Bull. Environm. Contam. Toxicol. 19, 715-723 (1978)

An Ecological Survey of the Effect of Sulfur Dioxide Emitted from an Acid Work Factory

Ming-Hung Wong
Department of Biology, Chinese University of Hong Kong, Shatin, Hong Kong

Sulfur dioxide is one of the most common air pollutants. The acid manufacturing factory at Ching Lung Tau, Hong Kong has emitted large quantities of sulfur dioxide into the atmosphere since 1955. Sulfur dioxide emitted from the factory moved according to the prevailing wind and damaged the surrounding vegetation. Erosion of the top soil followed the death of plants and heavy rainfall. Complients have also been received from the nearby inhabitants.

The present investigation is to study the degree of damage of the sulfur dioxide to the soil and vegetation near the Factory.

DESCRIPTIONS OF THE STUDY SITE

The study site is located at Ching Lung Tau, New Territories, north-east of the Hong Kong Acid Work Factory (Fig. 1). The area lies between 25 m to 95 m above sea level and 12 m away from the sea. A south-west to north-east wind from the sea prevails from October to February each year. The study area facing the wind received much damage from the pollutants emitted from the Factory. Only sparse cover of vegetation is found in the exposed area (Fig. 2.1).

The areas sheltered from the wind generally posses higher contents of nutrients and finer particles due to the runoff from the top of the hill and therefore the area has a more luxurous plant growth (Fig. 2.2). Fine particles were washed downslope and deposited at lower altitudes (Fig. 2.3). Serious erosion occurred after the disappearance of the vegetation and the continuous action of heavy rainfall especially in the summer/autumn monsoon season (Fig. 2.4).

The factory was founded in 1955 and sulfuric acid has been the major product. The method used in the production of sulfuric acid is the contact process. Vanadium pentoxide (V_2O_5) is used as a catalyst to convert sulfur dioxide to sulfur troxide which is then absorbed in 98-99 % sulfuric acid. Sulfur is burnt in oxygen in order to produce SO_2 and H_2SO_4 subsequently. SO_2 is the main reactant in the process and because of its physical property, it will emit easily and cause the irritating odor of SO_2 as well as damage to the sorrounding plants and soils.

The process of manufacturing concentrated sulfur acid can be summarized as follows :-

0007-4861/78/0019-0715 $01.80
© 1978 Springer-Verlag New York Inc.

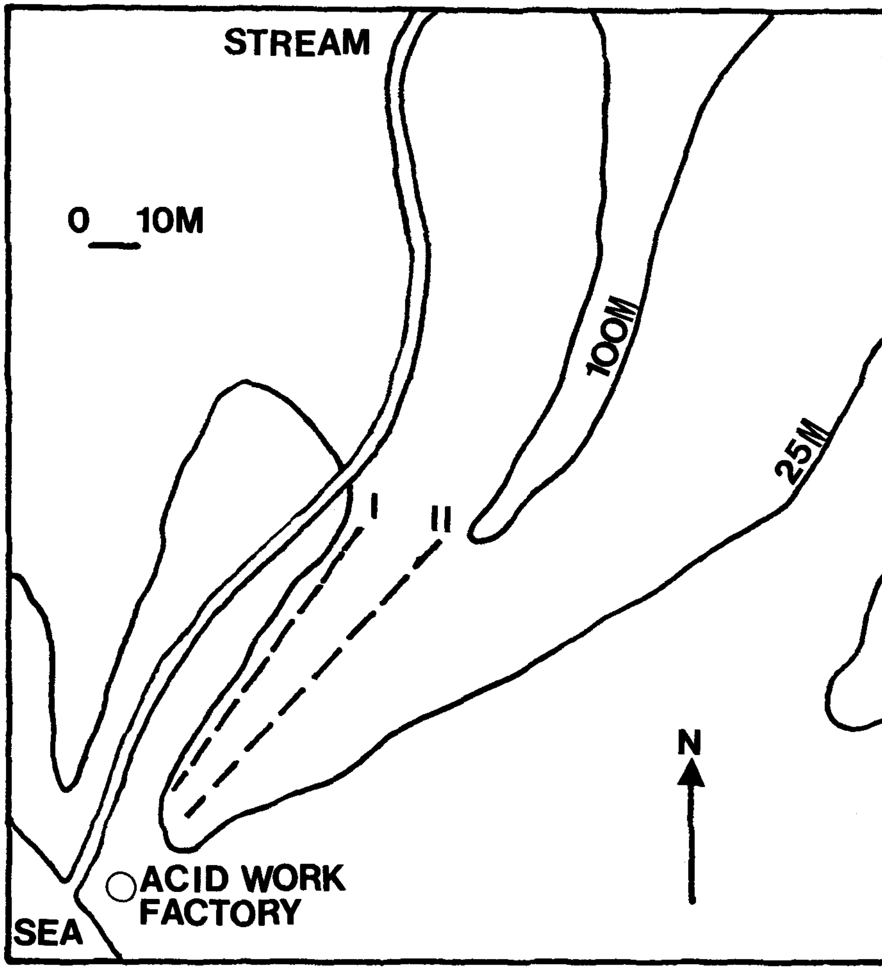

Fig. 1 Map of the study site, showing the positions of the Acid Work Factory and the two transects.

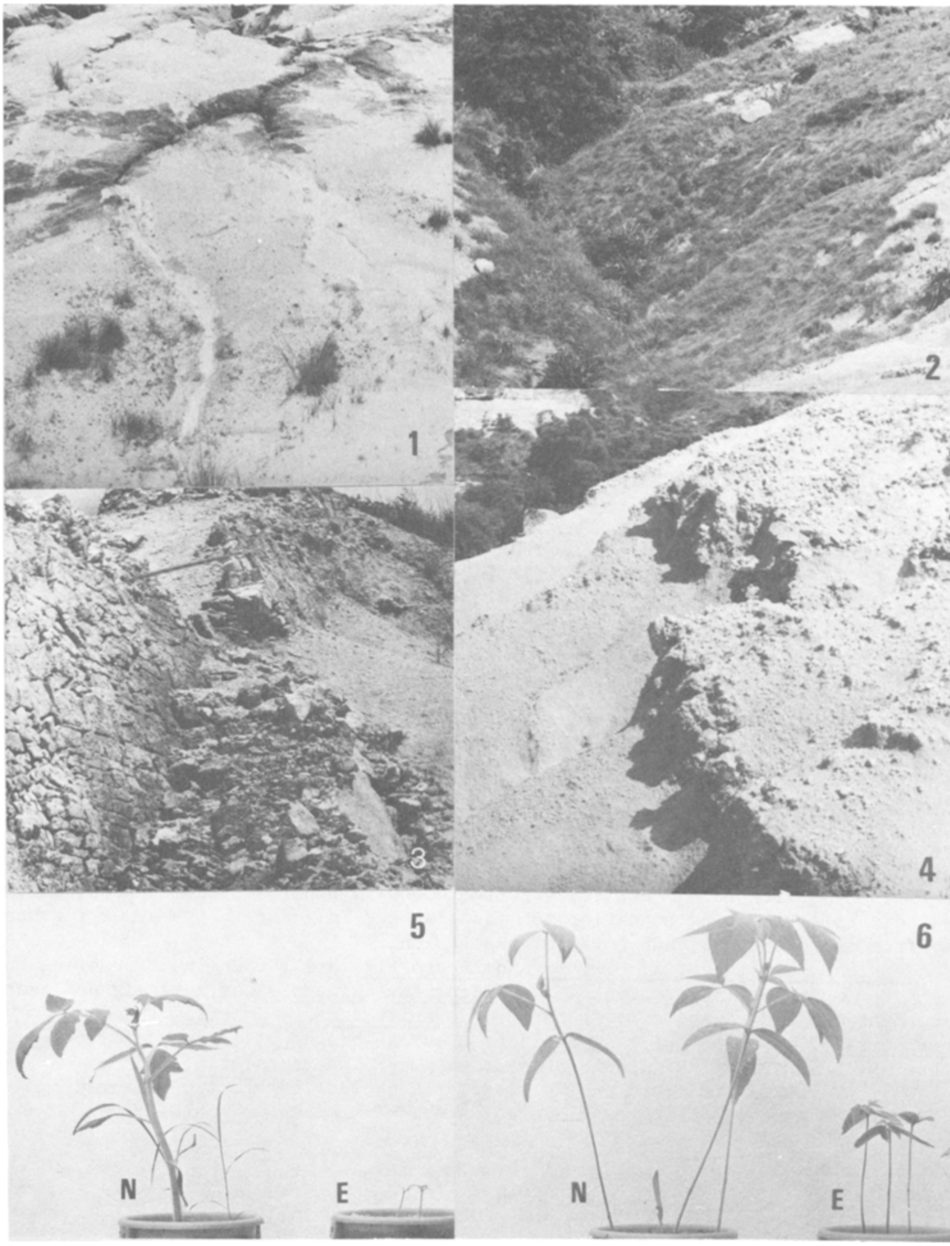

Fig. 2.1 The eroded area with only sparse cover of vegetation.
Fig. 2.2 A more luxurious growth of vegetation is found at the sheltered area.
Fig. 2.3 and Fig. 2.4 Erosion occurred after the disappearance of vegetation and heavy rainfall.
Fig. 2.5 and Fig. 2.6 The appearance of Phaselous mungo and Lycopersicon esculentum after being grown in the normal soil (N) and the eroded soil (E) for one month.

$$S + O_2 \xrightarrow{\Delta} SO_2$$

$$2SO_2 + O_2 \xrightarrow{V_2O_5} 2SO_2$$

$$SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$$

$$H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$$

MATERIALS AND METHODS

After a preliminary survey in the reaearch area, two belt transects were laid down (Fig. 1) and the different species of vegetation were identified and their occurrence recorded. The injury level of the plant species was noted. The samples of the soil (0-10 cm) along the transects were transferred into the laboratory for further analysis. The atmospheric content of sulfur dioxide was tested using the colorimetric method described by WEST and GAEKE (1956) at 3 m north-west of the Factory.

The soil samples were air-dried, passed through a 2 mm mesh seive and then determined for the following items: texture (BOUYOUCOS, 1926), pH (10 gm soil : 25 ml distilled water using a pH meter), contents of organic carbon (WALKLEY and BLACK, 1934), exchangeable potassium (flame photometry), soluble phosphate (colorimetric method, WATANABE and OLSEN, 1962) and soluble sulfate (turbidimetric method, BUTTERS and CHENERY, 1957).

Seeds of tomato, *Lycopersicon esculentum* and mungo bean, *Phaseolus mungo* were planted in the eroded soil and an unaffected soil after they had germinated. The appearance of both plant species was observed after being grown in a green house for one month.

RESULTS AND DISCUSSION

Plant analysis

The results of the vegetation analysis is listed in Table 1. Only sparse cover of vegetation was found on top of the hill and although existing, they appeared in dwarf forms. The coverage of the vegetation is higher in Transect II due to its position being sheltered and the downward runoff of the top soil which created a better growing condition for the plants. In general, the areas further away from factory had higher cover of vegetation.

Ischaemum aristatum, *I. ciliare* and *Erogrostis* were the dominant species at the beginning of the Transect I and *Mischanthus sinensis* was the only dominant species at the end of the same transect. *I. aristatum* and *I. ciliare* and *Erogrostis* sp. were the three co-dominant species throughout Transect II with *Smilax glabra* which inserted its importance half way down the transect.

Most of the plants found in the study area showed the symptom affected by SO_2 and the degree of damage on different species is shown in Table 2.

TABLE 1

The distribution of plant specis along Transects I and II (numbers indicate cover percentage)

Distance away from the Factory (M)	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Apocynaceae																				
Strophanthus divaricatus																				
Cyperaceae																				
Rhynchospora rubra																	5			
Gramineae																				
Digitaria sanguinalis		+																		
Erogrostis sp.	+	5	+	+	5	10	5						5	5						
Ischaemum aristatum			+	+	5	5	+	+	5				10	+						
Ischaemum ciliare		+	5	5	+	10	5	+	+	5			+							
Mischanthus sinensis													5	+	10	5	5	10	15	10
Paspalum scrobiculatum		+																		
Rhynchelytrum repens																				
Smilaceae																				
Smilax glabra																			10	5
Apocynaceae																				
Strophanthus divaricatus																			+	5
Cyperaceae																				
Rhynchospora rubra																	+	5	5	
Gramineae																				
Digitaria sanguinalis		+	5				+	+												
Erogrostis sp.				+	5	10	10	10	5	20	10	10	10	10	30	35	15	40	10	40
Ischaemum aristatum			+	+	+	5	10	10	15	15	10	+	10	10	10	5	10	5	5	10
Ischaemum ciliare			+	+	+	5	+	5	5	10	5	+	5		+	5	5	5	+	10
Mischanthus sinensis								+	+	5	5	5								
Paspalum scrobiculatum								5	5											
Rhynchelytrum repens	+	+																		
Simlaceae																				
Smilax glabra										+	+	10	15	20	10	10	5	5	10	5

TABLE 2

The degree of damage on different plant species by SO_2

Plant species	Type of necrosis	Color
Cyperaceae		
Rhynchospora rubra	marginal	brown
Gramineae		
Digitaria sanquinalis	intercostal	red
Erogrostis sp.	intercostal	red
Ischaemum aristatum	intercostal, marginal	red-brown
Ischaemum ciliare	intercostal, marginal	red-brown
Mischanthus sinensis	intercostal, marginal	red-brown
Paspalum scrobiculatum	terminal	red-brown
Rhynchelytrum repens	marginal, terminal	red

Sulfur dioxide enters the leaves of plants through the open stomata and absorbed on the moist surface of spongy tissue and palisade cells forming sulfites. The sulfite can kill these cells quickly if it is present in sufficiently high concentration. However, at low levels, the sulfites are slowly oxidized in the plant to sulfate which has a lower toxicity. Structural damage caused by corrosion by sulfuric acid, to which all atmospheric sulfur dioxide eventually degrades, is widely noticiable (Table 2).

The atmospheric content of SO_2

The hourly average of SO_2 concentration was 3 ppm. Normally SO_2 is present in the air at about 0.1 ppm with occassional speaks up to 0.5 ppm and the concentration of 3 ppm is usually found in heavily industrialized areas (FAITH and ATKISSON, 1972). The tolerance level of plants and animals to pollutants such as SO_2 depends on a number of factors : the concentration of the pollutant and exposure time, the type of plant and animal and their condition and age. Various reports demonstrated that small exposures for a long time are equally as destructive as large exposure for a short times.

Soil analysis

The results of soil analysis are shown in Table 3.

TABLE 3

The results of the soil analysis along Transects I and II

Distance away from the Factory (M)		5	25	45	65	85	Unaffected soil
Texture	Sand %	62.86	64.76	60.73	58.20	51.37	40.46
	Silt %	20.41	21.34	23.14	25.31	22.15	34.29
	Clay	16.72	13.90	16.13	16.49	26.48	25.25
pH		4.6	4.5	4.7	4.9	4.9	5.7
Organic carbon %		0.61	0.80	0.82	1.23	1.34	3.04
Exchangeable K ppm		0.91	0.81	1.40	2.50	2.45	6.50
Soluble phosphate ppm		0.02	0.02	0.03	0.02	0.04	0.08
Soluble sulfate ppm		1.62	2.27	1.34	1.35	1.26	0.52
Texture	Sand %	56.14	58.23	50.79	52.35	48.17	
	Silt %	21.19	23.76	25.76	29.94	29.32	
	Clay %	22.67	18.01	23.45	17.71	22.51	
pH		4.8	4.5	4.8	5.0	4.9	
Organic carbon %		0.72	1.20	1.40	1.62	1.53	
Exchangeable K ppm		1.20	0.80	2.12	2.75	2.62	
Soluble phosphate ppm		0.03	0.04	0.03	0.04	0.05	
Soluble sulfate ppm		1.24	1.35	1.25	1.01	1.43	

Texture

The content of sand was higher in the eroded area although a comparatively higher content was observed under sparse cover of vegetation in these areas due to the action of the plant roots that prevented the soil from being washed away by heavy rainfall, and therefore finer particles could be retained. In general, Transect II had a higher content of fine particles due to the deposits of the particles from higher altitudes. However, the content of sand was rather high when compared with the unaffected area.

pH

No significant difference of pH values were found along either transect. However, Transect I had a lower pH owing to its coarser texture with a higher leaching effect and runoff of rainwater whereas Transect II had a higher pH due to its position and reception of the runoff material from Transect I. The pH of the unaffected area had a value of 5.7compared with the eroded area of 4.7.

Organic carbon

A higher content of organic cabon was found in the area under vegetation and a lower content in the bare ground, as expected. In general, the contents were found to be increased according to the distance from the factory in both transects. Transect II also had a higher content due to the reasons described above. However, the contents were lower than the unaffected area.

Contents of exchangeable potassium and soluble phosphate

The content of these major nutrients were low in the eroded area due to the sandy nature of the soil texture with a low water holding capacity, and the great vulnerability of the dissolved nutrients to leaching. Higher contents were observed in areas with luxurios plant growth although the values were lower than the unaffected area.

Sulfate content

Although no significant difference was shown between the contents of sulfate and the distance from the factory, higher contents were found in the affected area than the unaffected one suggesting that the emmission of sulfur dioxide had inserted its influence.

Green house trial

The low fertility of the affected soil was further confirmed by the green house trial where Phaseolus mungo and Lycopersicon esculentum were cultivated in the affected soil and the unaffected soil collected from the field. Higher yield of crops was obtained in the unaffected soil whereas the crop yields of the affected soil were rather low especially L. esculentum (Figs. 2.5 and 2.6).

The geology of the study site is under the extent of the decomposed granite soil stretches (ALLEN and STEPHENS, 1971). The texture of decomposed granite soil is sandy gravel. The periodic wetting and drying of Hong Kong weather can destroy the texture of granite and the acid solution produced by the emitted SO_2 further decomposed granite quickly because felspar dissolves in acidic water so the components cannot join together. Therefore, the decomposed granite dissociated into various soil particles. Due to the steepness of the slope; loose soil, sand, gravel and even boulders are carried downward by rainwater. If rainfall is of short duration, stream channels are formed. If rainfall is prolonged, severs soil collapse occurs and results in the formation of gullies. As water continues to flow, the gullies are in general continuously deepended.

From the above results, the present investigation can be concluded as the following :

1. The factory emitted a rather high concentration of SO_2.
2. The area near the factory is devoid of vegetation, although it exists, the vegetation is usually in dwarf form with various symptoms depending on the type of vegetation.
3. The high concentration of SO_2 not only affected the vegetation but also formed concentrated H_2SO_4 after the emitted SO_2 reacted with the atmospheric moisture, especially in wet weather.
4. Erosion occurred after the death of the vegetation and heavy rainfall.
5. The poor fertility of the eroded soil was further demonstrated by the green house trial.
6. Legislation should be enforced to avoid further deteoriation of the environment. Possible effects of the high concentration of SO_2 on the local inhabitants should also be looked into.
7. A reclamation scheme should be enhanced and the possibility of planting resistant species would be valuable.

ACKNOWLEDGEMENTS

The author would like to thank Mr. K.Y. CHOI and Miss K.M. CHENG for their technical assistance.

REFERENCES

ALLEN, P.M. and STEPHENS, E.A. Report on the gelogical survey of Hong Kong. Hong Kong : Govern. Printer 1971.
BOUYOUCOS, G.J. Sci. 64,362 (1926).
BUTTERS, B. and CHENERY, E.M. Analyst, Lond. 84, 239 (1959).
FAITH, W.L. and ATKISSON, A.A. Air pollution. 2ed. New York London: Wiley-Intersci. 1972.
WALKLEY, A. and BLACK, I. A. Soil Sci. 37, 29 (1934).
WATANABE, F.S. and OLSEN, S.R. Soil Sci. 93, 183 (1962).
WEST, P.W. and GAEKE, G.C. Anal. Chem. 28, 1916 (1956).