Biotechnol Res 2016; Vol 2(3):132-141
eISSN 2395-6763

REVIEW ARTICLE

Environmental Impacts of Oil Palm Processing in Nigeria

Sylvester Chibueze IZAH[1]*, Tariwari C.N. ANGAYE[1], Elijah Ige OHIMAIN[1]
[1]Bioenergy and Environmental Biotechnology Research Unit, Department of Biological Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.
*Corresponding Author email: chivestizah@gmail.com

• Received: 18 June 2016 • Revised: 22 July 2016 • Accepted: 05 August 2016 • Published: 10 August 2016 •

ABSTRACT
Nigeria is the fifth largest producer of oil palm in the world with domestic production of 930 thousand metric tonnes accounting for about 1.5% of global output. Oil palm industry has positive economic impacts. As such, it is a source of employment to millions of people in Nigeria. In Nigeria, little is said about the environmental impacts of the industry. Therefore, this paper reviewed the environmental impacts of oil palm processing in Nigeria. The study found that oil palm processing emits three waste streams including gaseous (pollutant gases), liquid (palm oil mill effluent i.e. POME) and solid (palm press fibre, chaff, palm kernel shell and empty fruit bunch). Only small fractions of the solid wastes are utilized as boilers fuel by the oil palm industry, while the rest are discharged into the environment with little or treatment. POME impacts on the soil properties, the combustion of solid wastes emit suspended solid which often exceed the permissible limits stipulated by Federal Ministry of Environment/Department of Petroleum Resources which is a source of comparison since no limit for processing sectors like oil palm. This paper concludes by suggesting biotechnological application as options for wastes management.

KEY WORDS: *Biotechnological use, Environmental impact, Nigeria, Oil palm processing wastes*

Introduction

Global interests have progressively focused on the environmental impact of economic activities, and any other activity with unsustainable impacts to the ecosystem. As such, most industries strive to reduce the negative impacts associated with discharge of wastes during operations. In addition to industry, agricultural activities also lead to emission into the environment during various operation including bush burning, use of pesticides (herbicides, insecticides, fungicides). The use of these agrochemicals often results to pollution especially when they find their way into waterways through soil erosion and water runoff. Most synthetic pesticides are recalcitrant to degradation and may remain in the environment for a very long period (Ogamba *et al.,* 2015). These lead to contamination of the environment, killing aquatic organisms and resulting to sub-lethal effects when the affected organisms are consumed. According to Panapanaan *et al.* (2009), there are environmental implications associated with plantation agriculture such as soil erosion and loss of soil fertility during land preparation. Again, agricultural activities often cause several ecological problems including deforestation, loss of biodiversity or wildlife species (Siang, 2006), destruction of habitat, vegetation, environmental pollution (soil, air and water). In Nigeria for instance, a lot of biodiversity mainly vegetation and some wildlife including fisheries have gone on extinction, many are endangered and near threatened. This is caused mainly by excessive poaching, bush burning, urbanization, industrialization, population growth and agricultural activities leading to deforestation.

Oil palm is one of the major agro businesses in Nigeria. Oil palm industry has been recognized for its contribution towards economic growth and rapid development (Izah and Ohimain, 2016). The industry has also contributed significantly to environmental pollution due to the production of huge quantity of by-product from oil palm extraction processes (Rupani *et al.,* 2010).

Oil palm is the most vital raw material widely used as vegetable oil (palm oil) in the world (Izah and Ohimain, 2013a; Okechalu *et al.,* 2011; Rupani *et al.,* 2010). Oil palm is a tropical and semi tropical plant. The productivity of oil palm is higher than the yield of other vegetable oil such as ground nut, canola, soya bean etc. Authors have variously reported that a hectare of oil palm plantation can produce 10 – 30 tonnes of fresh fruit bunch (FFB) (Singh *et al.,* 2010, 2011; Sridhar and AdeOluwa 2009; Chavalparit *et al.,* 2006; Mahlia *et al.,* 2001). The oil palm enterprise started in West Africa by West Africa Institute for Oil Palm Research. Presently, oil palm has expanded to Asia nations including Malaysia, Indonesia and Thailand; where large plantations have been established. The global production and processing have been dominated by Indonesia, Malaysia and to a lesser extent by Thailand, Columbia, Nigeria. These five nations account for about 93% of the global output. Nigeria only accounts for about 1.5% of global output (Izah *et al.,* 2014), thus 930,000 metric tones at the end of 2014 economic year (Izah and Ohimain, 2015a). In Nigeria, three varieties of oil palm including *Tenera, Dura* and *Pisifera*. The *Tenera* (high oil yielding variety) is gradually been used to replace the Dura and Pisifera. As such over 80% of the varieties found in Nigeria are *Tenera*. *Dura* and *Pisifera* mainly exist in the wild.

Oil palm industry has been a source of employment globally especially in producing nations (Ohimain *et al.,* 2012a, b; 2014a) and the profitability margin of the enterprise is high (Ohimain *et al.,* 2014b). The areas of oil palm products and output that requires employment include sales of cultivation equipment, agrochemicals, farm operations and processing activities. The distribution and marketing of the useful economic crop product is also a good source of livelihood. Oil palm has indirectly employed people through industrial applications. Beside biodiesel production (Pleanjai *et al.,* 2007; Izah and Ohimain, 2013b; Izah and Ohimain, 2015b; Ohimain *et al.,* 2012a, b), oil palm have found application in food industry (Izah and Ohimain, 2013a; Okechalu *et al.,* 2011), industry (an active ingredient for making soap, detergents, cosmetics, lipsticks, pharmaceutical products, polish base etc) (Ohimain and Izah, 2015a; Ohimain *et al.,* 2012a; Embrandiri *et al.,* 2012; Izah and Ohimain, 2016a).

During the processing of oil palm, three major waste streams such as solid, liquid and gaseous emissions are generated. The solid wastes include empty fruit bunch (EFB), palm press fiber (PPF), chaff and palm Kernel shell (PKS) (Ohimain and Izah, 2013a; Ohimain *et al.,* 2013a, b; Rupani *et al.,* 2010). These solid wastes are mostly used as boilers fuel for the palm oil mill in most developing countries like Nigeria (Ohimain and Izah, 2014a, 2015b). During farm operation in mechanized farm, emissions are released from the vehicles, agrochemicals. The vehicular emissions which are mostly in form of oxides of carbon, nitrogen, sulphur, hydrogen sulphide and suspended particulate matters contaminate the environment. Similarly, during processing activities such as boiling and digestion in semi-mechanized and smallholder oil palm processing mills, gaseous emission are also generated requiring energy (Ohimain and Izah, 2013a; Ohimain *et al.,* 2013b). Apart from wood fuel, thermal/electrical energy used in the processing mills, human energy is applied (Ohimain and Izah, 2014b, c). Excessive exposure of these emissions often results to disease condition especially respiratory diseases. In addition, large quantity of solid waste that remains underutilized in processing mills (Izah *et al.,* 2016). Untreated palm oil mill effluents (POME) that is discharged into the environment causes environmental nuisances (Ohimain and Izah, 2014d).

A life cycle assessment (LCA) framework is used for assessing the environmental impacts attributable to life cycle a product which include climate change, stratospheric ozone depletion, photochemical ozone creation, eutrophication, acidification, toxicological stress on human health and ecosystem (Pleanjai *et al.,* 2007). Thus oil palm processing wastes could be potential source of environmental contamination by some of these LCA assessment methodology frameworks. In view of the positive and negative effects of oil palm enterprise this paper evaluates the environmental impacts of oil palm processing in Nigeria. The paper concludes my suggesting means of managing the wastes.

Waste generations from oil palm processing in Nigeria

The production of palm oil from FFB of oil palm often results to large waste streams. These waste streams are solid, liquid and gaseous emissions. These sections of the paper discuss the quantity of the processing wastes from Nigeria oil palm industry.

Solid wastes

The solid wastes are generated from the threshing, pressing and kernel cracking zone of processing activities including EFB, PPF, PKS and chaff (Ohimain and Izah, 2013a, b; Ohimain and Izah, 2014a, 2015b; Ohimain *et al.,* 2012a-d, Ohimain *et al.,* 2013a-d). The quantity of the generated wastes is presented in Table 1**.** In developing countries like Nigeria these waste are seldom used apart from as boilers fuel. These wastes are basically burnt in the palm oil mills resulting to atmospheric pollution hence they constitute nuisance in the mill. The compositions of solid wastes biomass from oil palm industry are presented in Figure 1. Chaff is the least produced solid wastes. Generally, the order of the solid wastes are EFB>PPF>PKS>chaff. Of this, the level of potential thermal energy utilized and unutilized in oil palm mills is presented in Figure 2. Based on these estimates, the quantity of solid wastes that have remained un-utilized in palm oil mills is significantly higher than the level utilized (used mainly as boilers fuel).

Liquid wastes (POME)

During the processing of oil palm a voluminous quantity of water are required. Specifically, the production of one tonne of FFB of oil palm requires 5 – 7.5 tonnes of water (Ahmad *et al.,* 2003, 2005; Wu *et al.,* 2009) to produces 10 - 30% of palm oil (Chavalparit *et al.,* 2006; Hambali *et al.,* 2010; Mahlia *et al.,* 2001; Ohimain and Izah, 2013a; Poku, 2002; Prasertsan and Prasertsan, 1996). Of the quality of water used, about 50 – 79% end up as POME (Ohimain and Izah, 2013b; Singh *et al.,* 2010; Okwute and Isu, 2007; Awotoye *et al.,* 2011; Chavalparit *et al.,* 2006), with mean value of 64.5% (4.03 tonnes of POME) (Ohimain and Izah, 2014d). The quantity of POME generated in Nigeria between 2004 – 2013 is presented in Figure 3.

POME contains several nutrients including light (nitrogen, potassium, magnesium, phosphorous, sodium) and heavy nutrients/metals (zinc, copper, cadmium, chromium, iron etc) (Awotoye *et al.,* 2011; Ohimain *et al.,* 2012c, 2013c). In addition, it contains high pollution indicators including oil and grease, chemical oxygen demand (COD) and biological oxygen demand (BOD). POME contains arable groups of microorganisms including lipolytic bacteria, methanogens, hydrocarbon degrading bacteria and fungi (Ohimain *et al.,* 2012d; 2013c; Ohimain and Izah 2014d).

Table 1: Oil palm processing solid wastes from palm oil mill in Nigeria

Quality	Ohimain *et al.,* 2014a		Ohimain and Izah, 2015b
	Smallholders		Semi mechanized
Variety	Dura	Tenera	Combination of Dura and Tenera
EFB %	23.7 – 32.4	25.7 - 28.2	26
PPF %	23.2 – 28.1	19.1– 20.3	30
PKS %	10.0 – 18.8	6.8 – 7.5	-
Chaff %	0.8 – 2.4	0.9 – 1.4	1.5

Gaseous emission

Oil palm processing waste biomass is often used as boiler fuel in most palm oil mills in developing countries like nation. Whereas most advanced oil palm producing nation often use electricity to generate steam for sterilization. Conventional diesel is used for digestion activity in Nigeria. These activities releases pollutant gases such as carbon monoxide (CO), nitrogen dioxide (NO), ammonia (NH_3), sulphur dioxide (SO_2), hydrogen sulphide (H_2S), volatile organic compounds (VOCs) and suspended particulate matter (SPM). Table 2 presents the concentration of pollutant gas/particulates emitted during oil palm processing In Nigeria. Some of the commonly used equipment that emits gaseous emission during oil palm processing is presented in Figure 4. This equipment involves drum sometimes known as barrel (used for boiling) and digester connected to diesel powered engine (used for digestion). This is a typical approach employed mostly by smallholder processors which cover about 80% of the Nigerian oil palm industry (Izah and Ohimain, 2016b; Ohimain and Izah, 2014a).

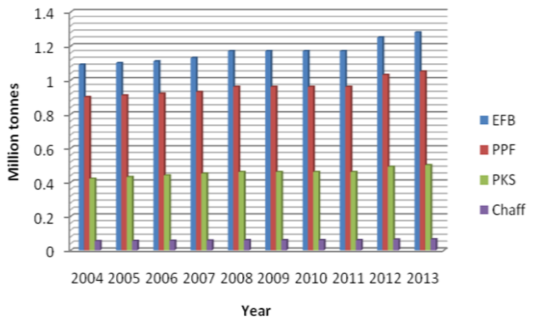

Figure 1: Estimates of Potential oil palm processing solid wastes in Nigeria between (2004 – 2013) Adapted from Izah *et al.* (2016)

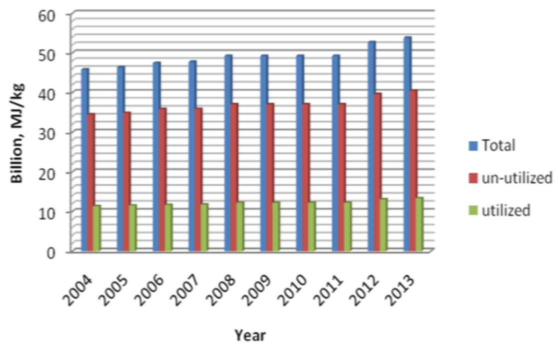

Figure 2: Estimation of potential thermal energy from oil palm processing solid wastes utilized and under-utilized in Nigeria, between (2004 – 2013) Adapted from Izah *et al.* (2016)

Environmental Impacts of the processing wastes

Like the wastes streams, there a three major component of the environment. This includes water (aquatic), soil (land) and air. This section of the paper discusses the impacts of the various wastes streams on the environment.

Air quality impacts

Oil palm cultivation has resulted to adverse environmental impacts (such as climate change and greenhouse effects) due to excessive emission and deforestation. The concentration of the pollutant gases typically decreases as the distance increases from the emission sources. Again the concentration of the pollutants gases increase toward the wind direction. The threshold value for these pollutant gases is lacking in processing sector like oil palm industry. Limits have variously reported in oil and gas industry in Nigeria. However, based on the permissible limits (for oil and gas industry), we can inferred that the emission from oil palm industry do not pose health harm apart from total suspended solid which often exceed the permissible limit. In most air quality parameters, emissions from lister engine during digestion are lesser than during boiling using oil palm processing biomass. This trend is due to the moisture content of the biomass during combustion. Also, seasonal influence could play a significant role as such during raining season the moisture content of the solid wastes biomass may be high and low during the dry season. Generally, Webb *et al.* (2009) stated that emissions are influenced by factors that affect the combustion efficiency. These factors include amount of oxygen available, combustion temperature, residue moisture content of the combusting materials, residence time of ventilation air, prevalent meteorological conditions (such as relative humidity, pressure, wind speed etc), rate of flame spread and turbulence. This may be associated with the moisture content of biomass prior to its use.

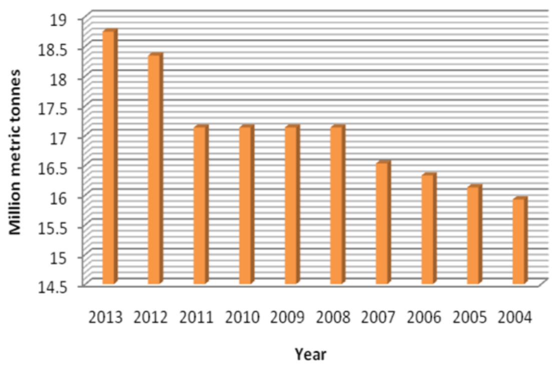

Figure 3: Estimation of POME generated from Nigeria Oil palm industry between (2004 – 2013) (Ohimain and Izah, 2014d)

The air pollution from palm oil mills is probably less in oil palm producing countries like Nigeria. The hazards allied to suspended smoke particles from biomass burning have become a common feature in Malaysia and Indonesia (Radzi *et al.,* 2004). The air emission from diesel engine have some health implications including cardio-respiratory disorders, pulmonary edema (Ana, 2011), eye irritation, central nervous system disorders, drowsiness, coughing and other respiratory disease (Ohimain, 2013). Like other solid wastes,

Table 2: Pollutant gases emission from palm oil mill in Nigeria

Parameters	Ohimain and Izah, 2013a					Ohimain *et al.,* 2013b					
	Emission direction	Combined activity (boiling and digestion)				(Boiling Activity) Distances			(Digestion Activity) Distance		
		10 ft	25 ft	50 ft	Control	10 ft	25 ft	50 ft	10ft	25 ft	50 ft
NO_2 (ppm)	Wind ward	0.2	0.1	<0.01	<0.01	<0.01 – 0.27	<0.01 – 0.13	<0.01	<0.01	<0.01	<0.01
NH_3 (ppm)		0.2	<0.01	<0.01	<0.01	<0.01 – 0.67	<0.01 – 0.43	<0.01	0.13 – 0.23	0.03 – 0.07	<0.01 – 0.07
CO(ppm)		0.7	0.4	0.2	<0.01	0.13 – 27.17	0.133 – 9.70	<0.01 – 9.13	0.63 – 0.87	0.27 – 0.60	0.133 – 0.30
H_2S (ppm)		0.4	0.4	0.3	0.4	<0.01 – 2.40	<0.01 – 2.07	<0.01 – 0.83	<0.01 – 0.30	<0.01 – 0.03	<0.01 – 0.03
SO_2 (ppm)		<0.01	<0.01	<0.01	<0.01	<0.01 - 2.03	<0.01 – 0.63	<0.01 – 0.47	<0.01	<0.01	<0.01
TSP μ/m_3		74	50	30	24	1634 – 7853	657 – 1110	81 – 854	57 – 167	14 – 84	17 – 70
NO_2 (ppm)	Lee ward	<0.01	<0.01	<0.01	<0.01	<0.01 – 1.17	<0.01	<0.01 – 0.17	<0.01	<0.01	<0.01
NH_3 (ppm)		<0.01	<0.01	<0.01	<0.01	<0.01 – 0.13	<0.01 – 0.17	<0.01	<0.01	<0.01	<0.01
CO(ppm)		0.2	0.1	<0.01	<0.01	<0.01 – 4.27	<0.01 – 0.40	<0.01 – 2.47	0.27 – 0.50	0.13 – 0.33	0.07 – 0.20
H_2S (ppm)		0.2	0.3	<0.01	0.4	<0.01 – 1.17	<0.01 – 0.57	<0.01 – 0.37	<0.01	<0.01	<0.01
SO_2 (ppm)		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01 – 0.17	<0.01	<0.01	<0.01	<0.01
TSP μ/m_3		35	27	25	24	46 – 236	44 – 120	30 – 58	28 – 177	14 – 43	44 – 540

Figure 4: Gaseous emission sources from smallholder oil palm processing mill in Nigeria

unused biomass is commonly disposed without treatment in the environment, where they cause environmental impacts together with emissions. The open air combustion often causes air pollution with the release of CO, smoke, NO_2. Oil palm processing impacts the air quality through odor pollution and it's seldom reported (Ohimain and Izah, 2014c).

These pollutant gases may be contributing to climate change, which in turn have an effect on biodiversity including vegetation, mammals, reptiles, amphibians, aves, fisheries, arthropods and even microorganisms (Ohimain and Izah, 2014e). Globally, biodiversity contributes to the survival of man in several forms including protein sources, hide and skins (wildlife), pollinator (insects), medicinal plants (vegetation), and employment generation. Due to emission of pollutant gases, the resultant impacts include changes in breeding pattern, spawning, pollination and encouragement of vector carrier's insects (Ohimain and Izah, 2014e).

Water quality impacts

POME causes environmental problems due to voluminous discharge of the waste water during milling processes. POME are produced in various processing lines including sterilizers, clarifying centrifuges and hydro cyclones (mechanized mills) and boiling, digestion and clarification (traditional/smallholder mills). Most POME produced by the small-scale traditional operators undergoes little or no treatment and is usually discharged into the surrounding environment (Okwute and Isu, 2007).These can cause pollution of waterways due to oxygen depletion, land use and other related effects (Sridhar and AdeOluwa, 2009; Awotoye *et al.,* 2011; Okwute and Isu, 2007; Ahmad *et al.,* 2003). During the rainy season, the POME is a breeding habitat for mosquito and emits offensive odors. Discharging of POME into aquatic ecosystem turns the water brown, smelly and slimy (Awotoye *et al.,* 2011), which may adversely affect aquatic life and water quality for domestic purposes (Ezemonye *et al.,* 2007). POME can alter potable water sources (surface and groundwater). Awotoye *et al.,* (2011) reported that POME which have higher concentration than water quality parameters increases water quality parameters including temperature, pH, total alkalinity, total solid, total dissolved solid, total suspended solid, magnesium, calcium, sodium, potassium, chloride, sulphate, nitrate, phosphate, zinc, iron, manganese, dissolved oxygen, biological oxygen demand in river receiving POME. Similarly, Edward *et al.,* (2015) reported POME is having an effect in the physico-chemical properties (i.e. pH, temperature, alkalinity, total suspended solid, dissolved oxygen, biochemical oxygen demand, nitrate, phosphate, potassium, oil and grease) in Ayanyan River, Ekiti state, Nigeria Concentration above the permissible limit make the water unfit for domestic consumption. Excess nutrient such as nitrate, sulphate, phosphate etc in the water could result to eutrophication. High acidic nature of POME causes acidification in water, thereby affecting aquatic life forms.

Soil impacts

Vegetation prevents soil erosion. The discharge of POME into soil affects its pH, which is one of the main factors influencing nutrient availability to plants (Okwute and Isu, 2007). This is because most plant grow and do better within a pH range of 6.5 – 7.5 (Hajek *et al.,* 1990). POME being acidic therefore increases the acidity of the soil. The soil can be impacted through the leaching of heavy metals and other POME physico-chemical properties into the soil. The POME increases pH (towards acidic), organic carbon, total, nitrogen, phosphate, sulphate, phosphorus, sodium, potassium, calcium, magnesium, aluminum and hydrogen (Okwute and Isu, 2007; Eze *et al.,* 2013) (Table 3). The availability of nutrients including sodium, phosphorus and potassium enhances plant growth. But high nitrogen, potassium and phosphorus cannot efficiently enhance crop yield if the soil pH is abnormal (Okwute and Isu, 2007). The available phosphorus in the POME soil leads to high absorption of material. This may lead to delay effect on the soil due to gradual biodegradation of the POME (Okwute and Isu, 2007; Eze *et al.,* 2007).

Available Phosphorus in POME soil is due to increase in pH level and other nutrient determinant available in the soil (Eze *et al.,* 2013). Organic matter plays an essential role in soil productivity because the solids in raw POME are good organic matter sources (Chan *et al.,* 1980).

Several organisms invade and grow in POME breaking down complicated molecules into simple ones (Okwute and Isu, 2007), thus biodegrading the POME (Ohimain *et al.,* 2012d).

The changes in the soil physico-chemical properties and other vital nutrients via POME discharge have the potential of affecting the soil texture and particulate size. POME discharge into the soil increases the soil bulk density, percentage of silt and clay and decreases the percentages of the clay (Table 4). Again textural class of the soil is

Table 3: Physico-chemical parameters of soil with raw POME and non POME

Parameter	Unit	POME	Non POME	References
Soil pH	-	6.59	3.57	Okwute and Isu, 2007
	CaCl2	6.6	7.5	Awotoye *et al.,* 2011
	-	5.5	5.5	Eze *et al.,* 2013
% Organic matter	Mg/g	1.01	1.80	Awotoye *et al.,* 2011
% Carbon	-	3.39	2.31	Okwute and Isu, 2007
	Mg/g	0.59	1.05	Awotoye *et al.,* 2011
	-	3.84	0.93	Eze *et al.,* 2013
% Nitrogen	-	13.53	13.19	Okwute and Isu, 2007
	Mg/g	0.20	0.30	Awotoye *et al.,* 2011
Available phosphorus	ppm	26.30	21.0	Okwute and Isu, 2007
	Mg/g	4.80	4.50	Awotoye *et al.,* 2011
Phosphate	Mg/kg	1.50	0.62	Eze *et al.,* 2013
Nitrate	Mg/kg	0.59	0.33	Eze *et al.,* 2013
Sulphate	Mg/kg	27.0	13	Eze *et al.,* 2013
Na^+	Cm^3	1.40	0.90	Okwute and Isu, 2007
	Cmol/kg	0.18	0.18	Awotoye *et al.,* 2011
	Mg/kg	116.0	83.0	Eze *et al.,* 2013
K^+	Cm^3	11.02	4.90	Okwute and Isu, 2007
	Cmol/kg	0.15	0.12	Awotoye *et al.,* 2011
	Mg/kg	6.0	3.0	Eze *et al.,* 2013
Ca^{2+}	Cm^3	10.0	7.00	Okwute and Isu, 2007
	Cmol/kg	0.80	4.70	Awotoye *et al.,* 2011
	Mg/kg	219.0	156.0	Eze *et al.,* 2013
mg^{2+}	Cm^3	9.00	9.00	Okwute and Isu, 2007
	Cmol/kg	0.80	0.40	Awotoye *et al.,* 2011
	Mg/kg	0.85	0.52	Eze *et al.,* 2013
Al^+	Cmol/kg	0.30	0.10	Awotoye *et al.,* 2011
H^+	Cmol/kg	0.20	0.18	

dependent on the organic matter content of the soil which POME is discharged into. The POME on soil retains water due to the presence of unrecovered oil and debris from processing.

POME changes the soil appearance and some properties including vegetation, color, odor, and constitution (Table 5). Despite the soil enrichment by POME, it makes the soil loss its vegetation cover, damp with humus. This causes clogging and water logging of the soil spores which could result to death of vegetation on contacts, with the environment being bare (Eze *et al.,* 2013). Besides that, it also contaminates the land and ecosystem leading to loss of land and resources to local inhabitant such as the soil micro flora and some biodiversity (Sridhar and Adeoluwa, 2009) such as earthworm which play a significant role in soil aeration.

Conclusion and potential options for the processing wastes management

Nigeria plans to go back to the agrarian economy that they are known for before the discovery of petroleum in the late 1950s. Meanwhile, oil palm cultivation and processing has been a major contributor of the nation's gross domestic product at that time. Now, the country plans to integrate the

Table 4: Particulate size/ textural class of soil

Soil type	unit	POME discharge site	Non POME site	References
% silt	-	22.00	6.00	Okwute and Isu, 2007
	g/kg	12.00	32	Awotoye *et al*., 2011
% sand	-	50.40	66.40	Okwute and Isu, 2007
	g/kg	82	54	Awotoye *et al*., 2011
% clay	-	27.60	27.60	Okwute and Isu, 2007
	g/kg	6	14	Awotoye *et al*., 2011
Bulk density	g/cm^3	1.66	1.49	Awotoye *et al*., 2011
Textural class	-	Sandy clay soil	Sandy loamy	Okwute and Isu, 2007
	-	Loamy sand	Loamy soil	Awotoye *et al*., 2011

petroleum sector with agriculture. The environmental attendant that emanate from cultivation of oil palm include deforestation (clearing), soil erosion and fertility, water cycle disruption and pollutions associated with fertilizer use, while emissions from combustion, POME discharged, unused solid wastes in the mills also causes pollution. This paper evaluates the environmental impacts of oil palm processing in Nigeria. The study found that enormous solid, liquid wastes are generated.

Table 5: Visual characteristics of the soil

Characteristics	POME soil	Non POME soil
Vegetation	Bare	Grown with weeds
Color	Dark brown with humus	Brown and sandy
Moisture	Damp	Dry
Odor	Odiferous	Ordour free
Constituents	Debris from processing mill	Debris from vegetation

Source: Awotoye *et al.,* 2011; Okwute and Isu, 2007

The gaseous emission is within the permissible limits as stipulated by Federal Ministry of Environment/ Department of Petroleum Resources for emission in the oil and gas industry which was used for the basis of comparison since no regulatory limit exists for other processing industry such as oil palm.

The liquid wastes could contaminate the aquatic ecosystem during runoff leading to acidification/eutrophication in the aquatic ecosystem. The liquid wastes on soil could increase the soil pH (tending towards acidity) and increase nutrient compositions including nitrogen, potassium, phosphorus etc). The POME could lead to loss of biodiversity mostly vegetation. The management of oil palm processing wastes is of great importance, because it reduces hazards associated with its processing while generating useful products. The various adverse impacts could be prevented through biotechnological reuse for solid wastes and liquid wastes. The air emissions can be managed by drying the biomass properly prior to use to as boilers fuel.

POME can be used to produce organic acids such as acetic and formic acid acids (Wu *et al.,* 2009), citric acids (Alam *et al.,* 2008), polyhydroxyalkonates, solvents such as actetone-butanol-ethanol, bioinsecticides and antibiotics (Wu *et al.,* 2009). Others include biohydrogen and biogas production (Ohimain and Izah, 2015c; Foo and Hameed, 2010; Atif *et al.,* 2005; Kelly-Yong *et al.,* 2007; Vijayaraghavan and Ahmed, 2006; Ohimain and Izah, 2014f), using microbial fuel cells technology (Cheng *et al.,* 2010), composting (Singh *et al.,* 2010) and vermicomposting (Rupani *et al.,* 2010) and fertilizer production due to ability to enrich the soil phosphorus, nitrogen and potassium.

The solid wastes can also be converted to a wide range of value added products that can be clustered into bio-based value added products and various bioenergy. The potential energy applications include direct power generation (Shuit *et al.,* 2009) bioelectricity (Sumathi *et al.,* 2008), bioethanol, bio-briquettes, biobutanol, biomethanol, bio-oil, biochar, syngas (Shuit *et al.,* 2009; Izah *et al.,* 2016) using various technologies. Other bio-valued products include application in the bioplastic industry and as fillers in thermoplastics and thermosites, composites (Shuit *et al.,* 2009), boosting soil fertility and preventing soil erosion (Embrandiri *et al.,* 2012). Specifically, the EFB is a good substrate for edible mushroom cultivation (Sridhar and Adeoluwa, 2009).

Additionally, PPF and chaff can be used for the cultivation of edible larva/maggot. In the local setting the EFB is used for soap production probably due to its high potassium content.

Through these biotechnological advances, the environmental impact associated with oil palm processing wastes will be adverted.

References

Ahmad, A.L., Ismail, S. and Bhatia, S. (2003). Water recycling from palm oil mill effluent (POME) using membrane technology. *Desalination*, 157: 87-95.

Ahmad, A.L., Sumathi, S. and Hameed, B.H. (2005). Adsorption of residue oil from palm oil mill effluent using powder and flake chitosan: equilibrium and kinetic studies. *Water Research*, 39: 2483 – 2494.

Alam, M.Z., Jamal, P. and Nadzir, M.M. (2008). Bioconversion of palm oil mill effluent for citric acid production: statistical optimization of fermentation media and time by central composite design. *World Journal Microbiology and Technology,* 5:1177 – 1185.

Ana, G.R. (2011). Air Pollution in the Niger Delta Area: Scope, Challenges and Remedies. In: Khallaf, M. (Ed.). The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources. Pp. 182 – 198.

Atif, A.A.Y., I-Razi, A.F., Ngan, M.A., Morimoto, M., Iyuke, S.E. and Veziroglu, N.T. (2005). Fed batch production of hydrogen from palm oil mill effluent using anaerobic microflora. *International Journal of Hydrogen Energy*, 30: 1393 – 1397.

Awotoye, O.O., Dada, A.C.and Arawomo, G.A.O. (2011). Impact of palm oil processing effluent discharging on the quality of receiving soil and rivers in South Western Nigeria. *Journal of Applied Sciences Research,* 7(2): 111 - 118.

Chan, K.W., Watson, I. and Lim, K.C. (1980). Use of oil palm waste material for increased production. Paper presented at the Conference on Soil Science and Agricultural development in Malaysia, Kuala Lumpur, Malaysia.

Chavalparit, O., Rulkens, W.H., Mol, A.P.J. and Khaodhair, S. (2006). Options for environmental sustainability of crude palm oil industry in Thailand through enhancement of industrial ecosystem. *Environment, Development and Sustainability,* 8: 271 – 287.

Cheng, J., Zhu, X., Ni, J. and Borthwick, A. (2010). Palm oil mill effluent treatment using a two-stage microbial fuel cells system integrated with mobililized biological aerated filters. *Bioresoure Technology,* 101: 2729 – 2734.

Edward, J.B., Idowu, E.O. and Oyebola, O.E. (2015). Impact of pam oil mill effluent on physic-chemical parameters of a southwestern River, Ekiti state, Nigeria. *Journal of Natural Sciences Research*, 4(14): 26 -30.

Embrandiri, A., Singh, R.P., Ibrahim, H.M. and Ramli, A.A. (2012). Land application of biomass residue generated from palm oil processing: its potential benefits and threats. *Environmentalist,* 32(17): 111 – 117.

Eze, V.C., Owunna, N.D. and Avoaja, D.A. (2013). Microbiological and Physicochemical Characteristics of Soil Receiving Palm Oil Mill Effluent in Umuahia, Abia State, Nigeria. *Journal of Natural Sciences Research*, 3(7): 163 – 169.

Ezemonye, L.I.N., Ogeleka, D.F. and Okieimen, F.E. (2008) Lethal toxicity of industrial chemicals to early life stages of *Tilapia guineensis. Journal of Hazardous Materials,* 157(1): 64-68.

Foo, K.Y. and Hameed, B.H. (2010). Insight into the applications of palm oil mill effluent: A renewable utilization of the industrial agricultural wastes. *Renewable and Sustainable Energy Review,* 14:1445 – 1452.

Hajek, B.F., Karlen, D.L., Lowery, B., Power, J.F., Schumaker, T.E., Skidmore, E.L. and Sojka, T. (1990) Erosion and soil properties. In: Larson WE, Foster GR, Alimaras RR, Smith GM (eds.). Research Institute in Soil Erosion Productivity. Pp. 23 – 40.

Hambali, E., Thahar, A. and Komarudin, A. (2010). The potential oil palm and rice biomass as bioenergy feedstock. 7th Biomass Asia Workshop, November 29 – December 01, 2010, Jakarta, Indonesia.

Izah, S.C., Ohimain, E.I. and Angaye, T.C.N. (2016) Potential thermal energy from palm oil processing solid wastes in Nigeria: mills consumption and surplus quantification. *British Journal of Renewable Energy,* 1(1): 38-44.

Izah, S.C. and Ohimain, E.I. (2016a). Microbiological quality of palm oil used in Nigeria: Health impacts perspective. *Point Journal of Botany and Microbiology Research*, 2(1): 037 – 045.

Izah, S.C. and Ohimain, E.I. (2016b). The opportunities and weakness of Nigerian oil palm industry. *Biotechnology Research,* 2(1): 33 – 43.

Izah, S.C. and Ohimain, E.I. (2015a). Bioethanol production from cassava mill effluents supplemented with solid agricultural residues using bakers' yeast [*Saccharomyces cerevisiae*]. *Journal of Environmental Treatment Techniques,* 3(1): 47 – 54.

Izah, S.C. and Ohimain, E.I. (2015b). Comparison of traditional and semi-mechanized palm oil processing approaches in Nigeria; Implications on biodiesel production. *Journal of Environmental Treatment Techniques,* 3(2): 82 – 87.

Izah, S.C., Oduah, A.A. and Ohimain, E.I. (2014). Effects of Temperature and fermentation period on the recovery of second grade palm oil from palm press fiber. *International Journal of Engineering Science and Innovative Technology,* 3(5): 131-138.

Izah, S.C. and Ohimain, E.I. (2013a). Microbiological quality of crude palm oil produced by smallholder processors in the Niger Delta, Nigeria. *Journal of Microbiology and Biotechnology Research,* 3(2): 30 – 36.

Izah, S.C. and Ohimain, E.I. (2013b). The challenge of biodiesel production from oil palm feedstock in Nigeria. *Greener Journal of Biological Sciences,* 3(1): 1 - 12.

Kelly-Yong, T.L., Lee, K.T., Mohamed, A.R. and Bhatia, S. (2007) Potential of hydrogen from oil palm biomass as a source of renewable energy worldwide. *Energy Policy*, 35: 5692 – 5701.

Mahlia, T.M.I., Abdulmium, M.Z., Alamsyah, T.M.I. and Mukhlishien, D. (2001). An alternative energy source from palm wastes industry for Malaysia and Indonesia. *Energy Conversion and Management,* 42: 2109 - 2118.

Ogamba, E.N., Izah, S.C. and Nabebe, G. (2015). Effects of 2, 4-Dichlorophenoxyacetic acid in the electrolytes of blood, liver and muscles of *Clarias gariepinus. Nigeria Journal of Agriculture Food and Environment,* 11(4): 23- 27.

Ohimain, E.I. (2013). The challenges of liquid transportation fuels in Nigeria and the emergence of the Nigerian Automotive biofuel programme. *Research Journal of Applied Sciences, Engineering and Technology,* 5(16): 4058-4065.

Ohimain, E.I. and Izah, S.C. (2015a). Physicochemical characteristics and microbial population of palm oil sold in major markets in Yenagoa metropolis, Bayelsa States, Nigeria. *Journal of Environmental Treatment Techniques,* 3(3): 143 – 147.

Ohimain, E.I. and Izah, S.C. (2015b). Energy self-sufficiency of semi-mechanized oil palm processing: a case study of Bayelsa palm mill, Elebele, Nigeria. *Energy Economics Letter,* 2(3):35-45.

Ohimain, E.I. and Izah, S.C. (2015c). Estimation of potential Biohydrogen from Palm Oil Mills' Effluent in Nigeria using different microorganisms under light independent fermentation. *Journal of Environmental Treatment Techniques,* 3(2): 97 – 104.

Ohimain, E.I. and Izah, S.C. (2014a). Energy self-sufficiency of smallholder oil palm processing in Nigeria. *Renewable Energy,* 63: 426 – 431.

Ohimain, E.I. and Izah, S.C. (2014b). Contribution of manual energy to palm oil processing by smallholders in Nigeria. *Sky Journal of Agricultural Research*, 3(7):137 – 141.

Ohimain, E.I. and Izah, S.C. (2014c). Manual energy contribution to palm oil processing by semi-mechanized mill in Bayelsa state, Nigeria. *International Journal of Farming and Allied Science,* 3 (7): 729-732.

Ohimain, E.I. and Izah, S.C. (2014d). Possible contributions of palm oil mill effluents to greenhouse gas emissions in Nigeria. *British Journal of Applied Science and Technology,* 4(33): 4705 – 4720.

Ohimain, E.I. and Izah, S.C. (2014e). Estimation of potential electrical energy and currency equivalent from un-tapped palm oil mill effluents in Nigeria. *International Journal of Farming and Allied Science,* 3 (8): 855-862.

Ohimain, E.I. and Izah, S.C. (2014f). Potential of Biogas Production from Palm Oil Mills' Effluent in Nigeria. *Sky Journal of Soil Sciences and Environmental Management,* 3(5): 50 – 58.

Ohimain, E.I., Emeti, C.I. and Izah, S.C. (2014a). Employment and socioeconomic effects of semi-mechanized palm oil mill in Bayelsa state, Nigeria. *Asian Journal of Agricultural Extension and Sociology*, 3(3): 206-216.

Ohimain, E.I., Emeti, C.I., Izah, S.C. and Eretinghe, D.A. (2014b). Small scale palm oil business in Nigeria; a feasibility study. *Greener Journal of Business and Management Studies,* 4 (3): 070-082.

Ohimain, E.I., Izah, S.C. and Obieze, F.A.U. (2013a). Material-mass balance of smallholder oil palm processing in the Niger Delta, Nigeria. *Advance Journal of Food Science and Technology,* 5(3): 289-294.

Ohimain, E.I., Izah, S.C. and Abah, S.O. (2013b). Air quality impacts of smallholder oil palm processing in Nigeria. *Journal of Environmental Protection,* 4: 83-98.

Ohimain, E.I., Izah, S.C. and Jenakumo, N. (2013c). Physicochemical and microbial screening of palm oil mill effluents for amylase production. *Greener Journal of Biological Sciences*, 3(8): 314 – 325.

Ohimain, E.I., Izah, S.C. and Fawari, A.D. (2013d). Quality assessment of crude palm oil produced by semi-mechanized processor in Bayelsa state, Nigeria. *Discourse Journal of Agriculture and Food Sciences*, 1 (11): 34 - 46.

Ohimain, E.I. and Izah, S.C. (2013a). Gaseous emissions from a semi-mechanized oil palm processing mill in Bayelsa state, Nigeria. *Continental Journal of Water, Air and Soil Pollution*, 4 (1): 15 – 25.

Ohimain, E.I. and Izah, S.C. (2013b). Water minimization and optimization by small-scale palm oil mill in Niger Delta, Nigeria. *Journal of Water Research*, 135: 190 – 198.

Ohimain, E.I., Daokoru-Olukole, C., Izah, S.C. and Alaka, E.E. (2012a). Assessment of the quality of crude palm oil produced by smallholder processors in Rivers State, Nigeria. *Nigerian Journal of Agriculture, Food and Environment,* 8(2): 28 - 34.

Ohimain, E.I., Oyedeji, A.A. and Izah, S.C. (2012b). Employment effects of smallholder oil palm processing plants in Elele, Rivers State, Nigeria. *International Journal of Applied Research and Technology*, 1(6): 83 - 93.

Ohimain, E.I., Seiyaboh, E.I., Izah, S.C., Oghenegueke, V.E. and Perewarebo, T.G. (2012c). Some selected physico-chemical and heavy metal properties of palm oil mill effluents. *Greener Journal of Physical Sciences,* 2(4): 131 - 137.

Ohimain, E.I., Daokoru-Olukole, C., Izah, S.C., Eke, R.A. and Okonkwo, A.C. (2012d) Microbiology of palm oil mill effluents. *Journal of Microbiology and Biotechnology Research*, 2(6):852 – 857.

Okechalu, J.N., Dashen, M.M., Lar, P.M., Okechalu, B. and Gushop, T. (2011). Microbiological quality and chemical characteristics of palm oil sold within Jos Metropolis, Plateau State, Nigeria. *Journal of Microbiology and Biotechnology Research*, 1(2): 107-112.

Okwute, L.O. and Isu, N.R. (2007). The environmental impact of palm oil mill effluent (pome) on some physico-chemical parameters and total aerobic bioload of soil at a dump site in Anyigba, Kogi State, Nigeria. *African Journal of Agricultural Research*, 2 (12): 656-662.

Panapanaan, V., Helin, T., Kujanpää, M., Soukka, R., Heinimö, J. and Linnanen, L. (2009) Sustainability of Palm Oil Production and Opportunities for Finnish Technology and Know-how Transfer. Institute of Energy Technology Research Report 1 March 2009.

Pleanjai, S., Gheewala, S.H. and Garivait, S. (2007). Environmental Evaluation of Biodiesel Production from Palm Oil in a Life Cycle Perspective*. Asian Journal of Energy and Environment*, 8(1and 2): 15-32.

Poku, K. (2002). Small-Scale Palm Oil Processing in Africa. Rome, Italy: Agriculture Services Bulletin 148. Food and Agricultural Organization of the United Nations.

Prasertsan, S. and Prasertsan, P. (1996). Biomass residues from palm oil mill in Thailand: an overview on quantity and potential usage. *Biomass and Bioenergy,* 11(5): 387-395.

Radzi, B.A.M., Oros, D.R. and Simoneit, B.R.T. (2004) Biomass burning as the main source of organic aerosol particulate matter in Malaysia during haze episodes. *Chemosphere,* 55(8):1089-1095.

Rupani, P.F., Singh, R.P., Ibrahim, H. and Esa, N. (2010) Review of current palm oil mill effluent (POME) treatment methods: Vermi-composting as a sustainable practice. *World Applied Sciences Journal,* 11 (1): 70-8I.

Shuit, S.H., Tan, K.T., Lee, K.T. and Kamaruddin, A.H. (2009). Oil palm biomass as a sustainable energy source: a Malaysia case study. *Energy,* 34: 1225 – 1235.

Siang, L.E. (2006). Biodegradation of oil and grease in upflow anaerobic sludge blanket reactor for palm oil mill effluent treatment. A master degree thesis in Engineering (Civil-Environmental Management). Faculty of civil engineering Universiti Teknologi Malaysia.

Singh, R.P., Embrandiri, A., Ibrahim, M.H. and Esa, N. (2011). Management of biomass residues generated from oil mill: vermicomposting a sustainable option. *Resour. Conserv. Recy.* 55: 423-434.

Singh, R.P., Ibrahim, M.H., Norizan, E. and Iliyana, M.S. (2010). Composting of waste from palm oil mill: a sustainable waste management practice. *Rev. Environ. Sci. Biotechnol.* 9: 331-344.

Sridhar, M.K.C.and AdeOluwa, O.O. (2009). Palm Oil Industry Residue. In: Nigam PS, Pandey A (eds.). Biotechnology for Agro-industrial Residues Utilisation. Springer Science. Pp 341 – 355.

Sumathi, S., Chai, S.P. and Mohamed, A.R. (2008). Utilization of oil palm as a source of renewable energy in Malaysia. *Renewable and Sustainable Energy Review,* 12: 2404 – 2421.

Vijayaraghavan, K.and Ahmed, D. (2006). Biohydrogen generation from palm oil mill effluent using anaerobic contact filter. *International Journal of Hydrogen Energy,* 31: 1284 – 1291.

Webb, J., Hutchings, N., Amon, B., Phillips, R. and Dämmgen, U. (2009). Field burning of agricultural wastes. In: EMEP/EEA emission inventory guidebook 2009.

Wu, T.Y., Mohammad, A.W., Jahim, J. and Anuar, N. (2009). A holistic approach to managing palm oil mill effluent (POME): Biotechnological advances in the sustainable reuse of POME. *Biotechnology Advances,* 27(1): 40-52.