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Lead and cadmium content in soil, oil palm fiber, and palm kernel in the oil palm plantation with mulch application

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ABSTRACT

Solid waste in palm oil mills is waste that has the potential to have a negative impact on the environment if not used properly. One of the solid wastes from palm oil mills is empty fruit bunche (EFB) which can be used as mulch on oil palm land. The mulch and inorganic fertilizer used can contain heavy metals, such as Pb and Cd. This study was aimed to assess the heavy metal content of Pb and Cd in the soil, fibers and kernels of oil palm fruit. This study evaluated the Pb and Cd content in the soil at depths of 0 – 20 cm and 20 – 40 cm, palm fiber and palm kernel. The results showed of the study showed that the Pb and Cd content of soil on land applied with inorganic fertilizer was greater than the Pb and Cd content of soil on land applied with mulch, where on land applied with mulch the level of Pb contamination was in the very slightly contaminated category, while Cd was in the quite polluted category, and inorganic fertilizer land is heavily polluted. On land where mulch was applied, the Pb and Cd content of fiber and kernel was smaller than the Pb and Cd content of fiber and kernel on land where inorganic fertilizer was applied.

INTRODUCTION

The yield harvested from oil palm plantations are fresh fruit bunch (FFB) which is used as raw material to produce crude palm oil (CPO) and crude palm kernel oil (CPKO) in the palm oil mill. The part of FFB that produces CPO is the fruit fiber (mesocarp) while the part that produces CPKO is the fruit core (kernel) (MURGIANTO et al., 2021). Apart from producing palm oil, the palm oil mill also produces waste in the form of liquid, solid and gas. Solid waste in the palm oil mills is waste that has the potential to have a negative impact on the environment if not used properly. One of the solid wastes from the palm oil mills is empty fruit bunch (EFB) which can be used as mulch on oil palm land.

Mulch functions as an organic material for land in the oil palm plantation. Using EFB as mulch can improve soil water and nutrient retention, thus playing an important role in soil conservation and soil fertility improvement (MORADI et al. 2015). The application of EFB mulch increased soil moisture (water conservation), suppressed weed growth and prevented soil erosion, and decomposition of mulch increased the nutrient content of the soil (ANYAOHA et al., 2018).

Inorganic fertilizers that are used intensively and continuously have a negative impact on the environment, this is because they increase the content of heavy metals such as Cd, and Pb in the soil (HAMID et al., 2019; CHEN et al., 2020). Continuous contamination of Pb and Cd in the soil will have a negative impact on the environment (NOVITASARI et al., 2017).

According to Dewi et al. (2023) inorganic fertilizers containing heavy metals will accumulate in the soil and be transported to the plants and enter the human food chain after being harvested. Plants that grow on potentially polluted soil will accumulate these metals in the roots, stems, leaves, and fruit (AGUSTINA, 2014). Based on the problems above, it is necessary to study the lead and cadmium content in soil, fiber and kernel of oil palm fruit on the oil palm plantation where mulch and inorganic fertilizer are applied.

MATERIAL AND METHOD

This study was carried out at the oil palm plantation PT Bina Mitra Makmur, Bathin II Distric, Muaro Bungo Regency, Jambi Province, Indonesia. The sampling plot was made by dimensions of 20 m x 20 m with a distance between the plot of 5 m. The sampling location was determined based on the similarity of soil type, altitude and the same slope class at each age of the oil palm plant (18 years old). Sampling locations were carried out at (1) EFB mulch and inorganic fertilizer application (L1), (2) inorganic fertilizer (L2), and (3) control land (without mulch and inorganic fertilizer), namely residential land (L3). Inorganic fertilizers used were urea, KCl, rock phosphate, dolomite, and borate. Each sample was taken at five points in each field. Locations 1 and 2 are next to each other, while control land was 400-500 m from L2. The land area of land type 1 was 10 hectares, while land type 2 was 20 hectares.

Soil sampling was carried out at up to 5 sample points at depths of 0 – 20 cm and 20 – 40 cm. Soil samples at a depth of

0 – 20 cm at five points were composited and also at a depth of 20 – 40 cm and put in a plastic bag of 1000 grams. Sampling of fresh fruit bunches (FFB) was carried out by taking FFB from oil palm trees at the same 5 points as the soil sampling points that have been determined and the FFB was composited both in mulch and inorganic fertilizer fields and in inorganic fertilizer fields. Fiber and kernel from FFB were taken for analysis of Pb and Cd content.

Soil samples were air-dried, crushed and sieved using a 2 mm sieve. Soil analysis was carried out to determine pH (pH H_2O 1:2), organic C (Walkley and Black) and soil Cd (wet ashing, a mixture of HNO_3 and $HClO_4$ acids) (SULAEMAN et al., 2005). Fiber and kernel were dried in an oven at 70^0 C until they reached a constant dry weight. The fibers and kernels were ground until very fine. Determination of the Pb and Cd content of fiber and kernel was carried out by wet ashing using HNO_3 and $HClO_4$ (SOIL SCIENCE SOCIETY OF AMERICA, 1973).

Data on Cd and Pb content in soil and plants obtained were compared with quality standards. In addition, the Pb and Cd content in the soil was analyzed using the contamination/pollution (C/P) index to evaluate the level of pollution which indicates the level of heavy metal contamination in the soil (Table 1). Determination of the level of heavy metal contamination in soil on residential land, mulch and inorganic fertilizer land, and inorganic fertilizer land using the Lacutusu equation in Yanova et al. (2020).

$$\text{Index C/P} = \frac{\text{Concentration of heavy metal in soil}}{\text{Soil heavy metal threshold values}} \text{ (Equation 1)}$$

Table 1. Contamination/pollution (C/P) rate based on Index of level of heavy metal contamination in the soil

Index C/P	C/P level
0	Not contaminated
< 0.10	Very slightly contaminated
0.10 – 0.20	Slightly contaminated
0.26 – 0.50	Quite contaminated
0.51 – 0.75	Heavily contaminated
0.76 – 1.00	Highly contaminated
1.10 – 2.00	A little polluted
2.10 – 4.00	Pretty polluted
4.10 – 8.00	Heavily polluted
8.10 – 16.0	Very polluted
> 16.00	Very, very polluted

Source: Yanova et al. (2020).

RESULTS AND DISCUSSION

The application of chemical fertilizer (inorganic fertilizer) shows an increase in the content of the heavy metals Pb and Cd in the soil (Table 2), where the Pb and Cd content in soil treated with inorganic fertilizer was 2,468-2,528 mg/kg and 2,880-2,930 mg/kg which was higher than the others, whereas the soil applied with mulch and inorganic fertilizer had a lower heavy metal content, namely 1.182-1.626 mg/kg Pb and 1.381 and 1.454 mg/kg Cd. The lowest Pb and Cd contents were obtained in residential land, namely 0.712-0.850 mg/kg and 0.608-0.665 mg/kg. The increase in Pb and Cd content in soil applied with chemical fertilizer or inorganic fertilizer is due to the heavy metal content Pb and Cd in urea fertilizer (< 0.4 mg/kg Pb and < 0.01 mg/kg Cd) (ROBARGE et al., 2003), muriate of potash (< 0.4 mg/kg Pb and 0.4 – 0.6 mg/kg Cd) (ROBARGE et al. 2003), rock phosphate (7 – 225 mg/kg Pb and 30 – 60 mg/kg Cd) (MAHENDRA et al., 2018).

The Pb and Cd content in the top layer of soil (0-20 cm) is higher than in the lower layer of soil (20-40 cm). This is because the application of chemical fertilizer is carried out on the soil surface to a depth of the tilled layer, namely 0-20 cm. The vertical translocation of heavy metals from the top layer to the bottom layer of the soil is relatively small. Nuralykyzy et al. (2021) also found that the content of heavy metals in the top layer of soil was higher than the content of heavy metals in the bottom layer of soil. Based on the standard quality standards for Pb metal in soil according to US EPA 2002 on residential land, mulch and inorganic fertilizer land, and inorganic fertilizer land does not exceed the quality standard standards. However, the content of Cd in residential land, mulch and inorganic fertilizer land, and inorganic fertilizer land exceed the quality standard standards. The sources of Pb and Cd pollution are related to anthropogenic activities, such as agricultural activities applying inorganic fertilizers that contain these metals (PATTY et al., 2018), while the source of heavy metal Cd pollution on residential land could come from household waste such as plastic, cement, steel, ceramics and paint (SUTRISNO; KUNTYASTUTI, 2015).

The fertilizer used on the land contains phosphate nutrients such as rock phosphate fertilizer. According to Wangge et al. (2022) the use of inorganic fertilizer containing phosphate elements can increase Cd in the soil. This causes the Cd content in land that applies inorganic fertilizer to be higher than the Pb content on residential land. Apart from testing the Pb and Cd content in soil samples, pH measurements were also carried out on soil samples at depths of 0 – 20 cm and 20 – 40 cm. The metals Pb and Cd are closely related to soil pH because soil pH is one of the chemical properties of soil. The soil pH value at the research location can be seen in Table 3.

Table 2. The content of Pb and Cd in soil of residential area, mulch and inorganic fertilizer, and inorganic fertilizer application in the oil palm plantation

No	Parameter	Soil depth (cm)	Location			Quality Standard Value*
			Residential area	Mulch and inorganic fertilizer	Inorganic fertilizer	
			mg/kg			
1.	Pb	0 – 20	0.850	1.626	2.528	200
		20 – 40	0.712	1.182	2.468	
2.	Cd	0 – 20	0.665	1.454	2.930	0.480
		20 – 40	0.608	1.381	2.880	

* US Environmental Protection Agency (EPA) 2002.

Based on Table 3, the soil pH in residential areas at a depth of 0 – 20 cm is 6.72 and at a depth of 20 – 40 cm is 6.54. On mulch and inorganic fertilizer land, the soil pH value at a depth of 0 – 20 cm is 6.32, while at a depth of 20 – 40 cm it is 6.21. Meanwhile, the soil pH in inorganic fertilizer fields at depths of 0 – 20 cm and 20 – 40 cm respectively are 6.52 and 6.45. The pH value of the soil on residential land is higher than on land with mulch and inorganic fertilizers, and inorganic fertilizers. According to Khasanah et al. (2021) soil pH can be used as an indicator of soil chemical fertility which can reflect the availability of metals in the soil, in which on the lower pH, the availability of metals in the soil tends to be higher. The Pb and Cd content in residential land is lower than in mulch and inorganic fertilizer land, and inorganic fertilizer land because its soil pH are higher than those on the other lands.

Table 3. Soil pH in the oil palm plantations of residential area, mulch and inorganic fertilizer, and inorganic fertilizer application

Soil Depth (cm)	pH		
	Residential Area	Mulch and Inorganic fertilizer	Inorganic fertilizer
0 – 20	6.72	6.32	6.52
20 – 40	6.54	6.21	6.45

Land can be declared polluted or not polluted depending on the level of heavy metal pollution. Internal heavy metal pollution is based on the Contamination/Pollution (C/P) index value. The level of Pb metal pollution in the soil at the research location can be seen on Table 4.

Table 4. Contamination/pollution (C/P) Index of Pb metal in soil in the oil palm plantations of residential area, mulch and inorganic fertilizer, and inorganic fertilizer application

Location	Depth (cm)	Pb concentration (mg/kg)	Threshold value	Index C/P	Level C/P
Residential Area	0-20	0.850	200	0.00425	Very slightly contaminated
	20-40	0.712		0.00356	Very slightly contaminated
Mulch and Inorganic fertilizer	0-20	1.626		0.00813	Very slightly contaminated
	20-40	1.182		0.00591	Very slightly contaminated
Inorganic fertilizer	0-20	2.528		0.01264	Very slightly contaminated
	20-40	2.468		0.01234	Very slightly contaminated

Based on Table 4, the C/P levels of Pb metal in residential land, mulch and inorganic fertilizer land, and inorganic fertilizer land at depths of 0 – 20 cm and 20 – 40 cm are categorized as very slightly contaminated with heavy metals due to the C/P index value on these lands. is < 0.1. This land is in the category of very little contamination, because according to Fitrianah and Purnama (2019) the increase of Pb content in the soil is due to a long-term and continuous use of chemical fertilizers on agricultural land so that the accumulation of heavy metals occurs.

The level of Cd metal pollution in soil in residential land, mulch and inorganic fertilizer land, and inorganic fertilizer land can be seen in Table 5.

Based on Table 5, the C/P level in residential land at depths of 0 – 20 cm and 20 – 40 cm is included in the slightly polluted category. This is because the Cd content in the land is 0.665 mg/kg and 0.608 mg/kg. C/P levels in mulched land and inorganic fertilizers at depths of 0 – 20 cm and 20 – 40 cm are categorized as moderately polluted. In this land, the Cd content at depths of 0 – 20 cm and 20 – 40 cm is higher than in residential land, namely 1.454 mg/kg and 1.381 mg/kg so that the C/P index value is in the range of 2.1 and 4.0. Meanwhile, the C/P level in the soil of inorganic fertilizer fields at a depth of 0 – 20 cm and 20 – 40 cm is categorized as heavily polluted because the C/P index value on this land is between 4.1 and 8.0. Heavy metal Cd pollution in soil occurs due to long-term use of phosphate fertilizers, that contain Cd (MAHENDRA et al., 2018).

The soil used as a planting medium on this land contains heavy metals, so the fresh fruit bunches produced have the potential to contain heavy metals such as Pb and Cd. According to Fitrianah and Purnama (2019), the metal content in the soil influences the metal content in the plants that grow on it. Based on this, this research tested Pb and Cd on oil palm fiber and kernels in mulch and inorganic fertilizer land, and inorganic fertilizer land. The values of Pb and Cd content in oil palm fiber and kernel can be seen on Table 6.

Tabel 5. Contamination/pollution (C/P) Index of Soil Cd in the oil palm plantations of residential area, mulch and inorganic fertilizer, and inorganic fertilizer application

Location	Depth (cm)	Cd concentration (mg/kg)	Threshold vallue	Index C/P	Level C/P
Residential area	0-20	0.665	0.480	1.385	A little polluted
	20-40	0.608		1.266	A little polluted
Mulch and Inorganic Fertilizer	0-20	1.454		3.029	Moderately polluted
	20-40	1.381		2.877	Moderately polluted
Inorganic fertilizer	0-20	2.930		6.104	Heavily polluted
	20-40	2.880		6.00	Heavily polluted

It can be seen on Table 6 that the values of Pb content in palm fiber and kernel on mulched and inorganic fertilizer land are 0.039 mg/kg and 0.024 mg/kg. Palm fiber and kernel on inorganic fertilizer land, contain 0.067 mg/kg and 0.027 mg/kg Pb. The Cd content value for oil palm fiber is 0.028 mg/kg, while the Cd content of palm kernel is 0.022 mg/kg. The Cd content of palm fiber is higher than the Cd content value of palm kernel. In inorganic fertilizer land, the value of Cd content in oil palm fiber is 0.049 mg/kg, while in oil palm kernel it is 0.032 mg/kg. The Pb and Cd content in palm fiber is higher than in palm kernel, this is because palm fiber is the outermost part of the empty palm fruit bunches (FFB). According to Suhaeni and Wardi (2016), the heavy metal content in plant parts decreases according to the order closest to the soil, namely roots, stems, leaves, fruit and seeds. Thus, the further away from the ground the smaller the heavy metal content. On land with much application, the contents of Pb and Cd on fiber and kernel are lower than those on land with inorganic fertilizer application. This occurred because soil organic material from the decomposition of some mulches can adsorb and form complex compounds with Pb and Cd so that its availability in the soil is reduced and the amount that can be absorbed by plants is also reduced (KHAN et al., 2017).

Table 6. Pb and Cd content of oil palm fiber and kernel on mulched and inorganic fertilized land, and inorganic fertilized land

No.	Parameter	Plant	Land	
			Mulch and Inorganic Fertilizer	Inorganic Fetilizer
			mg/kg	
1.	Pb	Oil palm fiber	0.039	0.067
		Oil palm kernel	0.024	0.027
2.	Cd	Oil palm fiber	0.028	0.049
		Oil palm kernel	0.022	0.032

CONCLUSIONS

The Pb and Cd content of soil on land applied with inorganic fertilizer is greater than the Pb and Cd content of soil on land applied with mulch, where on land applied with mulch the level of Pb pollution is in the very slightly contaminated category, while Cd is in the quite polluted category, whereas on inorganic fertilizer land, including heavily polluted.

On land where mulch was applied, the Pb and Cd content of palm fiber and kernels was smaller than the Pb and Cd content of palm fiber and kernels on land where inorganic fertilizer was applied.

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