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# A Preliminary Design of Two-Layer Deposition Model on the Sea near Cheju Island

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# 제주 주변 해양에 대한 2층 대기침적 모델의 기초적 설계

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제주도 인근 해역에서의 입자의 건성 침적량을 평가하기 위해서, 1995년 3월 10일부터 6월 10일까지 제주도 서쪽 끝단의 해안지역에서 다단 입자시료 채취장치를 이용하여 대기 중 분진 시료를 채취하였다. 이 입경별 분진 자료와 Slinn과 Slinn이 제안한 개념을 근거로 건성 침적속도를 산출하였다. 이로부터 계산된 건성 침적량을 근거로 볼 때, 타 연구결과에서 추정한 침적량 범위와 유사한 값을 보였고, 본 연구에서 작성한 모델은 아직까지 많은 불확실성을 내포하고 있지만 제주지역에서의 측정 자료들의 특징을 설명할 수 있는 가능성이 충분함을 알 수 있었다.

In order to predict the dry deposition flux of particles on the sea near Cheju Island, 18 sampling demonstration were carried out at the sea shore site, the western edge of Cheju Island, during the period from 10 March to 10 June, 1995. In this work, size-segregated air borne particulate matter samples were collected. Dry deposition velocities have been estimated using a two-layer of Slinn and Slinn and the particle size distribution.

The results for dry deposition fluxes calculated using these deposition velocities showed that its range of fluxes is very similar to the results predicted by other researchers and thus, the model designed here can appear to contain sufficient realism to explain the feature of available data collected at Cheju area, although large uncertainties still exist.

**Key words** : dry deposition, particle, deposition velocity

## INTRODUCTION

The atmosphere is an important source of the particulate matter and associated pollutants found in ocean and large lakes(Rojas et al., 1993; Wu et al., 1994; Erisman and Draaijers, 1995). The determination of the fluxes of particles and associated pollutants to the marine environment requires a quantitative estimate of its temporal

variability. This requires an assessment of factors influencing wet and dry deposition removal rates. Wet deposition is generally the major contributor to the total deposition fluxes of various substances in oceanic regions. However, the almost continuous dry deposition flux must also be known in order to assess the impact of atmospheric inputs on the marine system, since much of this material enters the water by the process of dry depositions. Several investigators have attempted direct measurements of deposition velocities. The results of those studies were still not conclusive since a direct assessment of atmospheric inputs over the sea is difficult (Sievering et al., 1982).

To circumvent the difficulties involved in making direct measurements of deposition velocities, others have proposed the use of models to predict the dry deposition of particulate matter. The most commonly used technique is to multiply the pollutant concentration in ambient air (C) by the deposition velocity($V_d$) to estimate the pollutant flux (F). Attempts to estimate dry deposition fluxes using the various models have been criticized, however, because the deposition velocities of small particles are not well known. In addition, none of dry deposition models yet include all of the relevant physics. Especially, the accuracies of the various models can not be verified through field measurements. Despite the limitations of dry deposition models, many investigators were able to investigate the effects of specific processes considered in the models(Slinn and Slinn, 1980; Sehmel, 1980; Williams, 1982; Dulac et al., 1989).

Many investigators recently suspect that the Chinese aerosol sources should induce higher dry deposition fluxes over the East China Sea than over other remote oceanic regions. Arid and semi-arid regions in northern and northwestern China are also a major source for mineral aerosol particles (called dust) and for various trace elements. A geochemically significant quantity of Asian dust, currently estimated to be 400~500 Tg, is deposited in the North Pacific each year (Zhang et al., 1993). Despite the magnitude and the significance of the Chinese dust flux, atmospheric dry deposition fluxes have been seldom reported.

This paper presents some calculations of dry deposition velocities and dry deposition fluxes of particles to the marine system near the Cheju Island. For this purpose, the preliminary dry deposition flux of particles are calculated using the dry deposition velocity model based on the concepts of Sinn and Slinn(1980), which have been applied to filed data on atmospheric concentrations as a function of particle size.

## MATERIALS AND METHODS

### Sampling

The field sampling started in 10 March, 1995 and lasted for 12 weeks. Airborne particulate matter was sampled at the western edge of Cheju Island(33° 17N, 126° 10'E). This sampling site has an unimpeded view of the sea, is 300m from the shore and an altitude of about 70m. Site-segregated aerosol samples were obtained for 7 days using a 8-stage cascade impacter, operating at a flow rate of 29±1 *l*/min. The particle size deposited on each size was 11㎛ above, 7.0~11㎛, 4.7~7.0㎛, 3.3~4.7㎛, 2.1~3.3㎛, 1.1~2.1㎛, 0.65~1.1㎛, and 0.43~0.65㎛, respectively. This data collected during the spring of 1995 are described in the report by Kang and Hu(1995). The detailed method of measurements are described in that report.

### Description of Dry Deposition Model

In this work, dry deposition velocities are calculated using the two-layer deposition model of Slinn and Slinn(1980) for deposition of particles on natural waters. Briefly, this model is based on the assumption of two layers over the sea surface. In this model, the lower atmospheric boundary layer beneath a reference height of 10m is conceptually divided into two layers. In the upper layer, called constant flux layer, the portion of the constant flux layer up to the reference height, particle transport is mainly governed by atmospheric turbulence and gravitational settling. In the lower layer, called deposition layer which is just above the interface, atmospheric turbulence is assumed to have negligible direct influence on particle transport. Therefore particle transfer is dominated by diffusion and phoretic effects. In this layer, hygroscopic particles can grow by humidity absorption.

This model assumes a stationary state and spherical particles. The re-emission of particles by the sea surface is neglected. Co-reactions for particle scavenging by wave breaking and spray formation are not introduced here, since they do not affect the dry deposition fluxes of large particles. The detailed equations used in this work are reported elsewhere(Dulac et al., 1989; Arimoto and Duce, 1986; Slinn and Slinn, 1980)

The mean wind velocity is considered for each impactor sample. For calculations author uses a constant drag coefficient of 0.0013, a null rate of water evaporation, a density of 2.5 for constant size hydrophobic mineral particles and a relative humidity of 90 % in the lower deposition layer. Under such conditions, NaCl particle density is respectively 2.1 for dry state and 1.1 for wet state. The equilibrium size is calculated as a function of the dry diameter of the particle, using the relation given by Fitzerald(1975).

Arimoto and Duce(1986) have calculated the dry deposition flux, dividing the total mass of each element into intervals that each contained 1% of the total mass. Then a deposition velocity is determined for each interval of mass. However, Dulac et al(1989) have shown that this procedure yielded similar results when the mass distribution is taken directly from the impactor and used in the calculation of the dry deposition velocities. This study also used the mass distribution given by the cascade impactor. Therefore, the dry deposition velocity is given by :

$$V_d = \frac{\sum V_i C_i}{\sum C_i}$$

where $V_i$ and $C_i$ are the dry deposition velocity and aerosol elemental concentration for particle size $i$ of the 8 stage impactor, respectively (Rojas et al., 1993).

## RESULT AND DISCUSSION

### Concentration and Size Distributions

Results of mean atmospheric concentrations and dry deposition fluxes from the impacter samplers collected near the shore are summarized for particle and Na in Table 1. The average concentrations of particles are 71.52 $\mu gm^{-3}$ for 12 weeks and 52.73 $\mu gm^{-3}$ for 11 weeks excluded the data of the first week. The concentrations of particle collected for the first week, yellow sand period, is increased up to 278.2 $\mu gm^{-3}$.

The concentration distribution profile is given in Fig. 1. As particles are present on each impactor stage, it can be said that particles are present showing wide continuous distributions. It can be also shown the tendency that the concentration for the smaller than 1.1$\mu m$ is higher than that for other size range. During the yellow sand period, the

**Table 1. Mean atmospheric concentrations and dry deposition fluxes on the sea near Cheju Island.**

| | | Mean concentration ($\mu gm^{-3}$) | deposition velocity ($cms^{-1}$) | Mean dry deposition ($\mu gm^{-2}day^{-1}$) | No. of samples |
|---|---|---|---|---|---|
| Particle | T | 71.52 | 1.288 | 72.732 | 12 |
| | N | 52.73 | 1.309 | 53.850 | 11 |
| | Y | 278.20 | 1.167 | 280.424 | 1 |
| Na | T | 40.94 | 1.176 | 41.695 | 7 |
| | N | 38.81 | 1.189 | 40.175 | 6 |
| | Y | 53.74 | 1.094 | 50.812 | 1 |

T : Whole sampling period
N : Normal period
Y : Yellow sand period

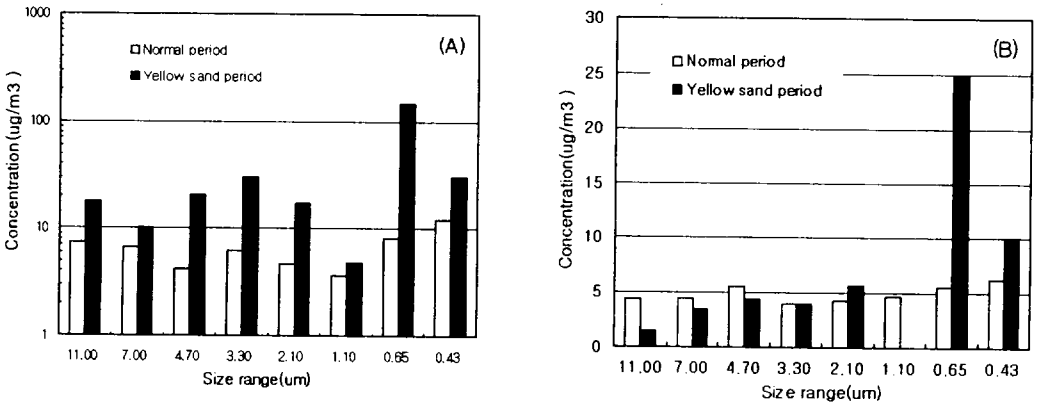


**Fig. 1. The average mass-size distributions of particles(A) and Na(B) obtained from the 8 stage cascade impaction sampler.**

concentration of particles ranging from 1.1~0.65 ㎛ is distinctively increased. Therefore, during this work, it is possible to determine two different particle size distributions(see Fig. 1) depending upon the occurrence of yellow sand.

## Dry Deposition Fluxes

As shown in Table 1, during the whole sampling period, dry deposition fluxes are 15,424~280,424 $\mu gm^{-2}day^{-1}$for particle and 25,360~57,981 $\mu gm^{-2}day^{-1}$ for Na. These results appear reasonable when compared with other estimates of dry deposition fluxes. Dulac et al.(1989) estimated the dry deposition flux of Na ranged from 4,000 to 208,000 $\mu gm^{-2}day^{-1}$(mean: 30,000 $\mu gm^{-2}day^{-1}$) over the Western Mediterranean Sea. In constast, when the deposition flux for yellow sand period is compared with that for normal period, the former is about 5 times as much as the latter.

Average influence of size distributions on the calculated dry deposition flux of particle and Na

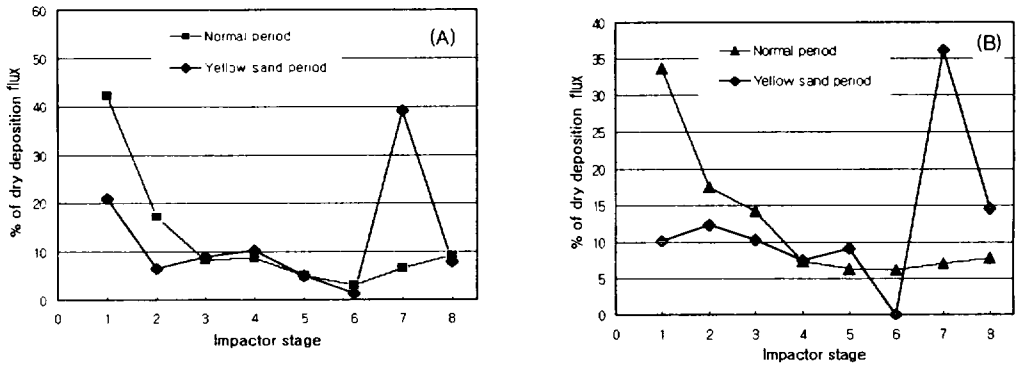


Fig. 2. Average influence of size distributions on the calculated dry deposition flux for particles(A) and Na(B) Particle size classes from stage 1 to 8 are respectively; )11㎛; 11~7㎛; 7~4.7㎛; 4.7~3.3㎛; 3.3~2.1㎛; 2.1~1.1㎛; 1.1~0.65㎛; 0.65~0.43㎛.

is shown in Fig. 2 The dry deposition velocities calculated here are based upon a particle size ranging from 0.43 to 11.0㎛ aerodynamic diameter. As shown in Fig. 2. the results indicate that dry depositions of particle and Na are controlled by the resistances in the constant flux layer. However, the contribution of large particles for yellow sand period is much lower than that for normal period.

The model considered here is also limited because it dose not take into account all of the processes that affect the dry deposition of particle. One important process that is not considered is the production of sea salt aerosols at the surface of the ocean. Fairall and Larsen(1984) suggest that by neglecting the surface production of sea-salt aerosols one will overestimate the fluxes of material that have significant oceanic sources. In the atmosphere over the open ocean, particles larger than about 1㎛ in radius are predominantly sea salt, and here aerosol particles many be enriched with trace metals, because the production of sea-salt aerosols may be particularly important for reactive elements such as copper and lead. Large sea-salt particles evidently are important for the dry deposition fluxes of reactive trace elements because the dry deposition of certain reactive elements is dominated by material recycled from the sea surface.

## CONCLUSION AND RECOMMENDATION

It can be shown that the range of dry deposition fluxes calculated using these deposition velocities is very similar to the results predicted by other researchers. So, it can be concluded that this model designed here appears to contain sufficient realism to explain major feature of available data collected at Cheju area, although large uncertainties are still existed.

Further information on the mass-particle size distributions of particles and elements in the marine atmosphere is needed to refine estimates of their dry fluxes. The difficulty in collecting giant particles limits our understanding of the mass size distributions of elements and thus our ability to accurately model the dry deposition flux of particulate substances. In addition, the changes in element concentrations and in mass-particle size distributions that occur as function of height and wind speed need to be determined, for these factors will influence dry deposition rates.

Non-steady state transfer also needs to be investigated because non-steady state processes may affect the dry deposition flux of particles to the sea surface.

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