



Heavy Metal Content of Cocoa Plantation Soil in East Kolaka, Indonesia

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ABSTRACT

Investigations of pH and heavy metals contents of Pb, Cd, Ni, Cu, and Zn in cocoa plantations soil of East Kolaka has been conducted by using pH starter Ohaus 3000 and Atomic Absorption Spectroscopy (AAS) Shimadzu AA6300. Based on the investigation, it is known that acidic soil plantation with pH ranges between 4.45 to 6.26, and also contains Pb, Cd, Ni, Cu, and Zn with an average concentration (mg/kg) are 1.45, 0.02, 0.85, 0.77, and 1.49, respectively. The existence of Pb and Cd in plantation soil have been exceeded the WHO permissible, whereas Ni, Cu, and Zn is still within the permissible limits. Acidic soil plantation will give opportunity metal ions such as Pb²⁺, Cd²⁺, Ni²⁺, Cu²⁺, Zn²⁺, and Al³⁺ absorbed by plants. Thus causing the accumulation in plant tissues and make the cocoa plants stress of heavy metals.

Keywords: East Kolaka, cocoa plantation soil, heavy metals, pH, cocoa plant (*Theobroma cacao* L.)

INTRODUCTION

The use of phosphate fertilizers and pesticides in an effort to increase crop production has been reported as a concern all over the world, both governments and environmental agencies^{1,2}. The use of fertilizer can increase the concentration of heavy metals on the soil of cocoa plantation³, while the use of pesticide in only distributed approximately 15% in the crop and the rest is distributed in the soil,

so it could eventually lead to heavy metal pollution in plantation soil⁴.

Accumulation of heavy metal in plantation soil will have an impact on crops⁵ and humans when the crops are consumed through the food chain². Several studies on the effect of heavy metals in the crop explained that heavy metals will affect growth, metabolism, inhibits the action of enzymes, and damage the structure of crop cells^{6,7}.

Special to the cocoa crop, Reis *et al.*, reported that Pb cause structural changes in mesophyll cell, the membrane disorganization thylacoidal, and chloroplast unfavorable developments⁶. In addition, Pb is also causing changes in the mitochondria, the outbreak of the nuclear membrane in root cells, and based on the analysis of proteomics with using gel electrophoresis two-dimensional and mass spectroscopy, exclusively illustrates that the stress of Pb causes the activity of proteins germination of cacao crop disrupted. In humans, heavy metals have also been reported as a harmful substance to the body^{9,10}. Pb can lead to damage of hematopoietic system, hematic, renal and gastrointestinal. Cu in the body causing insomnia, osteoporosis, liver disease, cancer, migraine, loss of memory, and gum disease¹¹. Cd causes kidney dysfunction, lung damage, and bone fracture¹².

In recent years, the heavy metal content in cocoa crop has been studied and reported¹³⁻¹⁶. This study is based on the increasing needs of the community to the cocoa product such as chocolate. Chocolate is reported to have health benefits such as reducing the risk of cardiovascular disease, cancer, diabetes, impotence, and hypertension¹⁷⁻²⁰. In Switzerland, the chocolate consumption in 2014 was about 9 kg/ person/year²¹.

East Kolaka is one of the regencies located in Southeast Sulawesi and the second largest region

in Indonesia with produce 146 tons per year of cocoa²². Increasing activity of anthropogenic such as the use of phosphate fertilizers and pesticides in the cocoa plantation in East Kolaka can lead to accumulation of heavy metal which will eventually contaminate the environment of a plantation. In generally, the soil in Southeast Sulawesi has contained the elements of heavy metals that have been reported by Nurdin *et al.*^{23,24}. It is can inhibit of cocoa plant growth so still needed the treatment for the management of the cocoa plant. Based on discussions with the owner of the plantation, it is known that the cacao crop age ranges from 10 to 20 years. Fertilizer application is done within 6 months while spraying pesticides on crops routinely every 2 weeks. Based on this problem, this study aims to investigate the content of heavy metals such as Pb, Cd, Ni, Cd, and Zn in the soil of cocoa plantation of East Kolaka. In addition, the purpose is also to identify of metal pollution potential through determination of pH value of plantation soil.

EXPERIMENTAL

Sampling location

Sample location was conducted in Anggaloosi and Lamoare (Figure 1). The selection of soil sample by the random method with a depth of ± 30 cm. Soil samples were stored in polyethylene bags in preparation for the investigation.

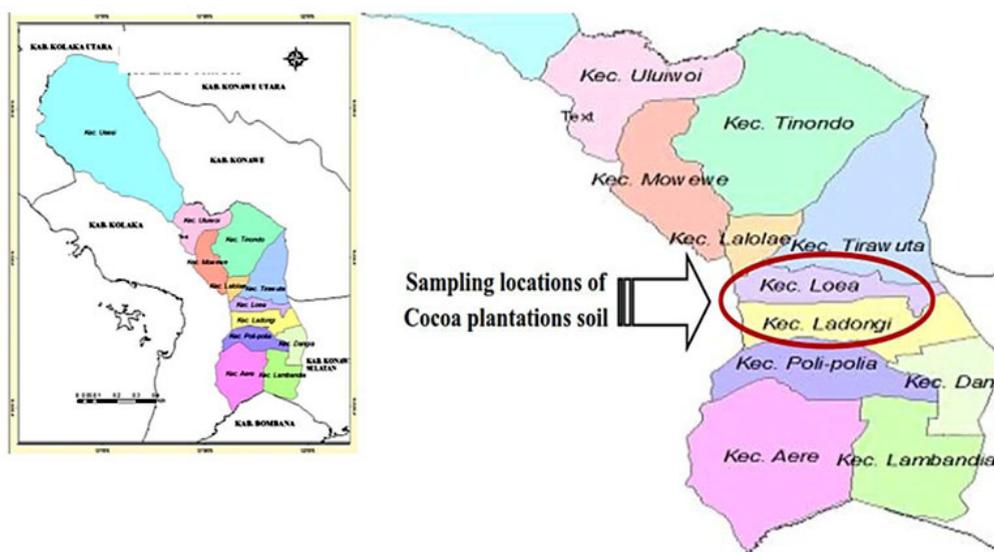


Fig. 1: Sampling location of cocoa plantations soil in East Kolaka

Sample preparation

Soil samples were dried at 105°C for 6 hours, then refined with a sieve size < 2 mm. Samples of fine soil will be used for all stages of analysis. Sample of soil from Anggalosi labeled I.1-I.5 for the location I, II.1-II.5 label for the location II, and label III.1-III.5 for the location III. The soil samples from the Lamoare labeled IV.1-IV.5 and V.1-V.4.

Cocoa Plantation Soil Investigation

The investigation conducted in this study consisted of the pH analysis, and the total content of heavy metals Pb, Cd, Ni, Cu, and Zn in plantation soil. An analysis of pH carried out by using pH starter Ohaus 3000. A total of 1 g of a soil sample mixed with 2 mL of distilled water. The mixture was then stirred using a magnetic stirrer for 30 minutes and measured value of acidity (pH). Analysis of heavy

metals such as Pb, Cd, Ni, Cu, and Zn in soil samples involves using Atomic Absorption Spectroscopy (AAS) Shimadzu AA6300. A total of 5.00 g soil samples < 2 mm is inserted into a plastic bottle and shake then added 20 mL of extracting diethylene triamine penta acetate (DTPA) pH 7.3. The filtrate obtained was analyzed by different wavelengths of each metal. Measurement of Pb, Cd, Ni, Cu, and Zn were 217.00 nm, 228.80 nm, 232.00 nm, 324.80 nm, and 636.00 nm, respectively.

RESULTS AND DISCUSSION

Analysis of heavy metal content

Based on Figure 2, cocoa plantations soil in East Kolaka for sampling location I, II, III, IV, and V contains Pb metals with a concentration were 1.436 mg/kg, 1.98 mg/kg, 1.004 mg/kg, 0.90 mg/kg, and 2.0775 mg/kg, respectively. Pb concentration

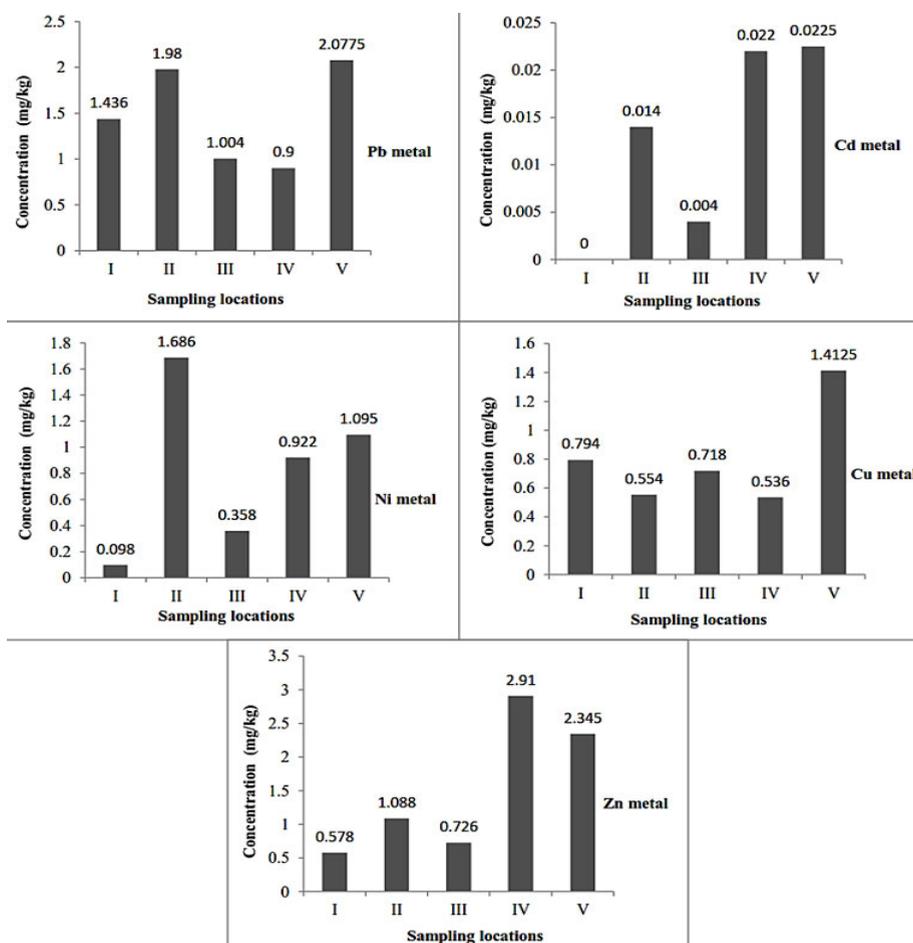


Fig. 2: Graphs of heavy metals content of cocoa plantations soil in East Kolaka

obtained from the analysis was greater than the results reported by Nazir *et al.*, and Adewole *et al.*, with concentration range were 0.061-0.461 mg/kg and 0.01 mg/kg, respectively^{25,26}. However resemblance by Ogunlade *et al.*, and Ekpete *et al.*, with a concentration range were 0.50-0.86 mg/kg and 0.669-2.624 mg/kg, respectively^{2,28}.

Cd metals content for sampling locations I, II, III, IV, and V were <0.01 mg/kg, 0.014 mg/kg, 0.004 mg/kg, 0.022 mg/kg, and 0.0225 mg/kg, respectively. Cd concentration obtained from the analysis has similarity values reported by Ogunlade *et al.*, Nazir *et al.*, and Adewole *et al.* with concentration range

were 0.02-0.05 mg/kg, 0.029-0.328 mg/kg; and 0.01-0.08 mg/kg, respectively^{2,25,26}. But smaller than reported by Ghorbani *et al.*, Gitet *et al.*, Ekpete *et al.*, Hugo *et al.*, and Mico *et al.*, with a concentration range were 0.12-0.33 mg/kg, 0.83 mg/kg, 0.049-0.089 mg/kg, 0.31-1.52 mg/kg, and 0.15-0.88 mg/kg, respectively^{1,27-30}.

Ni metals content for sampling locations I, II, III, IV, and V with a concentration were 0.098 mg/kg, 1.686 mg/kg, 0.358 mg/kg, 0.922 mg/kg, and 1.095 mg/kg, respectively. This result was much greater than that reported Ogunlade *et al.*, Adewole *et al.*, and Ahaneku *et al.* with concentration range

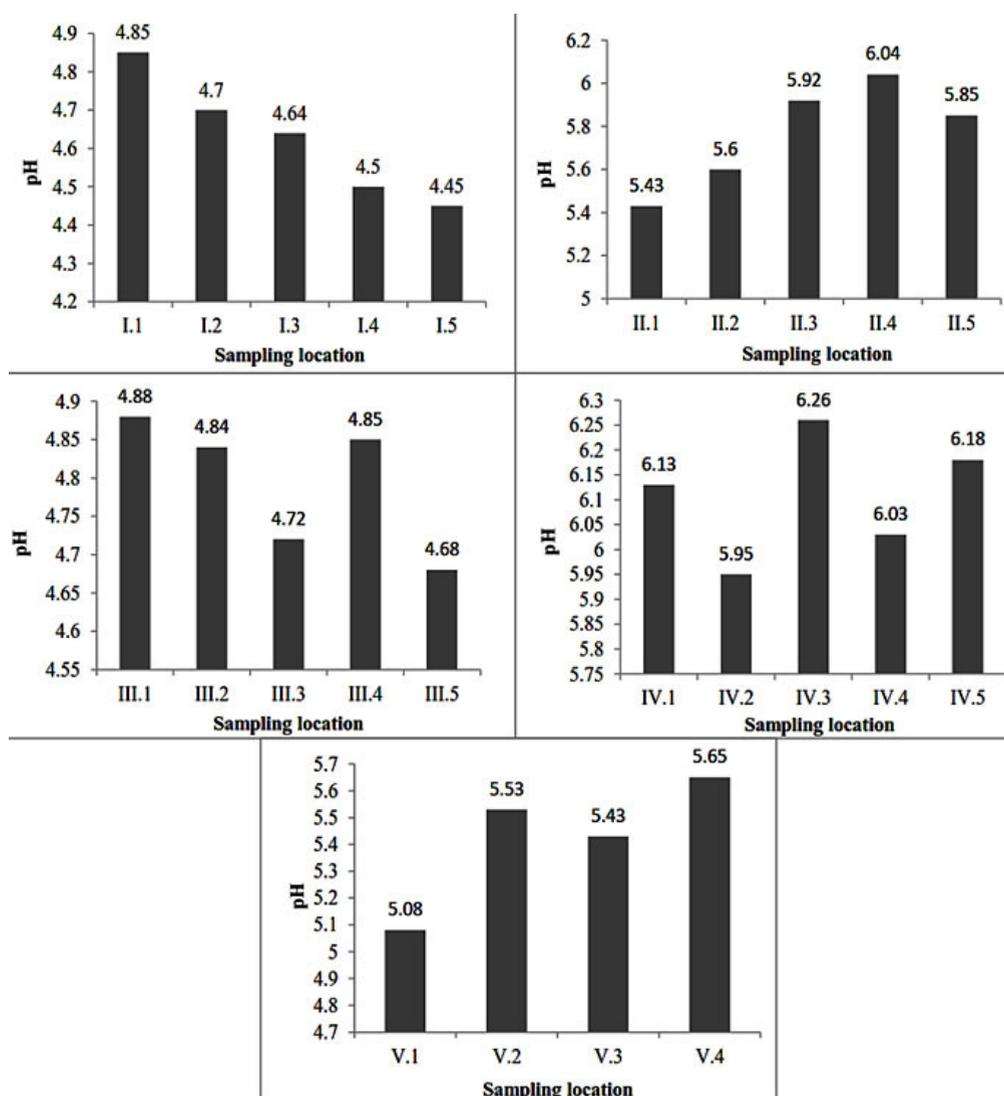


Fig. 3: Graphs of the pH value of cocoa plantations soil in East Kolaka

were 0.23-0.42 mg/kg, 0.02-0.03 mg/kg, and 0.01-0.91 mg/kg, respectively^{2,26,31}. But much smaller than reported by Nartey *et al.*, and has similarities with Nazir *et al.* with a concentration range from 0.150-1.031 mg/kg^{3,25}.

Cu metal content for sampling location I, II, III, IV, and V with a concentration were 0.794 mg/kg, 0.554 mg/kg, 0.718 mg/kg, 0.536 mg/kg, and 0.8029 mg/kg, respectively. This result was much greater than that reported Nazir *et al.*, and similar by Adewole *et al.*, with concentration range 0.536-1.504 mg/kg, but much smaller than the concentrations reported by Ekpete *et al.* with a concentration range 2.670-6.417 mg/kg^{25,26,28}.

Zn metals content for sampling location I, II, III, IV, and V with a concentration were 0.578 mg/kg, 1.088 mg/kg, 0.726 mg/kg, 2.91 mg/kg, 2.345 mg/kg, respectively. This result was much greater than that reported Nazir *et al.*, and Adewole *et al.*, with a concentration range was 0.033-0.349 mg/kg and 0.41-0.46 mg/kg, respectively^{25,26}, but much smaller than reported by Nartey *et al.*, and Ekpete *et al.* with a concentration was 14.50 mg/kg and 2.670-6.417 mg/kg, respectively^{3,28}.

In general, heavy metals content of Pd and Cd in cocoa plantation soil of East Kolaka have been exceeded the WHO permissible, whereas Ni, Cu, and Zn are still within the permissible limits. WHO permissible limits for heavy metals Pb, Cd, Ni, Cu, and Zn in soil was 0.05-0.1 mg/kg, 0.005-0.01 mg/kg, 0.5-6.5 mg/kg, 0.05-1.5 mg/kg, and 5.0-15.0 mg/kg, respectively.

Analysis of pH soil of cocoa plantations

Figure 3 shows the pH value of the cocoa plantations soil in East Kolaka. Cocoa plantation soil for the location of the I, II, III, IV and V were in the range 4.45-4.85, 5.43-6.04, 4.68-4.88, 5.95-6.26, and 5.08-5.65, respectively. The location I and III has a more acidic pH values with an average value of 4.62 and 4.79 compared to location II, IV, and V

with the average value were 5.84, 6.11, and 5.42, respectively. The pH soil conditions obtained were similar to those reported Ogunlade *et al.* Ahaneku *et al.*, Yatno *et al.*, and was generally lower than that determined by WHO^{2,31,32}. Acidic soil properties cocoa plantations can be caused by the high content of Al³⁺ ion and low content of bases that can be exchanged such as Ca²⁺, Mg²⁺, K⁺ and Na⁺, and also caused the increasing use of fertilizers^{32,33}.

Low soil acidity will cause problems for microbial activity³⁴, allows the formation of Al³⁺ ions to be more soluble in the pH range of < 5³⁵, which is reported ions was toxic to plants when in solution land exceeds 60% cation exchange capacity (CEC) of the soil^{36,37}. Stress metals Al reported to inhibit root growth³⁸, increasing the thickness of lateral roots and change the color of the roots become brown³⁹, interfere with the respiration of roots and enzymatic reactions of glucose phosphorylation⁴⁰, and reducing crop production³⁵.

CONCLUSION

Based on the investigation, the average content of heavy metals Pb, Cd, Ni, Cu, and Zn were 1.45 mg/kg, 0.02 mg/kg, 0.85 mg/kg, 0.77 mg/kg, and 1.49 mg/kg, respectively. The existence of Pb and Cd in cocoa plantations soil of East Kolaka have been exceeded the WHO permissible, whereas Ni, Cu, and Zn were still within the permissible limits. Soil conditions cocoa was acidic with the pH concentration range between 4.45 to 6.26. Conditions such as these will provide opportunities harmful metal ions such as Pb²⁺, Cd²⁺, Ni²⁺, Cu²⁺, Zn²⁺, and Al³⁺ absorbed by the cocoa crop in the excess amount that will accumulate and poison the crops.

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