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The Role of Peat Layers on Iron Dynamics in Peatlands

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ABSTRACT

The Role of Peat Layers on Iron Dynamics in Peatlands (A Fahmi, B Radjagukguk, BH Purwanto and E Hanudin): The research aimed to study the effect of peat thickness and humification stage of the peat material on Fe solubility at the peatlands with sulfidic material as substratum. The research was conducted at three conditionals of ombrogen peatlands ie ; deep, moderate and shallow peat. Soil samples were collected by using peat borer according to interlayer (the border layer of peat and mineral layer) and conditional of soil horizons. The sample point depth were (cm) $G.s_2$: 25, $G.s_1$: 50, Int.s : 70, $M.s_1$: 90 and $M.s_2$: 100 for shallow peat, $G.m_2$: 47, $G.m_1$: 100, Int.m : 120 and $M.m_1$: 135 for moderate peat and $G.d_3$: 50, $G.d_2$: 150, $G.d_1$: 200, Int.d : 220 and $M.d_1$: 235 for deep peat respectively. The results showed that most of Fe on the tested soils was found in organic forms. The peat layers above the sulfidic material decreased the Fe^{2+} solubility at peatlands. Fe^{2+} concentration in peat layer decreased with its increasing distance from sulfidic material. There was any other processes beside complexation and chelation of Fe^{2+} by humic material and its processes was reduction of Fe^{3+} and this conditions was reflected in redox potential values (Eh).

Keywords: Humic substance, iron, peatland, sulfidic material

INTRODUCTION

About 3% of earth surface is covered by peatlands (Limpens *et al*. 2008) and about 206,000 km^2 peatlands are found in Indonesia (Page *et al*. 2008). Most of peatlands in Indonesia formed in low altitude coastal and sub-coastal situations (Rieley and Page 2005) with 10.52 million hectras of them are situated in areas under tidal influence (Nugroho *et al*. 1992) therefore the fluctuating level of sea/river water may influence to soil water table. Based on geografic condition of peat formation, the sulfidic material is often found under peat layer.

Peat contains large amount of humic substances that composed of humic acid and fulvic acid. These humic substances play an important role in soil properties. Their role were affected by their humification stage, which sapric peat contain higher humic acids than hemic peat whereas hemic peat contain higher fulvic acid than sapric peat (Salampak 1999). Humic substances are able to complex with metal ions governing its insoluble forms, humic substances complex ability is depend on its functional group or total acidity. Fulvic acid has higher total acidity values than humic acid, but the substantially larger molecules and more complexes structures of humic acid to be more effective than fulvic acid in complexation or chelation (Tan 2003).

Iron (Fe) is main element that involved in redox system on wetland (Kyuma 2004). It occurs dominantly in soluble, exchangeable, reductable and residual forms on wetland soils (Reddy and DeLaune 2008). The abundance of Fe in wetland soils govern to plant toxicity and excessive its concentration in watersheed and environment. Most of Fe in peatland is in chelates form and only about 4 - 5% of total Fe in peatland are in water and exchangable forms (Yonebayashi 2006). The peat layer act as protective sponge that keeps the underlying mineral subsoil (Rieley *et al*. 2008), it mean peat material plays

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important role in reduce solubility of Fe from sulfidic material which would be release to the watersheed and environment.

Peatlands are formed under condition of organic matter accumulation is greater than its decomposition processes. In accumulation processes, there is a different thicknesss of the peat in a zones (dome shape) (Andriesse 1988). The differences in peat thicknesss is a drawing of different in peat age and material forming (Page *et al*. 2004) therefore each layer properties may be different. These properties include such as humification stages, elements concentration and solubility.

The purpose of the research was to study the effect of peat thickness and humification stage of the peat material on Fe solubility at the peatlands with sulfidic material as substratum.

MATERIALS AND METHODS

Site Description

The research was conducted on the three conditionals of ombrogen peatlands *i.e.*; deep, moderate and shallow peat with sulfidic material was as the substratum mineral. The study site was at Pangkoh IX, Pulang Pisau District, Central Kalimantan, with 8 m elevation, geografic positions were South (S) : 2 52.240 and East (E) : 114 05.409 for deep peat, S : 2 52.372 and E : 114 05.811 for moderate peat and S : 2 52.609 and E : 114 06.088 for shallow peat, respectively. The study site was 10 km west of Kahayan river and 20 km east of Sebangau river. This site was covered by shrubs and rubber.

Soil Sampling and Analysis

Soil sample was collected with using peat borer according to interlayer (the border layer of peat and mineral layer) and soil horizon status (Figure 1). The sample points depth were (cm) G.s**2** : 25, G.s**1** : 50, Int.s : 70, M.s**1** : 90 and M.s**2** : 100 for shallow peat, G.m**2** : 47, G.m**1** : 100, Int.m : 120 and M.m**1** : 135 for moderate peat and G.d**3** : 50, G.d**2** : 150, G.d**1** : 200, Int.d : 220 and M.d**1** : 235 for deep peat respectively.

There was sapric peat material only on the shallow peat, whereas sapric and hemic peat material were found on moderate and deep peat. The humification stage was determined in the field using with Von Post method. Exchangable Fe (extracted with 1 *N* NH_4OAc pH 4,8), organic-Fe (extracted with 0,1 *M* $Na_2P_4O_7$), total Fe (digested with $HClO_4$ + HNO_3 + H_2SO_4) were determined using atomic absorption spectrophotometer (AAS) (JICA 1978; Loppert *et al*. 1996). The soil redox potential (Eh) was measured in the field with using redox potential instrument (Hana HI 8424).

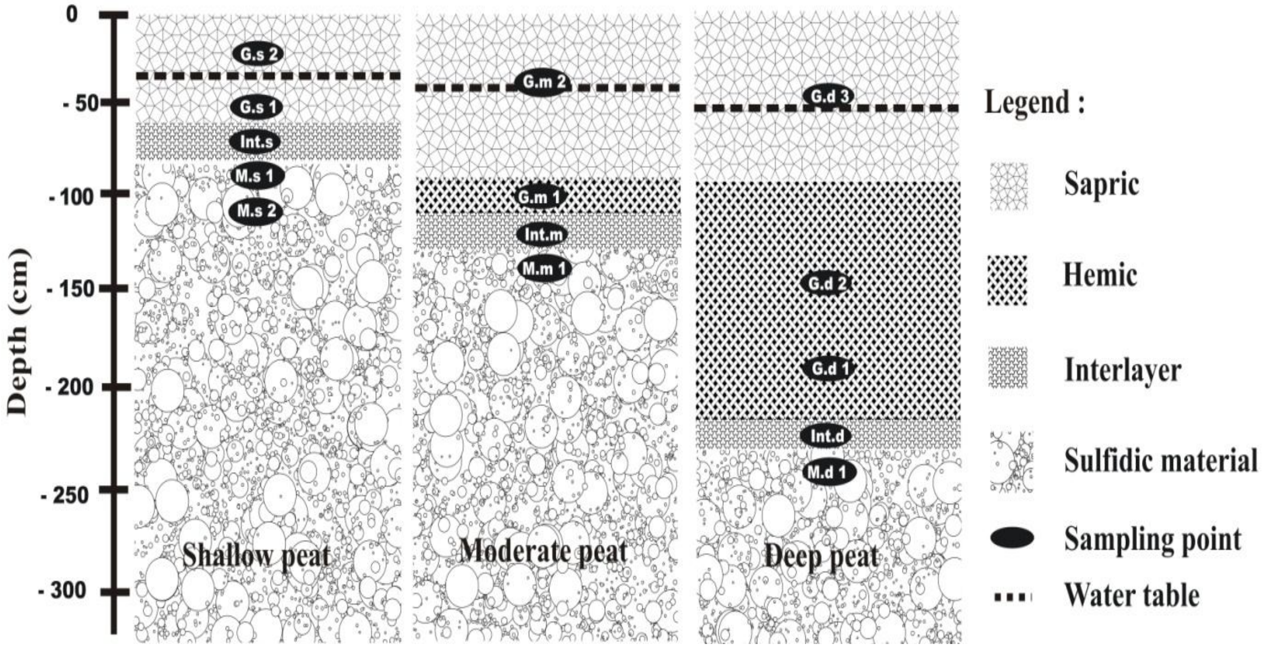

Figure 1. Soil profils and sampling points.

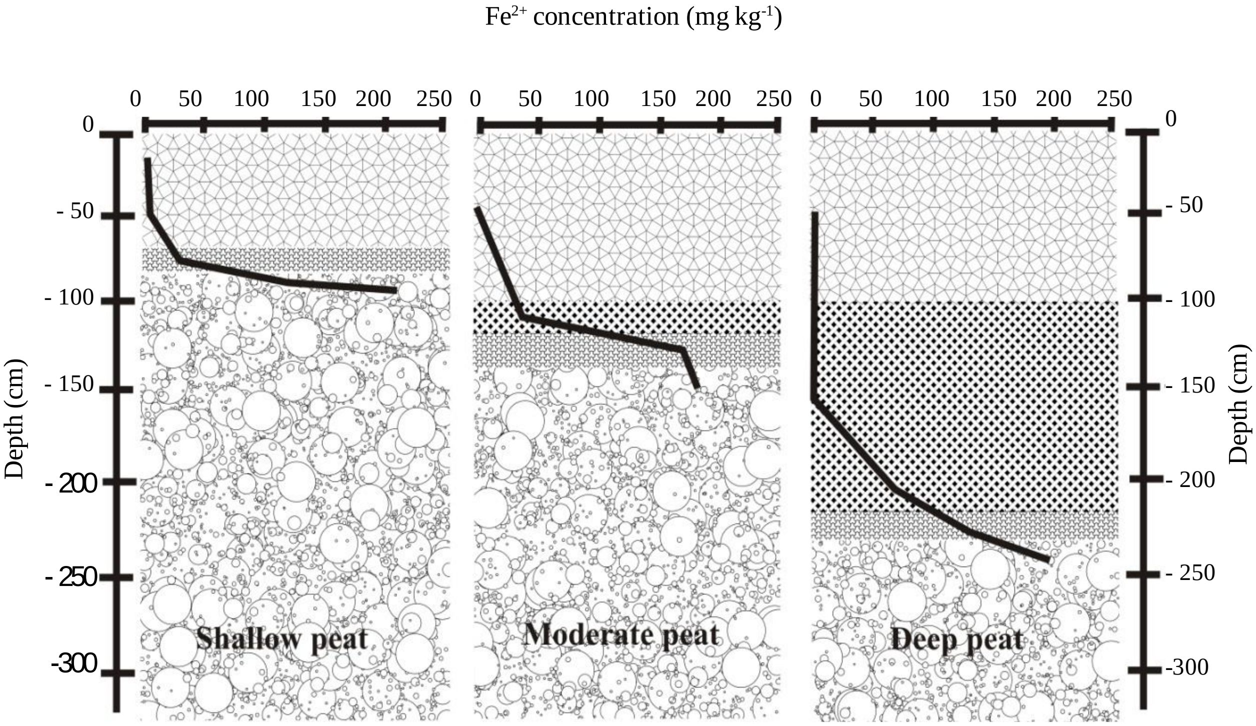

Figure 2. The dynamic of Fe^{2+} concentrations in peatlands with different thickness.

RESULTS AND DISCUSSION

Large amount of Fe^{2+} (178 to 217 mg kg^{-1}) in sulfidic material was caused by these material consist of large amount of pyrite (Figure 2). Same result was also obtained from experiment at Paduran site, Central Kalimantan by Iyobe and Haraguchi (2008). Fe^{2+} in peat layer especially in the nearest layer of sulfidic material indicated that Fe^{2+} moved to uppermost layer. Fe^{2+} was more mobile than Fe^{3+}, it may be moved to the upper layer with water table movement (Tan 2008).

Peat layers above the sulfidic material decreased the Fe^{2+} concentration (0 to 58 mg kg^{-1}) in upper layer of peatland (Figure 2). Lambert and Vanderdeelen (1992) and Yonebayashi (2006) also found that only about 4 - 5% of total Fe in tropical peat soil were in water soluble and exchageable forms. Low Fe^{2+} concentration in upper layer of peatland because chelated by humic substances or complex formation with humic substances. More than 50% of Fe in peatland were chelated by humic substances (Karlsson and Persson 2010) especially humic acid (Sarzynska and Sokolowska 2002).

Based on the results presented in Figure 2, Fe^{2+} concentration in peat layer increased with increasing peat thickness (especially for G1) where G.d1 (58 mg kg^{-1}) > G.m1 (45 mg kg^{-1}) > G.s1 (16 mg kg^{-1}). This possibly correlated with humification stage of peat material, G.d1 and G.m1 were hemic peat whereas G.s1 was sapric peat. Humic substances complex ability were depended on its humic acid content, sapric peat contain higher humic acid than hemic peat (Salampak 1999). Humic acid to be more effective than fulvic acid in complexation or chelation (Tan 2003).

Low Fe^{2+} concentration in peat layer (especially for G 1) showed that there was any other processes beside complexation and chelation of Fe^{2+} by humic material and its processes was reduction of Fe^{3+} (abiotic reduction). Although this process was minimal as compared to biotic reduction (Reddy and DeLaune 2008) but its processes might be occurred, this conditions was reflected in redox potential values (Eh), where soil redox potential were - 76 (G.s1), 35 (G.m1) and - 56 mV (G.d1) respectively (Figure 5), reduction of Fe^{3+} to Fe^{2+} occured in a redox potential range of 180 to -100 mV (Reddy and DeLaune 2008). Humic acid in soil solution could act as electron acceptor during reduction of Fe^{3+} (Tan 2008; Rakshit *et al.* 2009). The reducing capacity of humic substances in peat soil governed to less of Fe in Fe^{2+} forms (Lambert and Vanderdeelen 1992).

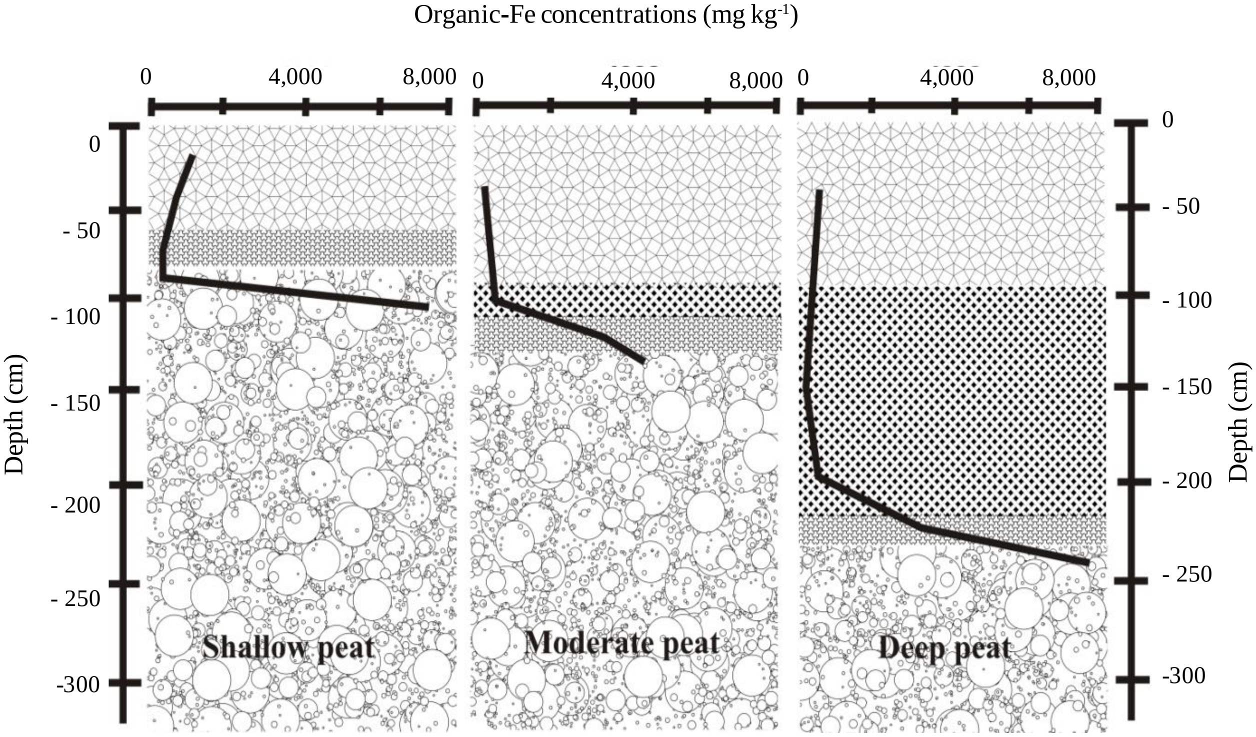

Figure 3. The dynamic of organic Fe concentrations in peatlands with different thickness.

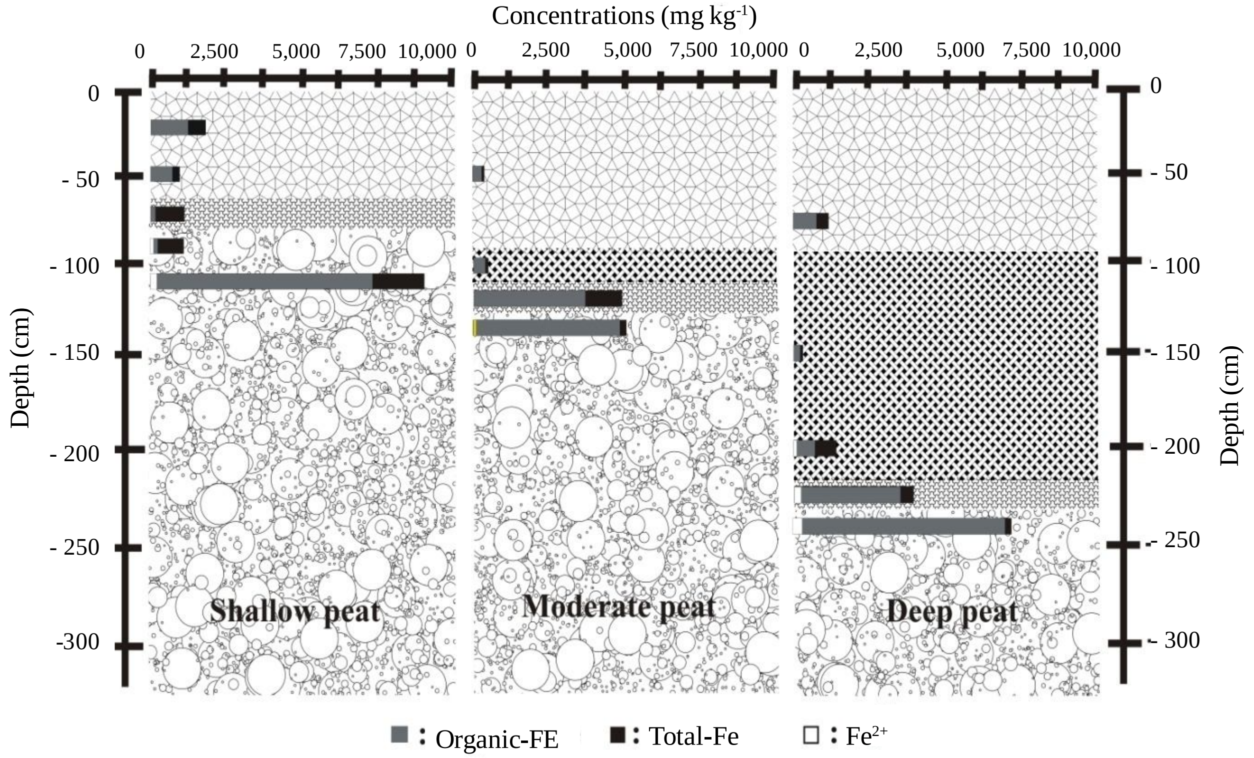

Figure 4. The relationship of Fe forms (total Fe, organic-Fe and Fe^{2+}) in peatlands with different thickness.

The concentrations of Fe^{2+} in peat layer decreased with its increasing distance from sulfidic material (Figure 2). This condition indicated the roles of peat thicknesss and peat material such as humic substances in complexation of Fe. Based on humification stages of peat layer at the study site, Fe^{2+} concentrations on G.s1 (16 mg kg^{-1}) was lower than those on G.m1 and G.d1(45 and 58 mg kg^{-1}). It indicated that different ability of sapric and hemic materials in complex formation, G.s1 was sapric peat whereas G.m1 and G.d1 were hemic peat (Figure 1). Complex formation ability of hemic material reflected to humic and fulvic acid contains. Sapric peat had humic acid higher than hemic peat material, where humic acid was more effective than fulvic acid in complexation or chelation (Tan 2003).

The role of peat thicknesss in Fe mobility was indicated with decreasing of Fe^{2+} concentrations in peat layer by increasing of a peat layer thickness (Figure 2 and 3, especially on deep peat), Fe-org and Fe^{2+} concentration in G.d**2** (193 and 0 mg kg^{-1}) were lower than G.d**1** (320 and 58 mg kg^{-1}). The same result was also obtained from other experiment at Paduran

Table 1. The percentage of Fe^{2+} and organic-Fe from total-Fe concentrations.

Sampling points	Fe^{2+} (%)	Organic-Fe (%)
Shallow peat		
G.s$_2$	0.0	81.0
G.s$_1$	1.7	77.0
Int.s	2.2	21.7
M.s$_1$	11.3	22.5
M.s$_2$	2.3	80.0
Moderate peat		
G.m$_2$	1.8	80.0
G.m$_1$	7.9	84.7
Int.m	1.3	76.7
M.m$_1$	3.5	93.3
Deep peat		
G.d$_2$	0.0	51.2
G.d$_1$	0.0	87.7
Int.d	8.0	44.0
M.d$_1$	3.2	88.6
M.d$_2$	2.7	95.4

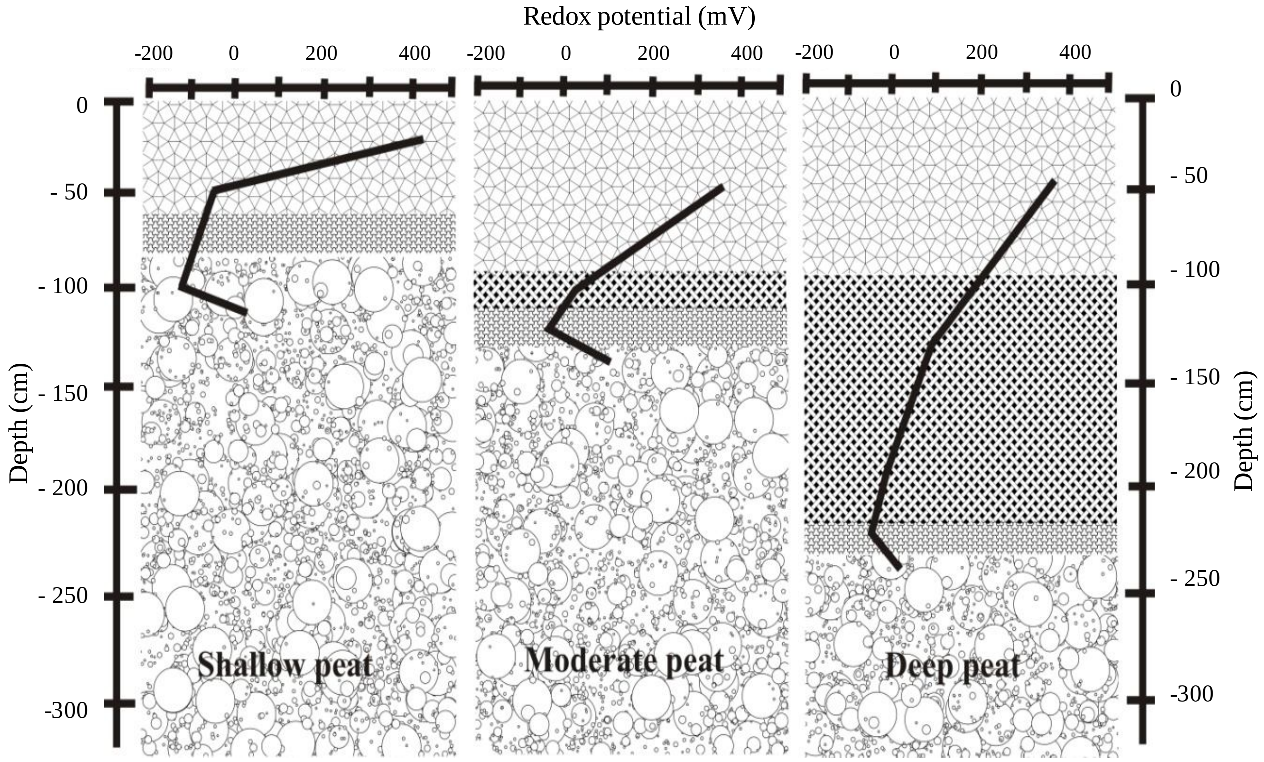

Figure 5. The dynamic of redox potential values in peatlands with different thickness

site, Central Kalimantan by Iyobe and Haraguchi (2008).

Figure 3 showed that there was a large concentration of organic-Fe on the layer of sulfidic material (7,291 for shallow, 4,710 for moderate and 6,811 mg kg^{-1} for deep peat). This phenomenon may be caused by: (1) organic substances from peat layer moved to lower layer and then form a complex with Fe, and (2) organic-Fe complex formed on the peat layer and then move to lower layer. Organic substances were the main carrier of the metal mobility in soil (Weerd 2000). Metal mobility in a peatland was determined by its interaction with organic substances (Kolka 2001). Possibility migration of iron in ionic forms looked very small. Other agents required to make them more soluble were decomposition products of soil organic matter, especially humic acid (Tan 2008). The solubility and mobility of organic-Fe complex derived from peat was higher than those of iron-hydroxide, and it may be transported and flocculated (Wolt 1994; Krachler *et al.* 2005).

Most of Fe on the peatland was found in organic forms (Figure 4 and Table 1). Similar result was reported by Sarzynska and Sokolowska (2002) and Yonebayashi (2006) that if the content of organic matter was even higher, such as in peaty environment, all of the Fe may be in the form of organic-Fe complexes. This result indicated that humic substances in peat material had an important role in Fe solubility and mobility. Fe has higher affinity to humic substances than Cu, Zn, Mn, Mg and Ca (Sarzynska and Sokolowska 2002; Tan 2003), Most of Fe which complex formation with organic substances was Fe^{2+} (Olomu *et al.* 1973).

CONCLUSIONS

Sulfidic material as substratum mineral of the tested soils was a source of Fe in the soils and most of Fe on the tested soils was found in organic forms. The peat layers above the sulfidic material decreased the Fe^{2+} solubility at peatlands. Peat thicknesss and material such as humic substances played an important roles in complexation of Fe, where Fe^{2+} concentration decreased with increasing distance from the layer of sulfidic material (increasing peat thickness). Low Fe^{2+} concentration in peat layer (especially for G_1) showed that there was any other processes beside complexation and chelation of Fe^{2+} by humic material and its processes was reduction of Fe^{3+} this conditions was reflected in redox potential values (Eh).

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