



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

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ABSTRACT

Palm oil, a commodity experiencing rapid global demand, plays a pivotal role in economic development. The escalating need for palm oil as a source of vegetable oils has led nations to foster the expansion of oil palm plantations. Consequently, the growth of the palm oil industry has resulted in a corresponding increase in palm oil mill effluents and solid waste. The sustainable management of solid waste, particularly in sectors with high waste generation rates like palm oil production, has become a matter of global concern. This research endeavors to assess the environmental ramifications associated with the solid waste generated by a local palm oil mill located in the Alaya community of Oluponna, Osun State, Nigeria. The primary objectives of this study encompass quantifying waste generation, evaluating its impact on air quality, and proposing efficacious waste management strategies. The investigation encompasses waste characterization, determination of waste generation rates, and air quality monitoring through the analysis of pertinent parameters, including particulate matter (PM_{2.5}), temperature, relative humidity, and volatile organic compounds (VOCs). The findings divulge that empty fruit bunches (EFB) constitute the predominant waste component, contributing to 52.1% of the total waste generated. Air quality assessments indicate that PM_{2.5} concentrations range from 93 $\mu\text{g}/\text{m}^3$ to 113 $\mu\text{g}/\text{m}^3$ during non-burning periods and between 109 $\mu\text{g}/\text{m}^3$ and 117 $\mu\text{g}/\text{m}^3$ during burning events of palm oil solid wastes in the dumpsite. These values notably surpass the World Health Organization (WHO) guideline, which prescribes an annual mean concentration of 10 $\mu\text{g}/\text{m}^3$ and a 24-hour mean concentration of 25 $\mu\text{g}/\text{m}^3$ as thresholds below which adverse health effects are significantly mitigated. Elevated PM_{2.5} concentrations during waste incineration underscore the imperative need for enhanced waste management practices. Recommendations for mitigating environmental impacts and fostering sustainable palm oil production include educational initiatives for workers, controlled incineration processes, and the utilization of waste materials. These measures are essential for minimizing environmental consequences and aligning palm oil production with principles of sustainability.

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

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Article Info:

Received Date: February 20, 2026

Published Date: March 23, 2026

Citation:

Adelakun OE, Ewemoje OE, Adebayo S. Environmental Impact and Management of Solid Waste in a Local Palm Oil Mill: A Case Study of Alaya Community of Oluponna in Osun State. *Ann Env Eng.* 2026;1(1):1-8.

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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 Palm oil is one commodity which demand is growing very rapidly in the world and provide an important contribution to economic development. The escalating need for palm oil as a source of vegetable oils has led nations to foster the expansion of oil palm plantations. Consequently, the rapid expansion of palm oil production has led to the generation of substantial quantities of solid and liquid wastes, which pose significant environmental hazards if not adequately managed.^{2,3} Studies have shown that optimizing waste utilization can reduce negative impacts and improve sustainability outcomes in palm oil processing systems.^{2,3} Recent reviews also emphasize the need to align waste management practices with broader ecological improvement goals and SDG targets (Palm oil mill waste review, 2025).

Generation of solid waste is a natural phenomenon and the amount of waste generated is directly proportional to the population. Within these last decades, with the population growth and food security, both developed and developing countries face many environmental challenges such as waste management. According to Ojonoma and Nnennaya,⁴ the sustainability of the palm oil sector is questioned in the majority of oil palm producing countries because of environmental harm due to the mismanagement of palm oil mill wastes.

Solid waste management is one of the challenging problems worldwide and it is becoming more complex by the increase in population and subsequently the waste generated. Wastes from the oil palm mill includes palm oil mill effluent (POME), decanter cake, empty fruit bunches, seed shells and the fibre from mesocarp. Generally, most of the waste generated is either disposed of via open dumping or used as fertilizers as such or as animal feed. Sustainable waste management practice is necessary to keep the environment clean. Under these situations it is advisable that waste products of one industry should be investigated with an objective to be used as raw material for other industry to get desired product. 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 odour nuisance.⁵ Sangodoyin⁶, 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 rapid growth of the palm oil industry has led to increased waste generation, raising concerns about its environmental impact if it is not properly managed. Therefore, there is a need to ensure good waste management and propose effective waste management strategies to mitigate environmental degradation to protect human health of the immediately community of the mill. Also, the appropriate waste management might become the major contributor for reducing overall global greenhouse gas emissions.⁷

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° 36' 60.00" North, longitudes 4° 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 six mill workers to find out the process of the waste generation. In addition, two families, living closer to the mill 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

Measurement of Air Quality of the Mill

The air quality parameters monitored by an air quality monitor (TES 5322A) include; fine particulate matter (PM_{2.5}), temperature, relative humidity and volatile organic compounds, which were recorded. These parameters were measured to assess the impact of waste burning on air quality. 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.

Survey Equipment/Materials

The equipment/materials used for the waste characterization study include weighing scale, hand gloves, nose cover, basket, safety boot, shovel, weighing pan, cutlass, PM 2.5 Air quality monitor (TES 5322A), box of known volume.

RESULTS AND DISCUSSION

Palm Oil Solid Waste Management in the Mill

From the oral interview with the mill workers, it was gathered that the basic processes for oil production include; FFB arrival, sterilization, stripping, fruit digestion, oil extraction and oil clarification. Solid wastes comprise mainly of EFBs, mesocarp fibers and shells. Furthermore, the collection, disposal and the management of the solid waste generated in the mill is through point collection

and final disposal at the dump site within the mill premises as shown in figure 3. At each section or point of operation of the mill as shown in Figures 1-3 respectively, the solid waste generated is collected with a pan or basket which is later disposed at the dump site, the waste is left for some days for it to dry (Air-drying) before the open burning. The ashes were sometimes returned to the field as fertilizer and sometimes the ashes were sold to third parties as fertilizer and for the making of black soap locally called (Ose dudu).

Moreover, the waste is left at the point of generation for 3-4days which is detrimental to the health of the mill workers and pose some threat to their well-being. After which is collected and disposed at the dumpsite. It is an open dump and there is no provision for leachate management. The leachate generated from the dumpsite will pose a serious pollution problem to the community as it will pollute the groundwater resources and the surface water of community located around the mill through leachate migration and runoff.

A lot of orientation has to be done with the mill workers for proper collection, handling and disposal of solid wastes within the mill. The response from oral interview shows that workers and the

houses within the environment where the mill is located knows next to nothing about waste sorting and separation thus making waste recovery and reuse a tall order. Due to the poor waste management system used in the study area some of the wastes were consequently scattered by animals and winds constituting nuisance to the environment.

In the mill, POMSW are not totally used. Consequently, they sell and/or discard the excess. The PMFs are more used in the extraction process as fuel and sold than EFB. However, the modern extraction method engaged by the mill enables the use of POMSW compared to other mill categories that sells and reject PMF. The problem of fiber and empty fruit bunches management is a thing of concern and does not relate to the quantity of oil produced or amount of waste generated.

In addition, the families within the study area make it point clear that houses down the slope suffers some problem as a result of deposition from the mill during and after heavy rainfall. Likewise, the dumpsite is an eyesore due to uncontrolled movement of man and animal in and out of the site.



Figure 1. Fruit Bunch Area.



Figure 2. The Processing Area.



Figure 3. The Mill Dumpsite.

Percentage of 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. The variation in generation shows that EFB is of 52% in the total solid waste generated at each production, while 25.4% PMF and 23% palm kernel shell were generated as shown in figure 4. The reason for the differences was that waste at the processing unit which comprises of PMF and palm kernel shell, are the by-product of the fruits subjected to extraction processes which has reduced in size and weight. This established the fact that more weight of EFB will be generated followed by PMF and palm kernel.

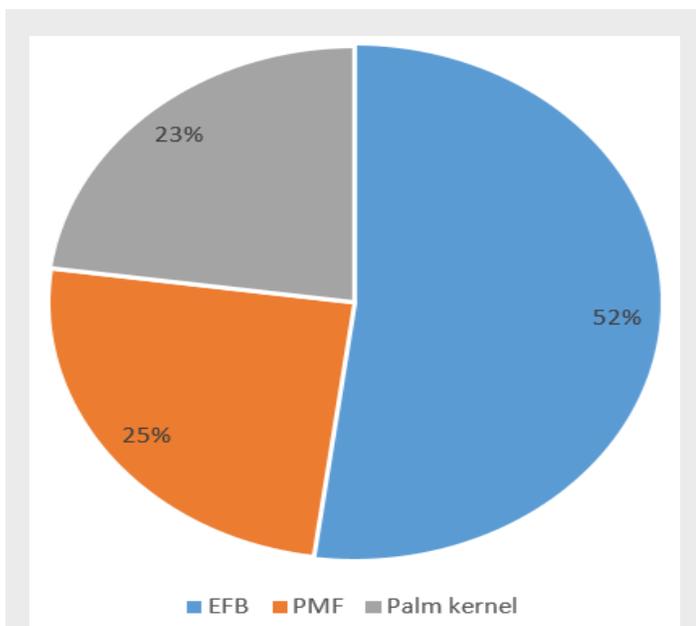


Figure 4. Total percentage composition of the solid waste generated in the mill..

Air Quality Results

The results of the air quality measurements conducted at the palm oil mill dumpsite and processing area are presented in Figures 5 and 6, respectively. These results characterize fine particulate matter ($PM_{2.5}$) concentrations during periods of active burning of palm oil mill solid waste (POMSW) and periods with no burning activity.

Particulate Matter ($PM_{2.5}$) Concentrations

At the dumpsite, $PM_{2.5}$ concentrations ranged from 93 $\mu\text{g}/\text{m}^3$ to 113 $\mu\text{g}/\text{m}^3$ during periods with no burning and 109 $\mu\text{g}/\text{m}^3$ to 117 $\mu\text{g}/\text{m}^3$ during active burning of the POMSW. At the processing area, $PM_{2.5}$ values during periods with no production activities ranged from 83 $\mu\text{g}/\text{m}^3$ to 95 $\mu\text{g}/\text{m}^3$.

These observed concentrations are substantially higher than the World Health Organization (WHO) Global Air Quality Guideline values, which recommend an annual mean of 10 $\mu\text{g}/\text{m}^3$ and a 24-hour mean of 25 $\mu\text{g}/\text{m}^3$ for $PM_{2.5}$ to significantly reduce health risks. The elevated $PM_{2.5}$ levels recorded in this study 3.3 to 4.7 times above the 24-hour WHO guideline even without burning and up to approximately 4.7 times higher during burning activities indicate a significant degradation of air quality associated with both waste disposal and combustion practices at the site.

The increase in $PM_{2.5}$ concentrations during burning periods confirms that open burning of POMSW contributes to elevated fine particulate emissions, consistent with global research showing that unmanaged combustion of biomass and waste significantly elevates PM emissions in developing regions.

Meteorological Conditions: Temperature and Relative Humidity

Temperature and relative humidity were recorded concurrently with $PM_{2.5}$ measurements to evaluate their influence on particulate matter dynamics. At the dumpsite, ambient temperatures during non-burning periods ranged from 31°C to 37°C, increasing to 36°C to 38°C during burning. Relative humidity levels varied from 54 % to 69 % during non-burning and 52 % to 54 % during burning conditions. At the processing area, temperatures ranged from 28°C to 31°C, with relative humidity between 69 % and 81 %.

The observed data demonstrate an inverse trend between temperature and relative humidity, whereby increasing temperature is associated with decreasing relative humidity. Although WHO does not establish specific outdoor temperature guidelines, meteorological conditions such as temperature and humidity are known to influence atmospheric dispersion and residence time of air pollutants.

Interpretation and Public Health Implications

The consistently high PM_{2.5} concentrations measured in this study present substantial public health concerns, particularly under conditions of active waste burning. Fine particulate matter (PM_{2.5}) is a well- established risk factor for a range of respiratory and

cardiovascular outcomes and contributes to millions of premature deaths worldwide, disproportionately affecting low- and middle-income communities where air quality monitoring and control are limited.

Contemporary research indicates that PM_{2.5} exposures exceeding regulatory guidelines are associated with increased incidence of asthma, chronic bronchitis, reduced lung function, and other non-communicable diseases. The magnitude of PM_{2.5} exceedances observed in this study — driven in part by open burning of solid waste — underscores the urgency of adopting more sustainable waste management practices that reduce combustion emissions and protect environmental and human health.

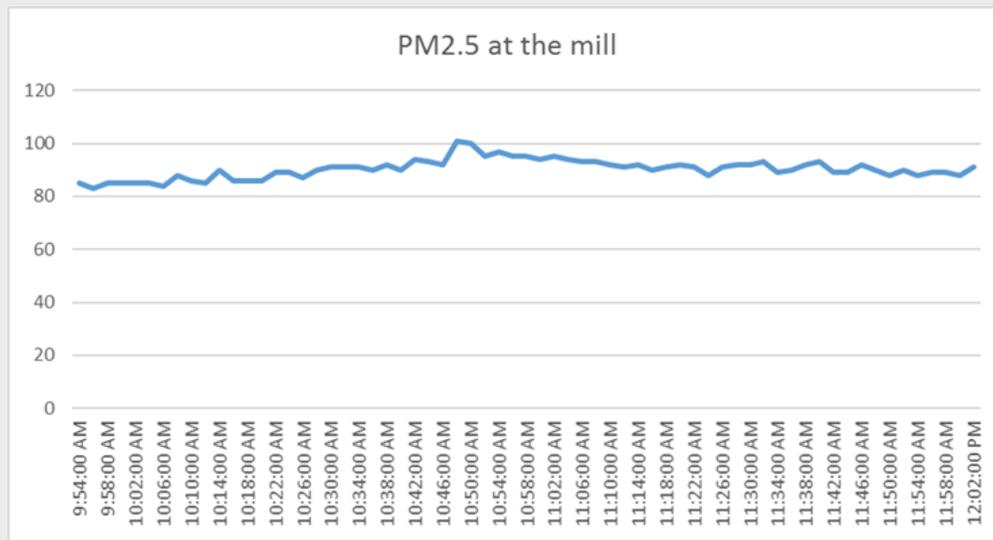


Figure 5. PM_{2.5} of the processing area on 09/11/2021 at 9:54am to 12:02pm.

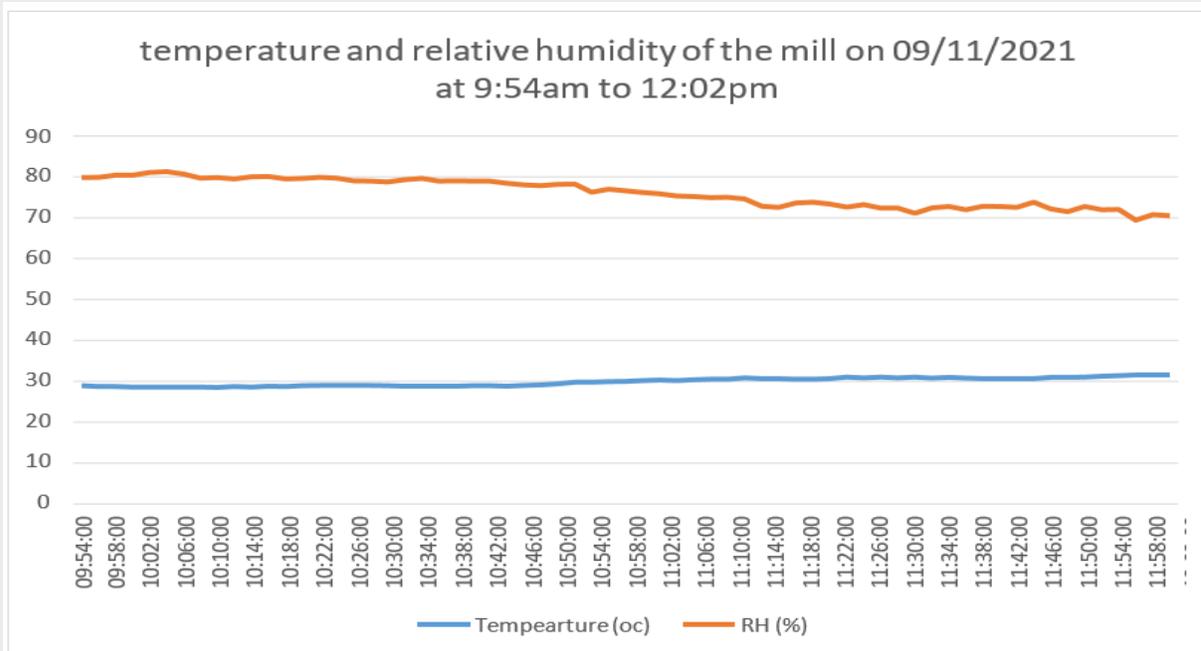


Figure 6. Temperature and Relative humidity at the processing area on 09/11/2021.

Environmental Impact of Solid Wastes in the Mill

In environmental impact assessment, the natural environment is broadly classified into three interrelated components: air, water (aquatic), and soil (terrestrial). The management and disposal of solid wastes within the palm oil mill significantly influence each of these environmental media.

The palm oil mill studied generates a substantial volume of solid waste (POMSW), much of which remains underutilized. Although a portion is used as boiler fuel, a large fraction accumulates and is often disposed of through open dumping and combustion. Such practices lead to multifaceted environmental impacts.

Impact on Soil and Aquatic Systems

Unregulated dumping of solid waste results in the formation and infiltration of leachate, especially during rainfall events. Leachate a liquid that forms when water percolates through waste can carry organic and inorganic contaminants into surrounding soils and potentially migrate into groundwater systems. This poses risks to soil quality and aquatic ecosystems, particularly through nutrient loading and the mobilization of heavy metals.⁸ As documented in recent studies, poorly managed palm oil waste sites in tropical environments contribute to soil acidification and decreased soil microbial diversity, affecting terrestrial ecosystems.⁹

The presence of odoriferous emissions from decomposing waste further indicates ongoing anaerobic degradation processes, which are known to produce volatile organic compounds (VOCs) and contribute to localized nuisance and health concerns.¹⁰

Atmospheric and Air Quality Impacts

The predominant method of POMSW disposal open combustion directly contributes to atmospheric pollution. Combustion of biomass waste releases pollutants such as carbon monoxide (CO), nitrogen dioxide (NO₂), particulate matter (including PM_{2.5}), and smoke. These emissions deteriorate ambient air quality and contribute

to regional air pollution burdens.^{11,12} PM_{2.5} fine particulate matter with a diameter of less than 2.5 micrometers is of particular concern due to its ability to penetrate deep into the respiratory system and cause adverse health effects, including respiratory and cardiovascular diseases.^{13,14} The atmospheric dispersion of these pollutants follows a concentration gradient influenced by prevailing wind patterns, such that pollutant concentrations decrease with distance from emission sources.

Seasonal variations, particularly moisture content of the biomass, further influence combustion efficiency and emission characteristics. Lower moisture content during the dry season tends to increase combustion intensity and pollutant release, whereas higher moisture during the rainy season can lead to smoldering conditions and prolonged emissions.⁸

Biological and Ecosystem Effects

The presence of extensive solid waste piles provides habitat for various organisms, including reptiles, rodents, flies, and other scavengers. While such biodiversity may superficially appear beneficial, it often reflects ecosystem imbalance and habitat degradation, as these species thrive in anthropogenically disturbed environments.¹⁵ The proliferation of vectors such as flies and rodents also raises public health concerns due to their association with disease transmission.

Implications for Environmental Management

Collectively, these environmental impacts demonstrate that current waste management practices at the mill are insufficient to mitigate pollution risks. Effective waste management strategies including waste reduction, recycling, composting, and controlled combustion systems with emission controls are necessary to protect soil, water, and air quality. Moreover, aligning waste management with regulatory frameworks and environmental best practices can contribute to sustainable palm oil mill operations and reduced community health risks.



Figure 7. The dumpsite with no perimeter fencing

Enhancing Sustainable Solid Waste Management Practices in Palm Oil Mills

In pursuit of the primary objective of this research, which is to propose enhanced strategies for solid waste management within the palm oil mill, a comprehensive examination was conducted. This involved conducting oral interviews with mill personnel to solicit insights into the prevailing waste management practices employed in the facility. The outcomes of these interviews have revealed that a limited number of workers possess an understanding of the challenges associated with improper disposal and management of palm oil mill solid waste (POMSW).

To address this critical issue, it is recommended that a robust worker sensitization program be instituted. This program should focus on raising awareness among the workforce regarding the adverse effects stemming from improper waste disposal. Additionally, it should emphasize the necessity for proper waste sorting into distinct constituents, which can curtail the decomposition period and enhance opportunities for waste reuse. Consequently, this approach will reduce the overall volume of waste generated over shorter time frames. Furthermore, it is imperative to bolster the enforcement of environmental regulations and legal frameworks applicable to local palm oil mills. This enforcement will serve to prevent, mitigate, and control pollution.

Moreover, as a means of mitigating gas emissions and mitigating the associated environmental impacts stemming from open burning practices, the adoption of incineration as a waste disposal method should be encouraged. A meticulously designed incinerator, complete with an ash tray for the collection of ash residues, should be implemented. These ash residues can be repurposed for local soap production, thereby adding value to the waste management process and fostering environmental sustainability.

CONCLUSIONS

This study examined the environmental impacts associated with solid waste generation and management practices in a local palm oil mill, with particular emphasis on air quality, waste disposal methods, and associated public health implications. The findings demonstrate that ineffective management of palm oil mill solid waste (POMSW), especially through open dumping and uncontrolled combustion, significantly contributes to environmental degradation across the air, soil, and aquatic systems.

Measured PM_{2.5} concentrations during both burning and non-burning periods substantially exceeded internationally reported safe exposure levels, indicating elevated air pollution within and around the mill environment. The observed increase in particulate matter concentrations during periods of open burning confirms that combustion of POMSW is a major source of fine particulate emissions, thereby posing serious respiratory and cardiovascular health risks to mill workers and nearby residents. These findings are consistent with recent peer-reviewed studies that link open biomass and waste burning to deteriorated air quality and adverse health outcomes.

Beyond atmospheric impacts, the accumulation and improper disposal of solid wastes at the dumpsite were found to generate odour nuisance, leachate formation during rainfall events, and habitat conditions favourable to disease vectors and scavenger species. Such conditions not only compromise soil and groundwater quality but also disrupt local ecosystems and degrade environmental aesthetics. These outcomes underscore the urgent need for structured waste handling, controlled disposal systems, and site management interventions within small-scale and local palm oil mills.

The study further reinforces the importance of resource recovery and waste valorisation as a sustainable pathway for addressing palm oil mill waste challenges. As documented in earlier and contemporary studies, POMSW can be converted into a wide range of value-added products, including bio-based materials and renewable energy sources such as bioelectricity, bioethanol, bio-briquettes, biochar, syngas, and bio-oil using appropriate technologies.^{16,17} Adoption of these technologies by local mills would significantly reduce environmental burdens while enhancing economic sustainability.

In place of open combustion, the use of engineered incineration systems equipped with emission control measures and ash collection trays is strongly recommended. Such systems can minimize atmospheric emissions while enabling the recovery of ash for potential agricultural or industrial applications. Additionally, the establishment of perimeter fencing and controlled access to dumpsites is necessary to prevent human and animal encroachment, thereby reducing nuisance, health risks, and environmental contamination.

Overall, this research highlights that achieving environmentally responsible and socially sustainable palm oil production requires a collaborative approach involving mill operators, workers, local communities, and regulatory agencies. Strengthening environmental regulations, promoting cleaner production technologies, and encouraging sustainable waste management practices will play a critical role in mitigating the environmental and health impacts associated with palm oil mill solid waste. If effectively implemented, these measures can support the transition of local palm oil mills toward sustainable production systems that balance economic development with environmental protection and public health preservation.^{18,19}

ACKNOWLEDGEMENTS

None.

FUNDING

The author declare that no funding was received for this article

CONFLICT OF INTEREST

No conflict of interest declared.

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