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Effect of Bio-Organomineral Fertilizer on Soil Chemical Properties and PB Content of Industrial Waste Polluted Soil

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ABSTRACT: Rancaekek Sub-district is one of the agricultural centers in Bandung Regency, Indonesia, which is currently experiencing land conversion into an industrial area. The industrial activities produce waste containing heavy metal lead (Pb), which if not treated can pollute the soil and surrounding waters. Efforts to overcome soil pollution are through fertilization. The purpose of this study was to determine the effect of the dose and incubation time of Bio-organomineral fertilizer with *Bacillus subtilis* biological agent on improving soil chemical properties and reducing soil Pb levels. This study used a two-factor Factorial Randomized Block Design, namely the dose and incubation time of Bio-organomineral fertilizer. The results showed that the combination of Bio-organomineral fertilizer dose of 225 kg ha-1 and an incubation time of 30 days was able to increase soil K-potential. The independent factor of Bio-organomineral fertilizer dose had a significant effect on increasing soil pH. The independent factor of incubation time had a significant effect on reducing soil Pb levels. In particular, there was an interaction between the dose and incubation time of Bio-organomineral fertilizer on soil K-potential.

KEYWORDS: *Bacillus subtilis*, Bio-organomineral fertilizer, polluted soil, lead

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INTRODUCTION

The agricultural area of Rancaekek experiences land conversion into an industrial area. Industries often produce waste and emissions that can pollute the environment, such as water and air. Over the years, the Cikijing river body has been polluted with waste that can endanger life, including humans, due to human-induced pollution (Sutono & Kurnia, 2013; Wijatmoko & Hariadi, 2008).

One of the main pollutants that is very dangerous for the environment and living things is lead (Pb). Amelia *et al*. (2015) shows that Pb levels in rice fruit reach 2,298 ppm, exceeding WHO/FAO and BPOM standards of 0,5 ppm. The impact of Pb on rice growth, such as plant height, number of leaves, and biomass, is very negative. Komarawidjaja (2016) also records Pb accumulation in water spinach plants at 69,42 mg.kg^{-1}, exceeding the content in soil polluted by industrial waste in Rancaekek Sub-district (<0,0005 mg.L^{-1}). Although the Pb content in the soil is still low, its presence can endanger human health if exposed to more than the safe limit due to its cumulative toxicity (Hananingtyas, 2017).

Various factors, such as soil pH and K-potential, affect the uptake of Pb metal by plants. Pb is more soluble and absorbed by plants in acidic soils (Azeem *et al*. (2019). Therefore, K-deficient plants absorb more Pb to fulfill their nutritional needs (McGrath & Zhao, 2003; Salt *et al*., 1998). One way to increase soil pH and K-potential and reduce Pb metal content is by using Bio-organomineral fertilizer.

Bio-organomineral fertilizer is a modification of Bio-organomineral N fertilizer with added biological agents, consisting of urea, palm bunch charcoal, zeolite, and compost with biological agents *Pseudomonas cepacia* and *Bacillus subtilis* (Sudirja *et al*., 2019). Bio-organomineral fertilizer application increases pH compared to the control (Widodo *et al*., 2018). Wulansari *et al*. (2022) records an increase in K-potential of 56,39 mg.100 g^{-1} in the 1 NPK + 1 BIOM treatment, compared to the control which is only 27,33 mg.100 g^{-1}. This study aims to determine the effect of dose and incubation time of Bio-organomineral fertilizer on improving soil chemical properties and reducing Pb content in industrial waste-polluted soil.

MATERIALS AND METHODS

Location

The greenhouse scale experiment was conducted at Jatinangor Campus, Faculty of Agriculture, Padjadjaran University, West Java, Indonesia. Soil samples were taken from paddy fields polluted by textile industry waste in Jelegong Village, Rancaekek District, Bandung, Indonesia. The soil sample had pH 6,48 (slightly acidic), N-total 0,29%, P-potential 65 mg.100 g^{-1}, K-potential 52,07 cmol.kg^{-1}, C-organic 1,5%, C/N ratio 6%, CEC 59,52 cmol.kg^{-1}, Pb 18,87 ppm, and Cr 45,81 ppm.

Experimental Design

This study used a two-factor Factorial Randomized Block Design with the following treatments:

a. Factor I (Bio-organomineral fertilizer dose)

d_0 = No fertilization
d_1 = NPK recommendation 225 kg.ha^{-1}
d_2 = Bio-organomineral 125 kg.ha^{-1}
d_3 = Bio-organomineral 225 kg.ha^{-1}
d_4 = Bio-organomineral 325 kg.ha^{-1}
d_5 = Bio-organomineral 425 kg.ha^{-1}
d_6 = Bio-organomineral 525 kg.ha^{-1}
d_7 = Bio-organomineral 625 kg.ha^{-1}

b. Factor II (Bio-organomineral fertilizer incubation time)

t_1 = 10 day
t_2 = 20 day
t_3 = 30 day

The treatment was replicated three times, resulting in a total of 72 experimental pots.

Experimental Setup

Urea, guano, and palm bunch charcoal were mixed to make Bio-organomineral fertilizer in the ratio of 10:1:1. In addition, NPK, zeolite, activated charcoal, and *Bacillus subtilis* bioagent compost were mixed in a formulation ratio of 60:20:10:10. Next, the mixture was put into a granulator to form Bio-organomineral fertilizer granules.

Soil samples were taken, dried, and cleaned of weeds. A total of 1 kg of soil was put into a pot and then mixed with 5 L of water until it was about 3 cm from the soil surface. Bio-organomineral fertilizer was immersed 2-3 cm in the soil, and the soil was flooded for 30 days. Fertilized soil samples were taken at 10, 20, and 30 DAI. Tests involved pH, K-potential, and soil Pb content.

Parameters and Statistical Analysis

Soil pH measurement was conducted using the electrometric method. Soil K-potential and Pb content were analyzed using Atomic Absorption Spectrometry (AAS). All data were analyzed by analysis of variance ($P<0,05$). If the treatment had a significant effect on the parameters, then further tests were conducted with DMRT (Duncan Multiple Range Test) using IBM SPSS Statistic 26.

RESULTS

Soil Acidity (pH)

Based on the data in Table 1, the interaction between dose and incubation time of Bio-organomineral fertilizer had no significant effect on increasing soil pH. The application of recommended NPK gave a significant effect that was higher than without fertilization and lower than the application of Bio-organomineral, with a pH value of 6,10. Bio-organomineral application with increasing doses significantly tended to increase pH compared to no fertilization and NPK recommendations. Bio-organomineral fertilizer doses of 525 kg.ha^{-1} and 625 kg.ha^{-1} showed an increase in pH value of 6,40 and 6,46 compared to the negative and positive controls.

Table 1. Effect of Dose and Incubation Time of Bio-organomineral Fertilizer on Soil pH

Treatment	pH
Dose	
d_0 (No fertilization)	5,92a
d_1 (NPK recommendation 225 kg.ha^{-1})	6,10b
d_2 (Bio-organomineral 125 kg.ha^{-1})	6,19c
d_3 (Bio-organomineral 225 kg.ha^{-1})	6,17c
d_4 (Bio-organomineral 325 kg.ha^{-1})	6,26d

d_5 (Bio-organomineral 425 kg.ha^{-1})	6,28d
d_6 (Bio-organomineral 525 kg.ha^{-1})	6,40e
d_7 (Bio-organomineral 625 kg.ha^{-1})	6,46e
Incubation Time	
t_1 (10 day)	6,30a
t_2 (20 day)	6,16a
t_3 (30 day)	6,21a

Note: The same letter behind the number indicates that it is not significantly different according to Duncan's Multiple Range Test ($p<0,05$)

Soil K-Potential

Based on the data in Table 2, the interaction between the dose factor and the incubation time of Bio-organomineral fertilizer significantly affected the increase in soil K-potential. The best interaction in increasing soil K-potential was the d_3t_3 treatment (Bio-organomineral dose 225 kg.ha^{-1} and incubation time 30 days) with a result of 48,13 mg.100 g^{-1}. Meanwhile, the lowest interaction was found in the d_2t_2 treatment (Bio-organomineral dose of 125 kg.ha^{-1} and incubation time of 20 days) with a result of 31,28 mg.100 g^{-1}.

Table 2: Effect of Dose and Incubation Time of Bio-organomineral Fertilizer on Soil K-Potential (mg.100 g^{-1})

Dose (kg.ha^{-1})	Time (day)		
	t_1 (10)	t_2 (20)	t_3 (30)
d_2 (Bio-organomineral 125)	37,77b A	31,28a A	43,74c AB
d_3 (Bio-organomineral 225)	41,21ab AB	34,74a AB	48,13b B
d_4 (Bio-organomineral 325)	37,42a A	36,95a AB	43,20b AB
d_5 (Bio-organomineral 425)	38,97a AB	39,93a B	39,79a A
d_6 (Bio-organomineral 525)	38,02a A	40,79a B	44,15a AB
d_7 (Bio-organomineral 625)	42,44a B	38,85a B	45,37a B

Note: Lowercase letters (dose), uppercase letters (incubation time); the same letter behind the number indicates that it is not significantly different according to Duncan's Multiple Range Test ($p<0,05$)

Soil Pb Content

Based on the data in Table 3, the interaction between the dose factor and incubation time of Bio-organomineral fertilizer did not significantly affect the reduction of soil Pb content. However, the independent factor of Bio-organomineral fertilizer incubation time showed a significant effect on soil Pb content. Bio-organomineral fertiliser incubation time of 20 days and 30 days showed a decrease in soil Pb content of 18,40 ppm and 16,01 ppm compared to 10 days Bio-organomineral fertiliser incubation time (23,27 ppm).

Table 3. Effect of Dose and Incubation Time of Bio-organomineral Fertilizer on Soil Pb Content

Treatment	Pb (ppm)
Dose	
d_0 (No fertilization)	19,12a
d_1 (NPK recommendation 225 kg.ha^{-1})	19,23a
d_2 (Bio-organomineral 125 kg.ha^{-1})	19,35a
d_3 (Bio-organomineral 225 kg.ha^{-1})	19,48a
d_4 (Bio-organomineral 325 kg.ha^{-1})	19,05a
d_5 (Bio-organomineral 425 kg.ha^{-1})	18,87a
d_6 (Bio-organomineral 525 kg.ha^{-1})	19,11a
d_7 (Bio-organomineral 625 kg.ha^{-1})	19,59a

Incubation Time	
t_1 (10 day)	23,27b
t_2 (20 day)	18,40a
t_3 (30 day)	16,01a

Note: The same letter behind the number indicates that it is not significantly different according to Duncan's Multiple Range Test ($p<0,05$)

DISCUSSION

Bio-organomineral fertilizers were the focus of research in improving soil conditions through their properties of enhancing pH, K-potential, and reducing Pb content. The success of these fertilizers was not only related to their effects independently but also to the complex interaction between dose and incubation time. The combination of ingredients in Bio-organomineral fertilizer could help the soil remediation process.

As a source of potassium, oil palm bunch charcoal had the ability to improve soil physical, chemical, and biological properties due to its high potassium content (Kesumaningwati, 2015). During the decomposition process, palm bunch charcoal released mineral base cations such as Ca, Mg, Na, and K. This release increased the concentration of OH ions and caused the pH to increase. In addition, organic matter also had the ability to buffer the pH value (Sandrawati *et al*., 2018).

Zeolite as a soil ameliorant had the ability to exchange H^+ and Al^{3+} ions in the soil by basic cations contained in zeolites, such as Ca, K, and Mg (Nursanti & Kemala, 2019). Zeolite also had a high CEC, the ability to absorb ammonium ions, and a porous structure (Arafat *et al*., 2016). The use of zeolite mineral powder increased soil pH in soils derived from acidic volcanic eruptions and could increase nitrogen retention (Sastiono, 2004).

Bacteria, particularly *Bacillus subtilis*, became the main agent in solubilizing potassium from non-exchangeable sources, allowing uptake by plants (Ahmad *et al*., 2016; Bashir *et al*., 2017). Potassium Solubilizing Bacteria (PSB) used several processes, including physical destruction and organic acid production (Mutmainnah *et al*., 2023). *Bacillus subtilis* also had the ability to bind heavy metals such as Pb, with compounds in the bacterial cell wall acting as electron receivers (Inggraini, 2014; Khastini *et al*., 2022). The interaction of metal ions with bacteria showed the role of carboxyl and phosphoryl groups in the secondary polymers of teicuronic and teichoic acids. The use of zeolite as an ameliorant in Bio-organomineral fertilizer functioned as a buffer by bacteria in the bioremediation process (Murtafi'ah *et al*., 2020).

Besides Bio-organomineral fertilizer, inundation also affected soil chemical properties such as soil pH. Inundation caused soil pH to become neutral (Sari *et al*., 2022). Jia *et al*. (2009) examined the effect of N, P, and K fertilizers on soil pH and Cd availability in flooded soils, observing that soil pH increased sharply after flooding, especially at the beginning of incubation, and then slowly decreased over time, approaching a neutral value at the end of incubation. The decrease in pH was caused by the accumulation of CO_2, which was produced when microorganisms broke down organic matter. CO_2 reacted with water to form H_2CO_3, which dissociated into H^+ and HCO_3^- (Munandar *et al*., 2018).

CONCLUSION

Bio-organomineral fertilizer increased pH and K-potential while reducing soil Pb content. The application of Bio-organomineral fertilizer at a dose of 225 $kg.ha^{-1}$ and an incubation time of 30 days was the most effective combination in increasing soil K-potential by 48,13 $mg.100\ g^{-1}$. The application of Bio-organomineral fertilizer at doses of 525 $kg.ha^{-1}$ and 625 $kg.ha^{-1}$ had the most significant effect on increasing soil pH. The incubation time of 20 days and 30 days for Bio-organomineral fertilizer was the most effective incubation time in reducing Pb levels in the soil.

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