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Column Study of Nitrate Downward Movement and Selected Soil Chemical Properties' Changes in Mine Spoiled Soil as Influenced by Liquid Organic Fertilizer

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Open pit coal mining is common practice to extract coal from lithosphere. This system, however, will bring about soil degradation. Organic fertilization is an alternative to recover fertility of the degraded soil. The objectives of the experiment were to determine nitrate downward movement and change of selected chemical properties in the soil column and to compare the growth of lamtoro (*Leucaena leucocephala*) as affected by local based liquid organic fertilizer. Column experiment was conducted using mine spoiled soil from Taba Penanjung Sub-District, Central of Bengkulu District, Bengkulu, Indonesia located at approximately 364.5 m above sea level. The experimental design was Completely Randomized Design with 3 treatments consisting of control, 75 and 150 ppm of local based liquid organic fertilizer (LOF). The treatment was replicated 3 times. Soil column was prepared using PVC pipe with diameter of 12.5 cm and length of 40 cm. Soil sample was put into the column and compacted by knocking the base of the column until the soil height achieved 35 cm. Lamtoro was raised in the column for 11 weeks. At the end of experiment, lamtoro shoot was cut and the PVC column was cleaved horizontally and soil was pushed out from the column. Soil sample was, then, sliced into 6 fractions, representing depth of 0-5, 5-10, 10-15, 15-20, 20-25, and > 25 cm. Fresh soil sample from each depth was extracted by distillated water and analyzed for NO_3-N. Remaining of soil samples was air-dried for 72 hours, grinded with 0.5 mm screen, and analyzed for available P, exchangeable K, soil pH and exchangeable Al. The experiment indicated that local based liquid fertilizer significantly increased soil NO_3-N, available P, exchangeable K, soil pH and reduced exchangeable Al. Higher rates of LOF caused increase in selected soil chemical properties but exchangeable Al. However, NO_3-N was potential to move downward to deeper depth of the soil profile. Change of exchangeable Al, soil pH and exchangeable K was observed until 20-25 m depth of soil profile, but change of available P was detected only to 10-15 cm depth. Better soil chemical properties were followed by enhancement of lamtoro growth.

Keywords: Nitrate, column study, liquid organic fertilizer, mine spoiled soil

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Introduction

Coal mining in the world has increased significantly in the last decades. Total coal world production in 2013 increased by 67.27% as compared to that in 1990. In 2013, Indonesia produced 489 Mt, fourth highest coal producer country in the world after China, USA and India (World Coal Association, 2014). This is an indication of high coal mining activity in the country.

Open pit mining with back filling method is commonly used to extract coal from lithosphere (Darmawan and Irawan, 2009). The system, however, causes soil deterioration. Chemical reaction of pyrite as by product generates acidic compound which in turn oxidizes to form sulfuric acid, ferrous sulfate, and associated toxic metal (Ibeanusi *et al*. 2012), leading to decrease in soil pH below 3.0 (Vahedian et al. 2014). Research conducted by Tripathi *et al*. (2012) and Maharana and Patel (2013) pointed out that coal mining also brought about to decline of soil organic-C, total-N, nitrate-N, ammonium-N, extractable-P, root biomass and increase in bulk density.

Application of organic matter to soil is an alternative solution to improve quality of the degraded soil since organic matter amendment to soil enhances soil physical, chemical and biological properties. Decomposition of organic matter slowly releases significant amount of nutrient (Foth and Ellis, 1997), consequently increase in organic-C, Total N, extractable P, exchangeable K, Ca, and Mg, NH_4-N and CEC (Smiciklas *et al*. 2008; Samaras *et al*. 2008; Kowaljow *et al*. 2010). Ammonium-N afterward transforms to nitrate-N through nitrification process. Previous study showed that NH_4-N declined within 1-3 weeks after incubation of organic matter in soil, followed by increase in NO_3-N (Burger and Venterea, 2008; Rutherford and Arocena, 2012).

In general, nitrate-N easily moves down to deeper depth of the soil profile. Lysimeter study of nitrate leaching on Alfisol conducted by Zhao *et al*. (2010) showed that higher rate application of nitrogen fertilizer caused higher NO_3-N leaching through the lysimeter. Coarse soil texture provided higher nitrate leaching as compared to finer soil texture (va Es *et al*., 2006). Application of organic fertilizer is able to prevent nitrate leaching as compared to synthetic chemical fertilizer (Nyamangara *et al*., 2003; Hepperly *et al*., 2009). Mechanism responsible to lower leaching load from organic fertilizer is associated with lower nutrient release from organic matter and temporarily immobilization of nutrient in the microbial biomass (Lehmann and Schroth, 2003). Another research, however, indicated that nitrogen leaching load was higher when soil fertilized with red clover manure as compared to that with ammonium nitrate (Bergstrom. and Kirchmann, 2004). The experiment aimed to determine nitrate downward movement and change of selected chemical properties in the soil column and to compare the growth of lamtoro (*Leucaena leucocephala*) as affected by local based liquid organic fertilizer.

Materials and methods

Experimental Design and Amendment.

Column experiment was conducted from December 2014 to April 2015 employing completely randomized design. Treatments consisted of 0, 75, and 150 ppm local based liquid organic fertilizer (LOF), with 3 replications. Liquid organic fertilizer (LOF) was man-made in Closed Agriculture Production System (CAPS) Research Station by mixing 20 kg fresh dairy cattle feces, 20 liters dairy cattle urine, 5 kg soil consisting of effective local microorganism, 10 kg green leaves of *Tithonia diversifolia*, 20 liter diluted effective microorganisms-4 (EM-4), sugar and fresh water to a total volume of 200 liters in blue container. The mixture was incubated for 3 weeks. After incubation, the mixture was sieved using white cloth and ready for application. Liquid organic fertilizer contained 240000 mg l^{-1} N, 144 mg l^{-1} P, and 3450 mg l^{-1} K

Soil Collection and Column Preparation.

Soil sample at depth of 0-20 cm was collected from coal mine overburden of Danau Mas Hitam Coal Mining Company in Sub-District of Taba Penanjung, District of Central Bengkulu, Indonesia, located at around altitude of - 3^{o} 45’ 4.92” and longitude 102^{o} 30’ 72”. Elevation of the site was approximately 364.5 m above sea level. Soil sample was composited from 4 sites, representing the area of 3 year- overburden spoil. The sample was, then, air-dried for 3 days and sieved with 2 mm screen. Soil contained 49.15% sand, 30.84% silt, 20.01% clay (loam textural classification), 0.61 mg kg^{-1} NO_3-N, 10.15 mg kg^{-1} available P (Bray I), 0.16 cmol kg^{-1} exchangeable K, 4.30 cmol kg^{-1} exchangeable Al, 19.49 cmol kg^{-1} Cation Exchange Capacity and soil pH of 2.80.

Soil column was prepared using PVC pipe with diameter of 12.5 cm and length of 40 cm. Soil sample was put into the column and compacted by knocking the base of the column until the soil height achieved 35 cm. Vermicompost at rate of 25 Mg ha^{-1} was incorporated in 0-10 cm depth of each soil column. The column was placed in 45 cm tall wooden rack and wetted to water holding capacity.

Greenhouse Operation.

Lamtoro seed was soaked with diluted sulfuric acid for 10 minutes, then, saturated with water for 24 hours to break the dormancy. The seed was germinated in growing media pan consisting of top soil and vermicompost with ratio of 1:1 by volume, respectively. After 2 weeks, lamtoro seedling with 4-5 leaves was transplanted into soil column. Each soil column received 200 ml of LOF every week for 11 weeks, according to each treatment. Instead of LOF, control soil column was wetted with 200 ml of distillated water. Plant was watered if necessary with the same amount of water.

After 11 weeks, lamtoro plant was sampled by cutting the stem, weighed for shoot fresh weight, dried at 60-70^o C for 48 hours and reweighed for shoot dry weight. Root sample was obtained during soil sampling by separating roots from soil carefully, dried at 60-70^{o}C, and weighed for root dry weight.

At the end of the experiment, the PVC column was cleaved horizontally and soil was pushed out from the column. Soil sample was, then, sliced into 6 fractions, representing depth of 0-5, 5-10, 10-15, 15-20, 20-25, and > 25 cm. Fresh soil sample from each depth was extracted by distillated water and analyzed for NO_3-N using spectrophotometer (Balai Penelitian Tanah, 2005). Remaining of soil samples was air-dried for 72 hours, grinded with 0.5 mm screen, and analyzed for available P (Bray I), exchangeable K (flame photometer), soil pH (electrometric using pH meter at water and soil ratio of 1:2.5 by weight), and exchangeable Al (neutral salt extraction by Thomas, 1982).

Results and Discussion

Mine Spoiled Soil Quality Improvement

Application of organic fertilizer had significant effect on selected soil chemical properties of mine spoiled soil. Improvement of the soil quality was indicated by considerable increase in soil pH, NO_3-N, available P, exchangeable K, and significant decrease in exchangeable Al. At depth of 0-5 cm, soil pH, NO_3-N, available P and exchangeable K increased by 38.2%, 555.7%, 152.8%, 812.5%, respectively, after application of highest organic fertilizer rate. At deeper layer of soil column, however, increasing percentage was lessened. On the other, at the same depth, exchangeable Al declined more than two folds from 4.30 to 2.06 cmol kg^{-1} after application of highest LOF rate. It was also observed that the reduction of exchangeable Al at deeper soil layer was also lessened.

Soil quality improvement substantially benefits to availability of plant nutrients. Decrease in exchangeable Al and increase in soil pH will be more favorable for growth of lamtoro. Study by Muktamar *et al*. (1998b) showed that decline of exchangeable Al in acid soil due to application of cattle manure recovered root environment indicated by increase in root length and root dry weight, leading to raise of P uptake and cutting down of Al uptake by soybean.

Nitrate-Nitrogen Downward Movement

Application of LOF significantly influenced downward movement of NO_3-N in mine spoiled soil as indicated in Figure 1. Nitrate-N was mostly accumulated at the depth of 0-10 cm where highest rate of LOF provided highest NO_3-N as compared to other rate of LOF. Ammonium-N from organic matter mineralization will undergo nitrification process, producing NO_3-N (Smith *et al*. 1993). This anion is easily leached to the lower part of soil profile. Figure 1 indicated that NO_3-N moved downward to the depth of 20-25 cm from the surface when mine soil was treated with either 75 or 150 ppm of LOF. Other possible way for the increase in NO_3-N at lower depth was the movement of LOF itself to deeper soil column, then, mineralized to release NO_3-N. In depth study is necessary to elucidate this phenomenon. Thirteen month lysimeter study conducted by Zhao *et al*. (2010) showed that application of high N fertilizer input brought about substantial increase in NO_3-N concentration of leachate, exceeding drinking water guideline.

Figure 1 also indicated that NO_3-N downward movement of mine soil fertilized with 75 ppm LOF was comparable to that of 150 ppm and much higher NO_3-N of mine soil fertilized with 150 ppm LOF was retained at 0-5 cm depth as compared to 75 ppm. This finding indicated that higher application rate of LOF did not accelerate leaching of NO_3-N.

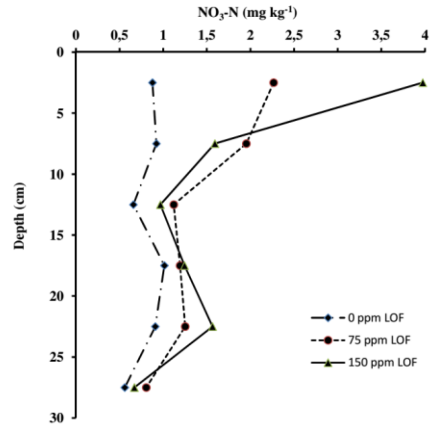

Figure 1. NO_3-N downward movement in mine spoiled soil

Exchangeable Aluminum Change

Liquid organic fertilizer (LOF) application to mine spoiled soil significantly lowered exchangeable Al (Figure 2). It was observed that the decrease in exchangeable Al was distinguished up to the depth of 25-30 cm and higher rate of LOF caused exchangeable Al to decline more drastically. Exchangeable Al was substantially reduced at the depth of 10-25 cm depth through application of LOF. Application of 150 ppm LOF reduced exchangeable Al by 60.7%, 35.5%, 149.7%, 104.7%, 587.1% and 4.4% at 0-5, 5-10, 10-15, 15-20, 20-25, and 25-30 cm depths, respectively as compared to control. Degradation organic matter will release organic substances such as humic and fulvic acids, leading to complexation reaction with Al to form very stable Al-humic substance complexes (Muktamar, *et al*., 1998a; Spark, 2003; Wahyudi *et al*., 2010), therefore, exchangeable Al lowers.

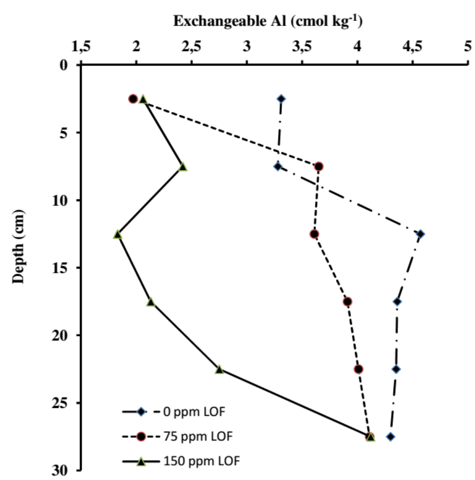

Figure 2. Exchangeable Al change as a function of LOF rates

Soil pH Change

The reduction of exchangeable Al as affected by LOF resulted in soil pH increase as indicated in Figure 3. Soil pH change was marked up to the depth of 20-25 cm. and higher rate of LOF application did not significantly increased soil pH. The highest increase in soil pH (from pH 3.40 to 3.87) was reached by application of 150 ppm LOF at depth of 0-5 cm. The pH increase was lessened as deeper in the soil column. As humic substance and Al complex was formed, the solubility of Al in soil solution would decrease substantially, lowering production of hydrogen ion (Ifansyah, 2013).

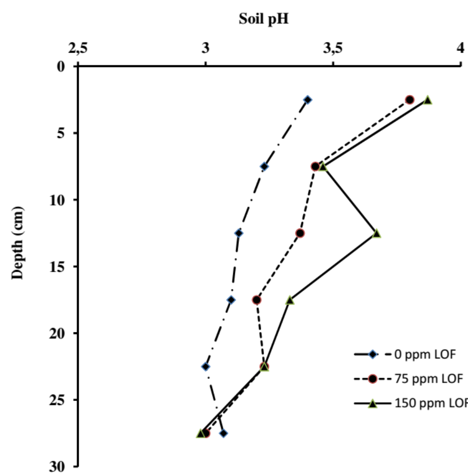

Figure 3. Change of soil pH as affected by application of LOF

Change in Available Phosphorus

Liquid organic fertilizer treatment to mine spoiled soil raised soil available phosphorus (Figure 4). Unlike other soil chemical properties, the effect of LOF was distinguished at upper 15 cm depth of soil column. Only was application of 150 ppm LOF notable at depth of 10-15 cm. The effect of LOF was not detected below the depth. This might be associated with high solubility of Al in soil solution as indicated by high exchangeable Al at lower depth of soil column, causing reaction of Al and phosphorus to form stable alumino-phosphate. This form of phosphate was not available to plant. Previous study conducted by Chardon *et al*. (2007) showed that total dissolved P was notable in leachate from 10 cm long soil column.

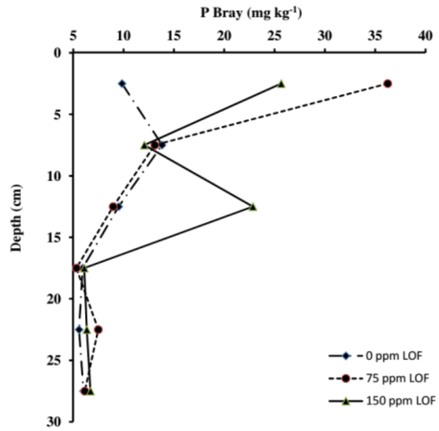

Figure 4. Change of soil available phosphorus as influenced by LOF

Change in Exchangeable Potassium

Soil exchangeable K significantly enhanced by application of LOF. Marked change of exchangeable K was observed up to 20-25 cm depth of soil column (Figure 5). Higher application rates of LOF resulted in significant increase in exchangeable K throughout the soil column but 25-30 cm depth. Exchangeable K of mine spoiled soil treated with 150 ppm LOF raised by 1.86, 2.30, 4.84, 1.50, 3.75 fold at depths of 0-5, 5-10, 10-15, 15-20, and 20-25 cm, respectively, as compared to control. This pointed out that K was easily moved downward to deeper soil column. Previous study showed that substantial leaching loss was observed in foliage plant nursery (Broschate, 1995) and biochar could lessen leaching of K in soil (Widowati *et al*. 2012).

Growth of Lamtoro

Improved chemical properties of mine spoiled soil were followed by good performance of lamtoro growth as shown in Table 1. Application of LOF to mine soil significantly increased plant height, shoot fresh weight, root fresh weight, shoot dry weight and number root nodules. Mine spoiled soil treated with 75 ppm of LOF provided best growth performance of lamtoro, even though it was not significantly different from that of fertilized with 150 ppm of LOF. Number of nodules was exception where lamtoro fertilized with 150 ppm of LOF significantly higher number of nodules than that of 75 ppm of LOF. This might be related to better root growth as detected with slightly higher root fresh weight due to higher nitrogen supply from LOF (240000 mg N l^{-1}). Study by Munawar (1996) showed that lamtoro met requirement for coal mine soil reclamation since it was able to grow at degraded soil and recovered soil physical, chemical, and biological properties.

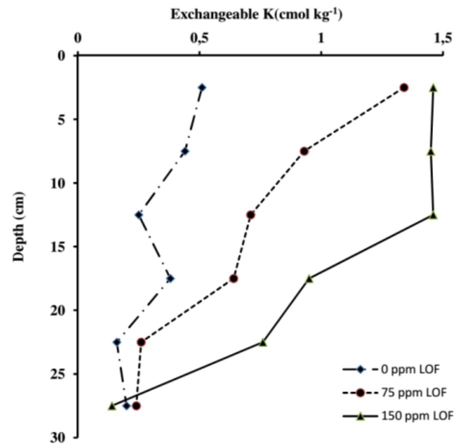

Figure 5. Exchangeable K change throughout soil column as a function of LOF.

In summary, Application of LOF significantly improved soil chemical properties of mine spoiled soil as indicated by increase in soil NO_3-N, available P, exchangeable K, soil pH and reduction of exchangeable Al. This improvement brought about better growth performance of lamtoro. However, NO_3-N was potential to move downward to deeper depth of the soil profile. Change of exchangeable Al, soil pH and exchangeable K was observed until 20-25 m depth of soil profile, but change of available P was detected only to 10-15 cm depth.

Table 1. Plant growth of Lamtoro as affected by liquid organic fertilizer

Treatment	Variables				
	Plant Height (cm)	Shoot Fresh Weight (g/plant^{-1})	Root Fresh Weight (g/plant^{-1})	Shoot Dry Weight (g/plant^{-1})	Number of Nodules
Control	26,1 a	6.77 a	7.93 a	2.77 a	37.7 a
75 mg LOF l^{-1}	64,2 b	22.6 b	19.4 ab	8.47 b	91.3 b
150 mg LOF l^{-1}	56,4 b	21.0 b	22.2 b	8.37 b	106.2 c

Treatment mean followed by the same letter within column is not significantly differences at 95% confidence level

References

Balai Penelitian Tanah. 2005. Petunjuk Tehnis Analisis Tanah, Tanaman, Air, dan Pupuk. Balai Penelitian Tanah (in Indonesian language).

Bergstrom, L. and H. Kirchmann. 2004. Leaching and crop uptake of nitrogen from nitrogen-15-labeled green manures and ammonium nitrate. J. Environ. Qual. 33(5):1786-1792.

Broschate, T.K. 1995. Nitrate, phosphate and potassium leaching from container grown plants fertilized with several methods. HortScence 30(1): 74-77.

Burger, M. and R.T. Venterea.2008. Nitrogen immobilization and mineralization kinetics of cattle, hog, and turkey manure applied to soil. Soil Sci. Soc. Am. J. 72:1570-1579.

Coal Producer Association. 2014. Coal Statistics. http://www.worldcoal.org/rsources/coal-statistics/ accessed 3 September 2015.

Darmawan, A. dan M.A. Irawan. 2009. Reklamasi lahan bekas tambang batubara PT Berau Coal, Kaltim. Proc. IPTEK Penyelamatan Hutan Melalui Rehabilitasi Lahan Bekas Tambang Batubara. pp: 17-26.

Foth, H.D. and B.G. Ellis. 1997. Soil Fertility, 2nd Ed. Lewis Publishers. New York.

Hepperly, P., D. Lotter, C. Z. Ulsh, R. Seidel, C. Reider. 2009. Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. J. Compost Sci. Util. 17(2):117-126.

Ibeanusi, V.M., E.J. Juandalyne Coffen and Y. Jeilani. 2012. Assessing Bioremediation of Acid Mine Drainage in Coal Mining Sites Using a Predictive Neural Network-Based Decision Support System (NNDSS). J. Bioremed Biodegrad 3(5):1-6.

Ifansyah, H. 2013. Soil pH and solubility of aluminum, iron, and phosphorus in Ultisol: Roles of humic acid.J. Trop. Soil 18(3):203-208.

Kowaljow, E., M.J. Mazzarino, P. Satti, and C. Jimenez-Rodriguez. 2010. Organic and inorganic fertilizer effects on a degraded Patagonian rangeland. Plant Soil 332:135–145.

Lehmann J and G. Schroth. 2003. Nutrient Leaching. p. 151- 165. . In- Schroth G and Sinclair FL (eds.) Trees, Crops and Soil fertility - Concepts and Research methods. CAB International, Wallingford, UK.

Maharani J.K. and A.K. Patel. 2013. Characterization of physico-chemical properties and their impact on enzyme activities in a chronosequence coal Mine overburden spoil as biomarker of reclamation process. J. Bacteriol Parasitol 4(4):1-10.

Muktamar, Z, D. Aneri, and Suprapto. 1998a. Penurunan alumunium teradsorpsi pada tanah asam dengan sitrat dan oksalat. . J. Penelitian UNIB 11:1-4 (in Indonesian language).

Muktamar, Z., I. Candra, M. Chozin. 1998b. Pengurangan keracunan alumunium pada tanaman kedelai melalui pemberian pupuk kandang sapi pada tanah masam. J. Penelitian UNIB 11:39-45 (in Indonesian language).

Munawar, A. 1996. Reklamasi tanah pada lahan bekas tambang batubara di Bengkulu dengan revegetasi. Laporan Penelitian. Fakultas Pertanian Universitas Bengkulu, Bengkulu (in Indoensian Language).

Nyamangara, J., L.T. Bergstrom, M.I. Piha, and K.T. Giller. 2003. Fertilizer use efficiency and nitrate leaching in a tropical sandy soil. J. Environ. Qual. 32(2):599-606.

Rutherford, P.M. and J. M. Arocena. 2012. Organic amendments and earthworm addition improve properties of non-acidic mine tailings. Applied and Environmental Soil Science vol. 2012, Arti. ID 395964 pp. 1-11. Hindawi Publishing Corporation.

Samaras, V., C. D. Tsadilas, and S. Stamatiadis. 2008. Effects of repeated application of municipal sewage sludge on soil fertility, cotton yield, and nitrate leaching. Agron. J. 100:477–483.

Smiciklas, K .D. P.M. Walker, and T.R. Kelley. 2008. Evaluation of compost for use as a soil amendment in corn and soybean production. Compost Science and Utilization 16(2): 183-191.

Smith, J.L., R.I. Papendick, D.E. Bezdicek, and J.M. Lynch. 1993. Soil Organic Matter Dynamics and Crop Residue Management. p. 65-94. in F.B. Metting (ed). Soil Microbial Ecology: Application in Agricultural and Environmental Management. Marcel Dekker, Inc. New York.

Spark, D.L. 2003. Environmental Soil Chemistry. 2nd ed. Academic Press. London.

Thomas, G. W. 1982. Exchangeable Cation. p. 159-164. in A.L. Page, R.H. Miller, D.R. Keeney (eds.). Methods of Soil Analysis: Part 2: Chemical and Microbiological Properties.2nd Ed. ASA Publisher. Madison.

Tripathi, N., R.S. Singh, and S.K. Chaulya. 2012. Dump stability and soil fertility of a coal mine spoil in Indian dry tropical environment: A long term study. Environmental Management 50:695-706.

va Es, H.M., J.M. Sogbedji, and R.R. Schindelbeck. 2006. Effect of manure application timing, crop, and soil type on nitrate leaching. J. Environ. Qual. 35(2):670-679.

Vahedian, A., S. Asadzadeh Aghdaei, and S. Mahini. 2014. Acid Sulphate Soil Interaction with Groundwater: A Remediation Case Study in East Trinity. 2013 5th International Conference on Chemical, Biological and Environmental Engineering (ICBEE 2013) and 2013 2nd International Conference on Civil Engineering (ICCEN 2013). APCBEE Procedia 9. pp. 274-279.

Wahyudi, I., E. Handayanto, Syekhfani, and W.H. Utomo. 2010. Humic and fulvic acids of glirisidia and tithonia composts for aluminum detoxification in an Ultisol. Agrivita 32(3):216-224.

Widowati, Asnah, and Sutoyo. 2012. Pengaruh penggunaan biochar dan pupuk kalium terhadap pencucian dan serapan kalium pada tanaman jagung. J. Buana Sain 12(2): 83-90 (in Indonesian language).

Zhao, C., C. Hu, W. Huang, X. Sun, Q. Tan, and H. Di. 2010. Lysimeter study of nitrate leaching and optimum nitrogen application rates for intensively irrigated vegetable production systems in Central China. J Soils Sediments 10:9–17.