Application of remediation treatment to reduce lead in the soil of shallot cropping

W Purbalisa, I Zulaehah and D M W Paputri

Indonesian Agricultural Environmental Research Institute, Pati, Indonesia

E-mail: purbalisa@gmail.com

Abstract. One of the pollutants on agricultural land is lead (Pb). Remediation is an effort to reduce contamination of heavy metals in agricultural soils. This study aimed to determine lead content in the soil through remediation with plus treatment. The study conducted at screen house on a pot scale using a completely randomized design with three replications and nine treatments, i.e. control/without organic fertilizer (P0), compost (P1), biochar+compost (P2), nanobiochar+compost (P3), nanobiochar+compost+consortia bacteria (P4), compost+consortia bacteria (P5), biochar+compost+consortia bacteria (P6), biochar+compost+botanical pesticide (P7) and biochar+compost+biological agents (P8). Biochar+compost (1:4) applied as basal fertilizer with dose of 2.5 t ha⁻¹. Parameters observed were lead content in the soil at 7 DAA, 37 DAA and harvest, lead content in shallot plants (leaves and tubers) after harvest. Lead analysis used wet ashing method measured by AAS. The results showed the levels of lead metal in soil decreased from time to time except in compost treatment, while the levels of lead metal in shallots were still below of critical limit ≤ 0.5 mg kg⁻¹. P3 treatment has potential to increase productivity while P4 and P0 could reduce lead soil higher than other treatment.

1. Introduction

The heavy metals are one of contaminants that are toxic to human health and can reduce the quality of agricultural soils. Heavy metals such as mercury (Hg), lead (Pb), zinc (Zn), chromium (Cr), cadmium (Cd), and cuprum (Cu) come from organic and inorganic materials from activity of agriculture, industry, and sediment [1]. Heavy metals are elements that have atomic weight more than 5 g cm⁻³ especially transition metals such as Pb, Cd, Hg [2]. Heavy metals can appear to the environment due to natural landslides in the exposed earth, exposed weathering of the exposed source rock, use of natural materials as fertilizers or soil amendments, disposal of factory waste and garbage [3]. Heavy metals are harmful to living things when they entering the metabolic system in amounts that exceed the threshold. Each heavy metal has a different threshold. Some heavy metals are dangerous because of their toxicity and often pollute the environment namely Hg, Pb, arsenic (As), Cd, Cr, and nickel (Ni) [4]. Horticultural activities using chemical pesticides intensively in shallot cropping, where it’s known that pesticide contained Pb [5]. Lead accumulation for long period causes many diseases such as reproduction failure, encephalopathy, inflammation of brain, neurophysical disorder, anemia, renal damage, hypertension and poisoning [6]. So Pb in the soil needs to reduce to produce a safe product for consumption.

Certain metals such as iron (Fe), cobalt (Co), Cu, Zn in certain amounts are needed by living things for body metabolism, but in the excessive amounts will be toxic. Meanwhile, Pb is a major chemical pollutant to the environment and very toxic to plants, animals, and humans [3]. The factors that cause heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of heavy metals to be included in the pollutant group are due to the non-degradable and easy absorption of
heavy metals [7]. Lead in the soil exists due to indigenous factors and anthropogenic inputs. Indigenous factors are caused by the parent material that forms the soil, while anthropogenic input is caused by human activities. Lead in the earth's crust is about 15 mg kg$^{-1}$ [8]. Human activities in agriculture such as the use of organic and inorganic fertilizers, pesticides, sludge, and vehicle pollution have the potential to increase the lead content in the soil, water, plants, and air [6,8].

Lead enters into the organism's body through water, food, and air. Water pollution by industrial waste can be carried away by drinking water. Vegetables can be contaminated with lead from the soil, irrigation water, or polluted air that is translocated to plant tissues. Air pollution from vehicle fumes contains lead which can stick to human skin. The standard of Pb in the blood according to WHO for children is 5 µg dL$^{-1}$ [9]. Lead causes poisoning when the content in the blood more than 10 µg dL$^{-1}$ [10]. Therefore, it is necessary to control the amount of lead in water, soil, and air for plant, human, and environmental health. Lead in the soil can be controlled through remediation. Remediation is an effort to reduce lead contamination on polluted soil. Some materials can be utilized to reduce Pb contaminants, i.e. treatments that consists of a combination of ameliorant, bacteria, nanotechnology, and botanical pesticides. This study aims to determine the remediation of Pb contaminants in the soil through applying treatments in shallots cropping.

2. Materials and methods

2.1. Materials
The materials used in this study were biochar from corncob, compost, nanobiochar, botanical pesticides, and biological agents produced by Indonesian Agricultural Environment Research Institute (IAERI), consortia bacteria (Bacillus aryabathai, Bacillus thuringiensis, Bacillus subtilis, Bacillus cereus, Achoromobacter sp., Catenococcus thiocyli, and Stenotrophomonas maltophilia). Shallot variety of Bima, fertilizers (urea, ZA, and KCl), and chemical materials for heavy metals analysis (nitric acid, perchloric acid, and lead solution standard).

2.2. Methods
The research was conducted in a screen house of IAERI in 2019 on a pot scale using a completely randomized design with 3 replications and 9 treatments as follows: control / without organic fertilizer (P0), compost (P1), biochar + compost (P2), nanobiochar + compost (P3), nanobiochar + compost + consortia bacteria (P4), compost + consortia bacteria (P5), biochar + compost + consortia bacteria (P6), biochar + compost + botanical pesticides (P7) and biochar + compost + IAERI biological agents (P8). Biochar + compost (1:4) and nanobiochar + compost were applied as basal fertilizer at a dose of 2.5 t ha$^{-1}$. Especially for P7 and P8 treatments, they were applied by spraying which was carried out once a week on the plants. Shallot plants were planted 2 clumps per pot, maintained for 60 days. The soil was from shallot cropping of Brebes Regency. Each pot was filled with 5 kg of soil. The parameters observed were lead in the soil at 7 Day After Application (DAA), 37 DAA and after harvest, and lead in shallot (leaves and tubers) after harvest.

The procedure of lead analysis used wet ashing method using nitric acid and perchloric acid [11]. After the digestion was complete, the extract from the digestion was used to measure lead metal concentration using the AAS flame method with a standard series of lead as a comparison. The flame method used a mixture of air and acetylene as the activator. Lead content was calculated using equation below:

$$\text{Pb concentration} = \text{ppm curve} \times 10 \times \text{fp} \times \text{fk} \ldots \ldots \ldots \ldots [11]$$

Where:

- ppm curve = sample rate obtained from the regression curve of the relationship between the standard series level and the reading after deducting the blank
- fp = dilution factor
- fk = moisture content correction factor = 100 / (100-% moisture content)
Statistical analysis carried out using analysis of variance (ANOVA) with DMRT test if there were significant differences.

3. Results and discussion

3.1. Lead dynamic in soil

The dynamics of lead metal in the soil after the treatment application until harvest can be seen in Figure 1. At 7 days after the treatment application, there was no decrease. At 37 DAA, lead concentration in the soil seems to decrease with treatment of nanobiochar + compost (P3). The application of soil amendment with nanoparticles can improve soil quality, reduce soil contamination, and control soil erosion and soil acidity [12]. The remediation of contaminated soil will be more effective using nanotechnology but less economical.

The highest decrease in lead at harvest time was shown by control treatment (P0), then followed by the treatment of nanobiochar + compost + consortia bacteria (P4) and biochar + compost + IAERI biological agent (P8). When applied to the soil, the minerals in the soil will cover the surface of the biochar and make the composition of the substance more complex [13]. The functional groups of carboxyl and phenolic on the surface of the biochar are responsible for the formation of complex organo-minerals. Organo-minerals function for the adsorption and transformation of nutrients from the soil. According to Purbalisa et al. [14] the application of ameliorant in the form of bio compost (biochar + compost with ratio 2:5) can reduce cobalt (Co) levels in the soil to a safe limit. In the remediation of polluted soils, the increased in cation exchange capacity (CEC) of biochar and compost will increase soil ability in adsorbing heavy metal pollutants. The presence of organic matter in biochar and compost will increase the adsorption ability of heavy metals and organic pollutants. According to Hua et al. [15] application of biochar with compost significantly reduces nitrogen loss and heavy metal movement during the composting process. Research conducted by Beesley et al. [16] showed that a combination of biochar and compost can be used to remediate the heavy metal lead in the soil. The humic acid existence in compost can chelate heavy metals.

Compost is organic material that affects the mobility of metals in the soil [14]. Organic acids are strong ligands that can hold metals in solution by forming metal-organic material bonds [17]. The result of Bahar’s [18] research showed that compost has the potential for ion exchange with a removal efficiency of 96.22%. However, in compost treatment (P1), the lead content in the soil at harvest increased. This is in line with Sukarjo et al. [19], who reported that adding compost alone increased lead and cadmium levels in the soil.

![Figure 1. Dynamics of lead metal in soil.](image-url)
The highest reduction concentration of lead in the soil in the control treatment from 26.1526 mg kg\(^{-1}\) became 21.6218 mg kg\(^{-1}\) and nanobiochar + compost + consortia bacteria treatment (P4) from 24.0770 mg kg\(^{-1}\) down to 21.8036 mg kg\(^{-1}\) (Figure 1). However, the metal was absorbed by shallots and accumulated in the tubers so that the lead metal content in the control tubers was greater than other treatments. Even though the metal content is still within safe limits. The maximum limit for lead metal in SNI 7387:2009 is 0.5 mg kg\(^{-1}\). Levels of lead in tubers are within safe limits, namely \(\leq 0.5\) mg kg\(^{-1}\) (Table 1). This showed that the shallot was safe and fit for consumption.

| Treatment                      | Tuber   | Leaves  |
|--------------------------------|---------|---------|
| Control (P0)                   | 0.5044 a| 0.2829 a|
| Compost (P1)                   | 0.4708 a| 0.1729 a|
| Biochar + compost (P2)         | 0.4433 a| 0.2154 a|
| Nanobiochar + compost (P3)     | 0.4204 a| 0.1424 a|
| Nanobiochar + compost + consortia bacteria (P4) | 0.4632 a| 0.0568 a|
| Compost + consortia bacteria (P5) | 0.4571 a| 0.1607 a|
| Biochar + compost + consortia bacteria (P6) | 0.4601 a| 0.0996 a|
| Biochar + compost + botanical pesticide (P7) | 0.4220 a| 0.1424 a|
| Biochar + compost + IAERI biological agent (P8) | 0.4739 a| 0.2462 a|

Note: Number with the same letter showed no significant difference in anova.

3.2. Plant growth and yield of shallot during treatment
The growth of shallot including plant height, leaves number, and tillers number was observed every 2 weeks (Figure 3a, 3b, 3c, 3d). Tillers number was observed at 28 Day After Planting (DAP) when the tillers formed. The results of the statistical analysis did not show significant differences between treatments, so the data was presented in graphical form. Based on agronomical observations, it appeared that P3 (nanobiochar + compost) treatment gave the highest value on plant height, leaves number, and tuber weight. This showed that nanobiochar + compost supports plant growth and production. Nanotechnology could increase production and provide better results [12].

Nanobiochar has a wider pore surface than biochar (Figure 2). These pores will be filled with nutrients and water which will work like electrolytes. The plants responded more to nanoparticles [20]. The interaction between nanobiochar + compost and roots can optimize nutrient uptake by plants to save fertilizer use. Nanotechnology is a smart delivery system that is effective in utilizing water and nutrients. Nanotechnology has the potential for an agricultural revolution.

**Figure 2.** The difference porosity between biochar and nanobiochar.
Figure 3. (a) Shallot plant height, (b) shallot leaves number, (c) shallot tiller number, (d) shallot tuber weight, P0 : control, P1 : compost, P2 : biochar + compost, P3 : nanobiochar + compost, P4 : nanobiochar + compost + contortia bacteria, P5 : compost + contortia bacteria, P6 : biochar + compost + contortia bacteria, P7 : biochar + compost + botanical pesticide, P8 : biochar + compost + botanical pesticide.

4. Conclusions
Lead in the soil of remediation treatment decreased from time to time except in the compost treatment. P4 (nanobiochar + compost + consortia bacteria) and P0 (control) could reduce lead soil higher than other treatment, while for the productivity P3 (nanobiochar + compost) was potential to increase production. Lead in plants was at a safe limit of ≤ 0.5 mg kg⁻¹. Lead needs to be controlled to maintain environmental and human health through remediation activity.

Acknowledgments
All authors involved in this paper are main contributors.

References
[1] Tangahu B V, Kartika A A G, Maulana A A, Nugraha F and Abdullah S R S 2020 Study of chromium (Cr) and lead (pb) distribution in soil in jetis district, mojokerto, Indonesia Technology Report of Kansai University 62 169-184 ISSN: 04532198
[2] Alloway B J 2012 *Heavy metals in soils* third edition Springer Dordrecht p 597
[3] Notohadiprawiro T 2006 Logam berat dalam pertanian (in Bahasa) Repro: Ilmu Tanah Universitas Gadjah Mada Yogyakarta pp 1-10
[4] Nasir M, Sulastri, and Hilda M M 2018 Analisis kadar logam timbal dan arsenik dalam tanah dengan spektrometri serapan atom (in Bahasa) *Jurnal IPA dan Pembelajaran IPA* 2 89-99
[5] Purbalisa W, Paputri D M W, Wahyuni S and Ardiwinata A N 2019 Evaluation of chelating agent for remediation of lead contaminated soil in Brebes Central Java *AIP Conference Proceeding* 2120 http://doi.org/10.1063/1.5115653
[6] Prasad M N V 2008 Trace elements as contaminants and nutrients (New Jersey: Jhon Wiley and Sons Publication) p 769
[7] Robin N 2014 Remediasi tanah tercemar logam timbal (Pb) menggunakan tanaman bayam cabut (*Amaranthus tricolor* L.) (in Bahasa) *Jurnal Teknologi Lingkungan Lahan Basah* 2 1-10 ISSN: 2622-2884
[8] Kabata-Pendias A 2011 *Trace elements in soils and plants* fourth edition (New York: CRC Press) p 467
[9] World Health Organization 2019 Lead poisoning and health https://www.who.int/en/news-room/fact-sheets/detail/lead-poisoning-and-health
[10] Albalak R, Gary N, Sharunda B, Dana F W, Carol G C, Dennis K, Robert L J, Rini S, Wendy B, Regina T, Gerald C and Michael A M 2003 Blood lead levels and risk factors for lead poisoning among children in Jakarta Indonesia *The Science of The Total Environment* 301 75-85, http://dx.doi.org/10.1016/S0048-9697(02)00297-8
[11] Eviati and Sulaeman 2012 Petunjuk teknis: analisis kimia tanah, tanaman, air dan pupuk edisi 2 (in Bahasa) (Bogor: Badan Litbang Pertanian) p 234
[12] Hemantaranjan A and A K Trivedi 2014 *Advances in plant physiology volume 15: potential applications of nanotechnology in agriculture* (India: Scientific Publisher) pp 106-126
[13] Ma X B, Zhou A, Budai A, Jeng X, Hao D, Wei Y, Zhang and D Rasse 2016 Study of biochar properties by scanning electron microscope-energy dispersive x-ray spectroscopy (SEM EDX) *Communications In Soil Science And Plant Analysis* 47 593–601. http://dx.doi.org/10.1080/00103624.2016.1146742
[14] Purbalisa W and T Dewi 2019 Remediasi tanah tercemar kobalt (Co) menggunakan bioremediator dan ameliorant (in Bahasa) *Jurnal Tanah Dan Sumberdaya Lahan* 6 1237-1242
[15] Hua L, Wu W, and Liu Y 2009 Reduction of nitrogen loss and Cu and Zn mobility during sludge composting with bamboo charcoal amendment *Env. Sci. Pollut. Res. Int.* 16 1–9
[16] Beesley L, Inneh O S, and Norton G J 2014 Assessing the influence of compost and biochar amendments on the mobility and toxicity of metals and arsenic in an naturally contaminated mine soil *Environment Pollutant* 186 195–202
[17] Hooda P S 2010 *Trace elements in soils* (New Jersey: Jhon Wiley and Sons Publication) p 595
[18] Bahar E 2009 *Uji kemampuan kompos bratang sebagai media penukar ion untuk menurunkan logam Hg*²⁺ *dengan variasi dosis dan waktu kontak pada proses batch* (in Bahasa) (ITS Press)
[19] Sukarjo, A Hidayah and I Zulaehah 2018 Pengaruh pupuk terhadap akumulasi dan translokasi kadmium dan timbal di dalam tanah dan tanaman (in Bahasa) *Proceedings of SNPBS III*: 205-211 ISSN 2527-533X
[20] Joseph S, Graber E R, Chia C, Munroe P, Donne S, Thomas T, Nielsen S, Marjo C, Rutlidge H, Pan G X, Li L, Taylor P, Rawal A and J Hook 2013 Shifting paradigms: development of high-efficiency biochar fertilizers based on nano-structures and soluble components *Carbon Management* 4 323-343