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APPLICATION OF FLY ASH AS AMELIORANT IN PEATLAND ENVIRONMENT: THE RELEASE OF MICRO NUTRIENTS AND HEAVY METALS

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ABSTRACT

Some researchers showed that fly ash can be used to improve the chemical properties of soil, such as increasing pH, exchangeable cations and base saturation. However, the application of fly ash as soil ameliorant in Indonesia is still constrained by government regulation that fly ash is classified as toxic and dangerous waste materials due to the contains of heavy metals. The objective of this research is to study the release of micro nutrients and heavy metals from fly ash in peat environment. This research was conducted by batch method with shaking fly ash in aquadest and peat water as solvent, and by column percolation method with flushing the mixture of fly ash and peat. Cations of Fe, Mn, Cu, Zn, Pb, Cd, Cr and Ni dissolved in filtrate were measured by Atomic Absorption Spectrophotometer (AAS). Fly ashes used in this study originated from peat boiler (PB), chip boiler (CB) and multi boiler (MB).

The results showed that peat water did not always dissolve elements from fly ashes higher than those of aquadest. There was no significant relation between shaking time and amount of elements dissolve in the solution. Elements of Fe and Mn were released more from fly ash from PB, whereas the other elements released relatively in the same amount in all fly ashes used. In column percolation test, peat treated with fly ash after 3 months flushing showed decreasing availability of heavy metals with increasing fly ash dosage. Leachate from column percolation test contain elements in various amount. Generally, the amount of elements in percolate decrease with the increase of flushing time in order of Fe > Cu > Mn > Zn > Cr > Pb > Ni > Cd.

Keywords: *Fly ash, heavy metal, leaching, micronutrient, peat*

INTRODUCTION

Fly ash is residue from burning of coals in electrical generators using coal as fuel or boiler. The material can be used as soil ameliorant for improving chemical properties in mineral and peat soils. Although fly ash contains relatively complete and vary (Iskandar, Suwardi dan Ramadina, 2008), the application in the field as soil ameliorant is still constrained by government regulation. Government act No. 85 year 1999 classified the fly ash as dangerous and poisonous waste due to the contain of heavy metals. In soil science, some elements classified as heavy metals, are also classified as micro nutrients those need for plants such as Fe, Mn, Cu dan Zn (Horn, 1992; Alloway, 1995). In order elements in fly ash can be utilized for improving soil fertility, with still concern of the behavior of heavy metals released to the environment and waters, the research of the utilization of fly ash as soil ameliorant needs to be done intensively.

Mc Carty et al. (1994) studied the utilization of fly ash for increasing soil pH, whereas Stuczynski et al. (1998a) and Stuczynski et al. (1998b) studied the effect of fly ash and bed ash on mobilization of nitrogen and carbon. More comprehensive research has been done by Inthasan et al. (2002) studying the effect of fly ash for soil developed from granite, sandstone, and limestone. They showed that the availability of Fe, Mn, Cu and Zn exctracted by DTPA tended to decrease due to the increase of pH, where as the other heavy metals could not be detected consistenly. Truter et al. (2001) used mixed fly ash, sewage sludge and liming, with the ratio of 60%, 30% and 10% (dry weight) found that there were positive effect on increasing pH, Ca, Mg and P available in the soil. The translocation of heavy metals (Ni and Cd), as well as essential micro nutrient of B, did not translocate significantly. The above important researches were conducted in mineral soils. Research on peat soil has been conducted by Iskandar, Djajakirana and Marolop (2003) through field experiment in forest plantation. The results showed that peat soil applied by 5 kg and 10 kg fly ash/plant of *Acasia sp* has pH, cation exchange, available P and base saturation higher than that of without fly ash application. Iskandar *et al*. (2008) was also showed the same results with percolation colomn experiment in the laboratory. Relation to heavy metals, Iskandar *et al*. (2003) showed that the content of heavy metal increase significantly in peat soil due to fly as application. Different from Fe, the other of heavy metals such as Ni, Pb, Cd and Cr did not increase significantly. On the other hand Fleming *et al.* (1996) showed the content of heavy metals Cd, Cr, Zn, Pb, Hg and As in their colomn percolation increase with the decrease of the solvent pH buffered at the pH 6.8; 41 and 3,0.

The objectives of this research is to study the solubility of micro nutrients and heavy metals in fly ash with the solvent of aquadest and peat water as well as the contents of those elements in peat applied by fly ash after 3 months leaching.

MATERIALS AND METHOD

This research was conducted using peat soil sample (pH 3.60) and peat water (pH 3.43) taken from Jambi. Fly ashes were collected from the furnace using peat as fuel peat boiler (PB), chip boiler (CB), and multi boiler (MB) from Indah Kiat Pulp & Paper, Perawang, Riau.

These researches were conducted simultaneously in two stages in batch method and leaching method. Batch method for studying the solubility of micronutrients and heavy metals in the fly ash where as the leaching method for studying the effect of fly ash on the chemical properties of peat soil and water quality leached from colomn containing peat soil.

Batch Method Experiment

Three kinds of fly ashes PB, CB and MB were added by aquadest with the ratio of fly ash : aquadest of 1 : 5. The mixtures were shaked during 30, 60, 120, and 240 minutes. With the same method, the fly ashes were added by peat water. After shaking, the pH of the mixture was measured by pH-meter and the contents of Fe, Mn, Cu, Zn, Pb, Cd, Cr and Ni in the filtate were measured by AAS.

Column Percolation Experiment

Some 1 kg peat soil (air dry basis) was added to percolation column having 8.6 cm in diameter and 24.5 cm long. Above the peat soil was added by PB with the dosage of 0, 25, 50, 75, and 125 g/kg peat soil. Each percolation column was watered by 50 ml aquadest everyday and the percolate was captured by container. This treatment was conducted during 3 months. The percolate was measured every month for pH and the content of Fe, Mn, Cu, Zn, Pb, Cd, Cr and Ni. After 3 months, the peat soils in the column were analyzed for pH and metal elements extracted by HCl 0.05 N.

RESUTLS AND DISCUSION

Solubility of Heavy Metals from Fly Ash

The pH of fly ashes of PB, CB and MB used in this experiment was alkalis ranging between 8.7 and 11.5. The contents of micronutrients and heavy metals varied, such as Fe 1.25 1.73%, Mn 200 300 ppm, Cu 7.90 43.3 ppm, Zn 24.3 97.8 ppm, Pb 0.40 26.3 ppm, Cd 0.11 0.70 ppm, Cr 9.78 27.9 ppm dan Ni 9.13 48.7 ppm (Iskandar *et al*., 2008). The solubility of those micronutrients and heavy metals in aquadest and peat water was highly variated **(Tabel 1)**.

Although peat water has pH of 3.43 but it did not meaning dillute heavy metals more than aquadest. This was because the pH of peat water mixed with fly ash changed to alkalis (pH 8,0 11,4). In this condition, some metals released from fly ash will precipitate in hydroxide compound forms. The duration of shaking did not have relation to the amount of metals released from the fly ashes. The number of metals Fe, Mn and Ni released from fly ash PB tended to increse with the longer duration of of shaking where as the other metals released from fly ashes of PB, CB and MB did not change or even decrease. The Fe and Mn released from fly ash PB were higher, where as the others elements relatively same in three fly ashes. The maximum concentration of elements diluted at batch test were as follows: Fe 1.67 ppm (PB), Mn 0.05 ppm (PB), Cu 0.01 ppm (PB, CB and MB), Zn 0.57 ppm (CB), Pb 0.02 ppm (PB and CB), Cd not detected, Cr 0.11 ppm (MB) and Ni 0.023 ppm (PB, CB and MB).

High variability of batch test results was due to the heterogeneous composition of fly ashes, solubility, and solubility kinetic of the metals in fly ashes (Reardon *et al.* 1995). Minerals and glasses phase compose of fly ash are formed in wide range temperature. Most of materials in fly ash are found in oxidized condition or partial oxidation. If the materials contact with water, some materials will dilute and the others more stable and presipitate. Glasses particles and crystalline aluminosilicate dilute very slowly. Moreover, there are minerals composed from the condensation of elements created in lower temperature adhering on the surface of glass particles. This mineral groups consist of sulfate, borate, fluoride and chloride having high solubility and fast velocity of solubility. Oxidation phases found in fly ash such as CaO, MgO, Al_2O_3, Fe_2O_3 and Fe_3O_4 have wide solubility range.

Table 1. Solubility of heavy metals from fly ashes of PB, CB and MB in quadest and peat water in different duration of shaking.

Kinds of fly ash	Extractant	Shaking duration (minute)	pH	Fe	Mn	Cu	Zn	Pb	Cd	Cr	Ni
				ppm							
PB	Aquadest	30	8.52	0.25	0.01	0.01	0.020	0.000	tr	0.080	0.013
		60	8.49	0.22	0.01	0.01	0.040	0.000	tr	0.069	0.015
		120	8.34	1.06	0.03	0.01	0.020	0.009	tr	0.080	0.023
		240	8.26	1.67	0.05	0.01	0.040	0.009	tr	0.046	0.015
	Peat water	30	8.34	0.44	0.01	0.01	0.040	0.019	tr	0.046	0.008
		60	8.30	0.58	0.01	0.01	0.030	0.009	tr	0.057	0.013
		120	8.22	1.06	0.02	0.01	0.040	0.000	tr	0.046	0.018
		240	8.17	1.26	0.05	0.01	0.030	0.009	tr	0.091	0.023
CB	Aquadest	30	8.49	0.06	0.01	0.00	0.510	0.009	tr	0.080	0.023
		60	8.45	0.02	0.01	0.00	0.060	0.009	tr	0.057	0.015
		120	8.42	0.03	0.01	0.00	0.050	0.000	tr	0.069	0.015
		240	8.38	0.05	0.01	0.01	0.010	0.009	tr	0.069	0.018
	Peat water	30	8.14	0.05	0.01	0.00	0.570	0.000	tr	0.057	0.015
		60	8.10	0.02	0.01	0.00	0.070	0.019	tr	0.080	0.015
		120	8.06	0.01	0.01	0.00	0.060	0.019	tr	0.057	0.015
		240	8.02	0.05	0.02	0.00	0.050	0.009	tr	0.080	0.015
MB	Aquadest	30	11.44	0.03	0.01	0.00	0.000	0.000	tr	0.069	0.013
		60	11.41	0.01	0.01	0.01	0.000	0.009	tr	0.103	0.000
		120	11.33	0.07	0.01	0.01	0.000	0.000	tr	0.114	0.023
		240	11.30	0.03	0.01	0.01	0.000	0.009	tr	0.103	0.010
	Peat water	30	11.38	0.03	0.00	0.01	0.010	0.009	tr	0.114	0.015
		60	11.35	0.05	0.01	0.00	0.000	0.009	tr	0.103	0.013
		120	11.26	0.04	0.00	0.00	0.000	0.000	tr	0.091	0.015
		240	11.24	0.01	0.01	0.00	0.000	0.000	tr	0.103	0.018

Notes : PB = Peat Boiler, CB = Chip Boiler, MB = Multi Boiler

Micronutrients and Heavy Metals Content in Peat

Figure 1 and **2** show the content of micronutrients of Fe, Mn, Cu, Zn and heavy metals of Pb, Cd, Cr, Ni in peat, respectively with the treatment of fly ash PB after leaching process with aquadest during 3 months. The two figures show that the higher fly ash dosages, the availability of metals Fe, Mn, Cu, Zn, Cd and Ni in the peat decrease. In the same treatment, the availability of Pb and Cr do not show the order change. The availability of Pb in peat after incubation during 3 months varied from not detected (control treatment) to 0.02 ppm, whereas Cr from 0.011 ppm to 0.034 ppm, but they did not found in the fly ash dosages of 75 and 125 mg/kg fly ash. The decrease of the availabiity of that metals seemly related to the increase of pH of the peat from 3.60 to about 5.12 6.67 causing the presipitation of metals in hydroxide forms (Iskandar *et al*., 2008).

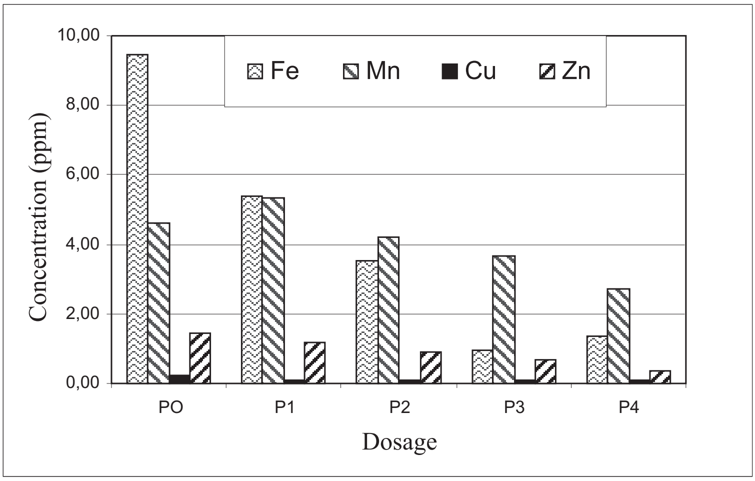

Figure 1. The concentration of micronutrients Fe, Mn, Cu and Zn in peat after treatments with fly ash in some dosages after incubation during 3 months.

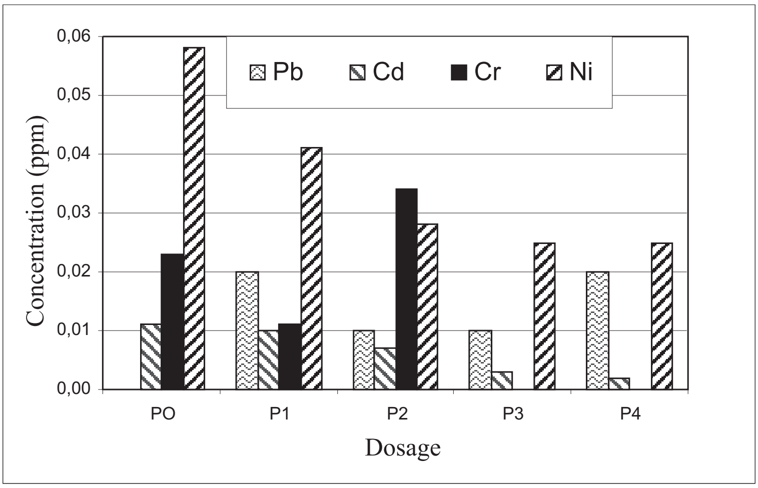

Figure 2. Heavy metal contents of Pb, Cd, Cr and Ni in peat after treatment with fly ash in some dosages after incubation during 3 months.

Diluted metals from fly ash besides adsorbed by peat, they also translocated with moved water. **Table 2** shows the contents of metals in the percolate from the leaching of peat with the treatment of the application of fly ash with some dosages. Metals that much translocated in the percolation column test were Fe (maximum 11.68 ppm), followed by Cu (1.81 ppm), Mn (0.50 ppm), Zn (0.15 ppm), Cr (0.069 ppm), Pb (0.05 ppm), Ni (0.028 ppm) and Cd (0.003 ppm).

Percolate from the above percolation column test contains metals with the variated amount with the trend of longer leaching time the content in the percolate tended lower. This trend is may due to the minerals easy dilute in fly ash immediately release the metals to the solution at the first contact with solvent. In the nextb step, the residue of fly ash are minerals having lower solubility. Moreover, the pH of percolate decrease with the longer of leaching time and the higher fly ash dosages.

Table 2. Percolate Analysis Result from Leaching Process of Peat and Fly Ash Treatment

Dosage (g/kg)	Incubation Time	pH	Fe	Mn	Cu	Zn	Pb	Cd	Cr	Ni
	Month		ppm							
0	1	3.43	0.00	0.12	1.40	0.11	0.00	0.002	0.011	0.023
	2	3.39	0.14	0.16	1.08	0.06	0.00	0.000	0.023	0.015
	3	3.63	0.21	0.12	0.81	0.02	0.00	0.001	0.023	0.015
25	1	3.59	0.10	0.24	0.80	0.09	0.02	0.000	0.023	0.013
	2	3.52	0.16	0.27	1.90	0.07	0.01	0.001	0.011	0.013
	3	3.72	0.94	0.13	1.81	0.03	0.00	0.001	0.046	0.020
50	1	4.23	0.20	0.25	1.10	0.12	0.00	0.002	0.011	0.020
	2	3.61	0.32	0.50	0.81	0.06	0.05	0.001	0.000	0.015
	3	3.64	0.69	0.09	0.96	0.02	0.00	0.001	0.000	0.015
75	1	4.15	0.26	0.26	1.47	0.10	0.00	0.003	0.023	0.018
	2	3.89	0.57	0.21	0.75	0.09	0.00	0.002	0.011	0.015
	3	4.26	1.41	0.08	1.23	0.02	0.00	0.001	0.057	0.013
125	1	4.04	1.86	0.17	1.66	0.15	0.05	0.001	0.011	0.023
	2	5.04	8.44	0.12	0.16	0.10	0.03	0.001	0.011	0.018
	3	5.75	11.68	0.22	0.41	0.08	0.01	0.000	0.069	0.028

CONCLUSIONS

Peat water having low pH (3.43) does not always dilute heavy metals from fly ash more than that of aquadest. Duration of shaking does not relation to the amount of metals released from fly ash. Maximum concentration of the elements dilute from fly ash at batch test were in order from high to low as follows: Fe (PB), Zn (CB), Cr (MB), Mn (PB), Pb (PB and CB), Ni (PB, CB and MB), Cu (PB, CB and MB), and Cd (did not detected).

With the higher dosage of fly ash added as ameliorant in peat, the availability of metals of Fe, Mn, Cu, Zn, Cd and Ni decrease, except Pb and Cr those did not give the regular change pattern. The decrease of the availability of metals seemly related to the increase of the pH of peat from 3.60 to 5.12 6.67 causing the precipitation of metals in the form of hydroxides. Translocation of metals togather with leaching of water variated with the pattern longer duration time of leaching, decrease the concentration in the percolate.

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