Acid discharge from the tropical peat swamp forest and its impact on local people – a review

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Summary

After destruction of the peat layer over pyrite-containing sediment, pyrite is oxidized and sulphuric acid is produced. Sulphuric acid contaminates soil and river water and then acidifies the environment. Soil chemical and limnological studies in peat swamp forest in Central Kalimantan showed that sulphuric acid loading from acid sulphate soil occurred widely in the coastal region ranging from the river mouth up to 150 km from the coast. The amount of sulphuric acid discharged to freshwater systems was much higher in the rainy season than in the dry season. By holding interviews with local inhabitants on the source of drinking water for inhabitants in polluted areas this was significantly different between dry and rainy seasons. During the rainy season, river and canal water in polluted areas is not available for drinking, and at this time people avoid using river water for drinking. This paper reviews our limnological and biogeochemical studies on acidification of peat by sulphuric acid, discharging process of sulphuric acid to freshwater system, and impact of sulphuric acid pollution on local inhabitants.

Key index words: acid sulphate soil, freshwater ecosystem, peat swamp forest, tropical peat, water resource

Distribution of pyrite and its impact on peat acidification

Pyrite (FeS_2) is formed in a reducing environment, e.g. salt marshes with a continuous supply of sulphur and iron in the presence of easily decomposable organic matter (Howarth and Giblin, 1983; King, 1983). Tropical peat, most of which belongs to the category of coastal peat, is deposited over marine sediments. After destruction of the peat layer over pyrite-containing sediment following agricultural land development and deforestation, pyrite is oxidized and sulphuric acid is produced.

The first objective of our research on the impact of pyrite oxidation on soil-water environment was to clarify the area of sulphuric acid contamination in peat soil. We investigated the chemical properties of peat pore water in peat cores collected at several sites in Central Kalimantan. Lahei is located in the upper basin of the Mangkutup River (pyrite not distributed). In Paduran, in the lower basin of the Sebangau River, pyrite is distributed in the mineral sediment under the peat layer. The effect of pyrite oxidation on the acidification of peat was evident only at the bottom layer of the coastal Paduran peat (Haraguchi *et al.*, 2000). The concentration of SO_4^{2-} in the peat pore water at the bottom layer of Paduran peat was much higher than the Lahei peat core. This implies that the bottom layer of the Paduran core is strongly affected by the sulphuric acid originating from pyrite oxidation within the mineral sediment under the peat layer.

Sulphuric acid discharge from acid sulphate soil to freshwater ecosystems

Sulphuric acid produced by pyrite oxidation affects not only the soil itself but also river and lake water systems after discharge from acid sulphate soil (Monterroso and Macías, 1998). The second objective of our research was to evaluate the impact of pyrite oxidation on the freshwater ecosystems. We estimated the range over which sulphuric acid originating from pyrite oxidation affects the water chemistry of rivers in Central Kalimantan. Data for the Sebangau River are presented in this paper. Water pH in the Paduran River in the rainy season was lower than water in the upper or middle basin of the river (Table 1), although water in the Sebangau River was constantly acidic owing to the high concentration of humic acids. Acidity in the Paduran canal in the rainy season was highest among these study sites and the concentration in the rainy season was much higher than the dry season.

Sulphate ion concentration tended to increase from the upper to the lower basin of the Sebangau River and the concentration in the Paduran Canal was the highest among the sites. The concentration of sulphate ion in the rainy season in the Paduran Canal was much higher than in the dry season. Although pH of the river water in Paduran and Paduran Canal was not lower than the other sites, sulphate ion concentration in the Paduran Canal was much higher than the other sites. High concentration of chloride ion as well as higher pH in the dry season in the lower basin of the

Table 1. Water chemical properties of surface water in the Sebangau River, Central Kalimantan, Indonesia. Data are presented in mmolc L^{-1}. Parts of the data appeared in Haraguchi (2007).

Sampling site	pH	Na^+	Cl^-	SO_4^{2-}
	9 March 2004 (rainy season)			
Kya	3.75	0.03	0.02	0.00
Rasau river	3.71	0.03	0.02	0.00
Bangah river	3.80	0.03	0.02	0.00
Paduran river	3.69	0.03	0.03	0.12
Paduran canal mouth	3.02	0.03	0.03	7.30
Paduran canal middle*	3.08	0.21	0.07	6.11
	8 September 2004 (dry season)			
Kya	4.05	0.03	0.03	0.03
Rasau river	4.08	0.03	0.03	0.00
Bangah river	4.05	0.04	0.05	0.01
Paduran river	4.06	0.27	0.55	0.07
Paduran canal mouth	4.36	2.96	6.96	0.63
Paduran canal middle**	4.28	2.08	4.56	0.47

Sebangau River implies inundation by sea water because of the low discharge rate of the river water. Data for the large area survey of river water showed that the effect of pyrite on the river water chemistry appeared downstream from the 135 km point from the river mouth (Haraguchi, 2007). Seasonal differences in sulphate ion concentration showed that discharge of pyritic sulphate from peat soil to the limnological system is much higher in the rainy (high water table) season than during the dry (low water table) season.

Iron content in the sediment of the Sebangau River increased from the upper to the lower basin (Table 2). This implies the higher contamination of iron oxide after pyrite oxidation especially in the lower basin of the river. Iron concentration in sediment was high even in the middle basin of the river. Although acidification of river water by pyrite oxidation was not evident in the middle basin of the river, pyrite distributed in the middle basin and it was oxidized to affect river water chemistry.

Table 2. Element content (mass %) in dry sediment in the Sebangau River, Central Kalimantan, Indonesia. Element content was determined by WDX-fluorescence X-ray analysis. Samples were collected on 9 September 2004. Data of Paduran Canal Middle is missing. (Haraguchi unpublished data)

	Sampling site				
	Kya	Rasau river	Bangah river	Paduran river	Paduran canal mouth
Na_2O	-	-	-	-	-
MgO	-	-	0.456	-	1.67
Al_2O_3	1.38	12.9	18.4	24.5	24.8
SiO_2	98.1	72.6	67	54.4	51.6
P_2O_5	-	-	0.275	0.425	0.269
SO_3	-	7.6	2.29	2.76	1.05
Cl	-	-	-	-	0.308
K_2O	0.117	1.77	2.01	2.45	2.29
CaO	-	0.784	0.576	0.254	0.472
TiO_2	-	-	1.91	2.5	-
Fe_2O_3	0.288	4.39	7.06	12.8	17.3
ZrO_2	0.0874	-	-	-	-
PdO	-	-	-	-	0.209
MnO	-	-	-	-	-

Table 3. Ratio of number of persons answering "true" or "false" to the statements concerning water quality and water utility of river. Parts of the data appeared in Haraguchi *et al.* (2008).

Statements	Area	Answer of "true" (%)	Answer of "false" (%)	No answer (%)
We can drink river or canal water after boiling.	Paduran	21.7	73.9	4.3
	Pangkoh	88.6	11.4	0.0
	Sigi	75.0	25.0	0.0
Swimming in the river is safe for the skin.	Paduran	21.7	73.9	4.3
	Pangkoh	93.2	6.8	0.0
	Sigi	90.4	7.7	1.9

Water and sediment in the upper basin of the Sebangau River had typical quality in peat swamp forest without human impact, and species diversity as well as abundance of macrozoobenthos was higher than the lower basin of the river (Welsiana *et al.,* unpublished data). Water and sediment in the lower basin of the Sebangau River were strongly affected by pyrite oxidation caused by agricultural development of the peat swamp forests, and species diversity as well as abundance of macrozoobenthos was the lowest. Thus we found that water and sediment chemistry strongly affect the the diversity, species composition and abundance of macrozoobenthos communities.

Impact of sulphuric acid concentration in river water on local inhabitants

The third objective of our study was to obtain information on utilisation of natural water from local inhabitants in the basin with water pollution by sulphuric acid contamination. We held interviews with local inhabitants in sulphuric acid polluted areas in Paduran and Pangkoh as well as areas around Sigi village concerning the sources of water and evaluation of water quality in their habitat. Pangkoh village is located in the lower basin of the Kahayan River and the basin was actually contaminated by sulphuric acid. Sigi village is located in the upstream of Palangkaraya City on the basin of the Kahayan River, and the water was not contaminated by sulphuric acid.

The type of water used for drinking and cooking was not significantly different between seasons in the Sigi area, whereas the difference was significant in the Paduran and Pangkoh areas. The main source of water for each purpose in Pangkoh and Paduran was rain water in the rainy season, but the type of water for these purposes significantly changed to river, canal or well water in the dry season. The significant shift by people to river and canal water in the dry season would correspond to lower contamination with sulphuric acid in the dry season. They prefer using river and canal waters because this was easily available without any apparatus for collecting rain water; however, they hardly use river or canal water in the rainy season. This clearly showed that local people in Paduran and Pangkoh avoided using sulphuric acid contaminated river water in the rainy season for drinking and cooking.

Although people in Pangkoh and Paduran avoid using sulphuric acid contaminated water in the rainy season, their consciousness on the risk of sulphuric acid contamination was quite the opposite. More than 70% of the Paduran people answered that river water presents a high risk for drinking and swimming, whereas only 11% or less of the Pangkoh people knew about the risk of sulphuric acid for human health (Table 3). The Pangkoh people avoided using river water contaminated with sulphuric acid, but the knowledge about sulphuric acid's effects on human health was not sufficient. Thus we concluded that although selectivity of water was similar for the local inhabitants of the two villages in polluted area, awareness about the risks of sulphuric acid pollution for human health proved to be quite different between the two villages.

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