Quest Journals
Journal of Research in Agriculture and Animal Science
Volume 3 ~ Issue 5 (2015) pp:01-08
ISSN(Online) : 2321-9459
www.questjournals.org

Research Paper

Toxic Effects of Pb and Cd Metals on Agricultural Cultivation In the Land Of Former Urban Landfill Sites

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Received 02 October, 2015; **A**ccepted 10 October, 2015

ABSTRACT:- This research is aimed at determining the toxic effects of Pb and Cd contained in former urban landfill sites used by society as agricultural land to grow palawija crops and vegetables. The research was conducted on a former landfill site wherein disposed of in urban waste Tlocor. It is located on $7^{O}32^{1}37.58^{11}$ to $7^{O}32^{1}46.62^{11}$ South Latitude and $112^{O}45^{1}00.64^{11}$ to $112^{O}45^{1}05,16^{11}$ East Longitude Kalisogo Village, Jabon District, Sidoarjo Regency, with a total area of approximately 2.25 ha. The statistical analysis was underaken to determine differences in the content of Pb and Cd metals contained in each plant part using a T-test at a 5% confidence level. The results obtained from the statistical test are expected to determine the effects of metal toxicity on the environment. The above experimental results show that the land in the former landfill site has been utilized by the surrounding community for the activity of agricultural cultivation and the Pb metal content is 28.20 mg kg^{-1} while the Cd metal content is 6.73 mg kg^{-1}. The lowest total Pb metal content is found in white pumpkin plants (1.17 ± 0.11 mg kg^{-1}) and the highest total Pb metal content is found in corn (1.82 ± 0.19 mg kg^{-1}). As for Cd metal, the lowest total metal content is found in white pumpkin plants (1.04 ± 0.15 mg kg^{-1}) and the highest total Cd metal content is found in corn (1.43 ± 0.14 mg kg^{-1}). In general, the total content of Pb and Cd metals in plants cultivated on and outside the land in the former landfill site (D x L) does not differ significantly. All the plants grown on the land in the former landfill site are resistant and hyperaccumulators characterized by the TF value by > 1.

Keywords:- Pb, Cd, Agricultural Cultivation, Former Urban Landfill Sites

I. INTRODUCTION

In most developing countries, large amounts of solid waste in major cities are produced by the activities of the human population. The waste is transported and disposed of in landfill sites (Nurita and Hassan, 2013). Very often, the management and disposal of urban solid waste pose the most common problems in major cities around the world (Xudong et al., 2010). Almost in all cities in the world, waste is collected in open landfill sites, where the consideration for the risks to the health of the environment and the public receive less attention (Zarate et al., 2008).

A great number of heavy metals bring toxic effects on the environment, which people have unknowingly added into urban waste (batteries, circuit boards, pigments, paints, and the like) which are no longer used (Aucott et al., 2010). These heavy metals will be mixed with other waste disposed of in landfill sites. The issue of pollution caused by the existence of heavy metals is increasing all over the world, causing long-term risks to the ecosystem and human beings (Fernández-Gómez et al., 2012). Th eissue of heavy metals has raise concern for human health, when the metal concentration level in the environment where people live near the environment is high. These metals may harm humans if the high concentration of these metals get into the system of human life, such as through the consumption of food crops containing such heavy metals (Akan et al., 2010; Essien and Hanson, 2014). A very serious problem is daily consumption of fresh vegetables, especially leafy vegetables planted in soil with heavy metal contamination (Essien and Douglas, 2012). Consequently, the consumption of metal-contaminated food by humans and animals pose a serious danger to human health (Khan et al., 2008). Lead (Pb) is a metal with the atomic number 82, bluish-grey coloured, soft, tender, ductile, and a

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poor conductor of electricity metal and highly resistant to corrosion (Bradl et al., 2005). Pb is the most abundant element, vital for the sector of industrial economy and used mainly for charging batteries, cable-sheathing pigments, ammunition and gasoline fuel additive, radiation coatings and heat stabilizers (Bradl, 2005). The Pb content in plants is slight. The chelate process of organic materials into Pb will cause it to get into plants (Huang and Cunningham, 1996). Pb may cause toxicity in humans and cancer, abdominal pain, convulsions, hypertension, kidney damage, loss of appetite, fatigue, and insomnia (Shanker, 2008). Cadmium (Cd) is a soft and ductile metal, it is also shiny and silvery-white with an atomic weight of 112.4 (Bradl et al., 2005). In nature, Cd is in the oxide state and has a valency of 2, as urban solid waste it is often found in urban landfill sites, this is what causes increased cadmium metal contamination in the food chain (Bradl, 2005). Human activities in manufacturing contribute significantly to the increased concentration of Cd in the environment. In agricultural land, anthropogenic activities have led to a significant increase in Cd concentration in agricultural land and this will pose a problem to human health. The existence of Cd in the environment will not be damaged by the degradation process but it will be converted into a different form. Cd can get into the soil and water, absorbed by plants and animals. Thus, Cd can move from the environment to plants and animals (Kuriakose and Prasad, 2008). This research is aimed at determining the toxic effects of Pb and Cd contained in former urban landfill sites used by society as agricultural land to grow palawija crops and vegetables.

II. MATERIALS AND METHODS

2.1. Research Sites

The research was conducted on a former landfill site wherein disposed of in urban waste Tlocor. It is located on $7^{O}32^{1}37.58^{11}$ to $7^{O}32^{1}46.62^{11}$ South Latitude and $112^{O}45^{1}00.64^{11}$ to $112^{O}45^{1}05,16^{11}$ East Longitude Kalisogo Village, Jabon District, Sidoarjo Regency, with a total area of approximately 2.25 ha. This landfill was functioned only for 9 years and in 2007 it was closed (not functioning anymore) as it was no longer able to accommodate urban waste from Sidoarjo City. Currently, a heap of waste has reached a height of approximately 10 meters and the local community have long used that land of waste heaps as a place to cultivate vegetables (Krai plants and white pumpkins) and palawija crops (corn) during the rainy season.

2.2. Implementation of Research

The research was performed using a survey method, consisting of 2 (two) stages, specifically (1) soil sampling and (2) plant sampling. At the first stage, sample soil was collected from 6 (six) points at a depth of 0 to 30 cm, assuming that on average the roots of the plants grow in the land formerly used as a landfill at those depths. The sample soil collected underwent chemical analysis. The chemical assessment measured the content of organic matterials (C-organic) using the Walkey-Black method, N-total using the Kjeldahl method, P-available using the Bray-I method and K-available using spectrophotometry (NH_4OAc solvent). As for the analysis of the heavy metals Pb and Cd, the wet destruction method was undertaken (HNO_3 and $HClO_4$ solvents).

Then, with regard to the plant sampling, the sample was taken from 2 (two) places, inside and outside the former landfill site. Plants taken from the latter place was done at a distance of 100 meters from the outer boundary of the building formerly used as a landfill site. The sample plants were taken inside the landfill on the area planted with corn, white pumpkins and krai plants, while outside the building the sample plants were taken from the area planted with corn. The sample plants were taken randomly and the soil and waste sticking on plant parts were then removed. For the sample plants which had been cleansed, the plant roots were separated from the upper part of the plants. Furthermore, these sample plants were dried using an oven at a temperature of 60 – 80 °C until their weight was constant, after the samples underwent the milling and refining processes until they could pass the 5-diameter mesh sieve for the purpose of performing the heavy metal analysis.

2.3. Statistical Analysis

The statistical analysis was underaken to determine differences in the content of Pb and Cd metals contained in each plant part using a T-test at a 5% confidence level. The results obtained from the statistical test are expected to determine the effects of metal toxicity on the environment.

III. RESULTS AND DISCUSSION

3.1. Landfill Conditions.

Landfills are a place where waste reaches the final treatment stage since it is disposed of in the source, collection, transportation, treatment and disposal. Landfills are a safely-isolated place for waste disposal so as not to cause any disturbance to the surrounding environment. Therefore, facilities and the correct treatment are necessary to reach that level of security well. Based on the foregoing, the land formerly used as the landfill for urban waste potentially influences public health if it is used for agricultural cultivation, it may carry the risk of affecting the crop products planted on such land. According to Lee and Lee (2004), urban waste disposal sites are a place for urban solid waste disposal, which further shall be remediated to make it harmless to people and the environment in the long run.

The utilization of the land of a former landfill site suggest that the monitoring of the hazardous impact arising in the land is very poor, it is evident as the government does not prohibit the use of such land for agricultural cultivation by the local community so as to prevent the widening of such an impact. According to Kruljac (2012), in the management of urban waste treatment, the absence of sustainable management of landfills not used any longer is often overlooked and therefore the negative impacts resulting from such land which used to function as a landfill on the local community are not specified in the sustainable development policy.

Land use by the local community is intended as an alternative for cultivation in open land. The difficult economic conditions make it not easy to meet the day-to-day needs in urban areas. Consequently, people living in the suburbs begin to make use of land on the edge of the city such as the land formerly used for landfill sites to undertake agricultural activities to meet their life necessities. Urban agriculture in many developing countries is often done in the suburbs by using marginal land with a view of meeting the needs of family life (Pearson et al., 2010). Cultivation carried out in landfills by humans to grow vegetables implies that landfill sites are marginal land in which its use is free of charge (Essien and Hanson, 2014).

3.2. Chemical Properties of the Land in the Former Landfill Site.

Former landfill sites carry the risk of being contaminated by heavy metals derived from inorganic materials and heavy metal contamination. Results of the chemical analysis of the land are presented in the table below.

Table 1. Results of the chemical analysis for the sample soil taken from the former landfill site.

Analysis of soil samples	The measurement results of samples
C-organic (%)	3,69
N-total (%)	0,12
C/N	32,07
P- available (mg kg-1)	37,57
K- available (mg 100g-1)	1,15
Pb (mg kg-1)	28,20
Cd (mg kg-1)	6,73

The analysis results for the sample soil taken from the former landfill site reveal that the content of C-organic, N-total, P-available and K-available is high, this indicates that the availability of plant nutrients in that land is very high to be used for agricultural cultivation. The existence of the heavy metal content, namely Pb (28.20 mg kg^{-1}) and Cd (6.73 mg kg^{-1}) indicates that the land in the former landfill site has been contaminated by heavy metals and thus, if used for agricultural cultivation, the plants carry the risk of heavy metal toxicity and it endangers the health of the community in the food chain. Jung (2008), Wang et al. (2009) and Chapman et al. (2013) state that the presence of heavy metals in soil largely depends on the concentration of these metals and the chemical property of the soil, especially the organic matter content in the soil. The presence of a high content of organic matters in the soil will affect the transfer of heavy metals from the soil to the plants.

Pollution resulting from the content of heavy metals Pb and Cd found in the land of the former landfill site is resulted mainly from a high concentration of those metals and they cannot be degraded. The toxic effects of these metals, through the cultivation activity carried out on the contaminated land, may enable the transfer of such metals to the food chain and endanger human health. Metal toxicity may occur if the metals are in an excessive concentration so that these metals will poison plants and animals. Plants and animals do not need heavy metals Cd and Pb and poisoning may occur those metals are concentrated in the environment (Sati et al., 2014). The increased level of heavy metals may cause toxic effects of these metals on the environment as these metals are not degradable. In so doing, heavy metals may pose a serious threat to organisms living in a contaminated environment, due to acute toxicity, unable to degrade and in a high concentration (Tang et al., 2013). Pb metal can accumulate in body tissues and cause a problem in humans even death (Chua et al., 2012). Cd metal can get into soil and water, absorbed by plants and animals. As a result, Cd can move from the environment to plants, animals and humans (Kuriakose and Prasad, 2008).

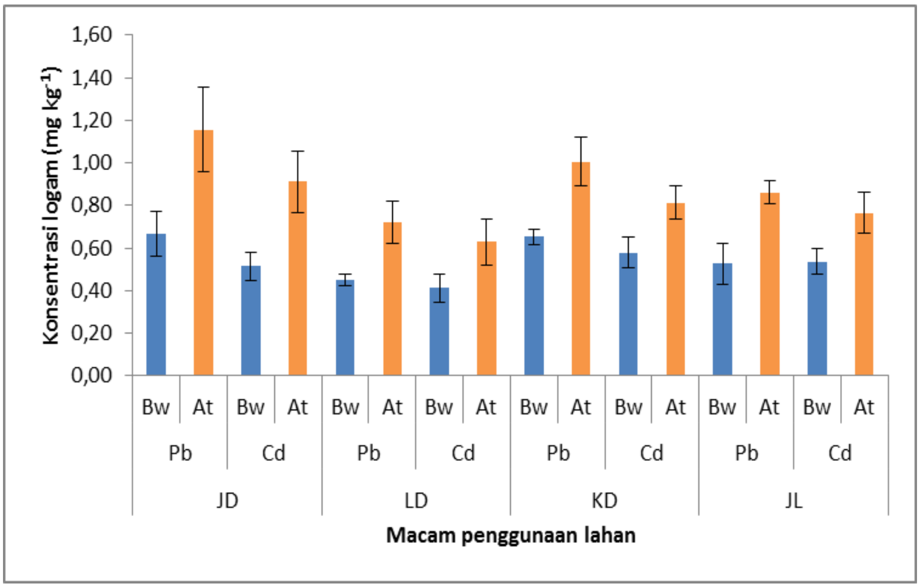
3.3. The Content of Pb and Cd Metals in Plants.

Toxicity of Pb and Cd metals is derived from urban solid waste transported and collected in the landfill site when it was still operating. These Pb and Cd metals cannot be degraded and accumulate, and therefore, even though the land is not used anymore as a landfill site, the metal toxicity is still hazardous if used for agricultural cultivation, transfer of those heavy metals may take place the uptake of heavy metals to plants, animals and humans. The amount of the content of Pb and Cd metals in plants being cultivated on the former landfill site is presented in the table below.

Table 2. The Pb metal content in plants grown in a landfill environment.

Plant wide	**The content of Pb in …… (mg kg^{-1})**				**Cd metal content in …… (mg kg^{-1})**			
	Low part		Top part		Low part		Top part	
	average	sd	average	sd	average	sd	average	sd
in landfill								
- Corn	0,67	0,10	1,16	0,20	0,51	0,07	0,91	0,15
- Pumpkin	0,45	0,03	0,72	0,10	0,41	0,07	0,63	0,11
- Krai	0,65	0,03	1,01	0,11	0,58	0,07	0,81	0,08
beyond landfill								
- Corn	0,53	0,10	0,86	0,06	0,54	0,06	0,77	0,09

The Pb metal content in plant roots ranges from 0.72 to 1.16 mg kg^{-1}, the highest metal content in the plant roots is found in corn, which is 1.16 ± 0.20 mg kg^{-1}. For Cd metal, it ranges from 0.63 to 0.91 mg kg^{-1}, the highest metal content in the plant roots is found in corn, which is 0.91 ± 0.15 mg kg^{-1}. In the upper part of the plants, the Pb metal content ranges from 0.45 to 0.67 mg kg^{-1}, the highest metal content is found in corn, which is 0.67 ± 0.10 mg kg^{-1}. For Cd metal content, it ranges from 0.41 to 0.58 mg kg^{-1}, the highest content is found in Krai plants, which is 0.58 ± 0.07 mg kg^{-1}.



Explanation :
Bw : the bottom (root) crop
At : the top of the plant

Pb : heavy metal pb
Cd : heavy metal cd

Jd : corn plants in landfill
Ld : pumpkin plants in landfill
Kd: krai plants in landfill
Jl : corn plants beyond landfill

Figure 1. a histogram illustrating the content of Pb and Cd metals in plants grown in the landfill site under study.

In general, an accumulation of heavy metals in the roots and upper parts of the plants (Figure 1) indicates that on the land formerly used as a landfill site, the accumulation of heavy metals Pb and Cd has occurred in plants cultivated on the land. This suggests that heavy metal toxicity has posed a hazard to the food chain in urban areas characterized by the metals getting into all plant tissues. According to Baylock and Huang (2000) and Mohebbi et al. (2012), one of the greatest concern to human health is caused by heavy metal contamination, where heavy metals accumulate in the roots of many plants and these metals accumulated in the roots are transported to the upper end of these plants. According to Pradeep et al. (2005), the process of heavy metal contamination in areas located close to urban landfill sites, the excessive amount of metals brought together with the waste enables the heavy metals to enter the food chain through plants cultivated near the land and accumulate in the biotic factors.

Table 3. The t-test of the Pb and Cd metal content in plants grown in the former landfill site.

Wide Test	t-calc				t-table
	Concentration Pb		Concentration Cd		
JD x LD	6,55	*	4,18	*	2,23
JD x KD	0,63	tn	0,40	tn	2,26
LD x KD	6,35	*	3,88	*	2,26
JD x JL	4,64	*	1,37	tn	2,31
LD x JL	3,10	*	2,74	*	2,36
KD x JL	3,15	*	1,11	tn	2,45
D x L	0,91	tn	0,19	tn	2,09

Explanation:

JD : Corn crops, cultivation in landfill
LD : White Pumpkin plants, cultivation in landfill
KD : Krai plants, cultivation in landfill
JL : Corn crops, cultivation outside the landfill
D : Plants are cultivated in landfill
L : Plants are cultivated outside the landfill
* : significant difference
Ns : No significant difference

Results of the statistical test (t-test with α = 0.05) for the total content of the heavy metal Pb in plants cultivated on and outside the former landfill site for each plant show significant differences, except for corn and krai plants (JD x KD) planted on the land of the former landfill site. As for the total content of Cd in the plants, it is not significantly different for corn and krai plants (JD x KD). In general, the content of Pb and Cd metals in plants planted on and outside the former landfill site (D x L) does not show significant differences. This suggests that the impacts arising from heavy metals Pb and Cd contained in the land of the former landfill site has the same effect on the accumulation of those metals both for the plants grown on and outside the land. Hence, the toxic effects of heavy metals Pb and Cd contained in the land of the former landfill site has contaminated not only the plants planted on the land but also those cultivated outside the land.

The research findings suggest that Pb and Cd metals found in the landfill environment both inside and outside it indicate that there has been a transfer from the environment of the waste media to roots and shoots (the upper part of the plants) in all plants cultivated on the former landfill site. It can be seen from the total content of Pb and Cd in plants grown in the region. The hazard of heavy metals will increase with the poor environmental conditions, even under high rainfall, as a result heavy metals will accumulate in the roots and the upper part of many plants (Mohebbi et al., 2012).

3.5. The Translocation Factor of the Plants.

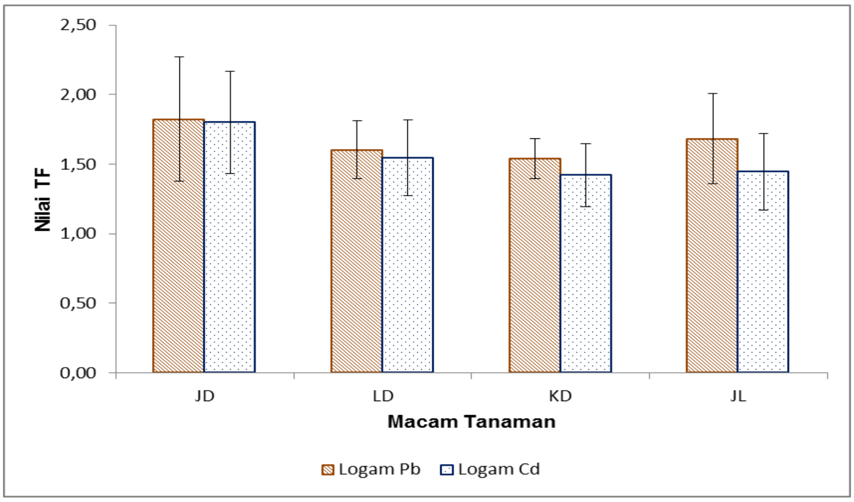
The translocation factor (TF) is calculated as the ratio of the heavy metal concentration in the upper part of plants to the metal concentration in the root of plants (Mohebbi et al., 2012) using the following equation: $TF = C_{\text{upper part of plants}} / C_{\text{root of plants}}$

Where $C_{\text{upper part of plants}}$ and $C_{\text{root of plants}}$, respectively, refer to the concentration of the metal content in the upper part of plants (mg kg^{-1}) and in plant roots (mg kg^{-1}). A TF value by > 1 implies that the metal translocation is effective if it is made to the upper part of the plants. The ability of plants to absorb heavy metals can be identified by determining the translocation factor (TF) of the heavy metals in plants. TF calculation results for plants cultivated on and outside the former landfill site are presented in the table and figure below:

Table 4. The translocation factor (TF) of Pb and Cd metals in plants grown on the land of the former landfill site.

Sample	In Landfill						Outside Landfill	
	Corn		Pumpkin		Krai		Corn	
	TF Pb	TF Cd	TF Pb	TF Cd	TF Pb	TF Cd	TF Pb	TF Cd
T1	1,14	1,87	1,64	1,42	1,36	1,28	1,91	1,70
T2	1,93	1,17	1,98	1,65	1,68	1,29	1,20	1,21
T3	2,01	1,73	1,64	1,94	1,55	1,67	1,81	1,65
T4	1,35	2,08	1,49	1,50	1,68	1,66	1,81	1,21
T5	2,33	1,72	1,46	1,65	1,43	1,20	-	-

T6	1,93	2,23	1,39	1,13	-	-	-	-
Average	1,78	1,80	1,60	1,55	1,54	1,42	1,68	1,44
Sd	0,45	0,37	0,21	0,27	0,14	0,22	0,32	0,27



Explanation:
JD : Corn plants in landfill
LD : Pumpkin plants in landfill
KD : Krai Plants in landfill
JL : Corn plants outside the landfill

Figure 2. A histogram describing TF values of various plants.

In general, all the plants cultivated on and outside the land of the former landfill site can translocate Pb and Cd metals. Table 4 and Figure 2 show that the values of the translocation factor (TF) for all plants cultivated on and outside the land of the former landfill site are higher than 1 (TF>1). For corn cultivated on the former landfill site, the TF value is 1.78 ± 0.45 and it is a type of plant with the highest TF value for Pb metal translocation in plants, while for Cd metal translocation in plants, it is equal to 1.80 ± 0.37. The lowest TF value for Pb content translocation is found in Krai plants cultivated on the land of the former landfill site, which is 1.54 ± 0.14, while for the lowest translocation for Cd metal, it is found in krai plants cultivated on the land of the former landfill site, which is 1.42 ± 0.22. The resulting TF is greater than 1, meaning that the plants cultivated in the environment used to function as a landfill site can effectively translocate heavy metals Pb and Cd absorbed and accumulated in plant roots to the upper plant tissues. Moreover, the value of TF by > 1 shows that the plants cultivated on the land indicate that heavy metals Pb and Cd can be effectively translocated from the roots to the upper part of the plants, which is the main characteristic of plants which belong to hyperaccumulators of heavy metals. According to Zhao et al. (2006) and Lorestani et al. (2011), the main characteristics of plants which are hyperaccumulators of metals are plants which can translocate metals effectively from roots to shoots of the plants as characterized by a TF value which is higher than one.

Plants grown both on and outside the land in the former landfill site have proved to be able to tolerate the toxicity of the Pb and Cd concentration contained in the environment, even these plants (vegetables and palawijaya crops) can move the metal absorbed in plant roots to the whole plant tissues as indicated by the TF value by > 1. Plants with tolerance to heavy metals which can translocate metals to the upper part of plants allow for remediation by plants or phytoremediation, which is able to reduce the concentration of metals contained in the soil. According to Cui et al. (2007), green plants which can reduce pollutants in the environment are termed Phytoremediation and can be used as a method for reclamation of contaminated soil as these plants share the hyperaccumulator property.

The metal content in plant tissues and the hyperaccumulator property make plants can tolerate the toxic metal-contaminated environment, and therefore the plants are not edible. Heavy metals may harm humans if a high concentration of these metals gets into the system of human life, through consumption of food crops that contain heavy metals (Will et al., 2010; Essien and Hanson, 2014). Consumption of contaminated food by humans and animals can pose a serious hazard to human health (Khan et al., 2008).

Table 5. The t-test for the translocation factor (TF) of Pb and Cd metals in plants grown on and outside the land in the former landfill site.

Wide Test	t-calc				t-table
	Concentration Pb		Concentration Cd		
JD x LD	0,81	tn	1,24	tn	2,23
JD x KD	1,09	tn	1,89	tn	2,26

LD x KD	0,51	tn	0,79	tn	2,26
JD x JL	0,35	tn	1,56	tn	2,31
LD x JL	0,42	tn	2,77	*	2,36
KD x JL	0,77	tn	0,13	tn	2,45
D x L	0,19	tn	0,80	tn	2,09

Explanation:

JD : Corn crops, cultivation in landfill
LD : White Pumpkin plants, cultivation in landfill
KD : Krai plants, cultivation in landfill
JL : Corn crops, cultivation outside the landfill
D : Plants are cultivated in landfill
L : Plants are cultivated outside the landfill
* : significant difference
Ns : No significant difference

Results of the statistical test (t-test with $\alpha = 0.05$) for the bioaccumulation factor (BAF) of the heavy metals Pb and Cd in plants cultivated on and outside the former landfill site for each plant show significant differences, but the general observation of the sample (D x L) does not indicate significant differences. This implies that the impact of the heavy metals Pb and Cd contained in the land of the former landfill site has the same effect on the accumulation of these metals both in plants grown on and outside the land. Thus, the toxic effects of the heavy metals Pb and Cd contained in the land of the former landfill site also have contaminated the plants cultivated not on the land.

IV. CONCLUSION

The above experimental results show that the land in the former landfill site has been utilized by the surrounding community for the activity of agricultural cultivation and the Pb metal content is 28.20 mg kg^{-1} while the Cd metal content is 6.73 mg kg^{-1}. The lowest total Pb metal content is found in white pumpkin plants (1.17 ± 0.11 mg kg^{-1}) and the highest total Pb metal content is found in corn (1.82 ± 0.19 mg kg^{-1}). As for Cd metal, the lowest total metal content is found in white pumpkin plants (1.04 ± 0.15 mg kg^{-1}) and the highest total Cd metal content is found in corn (1.43 ± 0.14 mg kg^{-1}). In general, the total content of Pb and Cd metals in plants cultivated on and outside the land in the former landfill site (D x L) does not differ significantly. All the plants grown on the land in the former landfill site are resistant and hyperaccumulators characterized by the TF value by > 1.

ACKNOWLEDGEMENT

This article is part of the first dissertation of the author in the Post Graduate program of Brawijaya University in Malang, Indonesia. I would like to express my gratitude to the Directorate of Higher Education for the financial support, and the PPIKID Team of Brawijaya University for their help in the preparation of this article.

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