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"PULER" INNOVATION: PALM OIL MILL SOLID WASTE AS ORGANIC FERTILIZER TO SUPPORT SDG'S 12

[1]Ika Ucha Pradifta R, [2]Tifany Zia Aznur, [3]Saroha Manurung, [3]Aulia Juanda, [1]Mahyunis, [2]Dina Arfianti Saragih, [2]Delyana R Pulungan, [4]Ritna Wahyuni
[1]Program studi Teknologi Pengolahan Hasil Perkebunan,
[2]Program studi Agribisnis,
[34]Program Studi Budidaya Perkebunan, Program studi Sistem&Teknologi Informasi, Institut Teknologi Sawit Indonesia
Corresponding author : ucha@itsi.ac.id

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Abstract

Palm oil mill boiler ash is a solid industrial waste available in large quantities, but its utilization is still limited. This waste has alkaline properties and nutrient content that has the potential to improve the physical-chemical properties of tropical acid soils, such as pH, cation exchange capacity, and macronutrient availability, making it a potential sustainable soil ameliorant. This study aims to process organic fertilizer, namely an organomineral product based on boiler ash, with the aim of evaluating its chemical characteristics and assessing its potential application as a soil ameliorant. The analysis results show that Puler has a pH value of 9 and a nutrient composition that can improve soil quality without heavy metal concentrations above the Indonesian national standard threshold. These findings indicate that Puler can be an efficient alternative ameliorant and supports the utilization of palm oil industry waste. In addition, this puler also meets the criteria for organic fertilizer standards according to SNI 7763:2024 .

Keywords: Boiler ash; Popular; Soil ameliorant; Organominerals; Coconut palm oil.

INTRODUCTION

The Sustainable Development Goals (SDGs), particularly SDG 12: Responsible Consumption and Production, emphasize the importance of efficient resource management and waste reduction through circular economy principles. In the palm oil industry, the use of solid waste such as boiler ash as a soil ameliorant is a concrete implementation of SDG 12, as it transforms industrial waste into environmentally friendly, value-added products. This approach not only reduces environmental pollution but also supports sustainable agricultural practices by improving soil quality and the efficiency of agricultural input use.(Tandiono et al., 2025) In the industrial era, anthropogenic pressure on the environment has increased and accelerated soil degradation in tropical regions, as evidenced by changes in the physical, biological, and chemical properties of soil—including decreased pH, base saturation, and organic matter content—due to intensive cultivation practices (HAFIF, 2020).

Palm oil mills produce approximately 5% boiler ash from the total biomass burned, thus offering significant potential for use as an ameliorant. Boiler ash contains 0.74% N, 0.84% P_2O_5, 2.07% K_2O, 0.62% Mg, and other micronutrients, all of which contribute to increasing soil pH. Utilizing this waste not only reduces environmental pollution but also provides agronomic benefits due to its high potassium content and its non-hazardous nature, making it suitable for reuse as a crude fertilizer (Gultom, 2023). Boiler *fly ash* is a solid waste product resulting from the combustion of palm kernel shells and fibers in palm oil mill boilers. Chemically, fly ash contains mineral compounds such as silica (SiO_2), calcium oxide (CaO), and aluminum oxide (Al_2O_3), which provide basic properties and functional potential in various applications. (Effendi et al., 2022) Based on previous research, the characteristics of boiler ash are grayish black, classified as granular soil (A-3), particle size 0.076 mm – 4.75 mm, boiler ash contains a number of macro and micro nutrients of N 0.74%, P_2O_5 0.84%, K_2O 2.07%, Mg 0.62%(Tri & Sasongko, 2023). Boiler ash applied to green peanut plants showed that the boiler ash had a significant difference in all observation parameters, namely 337.5 g/plot, which was measured through flowering age and harvest age. Boiler ash applications can meet plant potassium needs, while improving soil chemistry through the addition of organic matter, which increases cation exchange capacity, improves phosphate solubility, and provides nutrients. Organic fertilizers also

improve soil biology, with microbial activity indirectly improving the physical and chemical properties of the soil (Hidayati & Indrayanti, 2016). Previous research has shown that boiler ash can be used as an organic fertilizer, providing nutrients in oil palm plantations. Applied research should be conducted in oil palm plantations, applying boiler ash to oil palm plantations, and it is hoped that this will result in increased harvest productivity within 1-2 years. Several studies have shown that boiler ash can improve soil chemical properties, including increasing pH, cation exchange capacity, and nutrient availability. In peat agroecosystems, the application of boiler ash-based ameliorants has been reported to increase soil pH and chemical components and reduce CO_2 emissions (Tandiono et al., 2024). The combination of boiler ash with other organic materials has also been shown to increase pH and N, P, and K concentrations in Ultisol soils (Nurjanah et al., 2025). However, research related to the development of boiler ash-based organomineral products and the evaluation of their characteristics as ameliorants for tropical acid soils is still very limited. This research aims to develop a formulation of an organomineral ameliorant product based on boiler ash mixed with biochar and animal manure. This product, called puler, is intended as an alternative organic fertilizer that can meet organic fertilizer standards according to SNI 7763:2024 . It is also expected to improve the physicochemical properties of soil, often referred to as soil fertility, in plantations.

RESEARCH METHODS

The research was conducted by the Plantation Product Processing Technology Study Program, Indonesian Palm Oil Technology Institute, and the Palm Oil Research Center Laboratory, PT RPN, to test chemical characterization, product formulation, and quality standardization. Raw materials were sourced from the plantation of PT. Sahabat Sejati Setia Selalu.

2.1. Materials and Tools

The raw materials used are dried and sieved boiler ash. Biochar derived from empty bunches, dried and finely sieved cow dung with a mesh , 250 ml of water. The tools used in this study are a granulator machine with a diameter of 96 cm, a height of 103 cm, a length of 97 cm, a width of 175 cm, d2: 120 cm, R: 18 cm. 60 mesh vibrating sieve, a shovel, a tarpaulin.

Figure 1. Puler Raw Materials

2.2. Research Procedures

This research uses a laboratory experimental approach to characterize the "Puler" material produced from palm oil mill boiler ash. The process of making Puler organic fertilizer involves the following steps:

a. Puler Raw Material Preparation Process

The raw material preparation process begins with the preparation of boiler ash, the waste product from palm oil mill boilers. Fine boiler ash is used, which is sieved to obtain a fine powder. Next, empty oil palm bunches (EFBs) are used, which have been converted into biochar. This biochar is obtained from pyrolysis using a furnace for 24 hours under low-oxygen conditions. The cow dung is then sieved until the mixture is smooth and cohesive.

b. Mixing and Granule Making Process

After the raw materials, namely boiler ash, biochar, and cow dung have been prepared and obtained to the desired condition, a mixing process is carried out. This mixing process is carried out using water and is carried out using a granulator at 80 rpm for 10 minutes until granules are formed.

2.3. Popular Quality Analysis

The quality analysis of this pellet refers to SNI 7763:2024 for organic fertilizers. The fertilizer analysis is as follows:

1. pH
2. C-organic
3. N-total
4. C/N ratio
5. Heavy metals: Pb, Cd, Hg, Ni
6. macro content (N, P, K, Ca, Mg)

3. RESULTS AND DISCUSSION

3.1. Chemical Characteristics of Puler Content

The development of Puler products based on palm oil mill boiler ash is an innovative way to downstream industrial waste, aligning with SDG 12 on responsible consumption and production. Puler's chemical characteristics demonstrate that solid palm oil industry waste can not only be safely managed but also be enhanced to produce organomineral products that improve soil quality. This approach supports the concept of a circular economy, where industrial waste is reused in agricultural production systems without increasing the burden of environmental pollution.(Tandiono et al., 2025)

Table 1. Chemical Characteristics of Puler as a Solid Organic Fertilizer

Parameter	Unit	Test Result Value	Standard Limits
Nitrogen (N)	%	0.67	0.4–2.5
C-Organic	%	23.44	>15
pH	-	9.30	6–8
Associated Materials	%	9.25	<25
C/N	-	34.99	10–25
US	ppm	0.58	<10
Hg	ppb	<0.0034	<1
Pb	ppm	19.00	<50
CD	ppm	1.96	<5
This	ppm	16.88	<50
Water content	%	31.99	<50

Laboratory tests show that Puler has the potential to be a solid organic fertilizer due to its nutrient content and chemical properties, particularly in improving the pH of acidic soils and increasing nutrient availability. Therefore, Puler serves not only as an ameliorant but also as a sustainable solution for managing palm oil mill waste. PPKS–PT RPN's laboratory analysis of the "Puler" product shows that the boiler ash formulation has chemical characteristics that support its function as an ameliorant for tropical acidic soils. Based on Certificate of Analysis No. 39820/1/Sert/XI/2025, Puler has a pH of 9.30, indicating strong alkaline properties and high potential for neutralizing low-pH soils such as ultisols and peat. Based on the results of laboratory testing, the chemical characteristics of Puler generally meet the quality requirements for organic fertilizer according to SNI 7763:2024.

The organic carbon content of 23.44% exceeds the minimum limit set by the standard, indicating good organic material quality. The moisture content of 31.99% also remains below the maximum threshold, supporting product stability during storage and field application. Although Puler's pH (9.30) is slightly higher than the ideal range for organic fertilizers, its alkaline nature provides a functional advantage when applied to tropical acidic soils such as ultisols and peatlands. Furthermore, its heavy metal content, such as As, Pb, Cd, Hg, and Ni, is all below the maximum limits permitted by SNI, making Puler safe and suitable for use as a solid organic fertilizer. This high pH value is in line with research findings showing that palm oil boiler ash is able to increase soil pH through the release of base ions such as Ca^{2+}, Mg^{2+}, and K^{+}.(Tandiono et al., 2025b)

The organic C content of 23.44% indicates that Puler contains stable organic fractions that play a role in improving the physical quality of the soil, increasing aggregation, and supporting the activity of microorganisms. This percentage exceeds the minimum limit of SNI 19-7030-2004, thus meeting the national organic fertilizer requirements. The C/N ratio of 34.99 indicates that Puler has a slow-release character that has the potential to improve the soil in the medium to long term, as also reported in the study of the characteristics of boiler ash + organic matter in ultisol soil (Nurjanah et al., 2025)indicating that the use of this waste in organomineral formulations is a prospective approach. The content of macro nutrients such as N (0.67%), P (results not shown in the certificate), K (available from the mineral fraction of boiler ash) shows that Puler can function as a provider of additional nutrients in oil palm land, especially the element K which is very much needed by oil palm plants to support the production of fresh fruit bunches (FFB). This is consistent with previous studies that boiler ash can increase the availability of potassium in soil and plants (.Tri & Sasongko, 2023).

Heavy metal testing showed that As (0.58 ppm), Pb (19 ppm), Cd (1.96 ppm), and Ni (16.88 ppm) values were well below the national standard maximum threshold for ameliorant materials. These findings confirm that Puler is safe for use in palm oil production systems and does not pose a risk of heavy metal residues. These results are consistent with reports that boiler ash from palm oil mills is not classified as B3 waste and is very safe to be used as a plant cultivation material (Gultom, 2023). Boiler ash can significantly increase soil pH, increase available P and cation exchange capacity, (Nurjanah et al., 2025)become a cheap source of K, Ca, and Mg for oil palm plantations, improve the chemical quality of peat and ultisol soils, and have no negative impact on heavy metal content. From a downstream perspective, Puler's chemical characterization, which passed the standards, demonstrates that boiler ash waste can be upgraded into a ready-to-use organomineral product, thus supporting the innovation direction outlined in the Matching Fund proposal. These findings also provide empirical evidence that Puler meets the requirements for field application and commercialization.

3.2. Puler Granule Manufacturing Process

After the raw materials, namely boiler ash, biochar, and cow dung have been prepared and obtained to the desired condition, a mixing process is carried out. This mixing process is carried out using water and is carried out using a granulator at 80 rpm for 10 minutes until granules are formed.

Figure 2 shows the granules produced from the puler produced in the study. This puler was produced using a mixture of 60% boiler ash, 20% biochar, and 20% cow dung, with 250 ml of water per kg of puler produced.

Figure 2. Granulator Machine and Puler Granules as Organic Fertilizer

4. CONCLUSION

Based on the research results it was concluded that

1. Chemical characterization of Puler, an organomineral ameliorant product based on palm oil mill boiler ash, has met most of the organic fertilizer quality parameters according to SNI 7763:2024. Its high organic carbon content, standard water content, and low heavy metal content indicate that Puler is safe and suitable for application on agricultural land, especially tropical acidic soils.
2. Puler's alkaline properties provide the added benefit of increasing soil pH and improving nutrient availability, thus supporting oil palm productivity. Thus, the research objective of developing an organic fertilizer formulation based on boiler ash waste that meets national standards has been achieved.

5. THANK YOU

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