The Influence of Cadmium Heavy Metal on Vitamins in Aquatic Vegetables

Hening Widowati

Department of Biology, Universitas Muhammadiyah Metro, Lampung 34111, Indonesia

E-mail: hwummetro@gmail.com

Abstract

The absorption of cadmium heavy metal in 3 (three) kinds of aquatic vegetables; water lettuce (*Limnocharis flava*), water convolvulus (*Ipomoea aquatic* Forsk.) and watercress (*Nasturtium officinale* R. Br) was studied to determine the influence of the contents of vitamins A and C. The purpose of this research was to identify the accumulation of cadmium in the organs of the aquatic vegetables, and their influence to the contents of vitamins A and C. This research was conducted by employing the factorial experimental design of randomized block design (RBD) with 3 (three) factors. The data was analyzed by regression to detect the correlation and contribution of cadmium influence on the aquatic vegetables. The accumulation of cadmium in the 3 (three) aquatic vegetables was mainly occured in the stems and leaves. Water lettuce has the highest accumulation of cadmium, followed by water convolvulus and watercress has the least. Cadmium is responsible for the declining levels of vitamins A and C.

Abstrak

Pengaruh Logam Berat Cd terhadap Vitamin Sayuran Air. Serapan logam berat tiga jenis sayuran air yaitu Genjer (*Limnocharis flava*), Kangkung air (*Ipomoea aquatica* Forsk.) dan Selada air (*Nasturtium officinale* R. Br) diteliti pengaruhnya terhadap kandungan gizinya. Penelitian bertujuan mengidentifikasi logam berat yang berpotensi terakumulasi pada organ sayuran air, dan pengaruhnya terhadap kandungan vitamin A, dan vitamin C. Penelitian dilakukan pada lingkungan bersih dan tercemar. Data dianalisis dengan *One-Way Anova* dan uji lanjut LSD untuk mengetahui perbedaan serapan logam, dan vitamin; serta regresi untuk mengetahui kontribusi cadmium dalam mempengaruhi gizi sayuran. Akumulasi pada ketiga jenis sayuran dominan pada akar dan terendah pada daun. Genjer paling tinggi mengakumulasi semua macam logam, selanjutnya kangkung air dan terendah selada air. Cadmium memberi kontribusi pada penurunan vitamin A dan C.

Keywords: accumulation, aquatic vegetables, cadmium, heavy metal, vitamin

1. Introduction

Every human activity causes contamination of the environment. The contamination negatively affects life; thus, contamination control is a program that must immediately be implemented. One of the most outstanding contaminants resulting from human activity is heavy metal pollutants. Heavy metal is a metal element with heavy weight molecules; the specific gravity is more than 5 g/cm^3 [1]. In a low concentration, heavy metal is poisonous to plants, animals, and people. There are several heavy metals that commonly contaminate the environment; Hg, Cr, As, Cd, and Pb [2-5]. The observation of water quality at Brantas river drainage basin undertaken by Jasa Tirta 1 from between the years 2002-2009 revealed contamination by several heavy metals namely, Zn, Cu, Cr, Cd, As, and Pb although they had not yet exceeded the threshold.

Heavy metal pollution is not controlled from any source because its high density will give opportunities to metal accumulation in the environment. The accumulation may possibly occur in areas of agricultural crops including aquatic vegetables that grow easily in a polluted environment. Heavy metal can be absorbed by plant tissues through the roots and leaf stomata; in the next cycle it will enter the food chain [6]. When the accumulation of heavy metal exceeds the tolerance range, it can cause toxicity to plants, animals, and even humans. It has been observed that a lot of plant species of tolerant to metals have defensive mechanisms associated with the antioxidant cell and antioxidant enzymes which protect some vital physiological processes from damage caused by the reactive oxygen that forms as a response to the stress caused by the metal content [7].

The plant's tolerance or resistance toward the stress caused by metal content can be associated with one or more mechanisms, for instance: (i) the excretion of a selatin compound that lowers the presence of metals in the soil or water, (ii) the excretion of metal through certain absorption elements, (iii) the storing of metal in the roots that prevents the metal migrating to aerial parts, (iv) the sequestration of the heavy metal by a ligand, compartmentalization, biotransformation, and mechanisms of cell regeneration, (v) the development of metal-tolerant enzymes [8-11], (vi) the increasing production of intracellular compounds related to the metal, (vii) the immobilization of metals within the cell wall [12], (viii) the homeostatic cell mechanism to organize metal ions within the cells, (ix) the induction of heat-shock proteins, (x) the release of phenols from the root, (xi) the increasing tolerance of the mineral deficiencies or the decrease of nutrient needs, (xii) the increasing absorption of certain macronutrients, and (xiii) the development of a capacity to absorb and use mineral remainings despite the existence of heavy metals in the plant [13]. Due to the tolerant mechanism or resistance (single or combined), some plants can grow in contaminated environments, whereas other plants can not survive.

The stress of environmental pollutants improves the formation of free radicals, damages various enzymes, and reduces the amount of protein in the plant organs. To eliminate the effects of free radicals, the plants develop various defensive mechanisms. The application of an antioxidant system is to reduce pollutant stress which is characterized by the loss/decrease of the antioxidant vitamins (vitamins A, C, and E) [14].

Free radicals can damage cell membranes and alter DNA, change chemical substances in the body, increase the risk of cancer, and harm and disable proteins. Antioxidant substances (carotenoids/source of vitamins A, C, E, and Zinc mineral and selenium) can recover the body's cells, neutralize or wipe out the free radicals from oxygen forms that possess high levels of reaction and that naturally exist in the body. Vitamin C prevents oxidation of the liquid-based molecules, whereas vitamin E is diluted in the fat to work in lipid cells and cholesterol circulation [15].

Research conducted by a research agency and agricultural development of the Department of Agriculture revealed that sample analysis of cabbage, tomatoes and carrots which were obtained from production centers in west Java and east Java were generally contaminated by Iron (Fe) and lead (Pb) above the maximum residue limit (MRL). Meanwhile, the contaminant metals, such as AS, Cd, and Zn, were still at a safe level, but need to be monitored. Rice is noted to carry around 0.05 to 0.59 ppm, and has exceeded the threshold. Cd poisoning can trigger high blood pressure, testicular tissue damage, kidney failure, and damage to red blood cells. Itai-itai is a form of osteoporosis (bone fragility) caused by Cd. Besides that, Cd can cause growth and, reproduction irregularities, hypertension, tera-togenesis, and even cancer [16].

Based on the description above, a study of heavy metal Cd existing in the aquatic environment and absorbable by aquatic vegetables commonly consumed by humans and the nutrient content of vegetables, especially, protein, vitamin C and A, is required. The information obtained above is intended to encourage farmers to grow vegetables in uncontaminated fields and to raise consumer awareness about the origins of the vegetables. Thus, vegetable productions will be of a good quality, safe to eat, and highly nutritious.

2. Methods

The experimental design used a factorial randomized block design (RBD) with three factors. The first factor was the three kinds of aquatic vegetables, namely Water Lettuce, Water Convolvulus, and Watercress. The second factor was the type of growth media, *Hoagland* medium contains Cd, Pb heavy metals, and the mixture of the data analysis survey showed it had a significant effect in influencing the content of protein, vitamin A, and vitamin C. The third factor was the time for harvesting the aquatic vegetables, i.e, minus ½ (T1) of the customary harvesting time, exact harvesting time (T2), and plus ½ of the customary harvesting time (T3). Thus, the independent variables are different kinds of vegetables, a variety of heavy metals (Cd and Pb) and various times of harvesting the vegetables, and the dependent variables are the content of absorbent heavy metals, and the levels of vitamin A and vitamin C. The data collected were compiled and analyzed by Microsoft Excel 2007 software. The software is employed to find out whether there are any differences in the absorption of Cd metal, vitamin A, vitamin C, before and after the harvesting time treatment of T1, T2, T3 Anacova (*Analysis of covariant*) *Multivariate; One-Way Anova* to analysis was used to check whether there are any differences in Cd metal absorption, Vitamin A, Vitamin C, time of harvesting and treatment medium for each type of vegetables. If the data show that there are significant differences, it will be followed up on by undertaking a further test of the least significant differences (LSD/least significant difference test method) to 5%. The correlation of the metal absorption to the reduction of vitamins A, C, and stems and leaves of vegetables are analyzed by linear regression correlation and regression.

3. Results and Discussion

Cadmium Content in the Stem and Leaf of Water Lettuce for Vitamins A and C. Regression analysis of heavy metal cadmium content of water lettuce of vitamin A obtained highly significant correlation (F = 0.00) of the regression equation Y = 3967.432-65163.395X with R² 0.6170 to vitamin C which obtained a highly significant correlation (F = 0.00) of the regression equation Y = 57 193-770.415X with R2 = 0.7470. Based on the analysis, cadmium absorption is negatively correlated to the amount of vitamins A and C. Cadmium im's increase was followed by a decline in vitamins. Cadmium contribution to the reduction of vitamin A is 61.70%, and for vitamin C it is 74.70%. A longer harvesting time will cause a decline of vitamins A and C.

Cadmium Content in Stems and Leaves of Water Convolvulus of Vitamins A and C. The result of regression analysis of water convolvulus to vitamin A

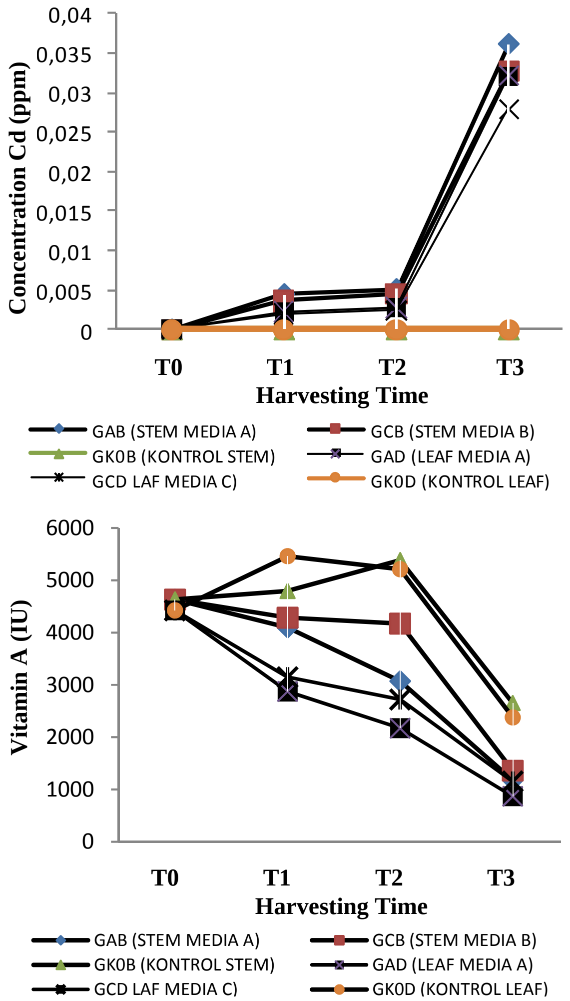

Figure 1a. Cd Accumulation and Vitamin A Content in Leaf and Stem of Genjer During Harvesting Period

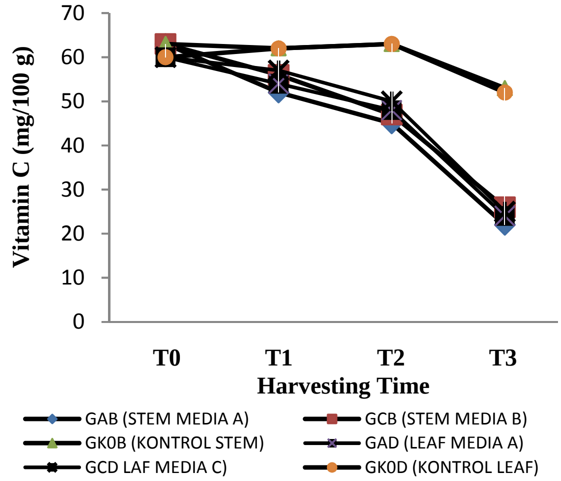

Figure 1b. Vitamin C Content in Leaf and Stem of Genjer During Harvesting Period

shows that there is a highly significant correlation (F = 0.00) of the regression equation: Y = 6703.422-62374.778X with R² 0.5860. There is also a very significant correlation to vitamin C (F = 0.00) of the regression equation Y = 34165-225 X .270 with R2 = 0.66. Based on the analysis, cadmium absorption is negatively correlated to the content of vitamin A and C of water convolvulus. It means that significant improvement will be followed by a decline in vitamins. The cadmium contribution towards the reduction of vitamin A is 58.60% and for vitamin C it is 66%. The cadmium content in the stems is higher than in the leaves. A longer harvesting time will cause a decline of vitamins A and C.

Cadmium Content in Stems and Leaves of Watercress of Vitamins A and C. The regression analysis result of watercress vegetable to vitamin A was significantly correlated (F = 0.00) with the regression equation Y = 2116.904-36193.228X with R² 0.5480. There is a very significant correlation to vitamin C (F = 0.00) of the regression equation Y = 52 445-267.047X with R2 = 0.6270. Based on the analysis, there was a correlation to cadmium absorption to the content of vitamins A and C of watercress. It means that the increase of cadmium was followed by a decrease of vitamins; the cadmium contribution to the reduction to vitamin A is 58.80% and to vitamin C it is 62.70%. The cadmium content in the stems was higher than in the leaves. The longer harvesting time of will cause a decline in vitamins A and C.

The accumulation in the three types of vegetables mainly occurred in the stems, with the least accumulation in the leaves. Although there is no maximum exceeding threshold of metals for vegetable consumption, the heavy metals have lowered the protein content and vitamins (C and A) in the vegetables. Water lettuce is the vegetable that accumulates most kinds of metals, followed by water convolvulus, and finally watercress.

The behavioral differences in the metal absorption are influenced by the types of plants. According to [17], metal accumulation in plants does not only depend on the content of metals in water and soil, but also on the chemical elements of the soil, the metal elements, the soil pH and the plant species. Dicotyledons (water convolvulus) generally have a larger absorption rate due to their type of arrow roots. However, monocotyledons can also have high absorption becauseof their high transpiration levelsand root systems which spread out in all directions in the growth medium. The large absorption of heavy metal in the roots of water lettuce is supported by fiber roots which are relatively large and long. The thin and wide leaves of water lettuce and its stem structures are equipped with water storage cavities. Water lettuce is also relatively embedded in the metal-rich sediment more than any other vegetables, such as water convolvulus and watercress that float on the water

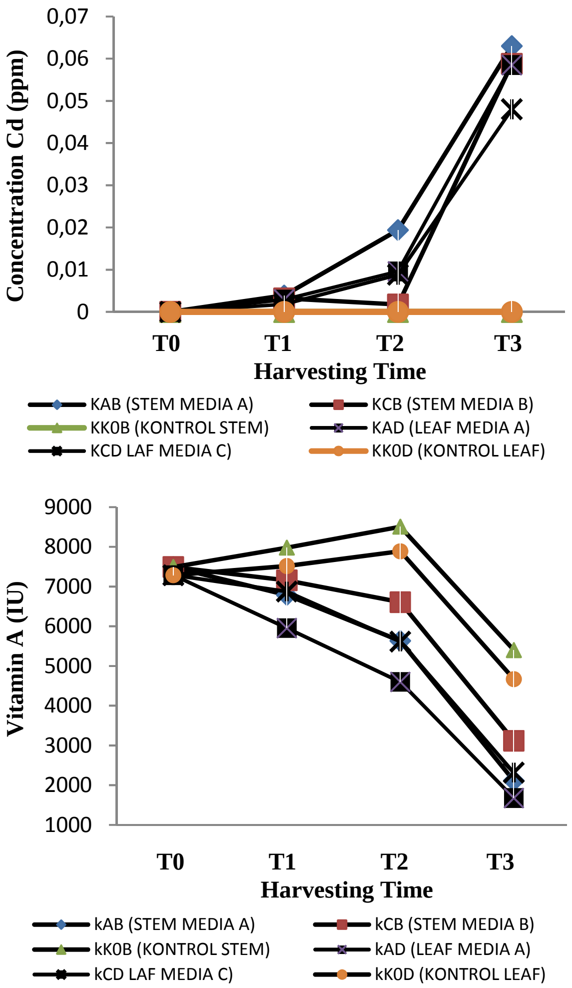

Figure 2a. Cd Accumulation and Vitamin A Content in Leaves and Stems of Water Convolvulus During Harvesting Period

and have relatively less metal content. The stronger the sediment is embedded the more the plants in the aquatic environment absorb the metal which is assisted by the aerial parts of plants. The tip of the leaves of aquatic

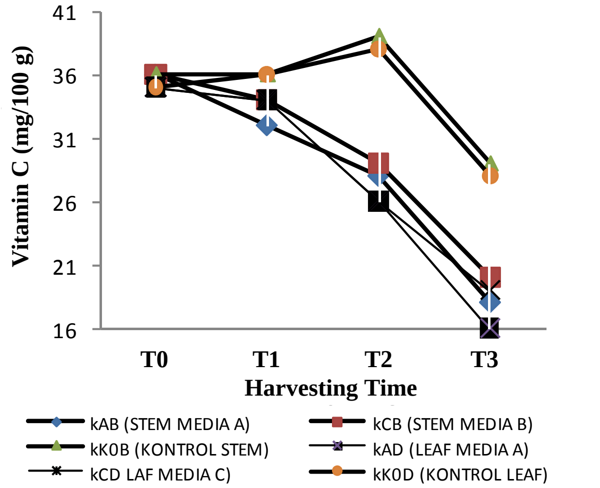

Figure 2b. Vitamin C Content in Leaves and Stems of Water Convolvulus During Harvesting Period

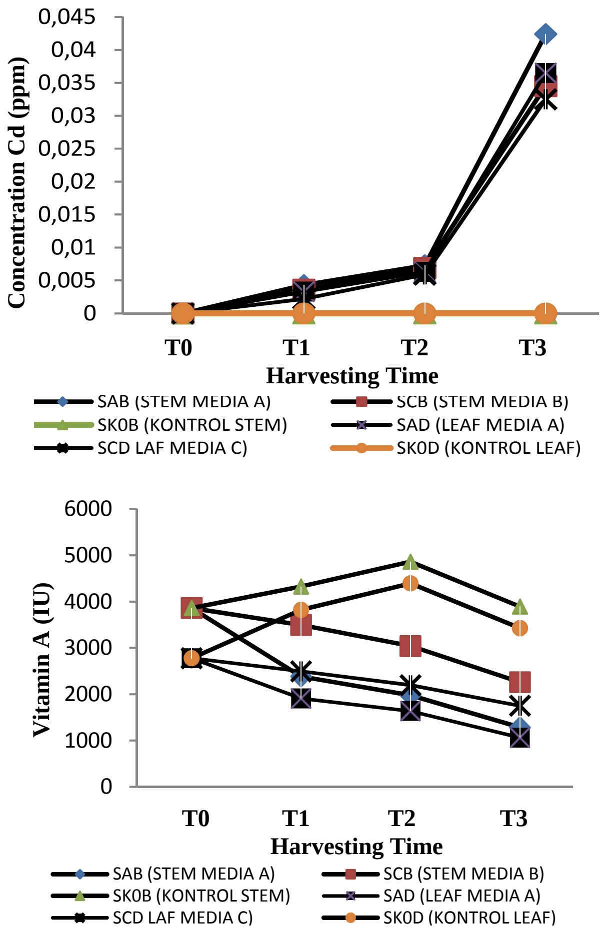

Figure 3a. Cd Accumulation and Vitamin A Content in the Leaves and Stems of Watercress During Harvesting Period

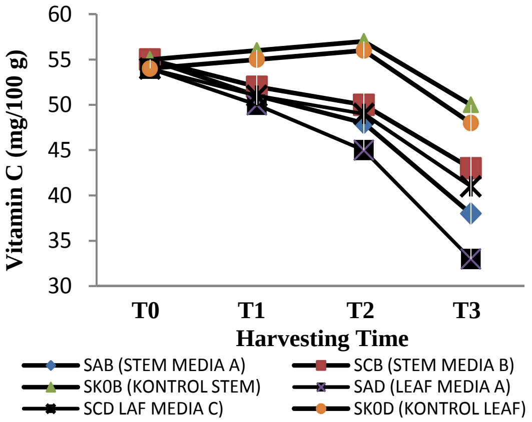

Figure 3b. Vitamin C Content in Leaves and Stems of Watercress During Harvesting Period

embedded plants in the wetlands can take in pollutants including heavy metals that dissolve in the water and travel through the roots [18]. When the plants grow in the environment, including in the water, the plants effectively lower the pH and amount of oxygen that affects the presence of metals [18], and is subsequently absorbed by the plant parts. Thus, water lettuce can absorb a higher amount of heavy metals than any other aquatic vegetable.

It is visibly recognized that the organ structures of water lettuce and water convolvulus are tougher, with more fibre, cellulose and high lignin, and the metal can be transported through this section so that the metal becomes immobile in metabolism. Then the damaged protein of plants can be suppressed, and the reduction of the antioxidants of vitamins A and C as the reaction of free radicals/oxidants can be reduced. This way the decrease is not as great as in watercress. Watercress has softer and less clay organs, and this thus less lignin. Hence, the heavy metal absorbed can not be transported but will follow the metabolism of plants allowing protein damage and a decline in vitamins.

The low absorption of heavy metals (despite beinglower than the permitted threshold) in the stems and in the leaves of vegetables can not guarantee that the vegetables are edible. As we know, heavy metal, in spite of its essential micronutrient (Cd), is deadly toxic to any kinds of organisms in varied types. It beginis with the action of accumulation. Eventually, accumulation will occur in the targeted organs and exceed the threshold which in the end can be fatal. If heavy metals enter the body tissues of the organisms, it is difficult to remove them; they will lead to a series of bioaccumulation, biotransformation, and biomagnification processes in the food chain. Although it is initially assimilated in small quantities, as time goes by, it will cause negative effects on the body (chronic). Therefore, no matter how small the heavy metal pollutant is, it needs to be recognized.

When the vegetable has been contaminated by the heavy metals, it will endanger the body. If the heavy metals exceed the threshold tolerance of the plants, they will act as free radicals which can block or hinder the cluster work of bio molecules that are essential for biological processes, such as the proteins and enzymes [19]. The effects are that the higher the absorbency of the heavy metal, the lower is the protein preserved in the vegetables. Vitamins C and A also declines.

The accumulation of cadmium in all kinds of aquatic vegetables occurs predominantly in the stems and to a lesser degree in the leaves. The highest cadmium accumulation occurs in water lettuce, water convolvulus, and the lowest accumulation was in watercress. The increasing accumulation of cadmium over a long harvest was followed by a decrease in vitamins A and C. The regression analysis of heavy metal cadmium content of water lettuce of vitamin A obtained a highly significant correlation (F = 0.00) of the regression equation Y = 3967.432-65163.395X with R^2 0.6170 to vitamin C which obtained a highly significant correlation (F = 0.00) of the regression equation Y = 57 193- 770.415X with R2 = 0.7470. Based on the analysis, cadmium absorption was negatively correlated to the amount of vitamins A and C. Cadmium improvement was followed by a decrease of vitamins. Cadmium contribution to the reduction of vitamin A is 61.70%, and for vitamin C it is 74.70%.

The result of regression analysis of water convolvulus for vitamin A shows that there was a highly significant correlation (F = 0.00) of the regression equation: Y = 6703.422-62374.778X with R^2 0.5860. There was a very significant correlation to vitamin C (F = 0.00) of the regression equation Y = 34165-225 X .270 with R2 = 0.66. Based on the analysis, cadmium absorption is negatively correlated to the content of vitamin A and C of water convolvulus. This means that significant improvement was followed by a decrease in vitamins. The cadmium contribution towards the reduction of vitamin A is 58.60%, and for vitamin C it is 66%.

The regression analysis result of the watercress vegetable to vitamin A was significantly correlated (F = 0.00) with the regression equation Y = 2116.904-36193.228X with R^2 0.5480. There was a very significant correlation to vitamin C (F = 0.00) of the regression equation Y = 52 445-267.047X with R2 = 0.6270. Based on the analysis, there was a correlation to cadmium absorption to the content of vitamins A and C of watercress. This means that the increase of cadmium will be followed by a decrease of vitamins. The cadmium contribution to the reduction in vitamin A was 58.80%, and for vitamin C it is 62.70%.

4. Conclusions

Our results showed that water lettuce was the highest heavy metal absorbent, followed by water convolvulus, and watercress. However, when the amount of metals absorbed was compared, the decrease in nutrients for protein, vitamin C or vitamin A, occurred in watercress.

To reduce the accumulation of metals and cadmium spreading into the environment and the food chain, it is recommended that the vegetables that grow in polluted environments should be harvested at the proper harvest time, and consumption should be limited to the leaves only.

Acknowledgement

The author would like to thank for the financial support from Hibah Penelitian Mahasiswa Program Doktor Tahun 2010 of Ministry of Education Republic of Indonesia Through Directorate or Research and Community Service- University of Malang with contract number 495/SP2H/PP/DP2M/2010.

References

[1] D.W. Connell, G.J. Miller, Kimia dan Ekotoksikologi Pencemaran, Terjemahan oleh Yanti Koestoer, UI-Press, Jakarta, 2006, p.518.
[2] Charlena, Disertasi, Program Pascasarjana, Institut Pertanian Bogor, 2004 (in Indonesia).
[3] Dahlia, Disertasi, Jurusan Pendidikan Biologi, Pascasarjana, Malang, Universitas Negeri Malang, Indonesia, 2006 (in Indonesia).
[4] H. Dahmani-Muller, F. van Oort, B. Gelie, M. Balabane, Environ. Poliet. 109 (2000) 600.
[6] B.J. Alloway, Heavy Metals in Soil, Jhon Willey and Sons Inc., New York, 1990, p.100.
[7] S.K. Panda, S. Choudhury, Braz. J. Plant. Physiol. 17 (2005) 95.
[8] J.L. Hall, J. Exp. Bot. 53 (2002) 1.
[9] C. Cobbet, P. Goldsbrough, Annu. Rev. Plant Biol. 53 (2002) 159.
[10] M. Patra, N. Bhowmik, B. Bandopadhyay, A. Sharma, Environ. Exp. Bot. 52 (2004) 199.
[11] A.R. Sahibin, I.W.M. Razi, A.R. Zulfahmi, L. Tukimat, G.M. Barzani, H.H. Jumaat, H.K. Low, Sains Malaysiana 37/4 (2008) 323.
[12] C. Cosio, L. DeSantis, B. Frey, S. Diallo, C. Keller, J. Exp. Bot. 56 (2005) 765.
[13] A.R. Meda, E.B. Scheuermann, U.E. Prechsl, B. Erenoglu, G. Schaaf, H. Hayen, G. Weber, N.V. Wiren, N. Plant Physiol. 143 (2007) 1761.
[14] O. Munzuroglu, E. Obek, F. Karatas, S.Y. Tatar, Pak. J. Nutr. 4/6 (2005) 402.
[15] Cyber Forums-Indonesian Cyber Community, Kerja Antioksidan di Tubuh, *http://www.cyberforums.us,* 2008 (in Indonesia).
[16] M.C. Linder, Biokimia, Nutrisi dan Metabolisme, UI Press, Jakarta, 1992, p.219.
[17] Darmono, Logam dalam Sistem Biologi, UI Press, Jakarta, 1995, p.140 (in Indonesia).
[18] A. Fritioff, M. Greger, Int. J. Phytorem. 5/3 (2003) 211.
[19] H. Palar, Pencemaran dan Toksikologi Logam Berat, Rineka Cipta, Jakarta, 2004, p.152 (in Indonesia).