CAFEi2012-218

DEVELOPMENT OF LOCAL PHYTO-ORGANIC FERTILIZER FOR MALAYSIAN AGRICULTURE

Zul Hilmi Saidin[1], Ramlah Mohd Tajuddin[1], Dzaraini Kamarun[2] and Norazah Abd Rahman[3]

[1]Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.
[2]Faculty of Applied Science, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.
[3]Faculty of Chemical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.
Email: ramlah2007@gmail.com

ABSTRACT

Phytoremediation had been well accepted worldwide as one of the successful green technologies for domestic wastewater treatment. This technology utilizes aquatic macrophytes to extract macronutrients from the wastewater and accumulate them in their plant tissues. The macrophytes are continuously multiplied and grown until the nutrients in the wastewater become exhausted. Hence, the macrophytes contain high concentration of macronutrients. In a manner to manage the wastewater treatment using the phytoremediation system, currently the macrophytes are harvested and disposed in landfill sites. Knowing that the macrophytes contain high concentrations of macronutrients, an attempt was made to produce an organic fertilizer from them. The phytoremediation system was designed and fabricated in the Hydrology Laboratory in Universiti Teknologi MARA (UiTM), Shah Alam. The macrophytes such as Water Hyacinth (*Eichhornia crassipies*), Caladium (*Caladium sp.)* and Water Lettuce (*Pistia stratiotes*) were used in the phytoremediation system. The macrophytes were harvested and windrow composted to produce local phyto-organic fertilizer, which was named as PhytoLizer (PL). The PL were analyzed for their physico-chemical parameters such as total carbon (TC), total nitrogen (TN), carbon-nitrogen ratio (C/N), phosphorous (P), potassium (K), sulfur (S) as well as pH and moisture content (MC). The performance of the PL produced was then characterized and reported.

Keywords: *Aquatic Macrophyte, Domestic Wastewater Treatment, Nutrients, Organic Fertilizer, Phytoremediation.*

INTRODUCTION

Most of the phytoremediation system used for wastewater treatment shows its ability to remove and extract macronutrients primarily the nitrogen and phosphorous components [1, 2, 3, 4]. Thus the technology currently becomes popular as an alternative technology in wastewater management. This is due to its ability to protect both the environment and public health in an economical way at a lower cost compared to the conventional wastewater treatment [5, 6]. Previous studies mainly focused on the species and the efficiency of the aquatic macrophytes to extract nutrients which were regarded as contaminants in the wastewater [1, 4, 7, 8, 9]. However, very limited studies have focused on the management of post-harvested aquatic macrophytes. Hence, the post-harvesting stage of the macrophytes becomes essential since naturally decay or dead aquatic macrophytes are directly supplied to organic contaminants in treated wastewater [1, 9]. At present, these macrophytes are harvested and disposed in landfill sites [10].

Knowing that these macrophytes contain high concentrations of macronutrients, an attempt was made to produce an organic fertilizer named PhytoLizer (PL) from them. The transformation of harvested macrophytes from the phytoremediation system to compost was through the windrow composting process. Windrow composting is acknowledged as the most efficient way to dispose organic waste, is a low-priced technology and suitable to produce organic fertilizers in large scales [11]. The technology is an open aerobic biological process that uses naturally occurring microbes to transform organic substances into a humus-like product [12, 13].

Recently, the application of organic fertilizers in the Malaysian agricultural activities has become popular as a result of excessive increases in the agricultural products [14]. In addition, the government has imposed policies on organic farming system. This is due to the capability of the organic fertilizer to act as an input to sustain soil fertility [14, 15]. Furthermore, supplies of organic fertilizers in the market were imported from neighboring countries since the production of domestic organic fertilizer is very minimal [16].

Therefore, this study aims to develop and characterize an organic fertilizer (PL) generated from phytoremediators (local aquatic macrophytes) harvested from the phytoremediation system of domestic wastewater. Nutrients extracted by these phytoremediators are stored in the composted phytoremediator and directly used as organic fertilizers. This waste to wealth concept possibly contributes to the supplementary organic fertilizer source and at the same time makes the phytoremediation system become sustainable.

MATERIALS AND METHODS

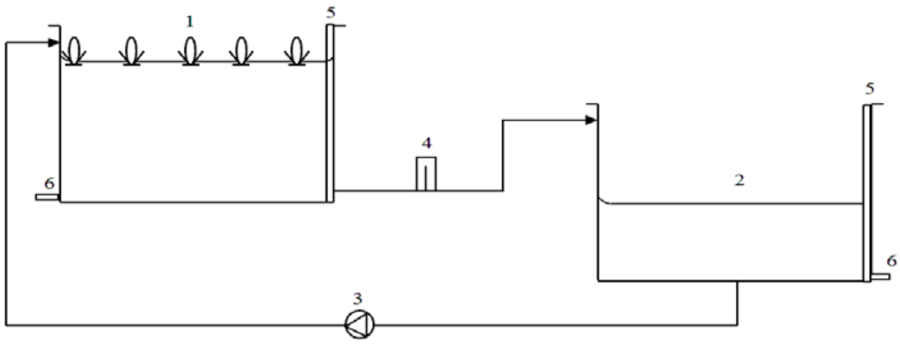
This study is performed in 3 phases: a) Design and fabrication of the phytoremediation system, b) Phytoremediation of nutrients from domestic wastewater, and c) PhytoLizer production through windrow composting process.

Design and fabrication of the phytoremediation system

The phytoremediation system was designed and fabricated in the Hydrology Laboratory of the Faculty of Civil Engineering in Universiti Teknologi MARA (UiTM), Shah Alam as shown in Fig. 1 and Table 1. This system was designed as a continuous system to harmonize it to the conventional wastewater treatment system when an integrated wastewater treatment system was to be used at site. The wastewater samples were collected from the Mawar Residential Sewage Treatment Plant in Universiti Teknologi MARA (UiTM), Shah Alam. As for the sampling, the containers were thoroughly rinsed with 10% of nitric acid and distilled water. Aquatic macrophytes were chosen as they were low-priced and easily available locally. They consisted of the water hyacinth (*Eichhornia crassipies*), caladium (*Caladium sp.*) and water lettuce (*Pistia stratiotes*). They were collected from the Section 8 Lake in Shah Alam. Each of the macrophytes was cleaned thoroughly with distilled water [8], softly trashing the soft tissues, before placing them in separated containers.

Table 1: Experimental details of the phytoremediation system

Experimental Detail	Description
Dimension of phytoremediation system	0.66 m x 0.44 m x 0.35 m
Depth of wastewater	0.22m
Volume of wastewater	34L
Flow of wastewater	6L/min



1, 2 Phytoremediation Tank 3 Water Pump 4 Flow Meter
5 Level Meter 6 Discharge Valve

Fig. 1: Schematic diagram of the phytoremediation system

Phytoremediation of nutrients from domestic wastewater

The macrophytes were cultured separately in the system filled with 24 L of domestic wastewater and in another system as the control without any macrophytes. As for the experiment, the wastewater was further filtered by using a cotton sieve to trap the major suspended solids. Volume losses in the treatment due to water

e-ISBN 978-967-960-322-4

sampling and/or evaporation were countered by adding distilled water [3]. The experiment was conducted until the macrophytes showed symptoms of death (survival capacity) or the results of the nutrient concentrations in wastewater became significantly consistent.

PhytoLizer production through windrow composting process

The phytoremediated macrophytes (PL) were harvested from the phytoremediation system. As for the control compost (CC), macrophytes were harvested at their original habitat without having any wastewater treatment. They were cleaned thoroughly with saline water (2M NaCI), aqueous EDTA (2g/L), tap water and deionized water [12], softly trashing with the soft tissues, before placing them in separated windrow composting reactors. This procedure was important in order to free the macrophytes from adhering microflora and muck. The macrophytes were categorized as: a) PhytoLizer of Water Hyacinth (PL_{WH}), b) PhytoLizer of Caladium (PL_{CD}), c) PhytoLizer of Water Lettuce (PL_{WL}), d) Control-Compost of Water Hyacinth (CC_{WH}), e) Control-Compost of Caladium (PL_{CD}), and f) Control-Compost of Water Lettuce (CC_{WL}). They were then weighed before being put into the windrow composting reactors. Each of the reactors was supplied with 0.5 kg of harvested macrophytes.

The composts were prepared by the windrow composting method. They were windrow composted until they reached the maturity state (approximately 90 days). In a manner to generate the average moisture content of 45-65%, the entire macrophytes were sprinkled with adequate water [13]. This indicated that the microbial activity happened perfectly during the composting process and led to an increase in the temperature. This average moisture content of the reactors was monitored and maintained at this average within periodic monitoring. The composting process was monitored and observed once in a week until the maturing period. The completion of the composting process was indicated when the content of composts did not lead to a rise in temperature after mixing the contents [13].

The composts were characterized for their physico-chemical parameters. TC was determined by the dry combustion method at 540°C for 4 h [17] and TN was determined by the Kjeldahl method [18]. The phosphorous (P), potassium (K) and sulphur (S) content in the solution were analyzed using the UV/VIS Spectrophotometer. Carbon-nitrogen (C/N) is the ratio between TC and TN values. pH was determined by the aqueous extract of compost which was obtained by mechanically shaking the samples with double distilled water at a solid and water ratio of 1:10 (dry weight/volume) for 1 hour [13]. Moisture content was determined by the gravimetric method by drying the samples for 24 hours at 105°C [19].

Data Analysis

The data were analyzed for mean, standard deviation (n=3) and error bar with 5% of value using the statistical package within Microsoft® Excel Version 2010.

RESULTS AND DISCUSSION

The physic-chemical compositions of the PL and CC were tabulated and compared to the commercial organic fertilizer and green manure, as shown in Table 2. The physico-chemical compositions of the PL and CC were compared with respective aquatic macrophytes, as shown in Fig. 2.

Acidity condition of PhytoLizer, control-composts and commercial organic fertilizer

The pH levels varied at the ranges of 7.44 to 8.01 and 7.53 to 8.13 for the PL and CC, respectively (Table 2). Hence, the CC was more alkaline than the PL. However, these pH values were still within the preferred ranges which were 6.5 to 8.5 as mentioned in Fong *et al*. [20]. The increase in the pH values during the composting process was caused by the microbial activity. The pH of the final compost was generally between 7.00 and 8.50 in which the limiting pH value could help to sustain the soil pH on light land [21]. According to Sánchez-Monedero *et al*. [22] and Dias *et al*. [23], the factors affecting the pH were the formation of ammonium from protein degradation, the mineralization and nitrification of N, the initial decarboxylation of organic acids and the production of humid acids.

Table 2: Physico-Chemical Compositions of the PhytoLizer (PL) and Control-Compost (CC) Compared to Commercial Organic Fertilizer and Green Manure

Parameters	PL			CC			Range of Physico-Chemical Contents from Commercial Organic Fertilizers* [15, 24]	Range of Physico-Chemical Contents from Green Manure# [15, 24, 25]
	WH	CD	WL	WH	CD	WL		
pH [1:10]	7.99±0.21	8.01±0.03	7.44±0.16	8.01±0.23	8.13±0.15	7.53±0.42	4.50-9.80 [1:5]	6.60 [1:5]
MC [%]	57.17±1.86	56.27±0.32	56.94±2.33	58.92±0.73	57.01±0.64	58.96±1.42	40.00-50.00	< 20
TC [%]	24.16±4.40	20.93±0.00	24.18±0.03	23.65±0.01	25.65±0.50	40.88±0.43	8.40-45.00	26
TN [%]	2.18±0.01	1.79±0.00	2.40±0.02	2.25±0.02	2.05±0.05	2.40±0.03	0.70-4.40	0.4-4.0
P [%]	0.39±0.03	0.33±0.01	0.59±0.01	0.34±0.01	0.47±0.03	0.31±0.02	0.04-8.85	0.04-1.39
K [%]	3.40±0.00	4.87±0.02	2.90±0.01	1.69±0.04	8.46±0.02	1.20±0.04	0.38-6.94	0.18-5.81
S [%]	0.54±0.00	0.27±0.00	0.46±0.00	0.26±0.00	0.24±0.02	0.57±0.02	0.20-0.30	0.2-0.3
C/N Ratio	11.08	11.69	10.08	10.51	12.51	17.03	3.80-42.70	20.9

Mean ± standard deviation of three samples (n=3)
WH: Water Hyacinth, CD: Caladium, WL: Water Lettuce, TC: Total Carbon, TN: Total Nitrogen, P: Phosphorous, K: Potassium, S: Sulphur, C/N: Carbon-Nitrogen Ratio
*The sources of commercial organic fertilizers consisted of oil palm wastes base, green manure base (e.g. sawdust, paddy straw, farm yard, fruit bunches) and manure base (e.g. cattle manure, goat manure, poultry manure).
The sources of green manure consisted of sawdust, paddy straw, barley straw, farm yard and fruit bunches.

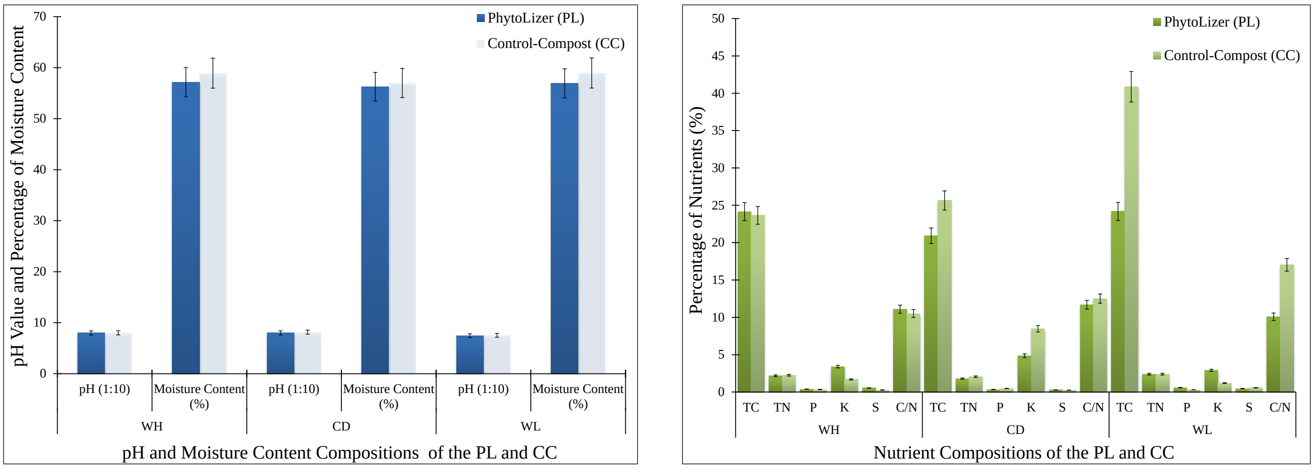


Figure 2: Physico-Chemical Compositions of the PhytoLizer (PL) and Control-Compost (CC) with the respective Aquatic Macrophytes. WH: Water Hyacinth, CD: Caladium, WL: Water Lettuce, TC: Total Carbon, TN: Total Nitrogen, P: Phosphorous, K: Potassium, S: Sulphur, C/N: Carbon-Nitrogen Ratio
Error bar denotes error amounts of mean (n=3) with 5% value

Moisture content of PhytoLizer, control-composts and commercial organic fertilizer

MC is a vital parameter to ensure that the microbial activity is in optimal condition during the composting process. Materials in dry compost will not decompose efficiently. Both Tchobanoglous *et al.* [26] and Liang *et al.* [27] recommended that 50% MC was the minimal requirement for the rapid increase in microbial activity. Meanwhile, Kumar *et al.* [28] recommended that MC for maximum microbial activity in composted materials of green waste and food waste at a low C/N ratio (19.6) was 60%. Liang *et al.* [27] also declared that MC was important during the composting process for transporting dissolved nutrients to microbes for their physiological and metabolic activities. Table 2 shows the moisture profile of the PL and CC which is in the range of 56.27% to 57.17% and 57.01% to 58.96%, respectively. It was seen that the PL satisfied the guidelines recommended by both Tchobanoglous *et al.* [26] and Liang *et al.* [27]. It also showed that the MC of PL was higher than the commercial organic fertilizer and green manure.

TC condition of PhytoLizer, control-composts and commercial organic fertilizer

The TC of the PL and CC in this study ranged from 20.93% to 24.18% and 23.65% to 20.88%, respectively (Table 2). The TC value was highest for PL (24.18%) and CC (40.88%) for both the WL species (Fig. 2). The results showed that the TC values of PL and CC were still in the range of commercial organic fertilizers except for CC_{WL} (40.88%) where only CC_{WL} was beyond the green manure value (26.00%). This result indicated that organic matters (OM) were difficult to decompose in WL during the period of windrow composting process compared to the other species. Reflecting upon this fact, Li and Zhang [29] and Solono *et al*. [30] have also mentioned that organic matters (OM) such as lignin were difficult to be degraded and they would be decomposed gradually during the humification of OM. Hence, lignin was a contributor for the major part of TC element in the composts that became humus. Whereas, biodegradable compounds such as sugars, organic acids, phenols, proteins and peptides were easily decomposed. During composting, OM was oxidized and transformed to CO_2, H_2O and new microbial biomass [30].

TN condition of PhytoLizer, control-composts and commercial organic fertilizer

The PL and CC had a concentration of TN ranging from 1.79% to 2.40% and 2.05% to 2.40%, respectively. The TN content was richest in the WL species for both the PL and CC (2.40%). It was remarkable that the TN of PL were in the range of the commercial organic fertilizer (0.70% - 4.40%) and green manure (0.40% - 4.00%). The TN content is the sum of the organic bonded N and the inorganic N (ammonium-nitrogen NH_4^+, nitrate-nitrogen NO_3^--N and nitrite-nitrogen NO_2^-). In the present study, the TN concentration in PL was lost during the composting period. In the other report of Barrington *et al*. [31] and Guo *et al*. [32], TN significantly decreased from about 16% to 76% until the end of the composting period. This phenomenon as the result of non-nitrogenous organic compounds were mineralized through three processes which were the weight loss of composts; NH_4^+ variation due to mineralization and to volatilization of organic bonded N, ammonia leaching and immobilization; and NO_3^- -N variation due to nitrification and to leaching, denitrification and immobilization [33, 34]. In this experiment, over added moisture and leaching were the major factors that affected the losses of the TN content, especially in PL. In order to reduce TN losses, the composts must be controlled by adjusting the pH value, controlling compost temperature, adding P and Mg and inoculating microbes [35, 36].

C/N condition of PhytoLizer, control-composts and commercial organic fertilizer

The C/N ratio of the PL and CC ranged from 10.08 to 11.69 and 10.51 to 17.03, respectively (Table 2). CC_{WL} (17.83) had highest C/N ratio compared to PL_{CD} (11.69) (Fig. 2). Both Fong *et al*. [20] and Liang *et al*. [27] have indicated that the optimum C/N ratio was approximately 25. From the results obtained, there was no PL and CC that achieved the range for green manure (26) and the optimum C/N ratio (25). Somehow, they were still in the range of the commercial organic fertilizer. There were enormous different values between the theoretical of C/N ratio and the present experimental results. This was because the existence of TC in both PL and CC was too low; thus it affected the value of C/N ratio. The ratio between C and N played an important role in the composting process where decomposition was decelerated if C (C/N ratio high) was in excess and the compost became malodourous if N (C/N ratio low) was in excess [37]. In order to encounter the ratio between C and N, brown materials such as leaves, straw, hay and sawdust which are high in carbon could be used. They could also be used as bedding material.

P, K and S condition of PhytoLizer, control-composts and commercial organic fertilizer

In this study, PL and CC had a concentration of P ranging from 0.33% to 0.59% and 0.31% to 0.47%; K ranged from 2.90% to 4.87% and 1.20% to 8.46%; and S ranged from 0.27% to 0.54% and 0.24% to 0.57%, respectively. The contents of P, K and S were richest in PL_{WL} (0.59%), CC_{CD} (8.46%) and CC_{WL} (0.57%), respectively (Table 2 and Fig. 2). It highlighted that PL was at the range of commercial organic fertilizer and green manure for the P, K and S contents. In addition, PL_{WL} exceeded the level of S content for both commercial organic fertilizer and green manure. According to the Official Fertilizer Standards of Korea [38], the contents of the P and K in organic fertilizer should be larger than 0.43% and 0.83%, respectively. Therefore, in the present study, the contents of P of PL_{WL} (0.59%) and CC_{CD} (0.47%) and K of all of PL passed the requirement. The low nutrient contents of P and S in PL and CC were remarkable in this study. The decrease of the P and S contents throughout the composting process might be a result of phosphate loss by volatilization and leaching [34] and volatilization and transformation of the S components [39, 40].

Performance of PhytoLizer and Control-Composts on the Influence of Aquatic Macrophytes

The phytoremediation process totally depended on the characteristics, capabilities and needs of the macrophytes. Even though the macrophytes were capable to extract, accumulate and concentrate the nutrients in their tissues, and/or convert them into non-toxic constituents [41, 42], the different plant species had different variation abilities for the nutrient uptake. It was notable that macronutrients accumulated by the WH and WL from the domestic wastewater contributed to the enrichment of the existence nutrient contents in their tissues. Thus, PL_{WH} and PL_{WL} significantly reached the high values of TC, P, K and S, and TN, P and K, respectively, compared to CC for the both species. Meanwhile, CD marked high values of TC, TN, P and K for CC compared to PL. This consequence was almost certainly because the CD species was not an accumulator in the hypereutrophic condition. This related to the fact that they were emergent species where their roots were naturally connected to the soil, whereas WH and WL were floating species where their roots were directly in contact with water. Hence, they did not react well in the state of hypereutrophic condition of the domestic wastewater.

CONCLUSIONS

In conclusion, PL showed high nutrient contents in WH and WL through their capability to accumulate and store nutrients in plant tissues and ability to maintain it throughout the composting period. Nutrient contents were the major aspect before any fertilizer was marketed. Through the results discussed above, the PL surpassed the minimum nutrient requirement practiced by the commercial organic fertilizer which included green manure bases. This was led to evidence that PL could be considered as an organic fertilizer and therefore making PL potentially be applied in the Malaysian agricultural sector.

The analysis of heavy metals of the PL and CC needs to be stressed on in future studies. This is an important measurement criterion for quality and safe practice before application in the organic farming system. The influence of nutrients in plant tissues after the phytoremediation process also needs to be assessed since nutrient accumulation from domestic wastewater by macrophytes showed a beneficial effect on PL and CC. The authors also recommend that an approach to control nutrient losses during the composting period need to be carried out since this period is vital for nutrient reservation, especially for PL.

ACKNOWLEDGEMENT

This research work was supported by a grant from the Research Management Institute (RMI) [No.: 600-RMI/ST/DANA 5/3/Dst (284/2009)], Universiti Teknologi Mara (UiTM). The authors would like to acknowledge the valuable technical support given by Noorul Hilmi Md Salleh and Muhamad Hazli Shariei. They also thank UiTM for its laboratory facilities.

REFERENCES

[1] Kohler, E.A., Poole, V.L., Reicher, Z.J. and Turco, R.F. (2004) Nutrient, Metal, and Pesticide Removal During Storm and Nonstorm Events by a Constructed Wetland on an Urban Golf Course. Ecological Engineering, 23, 285-298.

[2] Chang, H.Q., Yang, X.E., Fang, Y.Y., Pu, P.M., Li, Z.K. and Rengel, Z. (2006) In-Situ Nitrogen Removal from the Eutrophic Water by Microbial-Plant Integrated System. Journal of Zhejiang University Science B, 7(7), 521-531.

[3] Xian, Q., Hu, L., Chen H., Chang, Z. and Zou, H. (2010) Removal of Nutrients and Veterinary Antibiotic from Swine Wastewater by a Constructed Macrophyte Floating Bed System. Journal of Environmental Management, 91, 2657-2661.

[4] Zul Hilmi, S., Ramlah, M.T., Dzaraini, K. and Norazah, A.R. (2011) Phytoremediation of Nutrient Contaminants from Golf Courses Surface Water. Proceeding, Universiti Malaysia Terengganu International Annual Symposium (UMTAS 2011), Kuala Terengganu, Malaysia.

[5] Tajuddin, R.M., Abdullah, B., Baki, A.M. and Zaharudin, N. (2007) The Potential of Aquatic Plants as Phytoremediator for Treatment of Industrial Wastewater. Malaysia Water Resources, 21, 352-353.

[6] Raju, A.R., Anitha, C.T., Sidhimol, P.D. and Rosna, K.J. (2010) Phytoremediation of Domestic Wastewater by Using A Free Floating Aquatic Angiosperm, *Lemna Minor*. Nature Environment and Pollution Technology, 9, 83-88.

[7] Wiessner, A., Kuschk, P., Jechorek, M., Seidel, H. and Kästner, M. (2007) Sulphur Transformation and Deposition in the Rhizosphere of *Juncus effusus* in a Laboratory-Scale Constructed Wetland. Environmental Pollution, 155, 125-131.

[8] Mishra, V.K., Upadhyay, A.R., Pathak, V. and Tripathi, B.D. (2008) Phytoremediation of Mercury and Arsenic from Tropical Opencast Coalmine Effluent Through Naturally Occurring Aquatic Macrophytes. Water, Air and Soil Pollution, 192, 303-314.

[9] Chunkao, K., Nimpee, C. and Duangmal, K. (2012) The King's Initiatives using Water Hyacinth to Remove Heavy Metals and Plant Nutrients from Wastewater through Bueng Makkasan in Bangkok, Thailand. Ecological Engineering, 39, 40-52.

[10] Zhou, W.B., Zhu, D.W., Tan, L.F., Liao, S.J., Hu, S.H. and Hamilton, D. (2007) Extraction and Retrieval of Potassium from Water Hyacinth (*Eicchornia crassipies*). Bioresource Technology, 98, 226-231.

[11] De Bertoldi, M., Vallini, G., Pera, A. and Zucconi, F. (1985) Technological Aspects of Composting including Modelling and Microbiology. In Gasser J. K. R. (Eds.), *Composting of Agricultural and Other Wastes* (pp. 27-41), Elsevier Applied Science Publication, London.

[12] Gajalakshmi, S., Ramasamy, E.V. and Abbasi, S.A. (2002) High-Rate Composting-Vermicomposting of Water Hyacinth (*Eichhornia crassipies*, Mart. Solms). Bioresource Technology, 83, 235-239.
[13] Zhu, N. (2007) Effect of Low Initial C/N Ratio on Aerobic Composting of Swine Manure with Rice Straw. Bioresource Technology, 98, 9-13.
[14] Arifin, B., Bono, A. and Janaun, J. (2006) The Transformation of Chicken Manure into Mineralized Organic Fertilizer. Journal of Sustainability Science and Management, 1(1), 58-63.
[15] Kala, D.R., Rosenani, A.B., Fauziah, C.I., Ahmad, S.H., Radziah, O. and Rosazlin, A. (2011) Commercial Organic Fertilizers and their Labeling in Malaysia. Malaysian Journal of Soil Science, 15, 147-157.
[16] Matassan, Z. A. (2008), the Malaysian Fertilizer Market, IFA Crossroads Asia-Pacific, Melbourne, Australia.
[17] Abad, M, Noguera, P, Puchades, R, Maquieira, A, Noguera, V. (2002) Physico-Chemical and Chemical Properties of Some Coconut Coir Dusts for Use as A Peat Substitute for Containerized Ornamental Plants. Bioresour Technol, 82, 241-245.
[18] Bremner, JM. (1996) Nitrogen-Total. In Page AL, *et al*., editors, *Methods of Soil Analysis, Part3, Chemical Methods* (pp. 1085-1121), Madison WI, Soil Science Society of America.
[19] Tiqua, S.M. and Tam, N.F.Y. (1998) Composting of Spent Pig Litter in Turned and Forced-Aerated Piles. Bioresource Technology, 99, 329-337.
[20] Fong, M., Wong, J.W.C. and Wong, M.H. (1999) Review on Evaluation of Compost Maturity and Stability of Solid Waste. Shanghai Environmental Science, 18(2), 91-93.
[21] Litterick, A., Harrier, L., Wallace, P., Watson, C.A. and Wood, M. (2003) Effects of Composting Manures and Other Organic Wastes on Soil Processes and Pest and Disease Interactions. Final project report, Department for Environment, Food and Rural Affairs, London.
[22] Sánchez-Monedero M.A., Roig A., Peredes C. and Bernal P. (2001) Nitrogen Transformation during Organic Waste Composting by the Rutgers System and Its Effects on pH, EC and Maturity of the Composting Mixture. Bioresource Technology, 78, 301-308.
[23] Dias, B.O., Silva, C.A., Higashikawa, F.S., Roig, A. and Sánchez-Monedero, M.A (2010) Use of Biochar as Bulking Agent for the Composting of Poultry Manure: Effect on Organic Matter Degradation and Humification. Bioresource Technology, 101, 1239-1246.
[24] Myung, H.U. and Youn, L. (2001) Quality Control for Commercial Compost in Korea. Extension Bulletins, Food and Fertilizer Technology Center, Taiwan.
[25] Zublena, J.P., Baird, J.V and Lilly, J.P (1997) Soil Facts: Nutrient Content of Fertilizer and Organic Materials. North Carolina Cooperative Extension Service, USA.
[26] Tchobanoglous, G., Theisen, H., Vigil, S. (1993) *Integrated Solid Waste Management: Engineering Principles and Management Issues*, McGraw-Hill, New York, USA.
[27] Liang, C., Das, K.C., McClendon, R.W. (2003) The Influence of Temperature and Moisture Contents Regimes On The Aerobic Microbial Activity of a Biosolids Composting Blend. Bioresource Technology, 86, 131–137.
[28] Kumar, M., Ou Yan L. and Lin J.G. (2010) Co-Composting of Green Waste and Food Waste at Low C/N Ratio. Waste Management, 30, 602-609.
[29] Li, G. and Zhang, F. (2000) *Solid Wastes Composting and Organic Fertilizer Production*. Chemical Engineering Press, Beijing, China.
[30] Solono, M.L., Iriarte, F., Ciria, P. and Negro, M.J. (2001) Performance Characteristics of Three Aeration Systems in the Composting of Sheep Manure and Straw. Journal of Agricultural Engineering Resource, 79(3), 317-329.
[31] Barrington, S., Choinière, D., Trigui, M. and Knight, W. (2002) Effect of Carbon Source on Compost Nitrogen and Carbon Losses. Bioresource Technology, 83, 189-194.
[32] Guo, R., Li, G.X., Jiang, T., Schuchardt, F., Chen, T.B., Zhao, Y.Q and Shen, Y.J., (2012) Effect of Aeration Rate, C/N Ratio and Moisture Content on the Stability and Maturity of Compost. Bioresource Technology, 112, 171-178.
[33] Alburquerque, J.A., Gonzálves, J., Tortosa, G., Ait-baddi, G and Cegarra, J. (2009) Evaluation of ‘alperujo’ Composting Based on Organic Matter Degradation, Humification and Compost Quality. Biodegradation, 20, 257-270.
[34] Subramanian, S., Sivarajan, M. and Saravanapriya, S. (2010) Chemical Changes during Vermicomposting of Sago Industry Solid Waste. Journal of Hazard Material, 179, 318-322.
[35] Jeong, Y. and Kim, J. (2001) A New Method for Conservation of Nitrogen in Aerobic Composting Processes. Bioresource Technology, 79, 129-133.
[36] Wu, Y., Wang, Z., Liao, X., Liu, S., Liang, M., Wu, Q., Huang, H. and Zhou, L. (2001) Study on the Odor Production and Control of Swine Manure Composting. Trans. CSAE, 17(5), 82-87.
[37] Sharma, V.K., Canditelli, M. Fortuna, F. and Cornacchia, G. (1997) Processing of Urban and Agro-Industrial Residues by Aerobic Composting: Review. Energy Convers. Mgmt., 38(5), 453-478.

[38] Official Fertilizer Standards of Korea (2001). Ministry of Agriculture and Fishery (MAF), Korea.
[39] Tisdale, S.L., Beaton, J.D., Nelson, W.L and Havlin, J.L. (1993) *Soil Fertility and Fertilizers*, 5th Edition, Macmillan Publisher, UK.
[40] Gu, W.J., Zhang, F.B., Xu, P.Z., Tang, S.H., Xie, K.Z., Huang, X. and Huang, Q.Y. (2011) Effects of Sulphur and *Thiobacillus thioparus* on Cow Manure Aerobic Composting. Bioresource Technology, 102, 6529-6535.
[41] Schnoor, J.L., Light, L.A., McCutcheon, S.C., Wolfe, N.L. and Carreira, L.H. (1995) Phytoremediation of Organic and Nutrient Contaminants. Environment Science Technology, 29, 318-324.
[42] Zhang, B.Y., Zheng, J.S. and Sharp, R.G. (2010) Phytoremediation in Engineered Wetlands: Mechanisms and Applications. Procedia Environmental Science, 2, 1315-1325.