

DRY DEPOSITION OF ATMOSPHERIC SULPHUR SPECIES IN NORTHERN THAILAND: A REPORT ON METHODS AND EARLY RESULTS

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Summary

A study of both dry and wet deposition processes is being conducted in Northern Thailand. Dry deposition fluxes of sulphur dioxide and sulphate are being measured in an area close to Mae Moh Thermal Power Plant using a Circular Water Surface Sampler (total dry deposition) and Dry Deposition Plate (particulate deposition). The power station is fired by high sulphur lignite and sulphur emission control is operational. Sampling is being carried out on a daily basis during the dry season. Some preliminary results for dry deposition velocity of sulphur dioxide (SO₂) have been calculated using on-site measured sulphate flux and ambient SO₂ concentration data. Comparison measurement between coarse and fine particle fluxes are being carried out to determine the effect of gravitational settling force on the behavior of particulate deposition in the study area. In this paper, the research methodology and some early results based on data from one dry season are presented and discussed.

Keywords: Dry Deposition, Acid Deposition, Sulphur Dioxide, Particulate Sulphate, Deposition Velocity

1. Introduction

Atmospheric deposition, commonly classified as either dry or wet, has received a great deal of study due to concerns about the effect of deposited materials on the environment. Dry deposition is the transfer of airborne gases and particles to the earth's surface, including soil, water, and vegetation, where they are removed (Odabasi et al., 1999). The removal rate by dry deposition is a function of the physical and chemical properties of the pollutant, meteorological conditions and surface characteristics. Quantification of dry deposition is difficult due to large spatial and temporal variations and because interactions between surface and atmosphere can have large effects on the amount of deposited materials. The use of a surrogate surface to measure dry deposition is an increasingly important technique that can be used to directly assess deposited materials (Yi *et al.*, 1997, Holsen and Noll, 1992). Dry deposition studied by Noll *et al.*, (1988) indicated that a greased strip on the top of a smooth knife-edge plate can be used as a surrogate surface for particle dry deposition measurements. The grease prevents particle bounce, and the surface geometry allows the application of flat plate boundary layer models developed from wind tunnel studies (Yi *et al.*, 1997). Comparison between dry deposition measured with this type of surface and dry deposition modeled from

simultaneously measured complete size distributions using a multi-step model have been in good agreement (Holsen and Noll, 1992).

In comparison to greased coating materials, water surfaces exhibit some unique characteristics. Deposition of gaseous pollutants to water is controlled by a combination of atmospheric and surface resistance (Dasch, 1983). Nonvolatile species such as trace metals deposit irreversibly. Dry deposition to a water surface is one of the key mechanisms that determines the direction and magnitude of pollutant movement in the ecosystem. In this study, sulphate, which is, deposited as both gas (SO₂) and particulate (SO₄²⁻) is being measured and determined for its flux and deposition velocity using the water surface sampler and grease covered dry deposition plate.

2. Methods

2.1 Sampling equipments

Particulate dry deposition flux was measured by dry deposition plate using microscope slides coated with grease, supported on the stainless steel deposition plate with a sharp leading edge (<10⁰). The sampler was designed to collect particles simultaneously on both the top and the bottom of the plate and is patterned after that used by Noll et al., 1990. A pivoting support

system points the deposition plate into the wind by a wind vane as shown in Figure 1.

Apiezon grease (Type L) was used as a deposition sampling substrate because it is gravimetrically stable (does not absorb water vapor) and does not contain any particles. The microscopic glass slide was marked and masked for the area to be greased. Apiezon grease was applied with a spatula evenly to the unmasked portion. The greased area was 54 mm x 19 mm (area of 10.26 cm²). The greased slide then was heated for about 1 minute at 80 °C to get a smooth surface and was allowed to equilibrate in a dust-proof box for at least 24 hours. Samples were weighed before and after sampling in order to determine the quantity of deposited particles using an electronic balance (Sartorius model MC2103).

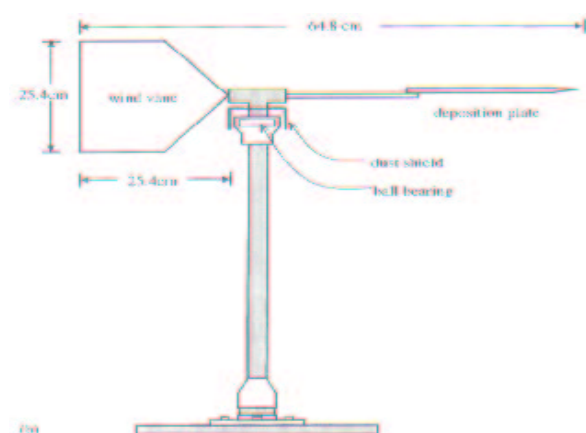


Figure 1 Dry deposition plate

A circular water surface sampler collected gaseous and particulate deposition. It consists of a water surface holder, designed to provide minimum airflow disruption and to allow comparison with other smooth surface samplers (Noll et al., 1988). The water surface holder is 50 cm in diameter and has an airfoil shape with a leading edge angle of attack of less than 10⁰ to minimize airflow disruptions caused by the collector geometry. A 37 cm in diameter water surface plate fits inside of the water surface holder so that there is an open area between the holder and plate to allow water to overflow from the plate into the bowl-shaped bottom of the water surface holder. The water drains from the bottom of the bowl into a water reservoir and returns to the water surface plate. The water surface plate and its holder were made from plastic in order to eliminate the contamination to the concerned measuring species. Deionized grade water is used as the collection surface. Overflow water collected in the reservoir is returned to the centre of the water surface plate with a pump at approximately 500 mL/min flow rate.

Both dry deposition plate and water surface samples were analyzed for sulphate concentration using ion chromatography (Waters model 432). The greased microscope slides were extracted by 20 mL of 1.8 mM

sodium carbonate and 1.7 mM sodium bicarbonate solution (ion chromatography eluent solution) and were put into an ultrasonic bath for 1 hour at 60⁰C and then allowed to equilibrate at room temperature before measurement by ion chromatography (IC).

For the water surface sample, the water volume in the bottle before each sampling run and after sampling was measured. These data are used for calculation of sulphate concentration for each sample. Sulphate collected by this equipment was also analyzed by IC.

2.2 Sampling site

The water and greased surfaces were exposed to the atmosphere at 1.5 meters above the roof of an ambient air monitoring station located in Mae Moh's health care office. The site is located approximately 5 km southwest of Mae Moh Thermal Power Plant in Lampang province, Northern Thailand. The Thailand Pollution Control Department operates the ambient air monitoring station which provides hourly measurements of criteria air pollutants and meteorological parameters at 10 m high.

3. Results and Discussion

SO₂ is hydrolyzed and oxidized to sulphate very rapidly in water so that the water resistance to SO₂ gas transfer is zero. It is reasonable to assume that the SO₂ gas-phase deposition to the water surface is equal to the difference in the deposition measured with the water and greased surfaces. Table 1 summarizes the amount of sulphate flux deposited on both surfaces and SO₂ dry deposition velocity is calculated from this measurement. Average sulphate flux deposited on the water surface sampler was 7.7 μg/m²/min while average particulate sulphate flux collected by greased surface was 4.7 μg/m²/min. SO₂ flux was calculated using Equation 1.

Table 1 Sulphate and SO₂ flux calculation (n = 76)

Parameters	Range	Mean	Median
Water surface flux (μg/m ² /min)	0.3-60	7.7	5.3
Greased surface flux (μg/m ² /min)	0.03-21	5.3	3.7
SO ₂ flux (μg/m ² /min)	0.1-26	3.9	2.7
SO ₂ dry deposition velocity (cm/s)	0.0028-0.54	0.12	0.073

$$\text{SO}_2 \text{ flux} = (\text{water surface sulphate flux} - \text{greased sulphate flux}) \times (64/96) \dots\dots\dots \text{Eq 1}$$

Where: (64/96) = unit conversion factor (sulphate to SO₂)

Average concentration of SO₂ measured by pulsed fluorescent SO₂ analyzer (API 100) was 1.1 ± 0.8 ppb. The concentrations were found to be quite low due to the use of Flue Gas Desulphurization (FGD) to control SO₂ emitted from Mae Moh Power Plant. Average SO₂ flux measured and calculated in this study was 3.9

µg/m²/min. Mean SO₂ dry deposition velocity was 0.12 cm/s.

Comparison of SO₂ dry deposition velocity measured by water media is shown in Table 2. It should be noted that the dry deposition velocity is dependent on the characteristics and specific environment in each area.

Table 2 Comparison of Dry Deposition Velocity Data for SO₂

References	Deposition velocity (cm/s)	Type of measurement
Owers and Powell (1974) Whelpadle and Shaw (1974)	0.5 ± 0.1 (neutral) 4.0 (unstable) 2.2 (neutral) 0.16 (stable)	2 x 10 m Artificial lake of sea water Gradient over Lake Ontario, Water pH 8.0-8.3
Garland (1977) Dasch and Cadle (1986) Yi <i>et al.</i> (1997) This study	0.41 0.69 ± 0.37 0.66-0.9 0.12	Gradient over reservoir water, pH 8 Cutoff PE water bucket Water surface sampler Water surface sampler

Comparison of sulphate flux deposited on water (WSF) and greased surface (SSF) indicated that about 40% of sulphate collected in this measurement was derived from particulates. The average fraction ratio between grease and water surface was 0.48 (median = 0.36) as shown in Figure 2.

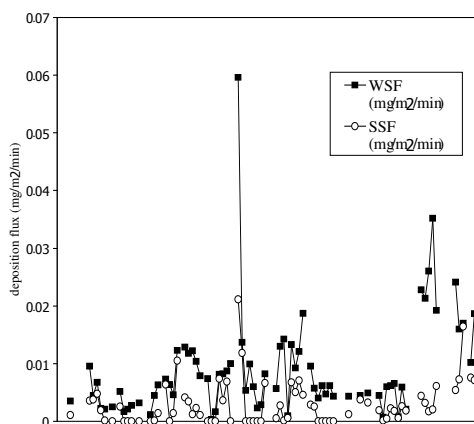


Figure 2 Sulphate flux on water and greased surface

The contribution of particulate sulphate to the total sulphate varied depending on the quantity of dust each day since SO₂ concentration in this area is quite constant. On some days when particulates deposited on the greased surface were found to be low, most deposited sulphate can be attributed to SO₂.

In this study, we used both the top and bottom sides of the dry deposition plate with the greased microscope slides attached in order to determine the quantity of coarse and fine particulate. Study from Noll *et al.* (1988) demonstrated that 99% of the mass deposited on both sides of the plate was contributed by particles greater than 2 µm equivalent volume diameter size.

The top plate of the dry deposition plate can collect both the fine particulates and fallout dust while the bottom plate can collect only the fine particles. This arrangement allows us to distinguish between the types of particle deposited in the study area. Figure 3 illustrates the comparison of particulate flux collected at top and bottom plates of greased slides dry deposition plate. Ratios of the fine and coarse particulates were found mostly in the range of 0.4--0.6 (37%). More than 75% from the measured data had a fine to coarse particulate ratio less than 0.6 indicating that most of the particulates in this area were derived more from coarse mode than those fine particles as shown in Figure 4.

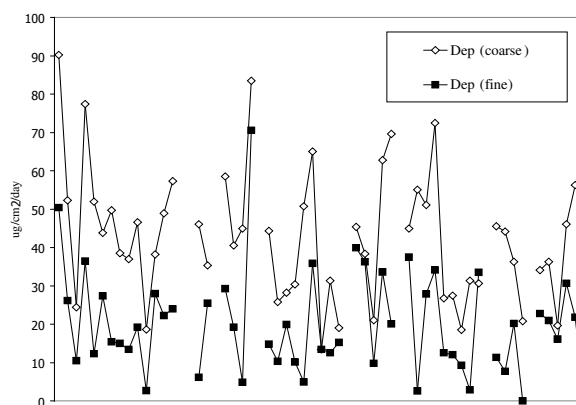


Figure 3 Coarse and fine particulate deposition

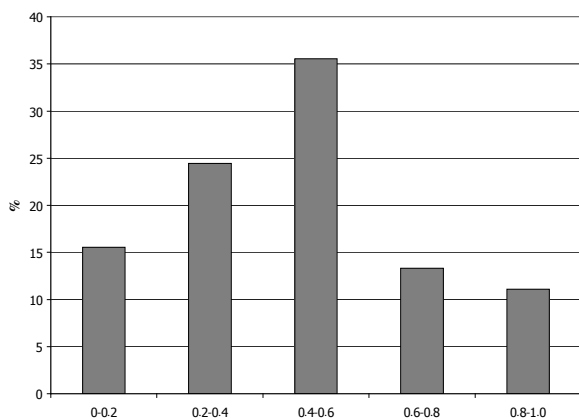


Figure 4 Frequency distribution of fine/coarse particulate ratio

Based on the site location, it is probable that most of the coarse particles in the sampling site were derived from road dust and the residue from the open and agricultural waste burning which typically exists in this area.

From this preliminary measurement, it should be noted that both the gas-phase flux and particulate-phase flux played an important role in the overall dry deposition of sulphur compounds.

Acknowledgements

The authors gratefully acknowledge the Pollution Control Department of Thailand for letting us work in its laboratory and The Electrical Generating Authority of Thailand for providing us with their facilities during the field measurements. The water surface sampler was designed according to the model from Dr. Thomas Holsen (Clarkson University, U.S.A).

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