organism as it is readily excreted through urine. Nevertheless, research in environmental toxicology conducted in recent years indicated that aluminiumcould be a cause of many diseases in humans, animals, and plants.Aluminum can be found in many food products and feed for animals. In this way, it enters the organism and accumulates in various tissues. Although the mechanism of toxic aluminium actions on humans has not been elucidated yet, prophylactic action should be undertaken aimed at limiting the contact of humans withaluminium. Most of all, it should be eliminated from food, food additives and medicines. Kitchen utensils and appliances made of aluminium as well as aluminium wrappings and containers should be avoided(Ma *et al*., 2001). Trace metals such as Zn, As, Pb has been determined in various vegetable oils but findings on the determination of aluminium in palm oil is sparse and more research needs to be focused in that area.

Chromium (Cr)

Chromium is an essential element that actively takes part in the metabolism of carbohydrates, cholesterol and cardiovascular diseases. It is linkedwith the inhibition of diabetesand cardiovasculardiseases. The Hexavalent Chromium (VI) is more toxic, mutagenic and carcinogenic in nature when compared toChromium III. Dietary intake is the main route by which chromium is absorbed by humans.Diets that contain foods made fromwhole wheat, brown sugar meat, cheese, cereals, nuts, and certain vegetable contributes to a high chromium intake. Packaging technology used in food and beverage processing can increase the natural levels of chromium in raw products, since this metal is widely used in the food industry, especially in stainless steels. The US National Research Council has concluded that a varied and balanceddiet is the best way to guarantee adequate chromium intake.Chromium is an essential elementthatfunctions in the regulation of blood sugar levels by insulin and helps the body absorb energy from food(Schwarz, 1972). A high dose of the essential element above 0.05mg in the environment is harmful to living things (WHO, 2004).

2. 5.1 Chromium in soils from oil palm plantations

Chromium occurs naturally in soil but contamination due to chromium related anthropogenic activities has been a matter of apprehension to researchers over the ages. Its complex speciation chemistry has been a major difficulty in unraveling its toxicity mechanism (Adriano, 1986).Absorption of chromium has resultedto acute effects such asstomach, blood and convulsionsyndromes.An epidemiological study has related occupational exposure with chromium (VI) compounds to mortality due to lung cancer(Adriano, 1986). Soil contamination is an important factor contributing to total chromium concentration in plant tissues.Another study has revealed that plants growing on high-chromiumrich soils contained higher chromium concentrations and vice versa.Studies have shown that there is sufficient evidence of respiratory carcinogenicity in humans exposed to chromium (VI) in occupational settings (Mohammed *et al.*, 2012).Data on lung cancer risk in other chromium-associated occupational settings and for cancer at sites other than the lungs are consideredinsufficient. The epidemiological data does not concede to an assessment of the relative contributions to carcinogenic risk of metallic chromium, chromium(III) and chromium (VI) or of soluble versus insoluble chromium compounds.It appears that exposure to a mixture of hexavalent chromium compounds of different solubility results in the highest risk to humans (Iwegbue*et al*., 2011).Research has been performed extensively on the determination of chromium in soils using different extraction techniques (Jankiewic*et al*., 2005; Hanharan and Krishna, 2012; Shah *et al*., 2013). Adequate information is lacking on the determination of chromium in soils on oil palm plantations.

2.5.2 Chromium in water from oil palm plantations

Chromium is widely distributed in the earth's crust.Hexavalent Cr (VI) that is the most toxic form of the metal chromiumis a major drinking water contaminant. In several countries, a limit of 50 εg/l has been established for the presence of chromium in potable water (Shils*et al.* 1994).Information was acquiredfrom the U.S. Environmental Protection Agency (EPA) and the State of California and the assessment was to identify general occurrence trends of chromium, capture regional occurrence patterns and to assess the geographical coverage with the extentof impact of a potential future revision of total chromium on the nationõs water utilities (USEPA, 1991; Seidal& Corwin, 2012).Analysis of chromium in various water bodies were analyzed by Nagaray*et al*., (2009); Sendil*et al.,* (2011) using recent analytical methods.Information is lacking on the analysis of chromium in water from oil palm plantations.

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2.5.3 Chromium in plants from oil palm plantations

Chromium whencomparedwithother toxic trace metals such as cadmium, lead, mercury and aluminum, has received little understandingconcerning its toxicity mechanism in plants. The impact of Chromium contamination in the physiology of plant depends on the metal speciation, which is accountable for its mobilization, toxicity, and consequent plant uptake. Chromium toxicity in plants is manifested by reduced yield, inhibition of plant growth and mutagenesis (Becquer*et al*., 2003;Shanker, 2005).Due to its extensive industrial relevance, chromium is considered a significant environmental pollutant. Toxicity of chromium to plants depends on its valence state: Chromium (VI) is highly toxic and mobile whereas chromium (III) is less toxic. Toxic effects of chromiumon plant growth and development include alterations in the germination and growthprocess thatconsequently affects total productivity and yield.Chromium toxicity in plants is exhibited by stunted growth, chlorosis, and finally the death of the plant Chromium also causes deleterious effects on plant photosynthesis. The potential of plants with the capacity to accumulate or to stabilize chromium compounds for bioremediation fromchromium contamination has gained interest in recent years.Sources of chromium in the environment have also ensued from human activity such as industrial and urban effluents and sewages (Alvarez-Cabal *et al.*; 1994).Information on the determination of chromium in some plants species is available in literature (Cary and William, 2013; Hernandez-Martinez and Padron-sanz, 2013) but that of Oil palm tree (*Elaeisguineensis*) is lacking.

2.5.4 Chromium in palm oil

The determination of the inorganic profile of oils is important because of the metabolic role of trace elements in humans. Information on food nutritional composition is significant to ascertain food quality concerning its regards to freshness, storability, and toxicity. Trace levels of metals like Iron, copper, calcium, magnesium, cobalt, nickel and manganese are known to increase the rate of oil oxidation. In addition, metals like arsenic, cadmium, chromium and selenium are identified for their harmfulness.The advancementof rapid and precise analytical methods for trace elements determination in edible oil has been a challenge to quality control and food analyst (Cordella, *et al*., 2002).Bratakos&Lazos, 2002reported that virgin olive oil contained significantly lower levels of chromium than other vegetable oils. This variance could be attributed to chromium uptake by these vegetable oils during purifying, as well as from the material of packaging. Oils are usually packaged in plastic containers, which often contain certain chromium compounds, with chromium (VI) and chromium (III)compounds being used as additives and polymerization aids (Bratakos&Lazos,2002). Utensils used in the preparation of food may contribute to chromium levels. Some operations such are grinding, sedimentationand/or centrifugation for oil separation may contribute to chromium uptake during processing. Thismay beminimizedby using other processing methods like the seed oil extraction and refining.

2.6 Copper(Cu)

Copper is a reddish metal that occurs naturally in rock, soil, water, sediment, and air. Copper has many practical uses in society. Itcan befound in coins, electrical wiring, and water pipes. It is an essential micronutrient needed in small concentrations for proper functioning of systemsfor

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humans and plants. Copper is a component of haemoglobin and alongside vitamin C, helps in the maintenance of elasticity of the skin, blood vessels, and lungs. It has high antioxidant properties protecting the body from the action of free radicals and the only defence against free radicals is a healthy supply of a diet rich in antioxidants such as red palm oil. Free radicals deplete antioxidant nutrients and trace elements. High levels of trace elements in plants suchpalm oil can generate oxidative stress; thereby increasing the activity of antioxidant enzymes such as superoxide dismutase, catalase and glutathione peroxidise. Therefore, the levels of these trace elements in red palm oil on the water and soil on palm oil plantation will have a significant effect on the antioxidant activity of the red palm oil. Copper is toxic at high concentrations and adverse health effects of copper toxicity in humans include vomiting and diarrhoea. It has also been linked with liver damage and kidney disease.Copper levels in water and food must be regulated on a daily basis.Copper II ion is water-soluble and functions at low concentration as antiseptics, fungicides, and wood preservatives.Chronic copper toxicity does not normally occur in humans due to transport systems, which regulate absorption and excretion.Small quantities of various copper salts have been used in suicide attempts that produced acute copper toxicity. The toxicity is due to red-ox cycling and the generation of reactive oxygen species that damage DNA cells.Recessiveautosomal mutations in copper transport proteins can disable such systems leading to Wilson's disease.Copperaccumulation is responsible for cirrhosis of the liver in persons who have inherited defective genes (Fry *et al.*, 2012).

2.6.1 Copper in soils from oil palm plantations

The amount of copper in soil available to plants varies. Available copper ranges from 1 to 200 ppm in both mineral and organic soils and this is a function of soil pH and soil texture. Fine textured mineral soils generally contain the highest amounts of copper. The lowest concentrations are associated with organic or peat soils(Aweto&Enaruvbe, 2010).A study characterizes variations in soil properties under a 30-year oil palm oil plantation established on sedimentary soil in southwestern Nigeria. A 300 metre transect was delimited in an oil palm plantation adjoining a tributary of Ossiomo River at Okhuo, near Benin, Nigeria. The transect was divided into upper, middle and lower slope segments. Each segment was further subdivided into ten 10 by 10metres quadrants, making 30 quadrants. Five soil samples were randomly collected from 0-20cm layer of each quadrant and analysed for macronutrients and micronutrients. There were no significant variations in the levels of extractable manganese, copper and zinc between the upper, middle and lower slopes. Iron was significantly higher in the lower slope due to the occurrence of acidic soils in the lower slope (Aweto&Enaruvbe, 2010).Neutron activation analysis was used for the determination of trace elements of soil samples in two oil palm plantation towns in Ghana. The Assin North Central townǿs soils were analysed for soil fertility. The acidity of the soil decreased with depth so was the concentration of Cu, Ca and Zn.

2.6.2 Copper in water from oil palm plantations

Copper can be found in many wastewaters of electronic and metallurgical industries.Although the judicious use of copper fungicides may not cause any problem to human health and environmental contamination, its indiscriminate use may lead to the presence of undesirable levels of copper content in water (ZhangandGao, 1999).Cu has been determined in wastewaters and effluents (Zhang *et al.,* 1999; Brun*et al*., 2001; Iwegbue*et al*., 2011). Limited research is available on the determination of Cu on oil palm plantations.

2.6.3 Copper in plants from oil palm plantations

Copper is an essential nutrient for plant growth especially for seed, chlorophyll formation and proper enzyme activity. It is animportant components of proteins found in enzymes of plants that regulate biochemical reactions. Plantsrequire the presence of these specific enzymes for growth.Deficiency symptoms of copper in plants aredepicted by leaf discoloration and stunted growth, which finally leads to death.The majority of Bud Rot Disease (BRD) cases in the oil palm tree isinitiated by the deficiency of copper in the tree amongst other trace elements. Affected plants, however, may require four months to three years to recuperate. During this time, plant production drastically declines. A typical symptom of copper deficiency in plants is the yellowing of young leaves during the months of high rainfall and humidity. Infected leaf tissue eventually becomes necrotic and withers as the disease progresses. The disease is most severe when growing palm tips are infected and the fungal pathogen is allowed to extend deep into plant tissues. Palms can recover from BRD if the infection is superficial. However, if enough plant tissue is damaged, measures such as the implementation of extrememeasures such as heavy pruning may fail to save the tree (Acosta &Munevar, 2003).

2.6.4 Copper in palm oil

Trace elements are significant in the diet of humans; however, trace elements such as mercury, lead, cadmium and arsenic have detrimental effects on health. Copper is an essential component of enzymes that plays an important role in Fe transport. The harmful effect induced by copper only occurs when taken in high concentrations. High levels of Cu in the body is known to cause blood and kidney disorders. In plants, toxicity is manifested as seen in stunted growth and low yieldTrace elements have been determined in oil due to its importance to animal and man. Trace elements are toxic and are available in edible oils from fertilizer applications, soil and anthropogenic activities. Significant research has been conducted quantitatively and qualitatively on the concentration of metals in oil (Obi *et al*., 2001; Anwar *et al.,* 2004; Asemave*et al*., 2011; Adepoju-Bello *et al.,* 2012). Umar (2011) investigated the trace element concentrations of four Nigerian based edible oils (palm oil, palm kernel oil, shea butter and groundnut oil) using neutron activation analysis. Results indicate that the concentration range of the elements were 19.4ï 44.0µg/g for Al; 30.0ï 81.0 µg/g for Ca; 11.9ï 60.4 µg/for Cl; 1.43ï 5.96 µg/g for Cu; 7.3ï 28.1 µg/g for Mg; 0.47ï 1.69 µg/g for Mn and 17.5ï 72.8 µg/g for Na. The experimental procedure was aimed to determine micronutrient element in foods for control and monitoring purposes (Umar, 2011). Limited research is available on the level of copper in palm oil.

2.7 Selenium (Se)

Selenium in its pure form is metallic grey in colour and referred to as elemental selenium or selenium dust. It is rare in the environment in its elemental form, but usually combined with ores of other elements. Selenium is a naturally occurring solid substance widely but unevenly distributed in the earth's crust in rocks and soils. It finds its way into the environment through weathering of rocks and soils, volcanic eruptions, burning of fossil fuels and waste dumps. Sources of selenium toxicity may also be from crops grown on soils contaminated with selenium (ATSDR, 2003). Elemental selenium is produced primarily as a by-product of copper refining. Theutmost function of selenium compounds is in the manufacture of electronics, industrial, medical and therapeutic agents. Selenium is an essential trace element needed by the body. It has a strong antioxidant activity and is a thyroid hormone producer. It is very antagonistic to toxic metals like lead, mercury, cadmium and aluminium. It works with Vitamin C and E in preventing free radical damage to cell membranes, proteins, and DNA. Adequate Selenium in the diet reduces the risk of cancer and cardiovascular diseases and slows the progression of HIV/AIDS.Selenium relieves symptoms of osteoarthritis, rheumatism, mood disorders, and cataracts. Though selenium is an essential trace element acute concentration in the body is related to symptoms such dizziness, tiredness, inflammation of the mucous membranes and chronic bronchitis(ATSDR, 2003).

2.7.1 Selenium in soils from oil palm plantations

The main threats to soils areurbanization,industrial revolution, erosion, acidification, poor agronomical farm practices and pollution. This leads to, organic matter loss and deteriorating soil structure (Aweto&Ekuigbo, 1994). Soil contamination by heavy metals can originate from a number of sources included above.Contaminants usually sink and are persistent. Land use pattern has also had a significant impact on the quality of the soil in a typical environment. The maintenance of natural systems or soil fertility in tropical forest ecosystems is achieved by high and rapid circulation of nutrients through decomposition of leaves (Ola-Adams &Egunjobi,

1992; Oliveira &Lacerola, 1993; Regina *et al.,* 1999). The regrettable occurrence of so many immune diseases in Africa is becauseof depleted soils. China has a low rate of colon cancer, probably because of the nation's low fat diet. Cases of cancer have been reported in China where soil is devoid ofselenium. A stu dy in China showed thatFoods containing significantly high levels of selenium are usually foods grown on selenium rich soils. The Selenium drained regions were known as illness belts. The amount of selenium in plant proteins depended upon the seleniumcontent of the soil on which the plants are grown. Brazil nuts grown in selenium-rich soil may supply 100-microgram mores of selenium. However, those grown in soil that had poor selenium content may provide 10 times lessselenium. Selenium has been determined in soils of various depths but information is lacking on soils of the oil palm (Levesque and Vendette, 1971; Garcia *et al*., 1996; Vinceti*et al*., 2001; Nazemi et al., 2012). Research needs to be intensified in the area of the oil palm.

2.7.2 Selenium in water from oil palm plantations

The forms of selenium absorbed from the digestive tract areinorganic sodium selenate and sodium selenite.People who eat food especially edible oils-containing excess selenium typically encounter hair and nail losses, numbness and circulatory system disorders. Major sources of selenium in drinking water are from discharges of petroleum, mining and metal refining industries (ATSDR, 2003).Various researches have been determined on the levels of selenium in vegetable oils (Wallschlager and Roehi, 2001; Tyburska*et al*., 2010; Jiang,*et al*., 2013).Research needs to be intensified in the area of the oil palm.

2.7.3 Selenium in plants from oil palm plantations

Despite seleniumǒs status as a toxic heavy metal when taking in high concentrations, the element is vital to good human health. Selenium is an important part of a molecule in the body that protects blood cells from certain radicals.Vitamin E and selenium helps the immune system produce antibodies, which keeps the pancreas and heart working properly. A deficiency of selenium is related to the development of leukaemia, arthritis, and heart diseases. Researchers have also found that the low concentrations of selenium in the blood stream have led to higher risks of cancer. Fish, grains and Brazil nuts are considered good dietary sources. Nevertheless, in the current global marketplace it is difficult to know whether the food you eat comes from selenium-rich or selenium-poor growing areas (Goldhaber, 2003).The antioxidant property of selenium has been extensively determined in various plants and seeds(Levesque and Vendette, 1971; Xu*et al*., 2003; Cartes, *et al*., 2005; Cartes*et al*., 2011) but information is lacking on the oil palm tree.

2.7.4 Selenium in palm oil

Selenium forms part of proteins known as selenoproteins, which help prevent cellular damage from free radicals.These vital antioxidant enzymes assist in controlling thyroid function that is important in immune system functioning (Goldhaber, 2003).Tiahou and colleagues, 2004 studied the lack of oxidative stress in a selenium deficient area in Ivory Coast due to the potential nutritional antioxidant role of crude redpalm oil. The study involved 57 subjects aged 15to 69 in the Glanle and Boudou regions who consume a vegetarian and crude oil diet. The absence of oxidative stress damage in the subjects provided evidence of a selenium independent protection

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against oxidative stress (Tiahou*et al*., 2004).Information on selenium in palm oil from oil palm plantations is lacking.

2.8 Lead (Pb)

Lead is highly poisonous to plants and animals and affects almost every organ and system in the body. Long-term exposure to lead or its salts can result in decreased performance of the nervous system, high blood pressure, particularly in middle-aged and older people and anaemia.Exposure to high lead levels can severely damage the brain and kidneys and eventually cause death. Acute concentrations may cause miscarriage and reduce fertility. Lead in the environment, has been identified as a health threat. It leads to mental retardation and learning disabilities in children even at very low levels. Lead pathway into the environment may be from the inhalation of airborne lead particulates, consumption of water, food or dust contaminated by lead. Several studies have indicated that young children have an increased risk of lead poisoning(Francek, 1994; Rabinowitz&Bellinger, 1988; Staudinger & Roth, 1988).

2.8.1 Lead in soils from oil palm plantations

Environmental levels of lead have been increasing for hundreds of years, and may just start declining in response to greater awareness of its harmful effects. Today,much of the lead in the environment is from the use of lead-acid batteries. Common industrial sources of lead pollution include mining, primary and secondary metal smelting, steel and iron production, car battery recycling, and the production of pigments (Ogunseitan*et al*., 2009 Chen*et al*., 2011).The application of fertilizer and animal manure may over time contaminate oil palm plantations with heavy and trace metals. This may pose risk to plants and animals and their environment. Uwumanrongie*et al.,* (2012) investigated the effect of Pb and Cr in soil from Nigeria Institute for Oil palm Plantations in Nigeria. The physicochemical parameters of the soil were also investigated. Fractionation studies revealed that the concentration of Pb and Cr were bound to different fractions especially the residual fractions after planting. The researchers concluded that cow dung could be used to immobilise heavy metals found on contaminated soils on oil palm plantations.

2.8.2 Lead in water from oil palm plantations

Aquaculture is an important industry in Malaysia due to water availability. Recent commercial development in the Sampadi river watershed may have an impact on the water quality of the river.Ling and colleagues conducted a study to determine the water and sediment of the river along a shrimp culture farm and a palm oil plantation. Results show that oxygen demand, nitrogen and phosphorus concentrations at both stations were lower at lowtides than high tides. The station along the palm oil plantations showed the lowest pH and dissolved oxygen and the highest in lead and calcium (Ling et al., 2011).

2.8.3 Lead in plants from oil palm plantations

Plants take up lead fromsoil and under certain conditions highlevels of lead can be accumulated in the leaves and other edible parts ofthe plant. For instance, the oil palm tree can takelead from the soils andinevitably, lead will be transported to the leaves. Plants grown in lead contaminated soils can accumulate into planttissue. Research on the translocation of lead contaminated from the soil and roots into leaves on palm oil plantation is limited.

2.8.4 Lead in palm oil

Palmoil is an edible substance with antiinflammatory and antioxidant properties. Nwokocha& colleagues (2012) examined the prospective effect of red palm oil against lead and calcium in the liver. Wister rats exposed to cadmium (200ppm) and lead (100ppm) in drinking water at different feeding regimes were fed with rat chow mixed with 12% w/w of palm oil. The heavy metal accumulation in the liver of the rats was determined using Atomic Absorption Spectrophotometry. Weight loses induced by the metal accumulation were significantly reduced due to the ingestion of red palm oil. The studies show that red palm oil is beneficial in reducing heavy metal accumulation in the liver (Nwokocha*et al.*, 2012).

2.9 Magnesium

Magnesiumis an essential element in biological systems. Magnesium occurs typically as the Mg^{2+} ion. Its ions are essential to all living cells, where they play a major role in biological compounds like ATP, DNA, and RNA. The main source of energy in cells, ATP, must be bound to a magnesium ion in order to be biologically active. Over 300 enzymesneed the presence of magnesium ions for their catalytic action, as well as allenzymes using or synthesizing ATP, nucleotides, DNA and RNA. Magnesium compounds are used medically as laxatives, antacids, in the stabilization of abnormal nerve excitation and blood vessel spasm.Cell types may regulate the concentrations of magnesium in different ways based on their unique metabolic needs.

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Magnesium is an important ion that activates and mediates many biochemical reactions(Marschner, 1995). An example of this is the fixation of carbon in thechloroplastsduring photosynthesis.Magnesium has many functions in the metabolism of the oil palm tree. It aids in photosynthesis, being the central atom of the chlorophyll molecule that captures light energy required for photosynthesis. It acts as a co-enzyme in carbon dioxide synthesis for the production of macromolecules such as starch, carbohydrates and some vitamins.The significance of magnesium to proper cellular function cannot be overemphasized. Deficiency of magnesium results in disease in animals and plants. These are seen as stress responses in plants and a decrease in photosynthesis.In humans, signs and symptoms are seen as muscle spasms, heart, kidney and bone dysfunction, diarrhoea, diabetes, anxiety and migraines(EuserandCipolla, 2009). Dietary sources of magnesium are, grains, lean meat, dairy products, vegetables and dark chocolates. Over 50% of total magnesium in the body is found in the bone and the remaining percentage is distributed between the tissues, organs and the blood. Magnesium is also essential in allowing the body control insulin levels in the blood. (Broschat, 1997; Uza*et al*., 1987;Saris *et al.*, 2000;Bo *et al*., 2008; Cunha *et al*, 2012;). Magnesium is practically used in the manufacturing industry as filler and fire retardant, in agriculture as a component of fertilizers, a flocculent in wastewater treatment and a laxative in medicine.

2.9.1 Magnesium in soils from oil palm plantations

Though the oil palm is a use economic tree, the expansion of the oil palm industry has resulted to some environmental impacts. One of such is the loss of wild life such as the orang-utan and a decline in soil fertility. Ogeh and Osiomwan (2012) evaluated the effects of the oil palm tree on the properties of Mg in the soil in a field of over 15 years. The results of the study revealedthe

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variation in some nutrients such as Mg could be attributed to the soil management properties and emphasised that the maintenance of the soil properties is of paramount importance.Soil analysis is not particularly useful for diagnosing palm nutrient deficiencies, since palm nutrient symptoms often bears little resemblance to soil nutrient profiles (Broschat, 1997). Macronutrients, micronutrients, pH and salinity were determined in soil samples from two palm plantation towns in Assin North District, Central Region of Ghana. Neutron Activation with conventional counting method was used for the elemental analysis. The pH of the soil was within the acidic range. The top soil 0-5cm had the highest pH followed by soil at the depth of 5-30cm and 30-40cm. The pH of the soil decreased with depth but then salinity of the soil increased with soil depth Magnesium concentrations in the soils analyzed also decreased with increasing depth. The soil of the area was fertile for palm oil cultivation (Golow*et al.,* 2010). Another study was also carried out in an Oil Palm Plantation bearing 20-year-old palm. The objective of the study was to understand variations that results in soils due to the impact of oil palm trees planted over the years. Descriptive statistical analysis rated the status of total nitrogen as high and phosphorus and potassium as low. Exchangeable calcium was rated high in the surface layer and subsoil while magnesium was rated high in the surface but low at the subsoil. The results of the study show oil palm not having influence on soil chemical properties. The high level variation in the organic carbon content, total available nitrogen, phosphorus, calcium, magnesium and potassium observed could be attributed to the impact of oil palm cultivation on the land for over fifteen years (Ogeh&Osiomwan, 2012).The importance of essential elements in physiological processes of the oil palm has made it of importance that the nutrient status of the soil for its cultivation be ascertained. Uwumarongie-Ilori&colleagues (2012), assessed the amount of exchangeable calcium and magnesium in soils cultivated for oil palm. The results obtained showed mean levels of 2.07 ± 0.78mgl/kg calcium and 0.93 ± 0.45mg/kg magnesium. There was significant variation in the amount of exchangeable calcium and magnesium in the soils investigated. The data obtained was used in monitoring the amount of exchangeable calcium and magnesium in the oil palm plantation (Uwumarongie-Ilori*et al*, 2012).

2.9.2 Magnesium in water from oil palm plantations

The provision of water for use is one of the most intractableproblems in society today. Access to water is essential to health, food and sustainable development .Contamination of surface and ground water from industrial, agricultural and municipal wastes is immense. The infiltration of rainfall into landfill and waste produces leachate, high in trace elements that seep into ground and surface water. Trace elements such as Mg have been determined in water and sediments of rivers (Chapman, 1986).Data on the studies of magnesium in water from oil palm plantation is limited.

2.9.3 Magnesium in palm leaves from oil palm plantations

Soil analysis is not particularly useful for diagnosing palm nutrient deficiencies, since palm nutrient symptoms often bears little resemblance to soil nutrient profiles (Broschat, 1997). Magnesium has many functions in the metabolism of the oil palm tree. It aids in photosynthesis, being the central atom of the chlorophyll molecule that captures light energy required for photosynthesis. It acts as a co-enzyme in carbon dioxide synthesis for the production of macromolecules such as starch, carbohydrates and some vitamins. Magnesium deficiency appears on the oldest leaves of palms as broad chlorotic (yellow) bands along the margins with the central portion of the leaves remaining distinctly green.In severe cases, only the leaflets remain green on the oldest leaves, but younger leaves show necrosis. For instance, in*Elaeisguineensis*, leaflet tips on the oldest leaves may be necrotic, but this necrosis is due to potassium deficiency superimposed on deficient leaves of magnesium. Where the two deficiencies occur on the same palm, the oldest leaves will show characteristicpotassium deficiency signs, while magnesium deficiency signswill be seen on the mid-canopy leaves. Deficient Mg and the imbalance between the ion and other cations may cause magnesium deficiency symptoms. Magnesium deficiency is often detected in very high rainfall areas (greater than 3,500 mm/year).This is likely when the amount of soil exchangeable ion is less than 0.3 mg/kg.Inadequate application of magnesium to high yielding palms or to palms on magnesium deficient soils may cause magnesium deficiency(Rankine&Fairhurst, 1999).

2.9.4 Magnesium in palm oil

The determination of trace elements in vegetable oil is one of the criteria for the assessment of quality of oil. Trace metals in vegetable oils are known to have an effect on the rate of oil oxidation and storage capabilities.Njoku and colleagues (2010) in Nigeria investigated the physio-chemical characteristics and dietary metal concentrations of oil from Elaeisguineensis species. Physiochemical and dietary metal components were analyzed using standard test methods such as Spectrophotometry, Titrimetry and Gravimetry. The three species of *Elaeisguineensis*studied were *Elaeispisifera, Elaeisdura*and *Elaeistenera.* The physicochemical parameters determined were acid values, saponification values, iodine values and antioxidant content. The dietary metal concentrations for the *Pisifera, Dura and Tenera*were 0.95, 1.13 and 0.37 mg/kg for dietary magnesium and 0.08, 0.24 and 0.05 mg/kg for dietary zinc respectively (Njoku*et al,* 2010).

3.0 RADIONUCLIDES IN OIL PALM

3.1 Radium (Ra)

Radium is a radionuclide formed when isotopes of uranium and thorium decay in the environment. It is a naturally occurring radioactive metal with common isotopes ^{226}Ra, ^{224}Ra and ^{228}Ra. It occurs at low levels in virtually all rock, soil, water, plants, and animals. Radium was discovered in the 1900ŝs and its potential health hazards were unknown by then. Its characteristics as a luminescence material made it popular in consumer goods. The use of radium declined due to health and safety reasons (Douglas *et al,* 1990). Radium is a radiation source in some industrial radiography devices and an early radiation source for cancer treatment. Safer, more effective radiation sources, for instance cobalt-60 have substituted it. Radium is highly radioactive and hence carcinogenic and microscopic quantities in the environment can lead to some accumulation in bone tissues. Radium, like calcium, is a group II element and our bodies treat it in a similar way. It is present in tiny amounts in all uranium ores and at very low concentrations in seawater, surface and well water. Exposure toradium can be from the burning

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of fossil fuels. Certain occupations such as working in uranium mines or ore processing plant can lead to highexposures.Phosphate rocks typically contain relatively high levels of both uranium and radium (Douglas *et al,* 1990).

3.1.1 Radium in soil from palm plantations

Naturally occurring and anthropogenic radionuclides depends on geological and geographical conditions in the soils of each region in the world (UNSCEAR, 2000). It is well known, for instance, that higher radiation levels are associated with igneous rock and lower levels with sedimentary rocks. There are some concessions, though, as a number ofshale and phosphate rocks have comparatively high content of radionuclides (UNSCEAR, 2000;Tzortzis*et al.*, 2004;Alias *et al*, 2008). Human beings have always been exposed to natural radiations from their surroundings. Transfer of long-lived radionuclides such as radium and cesium were analyzed in contaminated soils after the Chernobyl accident in Japan (Muramatsu*et al*., 1987; UNSCEAR, 2000). Much research has been conducted on radium in different soil types, mines, agricultural landsand phosphate fertilizers (Muramatsu*et al*.,1987;Banzi*et al*., 2000). Adequate research has not been conducted on the analysis of Uranium on soils from palm oil plantations.

3.12 Radium in water from oil palm plantations

Radionuclides have always been present in the earthôs crust but are usually brought to the surface by oil and gas production and processing operations.Occurrence of radionuclides in ground water depends on the presence and solubility of the parent element. Oil and gas exploration causes radionuclides to accumulate at elevated concentrations in streams.. Radium has a similar chemical behavior to other alkaline earth metals. Therefore, in aquifers with limited sorption or ion exchange sites, radium solubility can be improved by the common-ion effect when other cations are abundantly present. Recently, high concentrations of radium were associated with ground water affected by poor agricultural practices (Kraemer & Reid, 1984; Zapecza&Szabo; 1987 Focazio*et al.,* 2001).An environmental impact assessment of the coastal plain and freshwater zone vegetated by forest tree species and oil palm in crude oil exploration regions was conducted in Ogoni land Port Harcourt, Nigeria by UNEP ,2011. Radium as one of the naturally occurring radionuclides is usually encountered in oil and gas exploration in the region.The study conducted by UNEP, 2011 revealed high concentrations of radium in the streamsnearby oil palm plantations. The UNEP team recommended that restoring the livelihoods and well-being of futureOgoni generations is within reach but timing iscritical. Given the dynamic nature of oil pollution and the extent of contamination revealed inUNEPҫs study, failure to address crucialcivic health concerns and commencing a cleanup will only exacerbate and unnecessarily prolong theOgoni peopleҫs suffering. Atransition phase was recommended to begin detailed planning in the intervening period between the release of UNEPҫsenvironmental assessment and the commencement of a clean-up operation guided by an Ogonilandenvironmental restoration authority (UNEP, 2011).

3.13 Radium in palm leaves from oil palm plantations

Analysis of radionuclides uptake from contaminated soils by plants is important for remediation. Accumulation of radium has been studied in some plants like *Dicranopterislinearis* (Chao & Chuang, 2011), *Dicranopterisdichotoma*(Simon & Deming, 1986), vegetables and fruits (Tracy *et al.,* 1983) and in wheatgrass, yellow clover and rye (Rumble &Bjugstad,1985).Extensive research and literature has not been done on the investigation of radium in palm leaves from oil palm plantations.

3.14 Radium in palm oil

Radionuclidescan be released into the environment through accidents, poor waste disposals and other means. Some level of radiation are naturally present in surface and ground water but other degrees of radiation exposure come from rocks and soil that have been contaminated by artificially produced radionuclides. Some major pathways to commonly encountered hazardous radionuclides are food contamination and occupational exposure at mining and processing sites. Studies on acute toxicity of radionuclides have been conducted on radionuclide content in food, water, waste dumps, feed materials, environmental matrices and crude oil (Osibote*et al.,* 1999; Strouble*et al.,* 1985; Olomo*et al*., 1990; Przylibski*et al.,* 2002; Awodugba&Tchokossa, 2008).Faweya&Babalola (2010) carried out gamma spectroscopic assays of radionuclide and heavy metalsfrom waste dumpsites in southwestern Nigeria. The activity concentration level due to ^{40}K, ^{226}Ra, ^{226}Th, ^{137}Cs, ^{109}Cd,'210Pb, ^{214}Bi and ^{208}Tl in the samples were determined using coaxial-type Ge detector. Faweya&Babalola recorded maximum concentrations of ^{40}K, ^{226}Ra, ^{228}Th and ^{137}Cs as 357±12, 68±7, 132±10 and 0.96 Bqkg^{-1} at Ado, Abeokuta, Lagos and Ibadan; while the minimum concentrations were 180±6, 40±5, 22±2 and 0.19 Bqkg^{-1} at Akure, Ado, Oshogbo and Abeokuta respectively. The highest concentrations of heavy metals ^{208}Ti, ^{210}Pb, ^{214}Bi and ^{109}Cd are 35±1, 46±5, 40±1 Bqkg^{-1}were at Lagos, Ibadan and Ado, while the minimum concentrations were 5±0.24, 20±3, 17±2 and 40±1 Bqkg^{-1}wereat Ado and Ibadan respectively (Faweya&Babalola, 2010). Analysis of radium in palm oil is sparse.

3.2 Uranium (U)

Uranium is an abundantnaturally occurring element that can be found in low levels in rock, soil, and water. It occurs in combination with other elements. Significant concentrations of uranium occur naturally in phosphaterock deposits,ligniteand uranium-rich ores. In nature, uranium(VI) forms highly soluble carbonate complexes at alkaline pH.Uranium is produced from anthropogenic activities such as uranium mining, fossil fuels, phosphate fertilizers and nuclear power production(Zaini*et al.*, 2010). The primary health concern of uranium mining is exposure to cancer-causing radiation. In addition to causing cancer, radiation, uranium may cause genetic damage, disrupt hormone levels, and reduce blood cell counts.One of the most troublesome aspects of radiation exposure is that symptoms of diseases may not arise until decades after exposure. Exposure to uraniumincreases the chances of developing cancer. A review of literature revealed that uranium workersô risk of developing lung cancer is 2-5 times greater than average. Close proximity to uranium-contaminated siteshave been known to cause an increase in negative health effects. Uranium is known to cause kidney, brain, heart and reproductive disorders (Miah& Roy, 1998).

3.2.1 Uranium in soil from oil palm plantations

Information of distribution pattern of radionuclides in soils is necessary in controlling radiation exposure levels and sources (Miah& Roy, 1998). The natural radioactivity of soil and sediment depends on chemical and biological formation and transport processes (Tenniseen, 1994). Much research has been conducted on uranium in different soil types and in mines(Laure et al., 2011) agricultural lands and phosphate fertilizers (Muramatsu*et al*., 1987; Banzi*et al*., 2000).Zaini*et al.,* 2011, in a study focused on the presence of natural uranium isotopes using its progenies in soils in the river basin of the granitic region of Kuala Krai district, Malaysia.Granitic characteristics of these regions were believed to produce significant concentrations of natural radionuclide such as uranium and thorium. Therefore, the assessment of radiation dose from soils on oil palm plantations is of particular importance, though limited research has been conducted.

3.2.2 Uranium in water from oil palm plantations

Higher rates of uranium intake have been reported for some populations who consume foods grown in areas with elevated concentrations of uranium in the soil and drinking water. Occurrence of radionuclides in ground water depends on the presence and solubility of the parent material. Kris(1991), following a survey on ground water monitoring project in southwestern North Dakota in the United States of America, determined uranium in reclaimed abandoned mines. One hundred and fifty eight water samples were collected from wells and springs of which twenty-six exceeded the USEPA maximum contaminant level for uranium (Kris, 1991).Some researchers (Brunskilland Wilkinson, 1987; UNSCEAR, 1988) have studied the effects of uranium in wells, surface waters, shallow aquifers, old mines and hazardous wastes. Information on the uranium on water from palm oil plantation is sparse.

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3.2.3 Uranium in palm leaves from oil palm plantations

The accumulation of radionuclides by plants acting as a monitoring system in the environment may occur by foliar absorption through the leaves and shoots of the plants or by uptake from the roots. Accumulation of radionuclide in plants can be obtained from tracer or fusion studies. Fission track technique has been widely used for the determination of uranium in environmental samples such as leaves and soils. Leave samples were collected from Dumka region of Jharkland state of India and analyzed for uranium concentrations using fission track techniques. The fission track and lexan plastic technique was also used as the external detector for uranium that varies in the different parts of the plant.The plant species used for the study were *Helianthus sativus,Lycopersiconescculentum*, *Hibiscus esculentus*and *Capsicum annum*(Singh *et al*., 2008). Uranium has been analyzed in the leaves ofcypress trees at the uranium processing facility in France (Giere*et al*., 2012). The transport of uranium was also analysed on *Andropogonelliotti* grown on sediments from a former radiological settling pond (Punshon*et al.,* 2004).Some wild plant such as *Lagonychiumfarctum* native to Iraqiôs desert were also polluted with uranium from the desert of Iraqiôs nuclear centres of research (Riyad*et al.*,2012). Information on the analysis of uranium on*Elaeisguineensis*treeplantis sparse.

3.2.4 Uranium in palm oil

Radionuclide can also be released into the environment through accidents, poor waste disposals and other means. Some level of radiation are naturally present in surface and ground water but other degrees of radiation exposure come from rocks and soil that have been contaminated by artificially produced radionuclides. Some major pathways to commonly encountered hazardous radionuclides are food contamination and occupational exposure at mining and processing sites (Ahmad *et al.*, 2011).Uranium undergoes oxidation-reduction reactions in the environment and microbial reactions to form complexes with organic matter (Premuzie*et al*., 1995). Uranium can only be removed from the environment by radioactive decay. Arogunjo (2007), using a 7.6 by 7.6 cm NaI (Tl) detector, carried out gamma radiation levels due to primeval radionuclide in surface soils in some southwestern cities in Nigeria. The mean absorbed dose rate and annual effective dose were evaluated from the measurement of ^{40}K, ^{228}U, ^{232}Th. The absorbed dose rate values ranged from 18.6 to 68.4 with a mean (±SD) value of 44.2±15.9 nGyh^{-1} in Lagos area; 26.8 to 145.6 within a mean value of 72.9±35.6 nGyh^{-1} in Ibadan area and 30.9 to 98.9 with a mean value of 64.2±26.5 nGyh^{-1} in Akure area. The mean effective dose for these locations is 56.5, 93.3 and 82.2 µSv year^{-1}, respectively. The average value for the region is 0.8 mSv year^{-1}endorsed for normal environment (Arogunjo, 2007). Awodugba, (2008), determined the level of radionuclide concentration in water from boreholes in selected areas of Ogbomosoland. Concentration of ^{228}U, ^{232}Th and ^{40}K was determined for the water samples from eight boreholes around Ogbomosoland by y-ray spectrometry with a high purity germanium (HPGe) detector connected to a multichannel analyser. All the water samples from these bore-holes were found to contain acceptable levels of radionuclide with mean activity values of 3.98±0.26, 11.0±2.58 and 17.73±5.04 Bql*for*^{40}K, ^{232}Th and ^{288}U respectively. This shows that the mean activity of ^{238}U for all the samples is the highest when compared to those of ^{40}K and ^{232}Th. Therefore, the activity of uranium remains essentially unchanged over thousands of years. Analysis of uranium in palm oil is sparse.

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4.0 THE OIL PALM TREE IN REMEDIATION TECHNOLOGY

The palm oil tree is a cost effective alternative solution to phytoremediation. Nowadays, many types of treatment methods are available as tools to reduce water and soil contamination by trace/heavy metals. However, these treatment methods have several disadvantages such as high cost and maintenance. Over the past decades, there has been an increasing interest for the development of plant-based remediation technologies which have the potential to be cheap and environmentally friendly (Cunningham &Ow, 1996). There are several mechanism used by plants, which allow cleanup of surface water, groundwater, soils, sediments, and sludge contaminated by trace/heavy metals. Phytoextraction is the use of metal-accumulating plants that can transport and concentrate metals, from soil/water through roots to other parts of the plants. This ability of the plant is used to extract toxic metals from the environment and provides an interesting tool for the remediation of metal contaminated sites (Baker *et al*., 1994). Most plants in the ecosystem have great variation in the way they concentrate trace/heavy metals (Freedman & Hutchinson).The oil palm tree (*Elaeisguineensis*) has been investigated by various scientists as being able to absorb different concentrations of trace/heavy metals at various parts of the plants. Roots of *Elaeisguineensis* showed highest uptake of zinc metals (1.2810 mg/L) compared to the leaf (0.9298) mg/L and sediment (0.5924 mg/L). The results show that *Elaeisguineensis* is able to accumulate Zinc metals more in the roots than other parts of the tree. Lead trace element accumulation was in the order of 0.3297 mg/L, 0.3267 mg/L, and 0.2529 mg/L for sediments, roots and leaves respectively. This is in agreement with Koeppe (1977), Adriano (1986), and Alloway (1990), who stated that the amount of metal uptake from the soils is influenced by soil factors such as pH, redox potential, organic matter content, fertilizer application, plant age and species. Chromium uptake of trace/heavy metal was highest in the shoots and lowest in sediments. Furthermore, the concentration of copper showed lowest concentrations (0.0095 mg/L) for the roots while the leaf showed the highest uptake of Copper (0.217 mg/L). From the research, cadmium had the lowest metal uptake by *Elaeisguineensis*. The mean trace/heavy metal concentration uptake values showed that the root has the highest value of metal adsorption (0.0118 mg/L) followed by leaves (0.0111 mg/L) and then sediments (0.0110 mg/L). The conclusion agrees with Adriano *et al.* (1986) who discussed the relevance of phytoremediation technology where tree parts can vary in their ability to accumulate certain types and concentrations of trace/ heavy metals due to differentiation in their solubility in soil, availability for plant uptake and their ability to undergo translocation.

CONCLUSION

Palm oil is an importantdietary oil component of food, beverages and snacks. Findings from the present literature present strong evidence that essential and non-essential trace elements and radionuclide can be ingested from palm oil. Nevertheless, it also provides vitamins and carotenes that are powerful mediators for cellular functions and cure for several ailments. However, it is still difficult to find out the adverse human healtheffect of palm oil as related to trace elements and radionuclide and at the same time, it isdifficult to translate diverse scientific findings into public healthmessages and setting a health standard for trace elements and radionuclides.The concentration of the trace elements and radionuclides in red palm oil could be from natural and anthropogenic sources on thesoil, water and leaves/fruit of the palm oil tree on palm plantations.

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Despite significant research efforts, adequate research is lacking on the concentration levels of trace elements on water, soil, fruits and leaves on palm oil plantations. Research is required to comprehend the science of accumulation oftrace elements and radionuclides by oil palm plants, its specification of uptake and effects on human health by regularconsumption of palm oil and palm oil products.

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Table 1

Trace elements/ radionuclides in palm oil

Country of Origin	Sample analyzed	Number of samples	Purpose of investigation	Concentration range (mgkg^{-1})	Instrument used	references
Arsenic As						
Malaysia	Palm oil	21	Evaluation of trace element level	0.005-0.027	GFAAS	Hammid*et al.*, 2012.
Lagos, Nigeria	Red palm oil	25	Evaluation of purity and safety	0.5µg/g-25µg/g	AAS	Adepoju-Bello *et al.*, 2012.
China	Edible oils, red palm oil	3	Development of arsenic in edible fats and oil	0.005-0.027	Atomic fluorescence Spectrometer	Chen *et al.*, 2001
Cadmium						
Markurdi, Nigeria	Red palm oil	25	Trace element analysis	0.078 - 11.370	AAS	Asemave *et al.*, 2010
Zinc						
Nigeria	Palm kernel oil	25	extraction, composition and physicochemical characteristics	2.82-3.40	AAS	Atasie and colleagues (2009)
Chromium						
Thailand	Edible oils	6	Trace element determination in edible oils	0.01-0.02	GFAAS/ICP-MS	Surasak, 2011
Copper						
Nigeria	Edible Oils	4	Routine Microelement In Edible Oils	7-3-28.1	Neutron Activation Analysis	Umar , 2011.
Magnesium						
Nigeria	Palm oil	4	Physicochemical properties and dietary metal concentrations	0.05-0.95	Spectrophotometry, titrimetry and gravimetry	Njoku and colleagues (2010)

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Table 2

Trace elements/radionuclides in soil on palm oil plantations

Country of Origin	Sample analysed	Depth	Purpose of investigation	Concentration range (mgkg^{-1})	Instrument used	References
Arsenic						
New Guinea	Soil on a 20 year old oil palm plantation	150-200cm	EnvironmentalImpact Assessment	1.0	Atomic Absorption Spectrometer	Ben and John, 2006
Cadmium						
Tarkwa, Ghana	Soil on a palm kernel oil plantation	0-30cm	Routine analysis	1.23-4.63	Atomic Absorption Spectrometer	Asante andNtow, 2009.
Zinc						
Malaysia	Soil on a 10-20yr oil palmplantation	0-30cm	Environmental Impact Assessment	1.08-2.0	Atomic Absorption Spectrometer	Aini and colleagues (2010)
Aluminium						
NegeriSembilan, Malaysia	Soil on 5 yr old oil palmplantation	0-30cm	To improve soil fertility	1.0-5.0	Atomic Absorption Spectrometer	Alvaro *et al.* (2009)
Cote d'Ivoire	40yr oil palm plantation after post clearing	0-30cm	Physical, chemical and organic matter properties	0.35	AAS	Yebouaand Ballo,2000.
Copper						
Benin, Nigeria	30 yr old oil palm plantation	0-20cm	Macro nutrients and micro	0.32	ICP-MS/AAS	Aweto and Enaruvbe, 2010.

			nutrients			
Magnesium						
Assin, central Ghana	Soil on oil palm plantation	0-40cm	Macro nutrients, micro nutrients and physicochemical properties	0.01	ICP-MS	Golow*et al*., 2010
Nigeria	30yr oil palm plantation	0-30cm	Analysis of soil chemical properties	0.23	ICP-MS/AAS	OgehandOsiomwan, 2012
Nigeria	20 yr oil palm plantation	0-30cm	Exchangeable calcium and magnesium	0.93	ICP-MS/AAS	Uwumarongie-Ilori andcolleagues ,2012.
Uranium						
Jengka, Malaysia	Top soil on oil palm plantation	0 cm	Assessment of radiation dose from soils	Ò1	HPGe counting system	Alias *et al*., 2008

Table 3

Trace elements/radionuclides in water on palm oil plantations

Country of Origin	Sample analysed	Purpose of investigation	Concentration range(mgkg^{-1})	Instrument used	References
Cadmium					
Sampadi, Malaysia	River	Water and sediment quality of river	0.05-0.66	Atomic Absorption Spectrometer	Ling *et al*., 2011.
Johor, Malaysia	Drinking water	Physicochemical properties in selected palm oil estates	0.99 ± 1.52	Atomic Absorption Spectrometer	Farizwana*et al.*, 2010
Radium					
Ogoni, Porthar Court, Nigeria	Stream	Environmental Impact Assessment	0.05±0.01	Co-axial type germanium detector	UNEP, 2011

Table 4

Trace elements/radionuclides inplants on palm oil plantations

Country of Origin	Sample analysed	Purpose of investigation	Concentration range(mgkg^{-1})	Instrument used	References
Zinc					
United States of America	Soil, sediments, roots and leaves on oil palm plantations	Absorption of heavy metals from plants	0.05	Atomic Absorption Spectrometer	Anklam*et al.*, 2001
Chromium					
Greece	vegetables	Absorption of heavy metals from different parts of plants	0.04-0.27	ICP-MS/AAS	Toepfer*et al.,*1973.
Greece	vegetables	Absorption of heavy metals from plants	0.021 to 0.28	ICP-MS/AAS	Bratakos andLazos, 2002.
Lead					
Poland	vegetables	Absorption of heavy metals from plants	0.02-0.51	ICP-AES/FAAS	Finster*et al.,* 2004

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