ELSEVIER

Chemosphere 64 (2006) 1253–1263

CHEMOSPHERE

www.elsevier.com/locate/chemosphere

Dry deposition, ionic species measured and source interpretation during seasonal cycle at offshore areas near Taiwan Strait

Guor-Cheng Fang [a,*], Yuh-Shen Wu [a], Shih-Yu Chang [b], Jui-Yeh Rau [a], Shih-Han Huang [a]

[a] *Air Toxic and Environmental Analysis Laboratory, Hungkuang University, Sha-Lu, Taichung 433, Taiwan*
[b] *Research Center for Environmental Changes, Academia Sinica, Nankang, Taipei 115, Taiwan*

Received 13 September 2005; received in revised form 2 January 2006; accepted 2 January 2006
Available online 23 February 2006

Abstract

The characterization for water-soluble species of total suspended particulate (TSP), dry deposition flux, and dry deposition velocity (V_d) were studied at Taichung Harbor (TH) and Wuchi traffic sampling sites at offshore sampling site near Taiwan Strait of central Taiwan during March 2004–January 2005. The average concentrations of TSP and dry deposition flux at the TH sampling site were higher than at the WT sampling site during the sampling period. The samples collected were analyzed by a ion chromatography (DIONEX-100) for the ionic species (Cl^-, SO_4^{2-}, NO_3^-, NH_4^+, Na^+, Ca^{2+}, and Mg^{2+}) analysis. The dominant ionic species for TSP are SO_4^{2-}, NO_3^-, and NH_4^+ of the total mass of the inorganic ions at both sampling sites. In addition, the results indicated that the NH_4^+, NO_3^- and SO_4^{2-} showed higher concentrations in winter and lower in summer for both TH and Wuchi sampling sites. Statistical methods such as correlation coefficient and principal component analysis were also used to identify the possible pollutant source.

Keywords: Water-soluble species; TSP; Dry deposition flux; Dry deposition velocity; Statistical methods

1. Introduction

Atmospheric deposition is an important mechanism controlling the fate of toxic airborne pollutants and their transfer from the atmosphere to the natural surfaces. Atmospheric deposition of particles to ecosystem takes place via both wet and dry processes. Wet deposition is removal by precipitation scavenging and, to a lesser extent; impaction of fog or cloud droplets on vegetation; and dry deposition includes the uptake of gases at the surface and the settling and impaction of particles. For both gases and particles the dry deposition process comprises two stages, atmospheric transport and uptake at the surface. It occurs by several processes, such as Brownian motion of particles, sedimentation and impaction (Morselli et al., 1999; Yun et al., 2002).

Deposition of particles containing SO_4^{2-}, NO_3^- and NH_4^+ contribute to potent acidification and eutrophication of ecosystems. Base cation deposition can be important for nutrient cycling in ecosystems and it can also neutralize acid inputs (Ruijgrok et al., 1995). Despite the importance of this topic, dry deposition of particles has received far less attention. Theoretical methods used to assess or predict amounts of dry deposition are extremely diverse, largely because the types of contaminants and surfaces vary greatly. However, dry deposition fluxes are difficult to measure directly and instead are often estimated as the product of dry deposition velocity and corresponding pollutant concentration. Many studies suggested that the contribution by dry deposition to total atmospheric deposition is comparable to wet deposition in polluted areas (Hicks et al., 1989; Lindberg and Lovett, 1992; Goulding et al., 1998; Fan and Hong, 2001; Sanz et al., 2002). Therefore, dry deposition cannot be neglected in order to investigate the adverse effects of atmospheric deposition.

* Corresponding author. Tel.: +886 4 2631 8652x1111; fax: +886 4 2350 2102.
E-mail address: gcfang@sunrise.hk.edu.tw (G.-C. Fang).

0045-6535/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chemosphere.2006.01.004

In the recent years, suspended particle pollution has become a serious problem in Taiwan (Chou et al., 2004, 2005a,b). Emissions of anthropogenic air pollutants in Asia have been increasing drastically in past decade (Lee and Kang, 2001). With the growing industrialization and traffic increase in this region, some environmental problems have appeared which were unknown before the 1970s. Among them are the formation of ozone, nitric acid, nitrates and other nitrogenous compounds, including aerosols and particulate material, which generate from the emissions of NO_x and organic vapors (Fang et al., 2002). For most of the year the regional climate is dominated by local atmospheric processes (sea breezes and up-slope winds), which cause the air mass to re-circulate over the same area and keep it much warmer than in other European regions (Millán et al., 1997). These conditions promote photochemistry and ozone formation, so that the values detected in this area greatly exceed European directives for vegetation and crop damage (Millán et al., 1992, 1997). Sulfate, nitrate, and ammonium are the most common components of secondary particles in the atmosphere. These particles are formed in the atmosphere through the direct emissions of sulfur dioxides (SO_2), nitrogen oxides (NO_x), and ammonia (NH_3) gases. The chemical transformation and equilibrium processes for inorganic secondary aerosols have been extensively studied. Sulfur dioxide (SO_2) and nitrogen oxides (NO and NO_2) are gases that contribute greatly to acidification.

The objectives of this study are (1) to measure the total particulate mass and ionic (anion, cation) species at Taichung Harbor (TH) and Wu Chi Elementary School (WT) and (2) to characterize the mass, ionic species concentrations at offshore sampling site near Taiwan Strait of central Taiwan. In addition, meteorological conditions such as wind speed, wind direction and temperature were also measured.

2. Materials and method

2.1. Sampling program

Two sampling sites, Taichung Harbor (TH) and Wuchi, were selected to characterize the ionic species of ambient particulates in central Taiwan for this study (Fig. 1). TH which occupied about 37 600 acres and included 960 water and 2800 land areas was located in the western side of central Taiwan. TH was an artificial harbor and has the maximum amounts of 83 ports. The geological structure of coastal area is sands. The sampling apparatus were set up on the roof of the highest building (about 10 m height) at the chemical port area where about 400 m on the east side of Taiwan Strait. Wuchi was characterized as a traffic sampling site and it was about 30 km away from Taiwan Strait. In addition, Taichung Thermal Power Plant (TTPP), a coal-fired power plant, was developed on 281 ha and located along the coastland. Therefore, TTPP can afford about 4400 MW electric powers per day to supply the

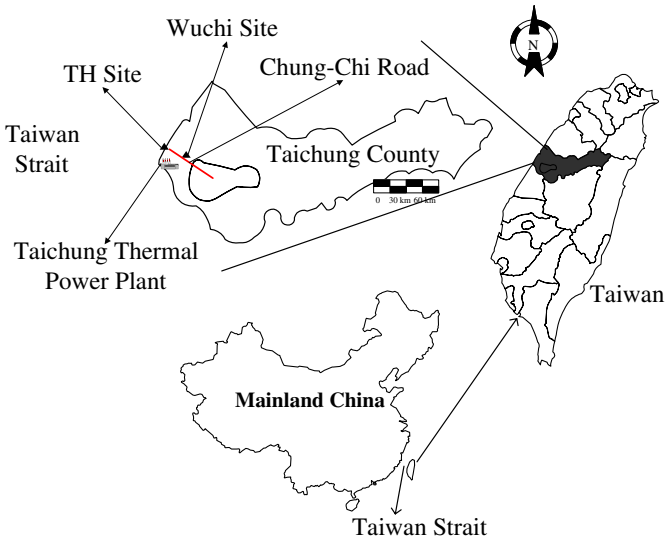

Fig. 1. The location of offshores for Taichung Harbor (TH) and Wuchi traffic sampling sites near Taiwan Strait in central Taiwan.

requirement of electric force in central Taiwan. TTPP was about 15 km southeast of TH and 12 km southwest of Wuchi sampling sites. The atmospheric dry deposition fluxes and particulate concentrations at TH and Wuchi were simultaneously collected by the dry deposition plates and PS-1, respectively. Twenty-four hours consecutive samplings for ionic species in ambient air were performed during March 2004–January 2005.

2.2. Sampling apparatus

2.2.1. PS-1 sampler

The PS-1 (GPS1 PUF Sampler, General Metal Work) consists of nine basic assemblies: dual chamber, sampling module, flow vent, magnehelic gauge, voltage, elapsed time indicator, pump, 7-day skip timer, exhaust hose and aluminum shelter. The PS-1 sampler is a complete air sampling system designed to collect total suspended airborne particles at flow rates up to 280 l min^{-1}; flow rate was adjusted to 200 l min^{-1} in this study. The quartz filter (diameter 10.2 cm) is used to filter the suspended particles in the study. The filters were first conditioned for 24 h in an electric chamber at humidity $50 \pm 5\%$ and temperature 25 ± 5 °C prior to both on and off weighing. Filters were placed in a sealed CD box during transport and storage.

2.2.2. Dry deposition plate

The dry deposition plate was made from polyvinyl chloride (PVC). It is 21.5 cm long, 7.6 cm wide and 0.65 cm thick with a sharp leading edge (<108 angle) that is pointed into the wind by a wind vane. The surrogate surface was secured at each end by an acrylic slat screwed into the plate. The plate was cut to slide on two 3.0 cm diameter rods, and two screws were fastened through the plate to a wind vane, allowing the plate to swing freely into the wind. The plate was fitted with a galvanized iron stand.