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Assessment of Solid Waste Management in a Local Palm Oil Mill: A Case Study of Alaya Community of Oluponna in Osun State

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ABSTRACT

Nowadays, the sustainable management of wastes are global issues, because of their increasing harmful effects on the environment. Population increase has led to increase in demand of palm oil, which has increased the production process and the quantity of solid wastes generated. This study assessed the quantity of solid wastes, their management in the local palm oil mill, rate of generation and palm oil mill air quality. Quantitative and physical assessment was done by collection and sorting the wastes into different components, followed by the weighing of the individual components. The rate of generation was determined by weighing the wastes generated which was divided by the number of fresh fruit bunches (FFB) at each production time. The result shows that all substances found in the products, by-products and residues were originated from the Fresh Fruit Bunches (FFB). The result revealed that an average of 745kg of fruits, 255kg of empty fruit bunch (EFB), 116kg of palm mesocarp fiber PMF, 107kg of palm kernel shells (PKS) and 152litre of palm oil from 999kg of FFB. The rate of generation ranges from 1.50, 1.64 and 3.41kg/FFB/production for PKS, PMF and EFB respectively. Palm oil production globally contributes to the environment pollution with the local mill workers having little or no substantial knowledge on the waste management. Since the use of POMSW depends on its importance and economic input. Furthermore, Local mill workers should be enlightened on solid waste generation, sorting and utilization so as to reduce waste that would find itself to the disposal site. Since the use of POMSW depends on its importance and economic input, furthers studies must be made on the relevant approach to manage the wastes generated, its use and their effects on the environment, furthers studies must be made on the relevant approach to manage the wastes generated, its use and their effects on the environment.

KEYWORDS: Palm oil mill, Fresh fruit bunch, Palm oil mill solid waste, Generation rate, Air quality.

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INTRODUCTION

The palm oil tree (Elaeis guineensis Jacq) is a native of the humid tropics of West Africa. It is one of the major oil crops in the world, producing more oil than all other oil plants.[1] It is economically important for its oil as well as an important source for edible oils. It is a raw material for cosmetics and detergents and more recently for biodiesel production.[2-5] Nowadays, food processing had improved by the introduction of new technologies and engines. This is the case of palm oil production in Nigeria, focusing on the significance of oil palm as an oleaginous crop. Oil palm, despite occupying only 7% of the global oleaginous plantation areas, contributes 39% of the world's vegetable oil production, surpassing soybean (61%), colza (18%), and sunflower (14%).[6]

Palm oil is one commodity whose demand is growing rapidly in the world and provides an important contribution to economic development. Increased demand for palm oil in the form of vegetable oils encouraged the countries to spur the development of oil palm plantations. Consequently, with the increasing development of the palm oil industry comes an increase in palm oil mill effluents and solid wastes. There are basically two kinds of solid waste generated during palm oil fruits processing, they are; the Empty Fruit Bunches (EFBs) and Palm Mesocarp Fiber (PMF), others are: the palm kernel shell (PKS) and decanter cake. The empty fruit bunch is obtained after the removal of oil seeds from fruit bunches. It is the supporting structures of the oil-bearing fruits in a bunch and comprises of spikelet (68-80% dry matter) and stalks (20-32% dry matter). The PMF is the fibrous residues separated from the mesocarp and kernel during palm oil extraction. Fortunately, all of the wastes are categorized as organic wastes that are environmentally degradable. However, owing to the large quantities generated, these wastes have the potential to pollute the environment.

Globally, integrated waste management frameworks emphasize reduction, reuse, recycling, energy recovery, and environmentally sound disposal, which collectively minimize negative impacts while maximizing resource efficiency. Recent studies have highlighted the need for improved waste sorting, valorization technologies, and stakeholder engagement to achieve sustainable SWM in agro-industrial settings.[7] In Nigeria, solid waste management challenges in palm oil mills are compounded by limited infrastructure, weak enforcement of environmental regulations, and low awareness of sustainable practices among mill operators and communities. In Nigeria, open dumping of solid wastes into wetlands, watercourse, drains and burrow pit is a prevalent form of disposal. This practice has sometimes resulted in the littering of the surroundings, creates eyesore and odor nuisance,[8,9] stated that open dumping of waste serves as breeding place for flies, insects and rats.

Oil palm solid waste management is an important part of palm oil mill processes that ensures the protection of the environment and human health. Proper management of solid waste is critical to the health and well-being of the people. The waste produced by the palm oil industry contributes greatly to environmental damage if it is not properly managed. Therefore, there is a need for proper disposal as a way to ensure good waste management in order to have a sustainable oil palm production without impairing the environment and to protect human health of the immediately community of the mill.

METHODOLOGY

Study Area

This study was carried out at a local palm oil mill in Alaya community of Oluponna town, in Ayedire Local Government area of Osun State, Nigeria. It's geographical coordinates are latitudes 7^0 36' 60.00" North, longitudes 4^0 10' 59.99" East. The town has a humid tropical climate with peak dry and wet season around February-April and June-August respectively. The mill gets supply of FFB from the surrounding farms and communities where the oil plantations were located

Oral Interviews

The small-scale mill in the study area was visited between May and August 2021. An oral interview was conducted with the mill workers to find out the process of the waste generation. In addition, two families out of many living within the environment were contacted to examine their view and effect of the palm oil mill solid wastes disposal to their environment and how it affects their well-being.

Waste Characterization Survey

The mill was divided into the fruit bunch areas, processing areas and the dumpsite for the purpose of this study. The fruit bunch areas are the areas where the palm fruits were received directly from the farm and where the fruits were removed from the bunches. The processing areas comprised of the areas in the mill involved in the step-by-step processes of the fruits into palm oil. The dumpsite is where all solid waste generated were finally dumped or disposed.

Data Collection

Following the division of the mill into three different areas, the compositions of each area were measured and recorded. The use of statistical approach facilitates the identification of processes that generate impacts such as solid wastes generation.

Measurement Procedures

The method used for this approach was site specific sampling. It involves collection and sorting of the fresh fruit bunches from the arrival area, fresh fruits detached from the bunch and the press mesocarp fibre at the processing area and empty fruit bunches which comprises of the stalks and spikelet's at the dumpsite. The collections were done with a container, pan and basket. Furthermore, sorting of waste into different components, followed by weighing the individual components. The FFB were weighed after reception in the mill before the separation of fruits and EFB. After three days when the fruits have become detachable from the spikelet's, the fruits and EFB were weighed and recorded for the different production process. The palm kernel shells were measured also at the processing area after digestion and pulping. The measurement of the solid wastes was done at different areas of the mill as stated above for this research using a weighing balance and each of the waste sampled were dumped at the dumpsite.

Determination of Solid Wastes Generation Rate

The rate of waste generated in the mill and quantity of waste were determined by the number of FFB and production day/time.

The solid waste generated per production time was divided by the number of FFB for the five production period to obtain the result in kilogram per FFB per production (kg/FFB/production).

$$\text{Generation rate (G.R)} = \frac{W}{Nffb} \text{ kg/FFB/Production} \quad (1)$$

Where, W stands for weight of solid waste generated in 5 production time. Nffb is the number of fresh fruit bunch in 5 production time and Np = number of productions.

Measurement of Air Quality of the Mill

The air quality parameters monitored by an air quality monitor (TES 5322A) include; fine particulate matter (PM2.5), temperature, relative humidity and volatile organic compounds, which were recorded. The meter was set at an interval of 10minutes at the dumpsite before and during burning of the waste. At the processing area it was set at an interval of 2minutes. This was done for period of 4hours :30minutes at the dumpsite and 2hours:6minutes at the processing area

Data Analysis

The generated data was analyzed for percentage composition and generation rate of solid waste in the mill for each production time. The data was used to suggest better ways to manage solid waste in the mill.

RESULTS AND DISCUSSION

Physical Assessment of Palm Oil Mill Solid Wastes (POMSW)

It was observed that palm oil mill generates three kinds of solid wastes during the production processes: empty fruit bunches (EFB) and palm mesocarp fiber (PMF), palm kernel shell (PKS) as shown in Figure 1. EFB was obtained after the removal of oil seeds from fruit bunches at the arrival area. It is the supporting structures of the oil-bearing fruits in a bunch and comprises spikelet and stalks. PMF is the fibrous residues obtained after palm oil extraction from the oil palm fruit it is a combination of debris and crushed kernel from the screw pressed. It appears as a deep-yellow colored and grease textured material, because of the substantial amounts of residual palm content in it. Palm kernel shell is the shell fractions left after nut cracking processes (removal of nut) after crushing in the palm oil mill. The amount of PMF and shell generated were lesser than EFB.

Generation Rates of EFB, PMF and PKS

The quantity or volume of waste generated varies according to their physical composition and the part of the mill where it is being generated. A total weight of 1003kg of EFB, 481.4kg of PMF and 440.2kg of PKS were generated in five different production period of this research. From the table 1, it was seen that there is a variation between the three waste components. The generation rate ranges from 1.50, 1.64 and 3.41kg/FFB/production for palm kernel shell, PMF and EFB respectively.



EFB



PMF



Palm kernel shell

Figure 1. Three types of solid waste components in the mill.

Table 1. Solid Waste Generation Rate in the mill

Waste components	Waste Generation Rate (Kg/FFB/ production)
EFB	3.41
PMF	1.64
Palm Kernel shell	1.5
Average generation rate	2.18

EFB, PMF and PKS in Oil Mill

Table 2 shows the average palm oil wastes generated in the mill at 5 different palm oil production processes with the volume of palm oil obtained. From 999kg of fresh fruit bunch generates an average of 745kg of fruits, 255kg of EFB, 116kg of PMF, 107kg of palm kernel and 152L of palm oil. This is compared to Maheswaran and Singam (1977) who found that 1ton of FFB composed of 230 to 250 kg of EFB, 130 to 150 kg of fibre, 60 to 65 kg of shell, 55 to 60 kg of kernel, and 160 to 200 kg of crude oil except that the PKS in this research comprises of shell and kernel. The variation can be attached to the method of palm oil production in the mill

Percentage Composition of EFB, PMF and PKS Generation in the Mill

The results of the waste composition in table 3 shows the total percentage of waste generated in the mill for each of the component at different production time which shows that more waste is generated at the arrival area, where the fruit detachment from FFB and sorting was done. The total waste generated at the arrival area which is the empty fruit bunch (EFB) in the 5 production times is 1003.5kg which has the highest percentage of 52.1% among the waste components, follow by PMF in the processing area with481.4kg weight and percentage of 25% then palm kernel shell with 440.2kg weight and percentage of 22.9% as shown in table 3.

The density for the total weight of each waste component is represented in table 4, and the total average was calculated. An average of 668.38kg/m^3 of the total waste was calculated for the number of production process of concern in this study. This will guide on the amount of waste that will be generated during production in the mill and help with waste management provisions that should be made.

Table 2. FFB, Fruit, Palm Oil and Waste generated in the Mill Per Production in (kg/production)

Day of production	No of FFB	weight of FFB (kg)	weight of fruits (kg)	weight of EFB (kg)	weight of PMF (kg)	weight of palm kernel (kg)	Volume of crude palm oil (L)
1	70	995.4	742.3	252.7	114.9	106.6	151.2
2	70	999.9	745	254.9	116.3	107.4	152.3
3	58	834.7	637.4	197.3	103.7	92.6	136.3
4	69	985.3	736.2	249.1	111.4	103.2	148.7
5	27	236.3	186.8	49.5	35.1	30.4	39.6
Total	294	4051.6	3047.7	1003.5	481.4	440.2	628.1

Table 3. Total Percentage of Waste Generated in the Mill at different Production Time

Waste components	Mass at each production (kg)					Total mass of components (kg)	Total percentage (%)
	P1	P2	P3	P4	P5		
EFB	252.7	254.9	197.3	249.1	49.5	1003.5	52.1
PMF	114.9	116.3	103.7	111.4	35.1	481.4	25
Palm kernel	106.6	107.4	92.6	103.2	30.4	440.2	22.9
Total	474.2	478.6	398.6	463.7	115	1925.1	100

Table 4. Density of Waste Generated in the mill at 5 different productions (kg/m^3)

Components	Mass (Kg)	Density (Kg/m^3)
EFB	1003.5	1045.15
PMF	481.4	501.45
Palm kernel shell	440.2	458.54
Average	641.7	668.38

Environmental Consequences of Solid Waste Management in the Industrial Context

Solid waste management in industrial agro-processing facilities such as palm oil mills has significant implications for environmental quality across the three major environmental media: **air, water (aquatic), and soil (terrestrial)**. In this study, the assessment revealed that the volume of unutilized palm oil mill solid wastes (POMSW) at the mill substantially exceeded the proportion employed for productive use (mainly as boiler fuel). This surplus waste, when improperly managed, exerts deleterious effects on environmental systems and public health.

Unutilized POMSW accumulates at the mill site, where it generates **malodorous emissions** and produces **leachate during rainfall events**. Leachate — formed when rainwater percolates through decomposing waste — carries organic matter and potential contaminants into the soil profile and, eventually, into groundwater systems, thereby posing risks to **soil health and aquatic ecosystems**.[10] In addition, decomposing waste contributes to the proliferation of nuisance organisms including flies and rodents, which have been linked to increased pathogen transmission in agro-industrial environments.

Atmospheric impacts are significant in scenarios where POMSW is disposed of through **open burning**. Combustion of biomass waste releases a mixture of pollutants, including carbon monoxide (CO), nitrogen dioxide (NO_2), fine particulate matter ($PM_{2.5}$), and volatile organic compounds (VOCs). These emissions degrade **ambient air quality** and contribute to regional air pollution burdens. Fine particulates ($PM_{2.5}$) are of particular concern due to their ability to penetrate deep into the respiratory system and cause respiratory and cardiovascular effects, as reported in recent environmental health studies.[7]

The spatial distribution of air pollutants around emission sources typically follows established atmospheric dispersion patterns, with concentrations diminishing with increasing distance and affected by prevailing wind directions and meteorological conditions such as temperature and humidity. Seasonal variations further influence emissions: during dry periods, lower moisture content in waste materials facilitates more complete combustion and higher pollutant release, whereas wetter conditions may promote smouldering combustion and prolonged emission episodes.[10]

The practice of leaving POMSW at various mill locations for extended periods also contributes to **olfactory pollution and nuisance impacts**. Persistent odours from decomposing organic matter not only reduce environmental quality within the mill area but also affect surrounding communities, consistent with findings from recent works on agro-industrial waste impacts. Additionally, unmanaged dumpsites provide habitats for reptiles, lizards, and other fauna, which while indicative of ecological interactions, typically reflect ecosystem stress and disturbed habitat conditions.

In summary, the environmental consequences of the current solid waste management practices at the mill are multifaceted, affecting soil, water, and air quality, and raising serious concerns for environmental sustainability and public health. These findings reinforce the need for structured waste management strategies, including waste reduction, segregation, controlled disposal, and technologies for resource recovery.

Palm Oil Mill Solid Waste Management in a Better Context

In pursuing the objective of this study to suggest better ways of solid waste management in the mill. From the oral interview, which was in form asking related questions regarding the existing waste management methods used in the mill. it was established that few of the workers are aware of the challenges pose by the improper disposal and management of palm oil mill solid waste (POMSW). Therefore, sensitization of the workers on the awareness of adverse effect of improper disposal and need for proper sorting of the waste into their constituents which will reduced the period of decomposition and improve the reuse of the waste for further purpose, thereby reducing the volume of waste generated in short period. Likewise, effort should be made to law enforcement and environmental regulations for local palm oil mills to prevent, abate and control pollution.

A decent and healthy environment is of great concern in this study, therefore suggestion was made on the need to have a septic tank within the mill for proper disposal of the POME and prevent improper discharge to the environment.

Furthermore, as a way to control the gas emissions and environmental impacts of the opening burning. Incineration of the solid waste should be encouraged and a typical incinerator should be design with an ash tray inclusive for the collection of the ash being used for local soap making which is of great concern to the mill owner and workers based on the data generated during this research.[11]

CONCLUSIONS

Palm oil production globally contributes to the environment pollution with the local mill workers having little or no substantial knowledge on the waste management. The statistical techniques might be an effective tool in the classification of waste and strategic planning of the solid waste management for oil mills. Proper attention given to any of the component in the waste generation will positively affects the whole management strategy or system. Incineration can be adopted by local mills over open burning with the incinerator design having an ash collector tray/basin inclusive due to the economic importance of the ash content to the mill workers or owner. Thus, the impact of such solid wastes on the environment can be minimized.

To mitigate the environmental impacts, proper waste management practices should be implemented in the palm oil mill. This includes implementing efficient waste treatment systems, promoting recycling and reuse of waste materials, adopting sustainable agricultural practices, and adhering to environmental regulations and guidelines. Furthermore, Local mill workers should be enlightened on solid waste generation, sorting and utilization so as to reduce waste that would find itself to the disposal site and a way to provide employment. Since the use of POMSW depends on its importance and economic input, furthers studies must be made on the relevant approach to manage the wastes generated, its use and their effects on the environment. POMSW was used as energy, in agriculture and cosmetic. However, the use of POMSW must be ensured in a way to preserve the environment.

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CONFLICT OF INTEREST

The author declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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