1990 Vth International Congress of Ecology. YOKOHAMA

AN ECOSYSTEM UNDER ACID RAIN AT MERAPI VOLCANO IN CENTRAL JAVA, INDONESIA

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ABSTRACT - The input of acidifying elements from volcanoes to the atmosphere seems weak compared to that of industrial activity; but it is not less true that a volcano with permanent activity like Merapi is a powerful local source of pollution in sulphur, chlorine, bromine, fluorine and selenium. The Merapi volcano has released 30 to 200 tons of SO_2 per day for centuries.

At Merapi, the SO_2 is released in an equatorial humid atmosphere containing more than 80% water vapour. It rains almost everyday and a large part of the acidifying elements fall in the immediate vicinity of the volcano. Around Merapi, in a radius of 8 to 10 km, it "has rained" 300 to 700 kg of SO_2 per hectare per year for centuries, maybe millenia.

Despite these acid precipitations, the negative effect of the acidifying elements is not obvious. The vegetation is always very lush. Outside the thermally destroyed zones caused by eruptions every 4 to 5 years, the forest vegetation climbs up to 2,500 m in altitude as close as 1 km to the main crater.

Despite the increasing number of publications concerning the acidification of rain water and the destruction of forests, nobody has really proved that sulphur is the main cause.

The facts reported are contradictory; in recent years, agronomists even recommend the use of sulphur as considerable yield increases have been shown after sulphur fertilization.

PRESENTATION

Since 1955, there has been an increasing number of publications concerning the destruction of forests in Europe and changes in the rain water composition, in particular increased acidification. The principal cause might be SO_2 and its oxidation in sulphuric acid (Gorham, 1955; Almer et al, 1947; Hofmann & Rosen, 1980; Overrein et al, 1980; Paces, 1985).

Despite the increasing number of publications, none has actually proved that sulphur is the main element which causes destruction. The facts reported in scientific literature are contradictory : agronomists recommend the use of sulphur as considerable increases in yields have been shown after sulphur fertilization (Morris, 1986; Fauconnier, 1986; Cornforth & Sinclair, 1986).

Furthermore, the literature concerning active volcanoes shows that all release a large quantity of sulphur in the form of SO_2, which can be hundreds and sometimes even thousands of tons per day (Buat Menard & Arnold, 1978; Phelan et al, 1982; Symonds, 1985). In addition to this, variable quantities of other toxic elements are also released :

- Chlorine, fluorine and bromine up to 100 tons/day.
- Zinc and copper up to 3 tons/day.
- Selenium, arsenic and lead up to 800 kg/day
- Mercury up to 100 kg/day
- Cadmium up to 30 kg/day.

Soil experts and agronomists working in volcanic equatorial areas know very well that outside the zones which are destroyed either mechanically or thermally by eruptions, the vegetation around a volcano is always very lush .

Despite undeniable improvements during the past 20 years in our knowledge of the sulphur cycle and the major fluxes (Lein & Ivanov, 1989; Brimblecombe et al, 1989), the negative effect of sulphur on vegetation remains to be proved.

We know well enough the SO_2 content in the atmosphere. In industrialized countries, the concentration varies from 0.2 to 100 ppb (Hidy, 1973). The content depends on the latitude and shifts from ± 3 ppb at 40° North to very low values 0.1-0.2 ppb in the equatorial zone (Georgii, 1970; Cullis & Hirschler, 1980; Delmas & Servant, 1983; Rodhe & Granat, 1984).

The SO_2 content in the equatorial zone is mainly the consequence of the high water vapour content of the atmosphere which plays the powerful role of "sink", and of the very high chemical reactivity of the gas itself. Therefore, the low SO_2 content cannot be correlated with the volume of discharge of sulphur sources at altitudes below 4,000 m.

If the input of metals and acidifying elements from volcanoes to the atmosphere is globally weak compared to that of industrial activity (Le Guern, 1982; Berresheim & Jaeschke, 1983; Möller, 1984; Rhode & Granat, 1984), it is not less true that a volcano with permanent activity is a powerful local source of pollution in sulphur, fluorine, zinc, selenium, arsenic, lead and mercury; and represents an ideal place for a study of the effect of these elements on the vegetation and soils.

In temperate zones with a relatively dry atmosphere, elements released by a volcano can self-maintain for a long time in the atmosphere and mixed with industrial pollution can be carried away over hundreds of kilometres. Rhode (1972) advances for these conditions, for SO_2, a possible life-span of 30-70 hours before its precipitation by rain. Things are different close to a volcano in a humid equatorial zone where the elements are released in an atmosphere containing more than 80% water vapour. In these conditions, they evolve very quickly and their residence time is only several hours (Scott & Hobbs, 1967).

At Merapi, a volcano with permanent activity, we are close to the equator where strong atmospheric disturbances are rare. It rains almost everyday and a large part of the released metals and acidifying elements have fallen down with the rain for centuries in the immediate vicinity of the volcano.

According to volcanologists (Bahar, 1986; Symmonds, 1985), Merapi releases 30 to 200 tons of SO_2 into the atmosphere per day (Table 1). We can expect, through experimental determinations of $(SO_4)^{--}$ in the precipitations, that 25 tons of SO_2 will fall in a radius of 8 to 10 km. That means a content of 12 to 28 ppm of SO_2 in the rain in that area for a rainfall of 2,500 mm per year.

TABLE 1

ELEMENTS		FLUXES IN KG/DAY
S	SULPHUR	200,000
Cl	CHLORINE	30,000
F	FLUORINE	1,500
Br	BROMINE	140
Zn	ZINC	89
Pb	LEAD	7
As	ARSENIC	4.6
Cu	COPPER	0.8
Sb	ANTIMONY	0.5
Cd	CADMIUM	0.2

Transport rates (Jan-Feb, 1984) of elements into the atmosphere by Merapi, (Symonds, R.B., 1985)

In other words, in layman's terms, this means that it has "rained" 300 to 700 kg of SO_2 per hectare per year in the area in question for centuries.

Following Van Bemmelen (1949), the essential landscape of the present Merapi was created by a paroxysmal eruption in the year 1006 AD. Volcanic activity has not changed since then, and we can evaluate the amounts of pollutants received by each hectare in the immediate vicinity since this eruption : some tens of tons of flourine, 2 tons of bromine, 3 tons of zinc, 1 ton of lead, and at least 500 kg of mercury. However, these figures signify little since we ignore the stay-span of these elements in the soils.

The Merapi landscape presents 3 exceptional characteristics :

1. An extremely rapid increase in pollutants on only some 30 km from the lowest to the highest values in the world is found in a radius of 30 km.
2. Homogenous Andosols catenas, with allophane type clay minerals, having variable charges, which allow us to expect particularly strong fixation of S, F, Se and As, in anionic form.
3. A forest ecosystem that has functioned for millenia which should allow us to see visual negative effects of these elements on the vegetation.

We can only conclude that despite high inputs of polluting and acidifying elements, there is no clear visible evidence at Merapi volcano of negative effects on the vegetation.

Again, we notice the same contradiction : in the zone where the acid precipitations seem particularly strong and have affected the environment for centuries, maybe millenia, the negative effect of acidifying elements such as sulphur, chlorine and fluorine on the vegetation is not obvious and one could even speak of beneficial effects.

REFERENCE

ALMER, B., DICKSON, W., EKSTROM C., HORNSTROM E., MILLER, U., (1974) Effects of acidification of Swedish lakes. Ambio, Vol. 3 no. 1, 30-36.

BAHAR, I. (1986) Volcanic survey of Indonesia (oral communication).

BERRESHEIM, H. & JAESCHKE W. (1983) The contribution of volcanoes to the global atmospheric sulphur budget. J. Geophys. Res., 88 (C6), 3732-40.

BRIMBLECOMBE, P., HAMMER, C., RODHE, H., RYABOSHAPKO, A. & BOUTRON, C.F. (1989) Human influence on the sulphur cycle. In SCOPE 39, Evolution of the global biogeochemical sulphur cycle, 77-121.

BUAT-MENARD, P. & ARNOLD, M. (1978) The heavy metal chemistry of atmosphere particulate matter emitted by Mount Etna Volcano. Geoph. res. Lett., Vol. 5, no. 4, 245-248.

CORNFORTH, I.S., & SINCLAIR A.G. (1986) Fertilizer advice for New Zealand farmers with particular reference to sulphur requirements. Int. Conf. Management and fertiliz. of upland soils. Ac. Sinica Proceedings, 144.

FAUCONNIER, D. (1986) Sulphur fertilization in grain legumes. Int. Conf. Management and fertiliz. of upland soils. Ac. Sinica Proceedings, 130.

GEORGII, H.W. (1970) Contribution to the atmosphere sulphur budget. J. Geophys. Res. Vol. 75, 2365-2371.

GORHAM, E. (1955) On the acidity and salinity of rain. Geochim. et Cosmochim. Acta. Vol. 7, 231-239.

HIDY, G.M. (1973) Removal processes of gaseous and particulate pollutants in : S.I. Rasool (ed); Chemistry of the lower atmosphere. New York, Plenum Press, 121-173.

HOFMANN, D.J. & ROSEN, J.M. (1980) Stratospheric sulphuric acid layer : evidence for an anthropogenic component. Science 208, 1368-70.

KUSUMADINATA, K. (1979) Data dasar gunung api Indonesia. Dir. Volcanologi, Dirjen Pertambangan dan Energi R.I., Bandung.
LE GUERN, F. (1982) Les débits de CO_2 et SO_2 volcaniques dans l'atmosphere; Bull. Volcanol. Vol. 45-3, 197-202.
LEIN, A.Y. & IVANOV M.V. (1989) Contribution of endogenous sulphur to the global biogeochemical cycle in the geological past. In SCOPE 39. Evolution of the global biogeochemical sulphur cycle, 65-74.
MÖLLER, D. (1984) Estimation of the global man-made sulphur emission. Atmos. Environ. 18, 19-27.
MORRIS, J.R. (1986) Sulphur - A major nutrient for field improvement. Int. Conf. Management and fertiliz of upland soils. Ac. Sinica Proceedings, 17.
OVERREIN, L., SEIP, M.H., TOLLAN, A. (1980) Acid precipitation effects on forest and fish. Final Report. Oslo-As, 175 pp.
PACES, T. (1985) Sources of acidification in Central Europe estimated from elemental budgets in small basins. Nature 315, 31-6.PHELAN, J.M., FINNEGAN, D.L. BALLANTINE, D.S., ZOLLER, W.H., HART, M.A. & MOYERS, J.L. (1982) Airborne aerosol measurements in the quiescent plume at Mount St. Helens : September, 1980. Geophys. Res. lett. Vol. 9, 1093-1096.
RHODE, H. (1972) A study of the sulphur budget for the atmosphere over Northern Europe. Tellus. Vol. 24, 128-8.
RHODE H. & GRANAT L. (1984) An evaluation of sulphate in European precipitations 1955-1982. Atmos. Environ. 18, 2627-39.
SCOTT, W.D. & HOBBS, P.V. (1967) The formation of sulphate in water droplets. J. Atm. Sci. Vol. 24, 54-7.
SOERAIS, S. (1975) Penelitian kontaminasi raksa terhadap lingkungannya sebagai akibat kegiatan gunung Merapi. Fak. Farmasi UGM, Yogyakarta, Indonesia.
SOERAIS, S., HARYONO, A. & IBNUHAJAR, MM (1977) Kontaminasi raksa terhadap kehidupan akibat kegiatan gunung Merapi. Fak. Farmasi, UGM. Yogyakarta, Indonesia.
SYMONDS, R.B. (1985) Transport and enrichment of elements in high temperature gases at Merapi Volcano, Indonesia. Thesis. Michigan Technology University, 102 pp.
VAN BEMMELEN, R.W. (1949) The geology of Indonesia. Vol. I A : Martinus Nijhoff, The hague, 732 pp.