Geochemical behavior of aluminum in saline acid sulfate soils of lower Casamance (Senegal): agricultural consequences for the rehabilitation of rice culture

J.P. Montoroi. *Département Eaux Continentales, ORSTOM, 72 Route d'Aulnay, 93143 Bondy, France.*

Introduction. High concentrations of dissolved aluminum have been found in acid sulfate soil waters, especially in watersheds equipped with an anti-salt dam (1, 2). A toxic hazard is assumed to be effective against fauna (3) and vegetation, especially rice culture. In acid aquatic environment, the solubilities of gibbsite and kaolinite control the aluminum concentration (4). During the dry season, the oxidation of pyrite has produced sulfuric acid in soils and the dominant anion is sulfate. The aqueous geochemistry of aluminum is significantly modified in the presence of sulfate. Other minerals than gibbsite and kaolinite are stable in acid sulfate waters (5).

Materials and Methods. The soils of the Djiguinoum valley are highly acid and saline with a wide range of salinity. They are clayed and the dominant clay mineral is kaolinite. They are submerged during the rainy season from june to october, and the surface water has evaporated during the dry season from november to may. Saline efflorescences and ground waters are sampled in different parts of the valley. The surface waters sampling is carried out at the anti-salt dam when the sluices are opened during the rainy season. The activities of water components were calculated using the PC-Wateq model.

Results and Discussion. The salinity of ground waters increases from the limit of the lowlands to the river axis and reaches high values of electrical conductivity close to 100 dS m^{-1}. The surface waters are more diluted. Three types of chemical composition are determined for the ground waters. The waters bordering on the valley are sulfated whereas chlore ion is dominant in other waters.

Efflorescences observed during the dry season form differents types of aluminum (alunogen) and ferrous (rozenite) sulfates which are bordering on the valley. Both theses minerals are associated with mixed aluminum sulfates such as halotrichite, pickeringite and apjohnite. In the central part of the valley where soil water is more concentrated, another aluminum sulfate, the tamarugite or the sodium alum, has been found and is associated with gypsum, halite and magnesium sulfates such as starkeyite or hexahydrite. Jarosite can precipitate in this area under favorable redox conditions.

The sulfate activity of surface waters and ground waters is fairly constant and is set at 10^{-2} mol L^{-1}. The pH is also relatively constant and is ranged from 3 to 4. The waters are undersaturated with respect to alunogen (figure 1). They are saturated with respect to the mineral proposed by Van Breemen (6) and assumed to be the jurbanite (5) except the ground waters from the upper part of the valley (figure 2). No mineralogical argument has enhanced the existence of a basic aluminum sulfate with a stoichiometric formula $AlOHSO_4$ and an amorphous form is considered (5) The recent criticism about the conventional stability diagram controlling this hydroxy sulfate need a reappraisal to explain the aluminum regulation with a precipitation-dissolution process (7).

The specific localization of aluminum sulfates on the border of the valley and the particular pattern of the efflorescences in relation with the distribution of surface soil particles agree with the adsorption properties of soil colloids. In extrem acid conditions, the sulfate adsorption is increased with positively charged surfaces of clay particles and aluminum is under an exchangeable form. The sorption phenomena is interpretable as a precipitation reaction which is catalyzed by surface reactions (5). The formation of the aluminum sulfates is assumed to be carried out when the water is highly rich in sulfates and when there are local acidic reactions such as the oxidation of ferrous iron which releases protons in the soil solution. The fixation of protons on the exchange complex mobilize cations which can combine with sulfates and form minerals during the concentration phase.

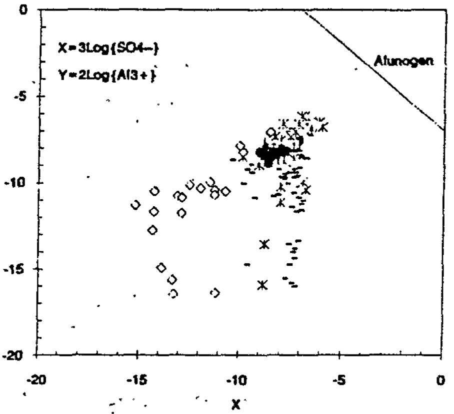

Figure 1
Solubility diagram for alunogen.
Plotted symbols represent surface waters (solid circles) and three types of ground waters for the upper part (open diamonds), border part (cross) and central part (dots) of the Djiguinoum valley (Senegal).

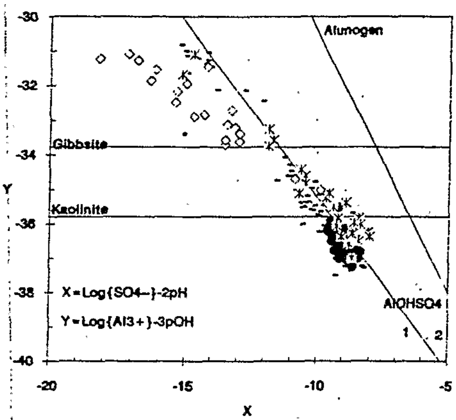

Figure 2
Solubility diagram for $AlOHSO_4$, alunogen, gibbsite and kaolinite.
The solid line (1) is from Van Breemen (1973) with Thailand waters and soil solutions and the dotted line (2) is from VIEILLEFON (1977)) with Senegal soil solutions. The symbols are similar to the figure 1

Conclusion. The important sources of aluminum in Casamance acid aquatic environment is now showed. The dilution of acid waters during the rainy season improves the mobilization of aluminum with the other ions and the decrease of their concentration in soils. The decrease of salinity and acidity in the upper layer of soil is required and sufficient to rice culture. If the water management is well-adapted to the growth of the plant, the rehabilitation of degraded lands can be induced in such conditions (8,9). The improvement of soil fertility (lime, phosphates and/or organic matter) must be associated with the water management so as to sustain the rice culture. The economic aspect must be taken in account to diffuse theses recommendations to the local populations.

Literature cited.

(1) LE BRUSQ J.Y., LOYER J.Y., MOUGENOT B., CARN M., 1987. Nouvelles paragénèses à sulfates d'aluminium, de fer et de magnésium, et de leur distribution dans les sols sulfatés acides du Sénégal. *Science du Sol*, 25, 3, 173-184.

(2) VIEILLEFON J., 1977. Les sols des mangroves et des tannes de Basse Casamance (Sénégal). Importance du comportement géochimique du soufre dans leur pédogénèse. *Mém. ORSTOM*, 83, Paris, 291 p.

(3) GALLE C., MONTOROI J.P., 1993. Ecological consequence of high aluminium content in acidified estuarian waters: the case of tilapia fishes in lower Casamance (Senegal). Acta Oecologica, 14, 1 : 87-100.

(4) LINDSAY W.L., WALTHALL P.M., 1989. The solubility of aluminium in soils. In G. SPOSITO (Ed.): "*The environmental chemistry of aluminum*", CRC Press, Boca Raton, Florida, 221-239.

(5) NORDSTROM D.K., 1982. The effect of sulfate on aluminum concentrations in natural waters: some stability relations in the system Al_2-SO_3-H_2O at 298 K. *Geochim. et Cosmochim.* Acta, 46, 4 : 681-692.

(6) Van BREEMEN N., 1973. Dissolved aluminium in acid sulfate soils and in acid mine waters. *Soil Sci. Soc. Amer. Proc.*, 37 : 694-697.

(7) NEAL C., SKEFFINGTON R.A., WILLIAMS R., ROBERTS D.J., 1987. Aluminium solubility controls in acid waters: the need of a reappraisal. *Earth Planet. Sci. Lett.*, 86 : 105-112.

(8) ALBERGEL J., BRUNET D., DUBEE G., MONTOROI J.P., ZANTE P., 1992. Gestion d'un barrage anti-sel en basse Casamance (Sénégal). In G. GREPIN, C. POMERLEAU et J.Y. PIROT (Eds) : "*Conservation et utilisation durable des ressources naturelles du bassin hydrographique de la Casamance*", AJAC-ZG/ISRA/ORSTOM/UICN, Ziguinchor-Dakar, 67-74.

(9) MONTOROI J.P., ALBERGEL J., DOBOS A., FALL M., SALL S., BERNARD A., BRUNET D., DUBEE G., ZANTE P., 1993. A suitable water management for the rehabilitation of rice culture in the acid sulphate soils of lower Casamance (Senegal): a successful two years experiment. In: DENT D. & Van MENSVOORT M.E.S., (Eds.), Selected papers of the Ho Chi Minh City symposium of acid sulphate soils. ILRI, Wageningen, in press.

15th World Congress of Soil Science

Acapulco, Mexico, July 1994

TRANSACTIONS

Volume 3b

Commission II: Poster Sessions

Acapulco, México 1994

INEGI
INSTITUTO NACIONAL DE ESTADISTICA GEOGRAFIA E INFORMATICA

COMISION NACIONAL DEL AGUA

International Society of Soil Science