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EVALUATING THE COMPOSITION OF PALM DREGS FOR USE AS AN ENHANCEMENT MATERIAL IN GROUNDING SYSTEMS

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Abstract:

This study introduces palm dregs, leftovers from the palm oil industry, as an alternative, nature-based supplement for electrical grounding applications. The investigation focuses on whether palm dregs can lower the resistance of surrounding soil and stabilize ground resistance over a long time. This potentially exceeds the performance of commonly used chemical enhancers while posing fewer environmental risks. Meanwhile, the organic and moisture-absorbing features of palm dregs help preserve higher soil conductivity even under varying climate conditions. Furthermore, utilizing palm dregs may reduce the likelihood of soil or water pollution that can happen with chemical additives. Results indicate that palm dregs offer equal or superior electrical performance, cost, and ecological benefits, including faster decomposition and reduced negative impact on local ecosystems. At the same time, these findings suggest that agricultural by-products can be transformed into beneficial materials for engineering tasks, which supports more responsible planning and operation of grounding structures in power networks. Overall, demonstrating that an abundant waste product can replace standard chemical enhancers also supports wider movements toward eco-friendly and durable infrastructure solutions.

Keywords:

Biodegradable Waste Composition, Electrical Grounding, Palm Oil Industry, Environmental Protection Agency (EPA), Palm Dregs, Soil Conductivity.

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Introduction

Palm oil is prominent in worldwide agriculture, with recent figures indicating an annual output of approximately 75 to 80 million metric tons (Choong & McKay, 2014). This quantity is estimated to be nearly one-third of the global supply of vegetable oils (Go & Lau, 2024). Notably, the considerable production scale is linked to palm oil's frequent use in various consumer applications, such as edible products, cooking fats, oleochemical processes, and biofuels. Consequently, international demand remains strong, particularly in regions like Asia, Africa, and Europe, where large volumes are shipped to meet growing consumption needs. In economic terms, palm oil generates billions of dollars annually, making it a vital contributor to the development strategies of producing countries.

Malaysia ranks second in the lineup of top palm oil-producing nations, following Indonesia (Teh et al., 2024). Its yield generally makes up about one-quarter to almost one-third of the worldwide supply, translating to roughly 19 to 20 million metric tons yearly (Choong & McKay, 2014). Such a high-volume underlines how fundamental palm oil has become for Malaysia's economic landscape. Oil palm plantations (Abdul-Hamid et al., 2021) extend across around 5.7 million hectares (around 14 million acres) within the country, revealing a strong commitment and substantial investment in this rewarding crop. In addition to offering job opportunities to many workers, especially smallholder growers, the sector also boosts connected fields such as refining, freight, packaging, and export operations. As a result, palm oil forms an essential pillar of Malaysia's foreign exchange revenue (Umar et al., 2013), rural progress, and overall economic growth.

Figure 1: Oil Palm Plantation Distribution by State in Malaysia

Source: Abdul-Hamid et al. (2021)

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Table 1: Number of Oil Mills, Refineries, and Palm Kernel Crushing Factories in Operation

Region	Oil mills		Refineries		Crushing factories	
	No.	Capacity[a]	No.	Capacity[b]	No.	Capacity[c]
P. Malaysia	244	45,373,720	38	10,952,900	30	3,254,600
Sabah	89	18,750,600	9	4,596,500	8	1,057,500
Sarawak	19	3,620,400				
Total (Malaysia)	352	67,744,720	47	15,549,400	38	4,312,100

Source: Malaysian Palm Oil Board (www.mpob.gov.my)
[a] Tonnes FFB/year.
[b] Tonnes CPO/year.
[c] Tonnes Palm Kernel/year.

Source: Abdullah et al. (2007)

Beyond the oil, the production process generates significant quantities of biomass by-products, often called palm dregs (Abdullah et al., 2009). This category typically comprises leftover fibers, fruit remnants, and other residual elements. In earlier times, such materials were frequently viewed as either having limited value or were incinerated, contributing to environmental issues. However, a growing shift is taking place toward repurposing these resources. One promising application involves incorporating palm dregs into grounding systems, where low soil resistivity and consistent electrical properties are vital. By capitalizing on this resource, the palm oil industry could convert waste into valuable input, fostering economic returns and supporting eco-friendly approaches (Umar et al., 2013).

A growing use for palm dregs involves adding them to grounding systems (Hassan et al., 2024). These systems, standard in electrical grids, telecommunications, and high-voltage setups, demand materials with reliable conductivity and the ability to remain effective in soil over an extended period (IEEE, 2018). Many existing solutions rely on chemical compounds, which can lead to concerns regarding costs or environmental impact. By contrast, palm dregs present a biodegradable option that may improve soil resistivity while maintaining stable grounding quality (Wu et al., 2017). Furthermore, incorporating this fibrous, nutrient-rich residue uses an underused by-product and opens a fresh revenue path for Malaysia's palm oil producers. Accordingly, such measures can help reinforce local economies and enhance Malaysia's position within the global agricultural arena.

Considering all these points together, it becomes evident that palm dregs are vital in creating an eco-friendly and rewarding path for palm oil production. Using unusedagricultural by-products allows Malaysia to foster innovative ideas, curb waste, and fortify itsglobal standing in the palm oil market (Rajakal et al., 2024). This paper examines the practicalbenefits of employing palm dregs in grounding systems, exploring their features, performancein actual applications, and ability to produceextra revenue. In line with this, converting palm dregs from waste into valuable materials could drive economic progress while encouraging responsible environmental practices in Malaysia's palm oil industry (Zakaria et al., 2024).

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Literature Review
Numerous studies have sought to identify effective natural or chemical materials for enhancing the effectiveness of grounding systems(Wan Ahmad, Mohamad Roslan, et al., 2023). investigated the electrical and physical properties of bentonite and kenaf, observing that kenaf's high water uptake and conductivity are promising for grounding applications. However, they emphasized the need for additional long-term field trials across diverse environments. In a subsequent study, the same authors evaluated bentonite-kenaf composites for 150 days and demonstrated that the formulation further reduced ground resistance; however, the availability of raw materials on a large scale remains unresolved.

Similarly, the influence of chemically active substances such as magnesium sulphate, copper sulphate, and sodium chloride on soil resistivity was assessed, magnesium sulphate produced the most significant reduction, yet potential long-term environmental impacts were not considered, indicating the necessity for more comprehensive life cycle analyses .(Ibrahem & Sabry, 2022) developed a concrete-encased electrode system for floating-roof petroleum tanks, which achieved a 62% reduction in resistance. Nevertheless, validation in various soil types was recommended to support broader applicability.

(Wan Ahmad, Abdul Rahman, et al., 2023) evaluated a combination of bentonite and peat moss; the mixture labelled Mix A performed very well, and future work should address seasonal influences and alternative soil compositions. The same author later introduced zeolite as a modifier for bentonite, reporting an extended service life, however, no microstructural analysis was provided, and interaction studies between the constituents were suggested. In a further investigation, (Ahmad et al., n.d.) studied mixtures of fly ash and wood ash with bentonite and found that wood ash enhanced conductivity and structural properties; however, additional research is required to assess the long-term leaching behavior and environmental safety of wood ash.

Another study (Ahmad & Palahuddin, 2024)examined blends of bentonite, kenaf, and pine wood and identified pine wood as a highly efficient additive, however, economic assessments and synergistic evaluations have yet to be conducted. (Sinchi-Sinchi et al., 2022) conducted in situ tests on low-resistivity materials and chemical electrodes, reporting soil resistivity reductions of approximately 90 percent. However, the absence of long-term monitoring was noted as an important future research direction. Finally, (Hasni et al., 2020) performed laboratory experiments on the mechanical and electrical properties of kenaf fibres, confirmed their potential owing to a high dielectric constant, and highlighted the scarcity of practical field applications.

Collectively, these studies advance the knowledge base on grounding enhancement materials by integrating natural, industrial, and chemical components and by recognizing the importance of environmental testing, material sustainability, and long-term performance validation.

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Materials and Methods

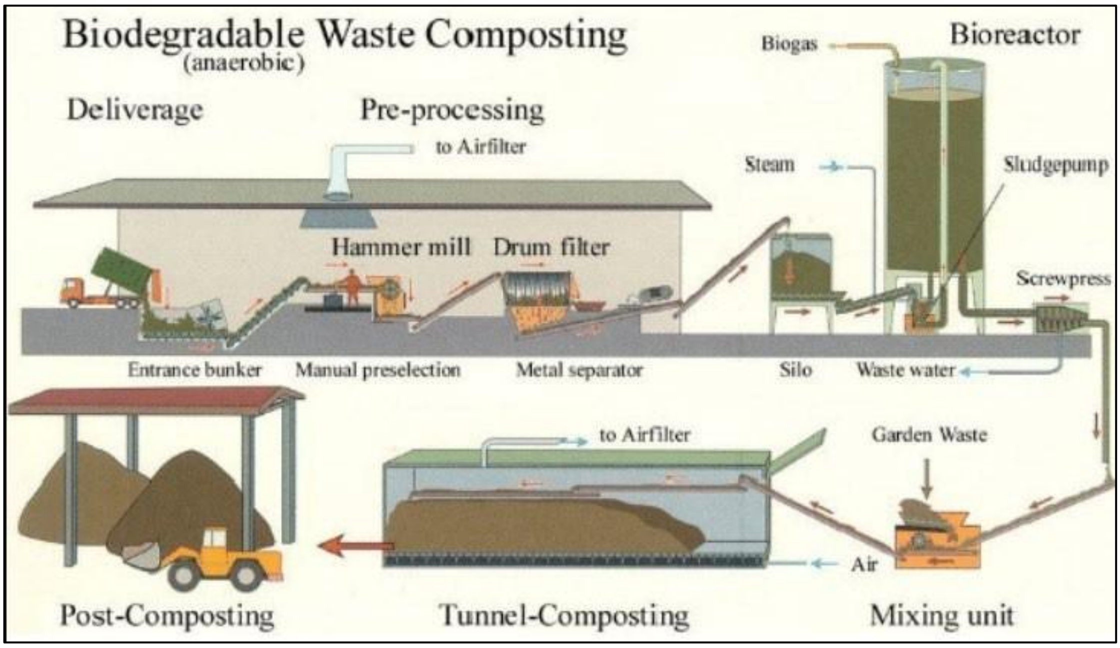

Figure 2: The Process of Biodegradable Waste Composition
Source: Zakaria et al. (2024)

The palm dregs samples used in this research were obtained through a cooperative effort with FGV Palm Industries Sdn Bhd, a major palm oil production company based in Kemahang, Kelantan, Malaysia. To begin, a formal communication was established with the factory's management team to explain the study's goal of assessing palm dregs as a potential material for improving grounding systems. Approval for sample collection was granted after following established ethical procedures and agreements between the research institution and the company. Subsequently, a visit to the facility was arranged to meet with the senior operations manager, who oversees environmental and safety matters. During discussions, the purpose of the research, methods for collecting samples, and the broader significance of reusing industrial waste were clearly communicated to align with the factory's policies. Official permission documents were signed, which included commitments to confidentiality and safety guidelines. Consequently, the manager assigned a trained worker to assist the research team during sample collection, ensuring safety rules were followed and guiding access to the storage area for palm waste.

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Figure 3: FGV Palm Industries Sdn Bhd (Kilang Sawit Kemahang, Kelantan)

Figure 4: FGV Palm Industries Sdn Bhd (Entrance of Factory)

To maintain sample quality and reduce contamination, a specific collection process was followed. By referring Figure 2, Palm dregs, a fibrous waste product from palm oil processing, were gathered from three levels (upper, middle, lower) of a large waste pile. Additionally, sterilized metal tools and sealed plastic containers were used for this purpose. Note that collecting samples from multiple layers helped account for differences in moisture levels across the pile. Approximately 15 kg of raw material was collected, mixed thoroughly on-site with a heavy-duty blender to ensure consistency, and divided into smaller 1 kg portions for transportation. These portions were placed in cool, insulated boxes stored at 4°C to prevent microbial growth and breakdown during delivery to the lab. The assisting worker shared notable details, such as the age of the waste pile, initial moisture measurements, and standard disposal methods, which were later used to guide lab analysis.

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Figure 5: Palm Dregs Dried Sample (Kilang Sawit Kemahang, Kelantan)

Figure 6: A Bulk of Palm Dregs sample (Kilang Sawit Kemahang, Kelantan)

Referring to Figure 5 and Figure 6, after collecting samples, the operations manager led the research team and received a guided tour of the factory's palm oil processing and waste management sections. This visit provided an overview of large-scale operations, such as sterilization, fruit separation, oil extraction, and waste sorting, which helped clarify the origin and basic properties of the dregs. Concurrently, observations were recorded with regard to the factory's wastewater treatment methods and drying techniques for organic byproducts, linking these practices to the characteristics of the collected samples. It was noted that the dregs were dried under sunlight for two days after extraction to lower moisture levels, a key factor in explaining the lab-measured moisture value of 12.4%. After the tour, further discussions with technical staff resolved uncertainties about waste processing timelines and storage environments, allowing adjustments to experimental conditions for accuracy.

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Standard Used

The methodology followed recognized standards, such as ASTM D2216-19 (ASTM International, 2019), for sampling soils and organic materials, with adjustments to accommodate the fibrous nature of palm dregs (Awalludin et al., 2015). All steps were performed under clean conditions, and records were retained to track sample handling. Partnering with FGV Palm Industries ensured access to authentic samples and connected the study to actual industrial processes, improving the relevance of results. This method combines practical field data with laboratory testing, a vital approach for applied studies. Following industry norms and focusing on repeatability creates a model for future research on converting agricultural waste into useful materials, advancing knowledge in sustainable engineering and environmental science.

Industry Collaboration and Sample Acquisition

Partnering with FGV Palm Industries Sdn Bhd (FGVPI), a leading palm oil producer managing over 60 mills, was central to this study. Through this collaboration, authentic palm oil byproduct samples ("palm dregs") were obtained directly from an operational mill. The term palm dregs here refers to the fibrous residual biomass left after palm oil extraction, analogous to palm press fiber or empty fruit bunch remnant (see figure below). FGVPI's involvement ensured the samples reflect actual industrial conditions, including real moisture content, composition, and variability, improving the relevance and applicability of the results. The collaboration also provided insight into the waste generation process on-site, informing the sampling strategy (e.g., timing of collection post-extraction to capture representative moisture levels). Moreover, this academia-industry partnership supplied material and strengthened the study's practical significance* results obtained are immediately relatable to industry scenarios, and the approach lays the groundwork for future cooperative projects (such as pilot-scale trials at FGV mills). Building on this, FGV's interest in sustainable waste management (as evidenced by their corporate "Waste-to-Wealth" initiative that uses mill biomass for energy) further reinforced the mutual benefits of the partnership. This aligns with research objectives and industry sustainability goals and opens avenues for ongoing innovation.

Figure 7: Bulk Fibrous Oil Palm Residue (Empty Fruit Bunches) at a Palm Oil Mill

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Similar in nature to the palm dregs used in this study. Such fibrous wastes are abundant byproducts of palm oil production, traditionally used as fuel or compost. Due to their course and organic nature, they require tailored handling in laboratory testing.

Sample Collection and Preparation

Field sampling followed established protocols for soils and organic materials, adapted to manage the coarse, high-fiber content of palm dregs. Accordingly, samples were collected at the FGV mill immediately after the milling process to ensure freshness. Workers used clean stainless-steel tools (forks and trays) to gather the fibrous mass from the mill's discharge area. Approximately 50 kg of raw palm dregs were collected and divided into batches. Each batch was sealed in airtight polyethylene bags to preserve the native moisture content during transport. Moreover, the material was kept out of direct sunlight and cool during transit to maintain sample integrity. Upon arrival at the laboratory, the samples were logged and homogenized: large fibrous clumps were manually broken down and mixed on a disinfected tarp to ensure that subsequent sub-samples would be as uniform as possible. Any extraneous debris (e.g., palm nuts or gravel) was removed. Considering the fibrous nature of the material, an industrial shear cutter was used to trim fibers to lengths of roughly 20 to 50 mm for consistency. This sizing was performed to improve handling and to allow the material to fit into standard test containers. Note that all preparation work was conducted under clean laboratory conditions. Surfaces were covered with clean plastic sheets, and latex gloves were worn to prevent contamination by dust or foreign soil. Note that each bag and subsample was labeled with a unique code and date. A detailed chain-of-custody record was maintained, noting each handling, to track sample history from field to testing. This careful preparation ensured that the palm dregs samples remained representative of the source material and ready for accurate laboratory analysis.

Laboratory Testing and Standard Protocols

Laboratory analyses were conducted to characterize the palm dregs' basic properties, with procedures grounded in recognized standards for soil and organic matter testing (Bakar et al., 2022). Key equipment included a forced-draft drying oven (set at 105 ± 5°C), an analytical balance (0.01 g precision), stainless steel sample tins, and a muffle furnace. Throughout testing, quality control measures (equipment calibration, duplicate samples, and clean work areas) were employed to guarantee reliable results. By adhering to standard methods, the study ensured results comparable to existing data and repeatable by other researchers, which is vital for applied engineering studies.

Moisture Content Determination

The natural moisture content of the palm dregs was measured following ASTM D2216-19 guidelines (ASTM International, 2019). This standard (ASTM D2216-19, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass*) is widely used in geotechnical engineering to quantify how much water a material contains. Using this method provides a reliable baseline and comparability with conventional soils. In practice, about 100 g of the prepared fibrous sample was placed in a pre-weighed aluminum moisture tin. The tin was immediately covered to prevent moisture loss and weighed to record the "wet" mass. Next, the sample was oven-dried at 105°C for 24 hours (or until a constant mass was achieved, as indicated by two successive weighing differing by < 0.1%). The drying oven temperature of 105°C comes from the ASTM standard requirement for soils.

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However, an adaptation was necessary since palm dregs are rich in organic fibers, and there was a risk of charring at this temperature. Thus, to address this, the samples were spread in a thin layer in the tins (improving moisture evaporation and preventing heat buildup), and the oven was calibrated to avoid exceeding 105°C. In addition, a trial run was performed at a slightly lower temperature (95°C for a longer duration) to verify that no significant mass difference or material degradation occurred compared to the standard method. The outcome confirmed that standard conditions could be used without damaging the fibrous content, so the procedure reverted to the ASTM-specified 105°C with careful monitoring. After drying, the tins were cooled in a desiccator and re-weighed to obtain the "dry" mass. Subsequently, moisture content (% by mass) was calculated as the ratio of water loss to dry mass. Each was measured in triplicate to ensure repeatability, and the average value was recorded. The use of ASTM D2216-19 for this step is justified by its rigorous definition of technique and accuracy for water content. In addition, following this process helps standardize the results, making them credible and usable in design calculations or comparisons with soil data (ASTM International, 2019). Overall, the slight procedural tweaks for the fibrous material did not deviate from the standard's fundamental principle. Therefore, the results remain compatible with industry norms.

Sustainability and Innovation Considerations

This methodological approach is grounded in principles of sustainability and engineering innovation. Rather than treating palm oil mill byproducts as waste, the study treats them as raw materials for construction/geotechnical use, a perspective aligned with the concept of a circular economy and sustainable resource management. Notably, the palm oil industry produces millions of tonnes of waste annually (Zakaria et al., 2024), leading to serious storage and environmental challenges. Hence, the research addresses these challenges head-on by developing a method to convert palm dregs (an underutilized waste) into useful engineering material (Teh et al., 2024). Working with actual agricultural waste diverts it from landfills or open piles (mitigating pollution and greenhouse gas emissions from decomposition) and reduces the need to harvest new natural materials for construction. In a broader context, reusing agro-waste in construction can significantly reduce environmental and engineering issues and offer benefits over traditional materials (Rajakal et al., 2024). For example, bio-fibrous materials tend to be lightweight and insulating, and their use helps conserve non-renewable resources. From an environmental standpoint, our methodology contributes to waste minimization and resource conservation. It implements the reduce and reuse strategies that top the waste management hierarchy (Hassan et al., 2024). According to the US EPA, waste management approaches emphasizing reuse and recycling are key to sustainable materials management and help reduce greenhouse gas emissions (Tan & Lim, 2019). In this study, the reuse of palm dregs exemplifies such an approach, offering a second life to what would otherwise be an emission-producing waste.

Importantly, conducting the research with real industrial byproducts (through the FGV partnership) demonstrates innovation in practice. Many prior studies on palm oil waste have focused on more established wastes like shells, clinker, or ash, which are now recognized as alternative construction materials. In contrast, fibrous palm dregs are less commonly utilized (Awalludin et al., 2015). Hence, our methodology breaks new ground in exploring this material's potential. The entire process, from field collection to lab testing, was designed to be scalable and transferable. Furthermore, by following industry standards and documenting adjustments, our research creates a model that industry practitioners or other researchers can adopt, accelerating the transfer of this sustainable innovation into real-world applications. The

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collaboration with FGV further ensures that the research stays oriented towards practical implementation. Looking ahead, this methodology solves a local waste issue and contributes to global sustainable engineering knowledge. It showcases how adhering to rigorous methods and standards can be combined with creative adaptation to turn an environmental problem into an engineering solution. In sum, the methodology embodies a sustainable engineering framework. It is technically sound, industry-relevant, and environmentally responsible, illustrating a path forward for converting agricultural waste into valuable resources in line with international sustainability goals.

Sample Send to Makmal ICA, UTMCampus Pagoh for Analyse

A 500 g palm dregs sample was submitted to MAKMAL ICA, UTM Kampus Pagoh, for laboratory testing to analyze the physical, chemical, and electrical properties of palm dregs to examine whether they can serve as an enhancement material in grounding systems. This includes an evaluation of how the soil behaves regarding moisture retention, Electrical Conductivity (EC), pH level, organic matter percentage, and soil composition, which are significant in determining its function in enhancing the efficiency of the grounding system. Correspondingly, the test method was standardized, and the reported outcomes were reliable and validated accordingly.

The laboratory specialists at MAKMAL ICA, UTM Kampus Pagoh, examined and validated the data after a 14-day period of testing to assure its precision and consistency. Once the verification process has been completed, this formal report, including the test results, will be submitted to the researcher for review. The results of this study will provide valuable information on the feasibility of using palm dregs in grounding applications. They can be used as a basis for the technical evaluation of their practical application in grounding system improvement.

Data Collection For Palm Dregs Sample from Makmal ICA, UTM Kampus Pagoh

Table 2: Parameter for Palm Dregs

No	Parameter	Unit	Method	Result
1.	pH analysis	-	LAB- STP-5001	5.51
2.	Electroconductivity	mS/c m	LAB- STP-5002	1.84
3.	Moisturecontent	%	LAB- STP-5003	12.4
4.	Organic matter	%	LAB- STP-5004	92.60
5.	Soil texture	%	LAB- STP-5005	Sand:17.72 Silt::51.50 Clay:30.78

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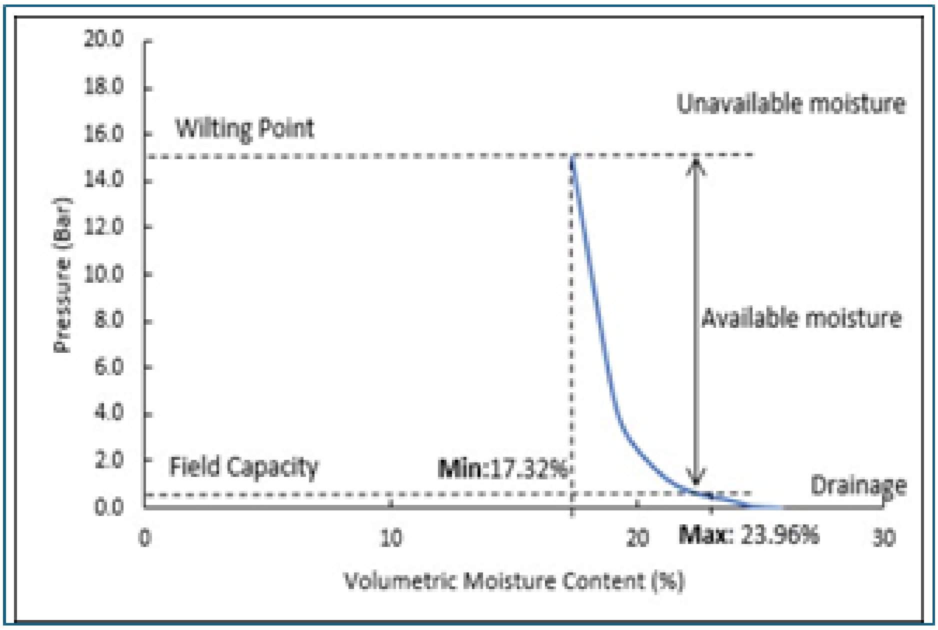

Figure 8: Water Retention for Palm Dregs Sample From Makmal ICA, UTM Kampus Pagoh

The Certificate of Analysis (COA) offers crucial data regarding the feasibility of palm dregs as a supplementary material in grounding systems. Various parameters, including pH, conductivity, moisture retention, soil composition, and organic content, play a fundamental role in assessing its effectiveness in improving electrical grounding performance.

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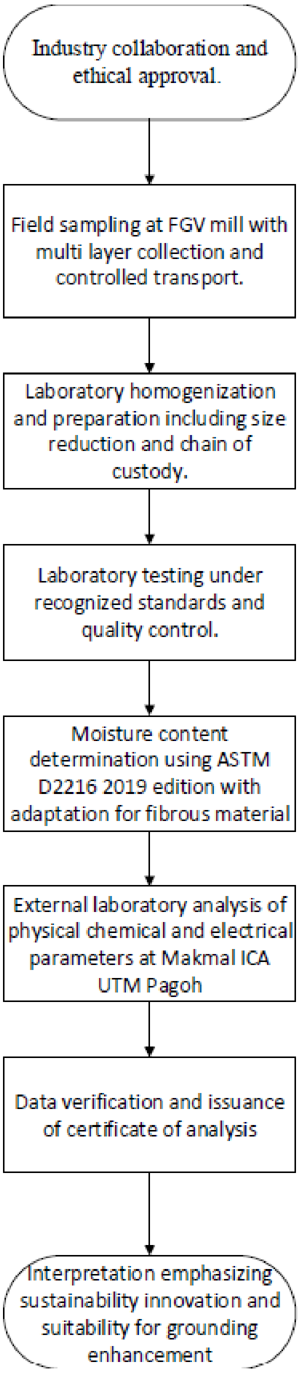

Figure 9: Flow Chart of Methadology

Flow Chart of Methodology

1. **Collaboration and approval**
   The project began with written permission from FGV Palm Industries Sdn Bhd. This step satisfied all safety and confidentiality requirements.

2. **Field sampling**
   Palm dregs were taken from three depths of the waste pile to capture natural variation.

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About fifteen kilograms of material were mixed, split into one-kilogram bags, and kept at four degrees Celsius during transport.

3. **Sample preparation**
   In the laboratory the material was logged, cleaned, cut to uniform fibre length, and labelled to keep a clear chain of custody.

4. **Standard testing**
   The prepared samples were analysed with recognised soil and organic matter tests using calibrated instruments and routine quality checks.

5. **Moisture measurement**
   Moisture content was measured three times with the ASTM D2216 (2019) method. Thin layers were dried at one hundred five degrees Celsius to avoid overheating the fibres.

6. **External characterisation**
   A five-hundred-gram subsample went to Makmal ICA UTM Pagoh for pH, electrical conductivity, organic matter, water retention, and texture tests relevant to grounding performance.

7. **Data verification**
   Laboratory specialists reviewed the results and issued a certificate of analysis within fourteen days.

8. **Interpretation**
   The combined data were evaluated against engineering needs and sustainability goals, showing that palm dregs can enhance grounding systems while reducing biomass waste.

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Findings

Table 3: Summary of Findings on Parameter for Palm Dregs

Parameter	Value / Characteristics	Implication on Grounding System
pH Level	5.51 (mildly acidic)	Enhances ion movement and suitable for reducing resistance
Electrical Conductivity (EC)	1.84 mS/cm (moderate)	Moderate current dissipation and enhances long-term stability with other materials
Moisture Content	12.40%	Promotes consistent grounding performance across climates
Organic Matter	92.60%	Supports moisture and ion retention and degrades slowly for lasting performance
Soil Texture	Loamy (Sand: 17.72%, Silt: 51.50%, Clay: 30.78%)	Favourable balance between permeability and compaction and supports effective ion exchange
Moisture Retention	Max: 25.86%, Min: 17.32%, Saturation: 23.96%	Ensures water availability across different conditions and aids stable conductivity
Practical Suitability	Good Electric Conductivity, high moisture retention, biodegradable, cost-effective	Viable eco-friendly alternative and may be combined with high-conductivity materials for enhanced effect

Acidity Level and Influence on Grounding Conductivity
From Table 2 and Table 3, the pH level recorded for the sample is 5.51, indicating a mildly acidic characteristic. In grounding applications, the pH of the soil or enhancement materials is crucial as it impacts the movement of ions. Typically, a pH range between 5.0 and 8.0 is favorable for proper grounding efficiency. Since slightly acidic conditions help ion exchange, palm dregs may contribute to lowering resistance, particularly in areas where the soil tends to be neutral or alkaline.

Electrical Conductivity and Performance Considerations
The measured EC is 1.84 mS/cm refer to Table 2 and Table 3, which suggests moderate ionic conductivity. In grounding systems, materials with a high EC value are preferred, as they enable better current dissipation into the earth. While the conductivity of palm dregs is not extremely high, it is still sufficient for use when mixed with other materials, such as bentonite or conductive salts. Furthermore, organic composition and moisture absorption enhance the stability of ion exchange, making palm dregs potentially useful in reducing grounding resistance over time.

Water Retention Capacity and Moisture Stability
From Figure 8, moisture content is one of the key factors influencing Electric Conductivity(EC) in grounding materials. The analysis reveals:

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i. Maximum moisture retention: 25.86% (v/v)
ii. Saturation threshold: 23.96% (v/v)
iii. Minimum water availability: 17.32% (v/v)

These values indicate that palm dregs retain moisture effectively without excessive drainage, which is beneficial in grounding applications. Hence, grounding materials should maintain moisture for stable resistance levels, as dry conditions increase soil resistivity. Since palm dregs hold an optimal moisture range, their use in areas where humidity varies significantly could improve the reliability of grounding systems.

Organic Matter Content and Long-Term Effect

A key characteristic of palm dregs is their high organic matter content (92.60%) refer to Table 2 and Table 3, which indicates a significant presence of decomposable materials. Organic matter improves soil structure by retaining moisture and enhancing ion movement, which is necessary for maintaining stable grounding performance. Additionally, materials with high organic content degrade slowly, ensuring that the conductive properties remain effective over time.

Soil Composition and Structural Benefits

From Table 2 and Table 3, Palm dregs exhibit a loamy texture with the following particle distribution:

i. Sand: 17.72%
ii. Silt: 51.50%
iii. Clay: 30.78%

Loamy soils are ideal for grounding applications since they balance moisture retention, conductivity, and compaction resistance. In particular, the presence of 30.78% clay ensures moisture retention, while silt (51.50%) helps maintain permeability. Thus, this combination allows good ion flow without excessive compaction, ensuring grounding systems remain effective over time.

Practical Application and Suitability

Palm dregs have a unique combination of chemical and physical properties (Umar et al., 2013), making them a viable solution to optimize the grounding system's performance. It has a high moisture retention capacity, stabilizing soil conductivity and preventing resistance from rising in dry soil conditions. Meanwhile, loam, a soil type with a texture comprising a balanced mixture of sand, silt, and clay, provides sufficient permeability and structural integrity with improved ion exchange and current conduction. Furthermore, the moderate EC, precisely at 1.84 mS/cm, drives consistent discharge characteristics of electrical currents, helping to sustain consistent voltage over time while also improving the long-term effectiveness of the ground connection. In addition, a pH of 5.51 is slightly acidic and helps in better ion movement in the soil, which plays a vital role in keeping resistivity low and enabling an efficient grounding system. The alternative mixture consists of 92.60% organic matter that increases moisture retention, reduces degradation, and decreases the possibility of soil erosion, providing a better and more reliable long-term grounding solution. Accordingly, palm dregs can be utilized independently or combined with high-conductivity materials like bentonite or graphite as an economical and environmentally friendly substitute for standard grounding enhancement agents. It, ultimately, provides a practical option for optimizing grounding in various environmental settings.

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Conclusion and Future Research Recommendations

These findings indicate that palm dregs could be a sustainable alternative for enhancing grounding system performance. It has been reported that palm dregs have sufficient EC, moisture-holding capacity, and balanced soil composition, which collectively promote a conductive function, helping improve soil conductivity and stabilize grounding resistance. Concurrently, palm dregs exhibited a charge dissipating ability (EC = 1.84 mS/cm), and due to their high contents of organic matter (92.60%), they can effectively absorb moisture (the optimal water level increase) and assist in mass stabilization in the soil. Moreover, the soil texture of the soil is loamy, as it is composed of sand (17.72%), silt (51.50%), and clay (30.78%), indicating it maintains a good soil structure that favors the retention of water and the movement of ions needed to decrease electrical resistance in grounding systems. However, although palm dregs have beneficial characteristics, their standalone conductivity may be insufficient to replace conventional chemical-based grounding enhancers completely (Ahmad et al., 2018). Additionally, blending with high-conductivity materials (bentonite, graphite, conductive salt additives) can improve efficiency. Nevertheless, by assuring a steady and swift reduction in overall grounding resistance for a longer duration (days, months, and years), palm dregs can be considered a feasible, sustainable, and low-cost solution for grounding.

Recommendations for Future Research

To enhance the understanding and improve the effectiveness of palm dregs as a grounding material, future studies should focus on the following key areas:

Long-Term Stability and Decomposition Analysis

i. Conduct detailed studies on the degradation of palm dregs in different soil types to examine how their properties change over time.
ii. Investigate biodegradation rates and microbial activity to assess how decomposition affects long-term stability in grounding applications.

Synergistic Effects withConductive Enhancers

i. Perform experimental studies on blending palm dregs with high-conductivity materials, such as bentonite, graphite, and other conductive additives, to improve grounding efficiency.
ii. Identify optimal mixture ratios that best balance cost-effectiveness and conductivity improvement.

Performance Across Different Environmental Conditions

i. Evaluate the suitability of palm dregs in various climates, including humid, dry, and saline conditions, to determine their adaptability in different geographical locations.
ii. Assess material stability and moisture retention in extreme environmental scenarios, such as extended droughts followed by heavy rainfall, to evaluate its reliability in real-world applications.

Field Trials and Large-Scale Implementation

i. Conduct on-site grounding tests in industrial and electrical facilities to compare real-world performance with laboratory results.
ii. Monitor long-term variations in soil resistance and moisture content to validate the practical effectiveness of palm dregs in different soil types.

Economic and Environmental Considerations

i. Assess the financial feasibility of using palm dregs compared to conventional grounding enhancement materials through a cost-benefit analysis.
ii. Investigate environmental impacts, particularly in terms of soil quality, potential leaching, and sustainability, to ensure that palm dregs provide a safe and eco-friendly alternative.

Using palm dregs as an alternative grounding enhancement material could be an interesting way to reduce agricultural waste and promote sustainability in the electrical engineering industry. These fibrous by-products, which are usually treated as waste products in the palm oil industry, contain inherent properties like carbon-rich content and adequate particle size to facilitate soil conductivity. Furthermore, this reformed soil improves electrical grounding systems by dissipating fault currents, reducing voltage potentials, and improving the safety of personnel and equipment. In addition, palm dregs have other advantages concerning their use as material to lower the total costs of a given grounding system, such as their biodegradability, abundant availability, and relatively minor harm compared to traditional backfilling materials. Their use would also lead to more circular agricultural systems, turning waste into valuable resources rather than letting them sit in landfills. However, mixing palm dregs with grounding requires optimized conductivity, moisture retention, and stable long-term performance. This can also involve testing exhibiting potential heating techniques such as pyrolysis or controlled decomposition and utilizing palm dregs with peripherals or extra additives that could build conductivity or decrease material crumbling or pressing over a time frame.

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