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Variation of Anion Concentration in Aerosol at Mt. Kinabalu, Sabah, Malaysia

HIDEMITSU KATSURA[1,2,3,*]

[1]Institute of Product Design & Manufacturing, Universiti Kuala Lumpur, 119 Jalan 7/91, Taman Shamelin Perkasa, 3.5 Miles, Cheras, 56100 Kuala Lumpur, Malaysia
[2]Coimbatore Institute of Technology, Coimbatore-641 014, India
[3]The United Graduate School of Agricultural Science, Tokyo University of Agriculture & Technology, Saiwai-Cho 3-Chome, Fuchu-Shi, Tokyo 183-8509, Japan

*Corresponding author: Fax: +81 467 541383; Tel: +60 3 91795000; E-mail: hi@katsura.dk

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Aerosol field sampling was conducted at Mt. Kinabalu, Sabah, Malaysia in September 2009 and November 2009. The samples were analyzed for anions using ion chromatography. The results indicated that the anion concentrations of aerosol at the cloud-shrouded mountain were remarkable. The clouds at the mountain did not have F^- and the concentrations of Cl^-, NO^{2-} and NO^{3-} were low, in spite of the sampling duration being 24 times that of the other samplings. The result implied that the clouds had some effect on the aerosol concentration.

Keywords: Variation, Anion concentration, Aerosol, Mt. Kinabalu, Malaysia.

INTRODUCTION

It is very important to examine the inorganic anions concentration in aerosols in cloud-shrouded mountains and in clear skies and to understand the geochemical behaviour of aerosols to gain knowledge and insights into the atmospheric environment[1-3]. To date, there have been a considerable number of reports and investigations regarding aerosols. Although there have been several studies comparing the inorganic anions concentration in aerosols in cloud-shrouded mountains and clear skies, the function of clouds is not well understood[4,5]. Furthermore, the relationship between the phenomena of aerosols and the electric charge of either clouds or the atmosphere has never been considered. It is known that many types of cloud, not only thunderstorm clouds and even the atmosphere itself, have electric charges. In this study, aerosol samples were collected from both the cloud-shrouded mountain and the clear sky at Mt. Kinabalu, Sabah, Malaysia to analyse and investigate the trends in the inorganic anions concentration. We sought to elucidate how the electric charge of clouds affects aerosols in terms of nitric-oxide substances and the anion concentration.

EXPERIMENTAL

At Mt. Kinabalu, Sabah, Malaysia, the aerosol samples (PM 4.5) were taken from under the cloud (altitude: 1540 m; duration 1 h from 0533 to 0633 local time on 06-SEP-2009; local time = UTC + 8 h), above the clouds (altitude: 3290 m; duration 1 h from 0822 to 0922 local time 07-SEP-2009; local time = UTC + 8 h) and at the cloud-shrouded mountain (altitude: 2702 m; duration: 24 h from 0800 local time 25-NOV-2009 to 0800 local time 26-NOV-2009; local time = UTC + 8 h). A sampling pump (model: SP 250, GL science) was used at altitudes of 1540 m, 3290 m and 2702 m at Mt. Kinabalu, Sabah, Malaysia for sample extraction and the samples were collected onto polyamide filters (NX047100, Pall Corporation) at a flow rate of 5 L/min. The sampling was conducted from 0533 to 0633 local time on 06-SEP-2009 (local time = UTC + 8 h) at an altitude of 1540 m, from 0822 to 0922 local time 07-SEP- 2009 at an altitude of 3290 m and from 0800 local time 25-NOV-2009 to 0800 local time 26-NOV-2009 at an altitude of 2702 m. The polyamide filters were then transferred into 20 mL of ultra-pure water and shaken for approximately 40 min. The extracts were filtered and analyzed using an ion chromatograph (DX 120/AS, Dianex Inc.). The anion concentrations were measured at the Laboratory of Social Biogeochemistry (Laboratory of Professor YOH Muneoki & Associate Professor KOBA Keisuke), Tokyo University of Agriculture & Technology (TUAT), Building: #2, Room: 328 & 2N-101, 5-8,Saiwai-Cho 3-Chome, Fuchu-Shi, Tokyo 183-8509, Japan[6].

TABLE-1
VARIATION IN THE ANION CONCENTRATION IN AEROSOL AT Mt. KINABALU, SABAH, MALAYSIA

Time & Date (local time)	Altitude	F^-	Cl^-	NO^{2-}	NO^{3-}
Formula Weight		19.0	35.5	46.0	62.0
0533 to 0633 06-SEP-2009	1540 m under the cloud	0.3582 µmol/L/h	0.3977 µmol/L/h	0.1412 µmol/L/h	0.0289 µmol/L/h
0822 to 0922 07-SEP- 2009	3290 m above the cloud	0.2805 µmol/L/h	0.2799 µmol/ L/h	0.03 µmol/L/h	0.0325 µmol/L/h
0800 25-NOV-2009 to 0800 26-NOV-2009	2702 m at the cloud-shrouded mountain	0 µmol/L/24 h 0.00 µmol/L/h	1.3244 µmol/L/24 h 0.05518 µmol/L/h	0.3362 µmol/L/24 h 0.0140 µmol/L/h	0.2619 µmol/L/24 h 0.0109 µmol/L/h
Local time: 8 h + UTC					

RESULTS AND DISCUSSION

Table-1 shows the variation in the inorganic anion concentrations in the aerosol at Mt. Kinabalu, Sabah, Malaysia. The results indicated that the anion concentrations of aerosol at the cloud-shrouded mountain were remarkable. The atmosphere at the mountain did not have F^- and the concentrations of Cl^-, NO^{2-} and NO^{3-} were low, in spite of the sampling duration being 24 times those of the other samplings.

Not only thunderstorm clouds but also all other types of clouds and the atmosphere itself have electric charges[7-9]. Usually, the cloud top has a positive electric charge and the cloud base has a negative electric charge[10-12] (Fig. 1). However, these results of the sampling from 25 to 26 November 2009 (Table-1) indicated that if the cloud touched the earth (cloud-shrouded mountain, also known as fog), electric charges of the cloud can escape from the cloud to the earth (the mountain). Hence, the electric charge of clouds that touch the earth should be decreasing or zero (Fig. 2). Thus, the function of the cloud, as an electrolyser or electrophoretic equipment for the aerosols, was decreasing or terminated at the cloud-shrouded mountain. This result implied that the cloud had lost some ability to increase the aerosol concentration. Hence, the cloud did not have F^- and the concentrations of Cl^-, NO^{2-} and NO^{3-} were low, in spite of the sampling duration being 24 times that of the other samplings.

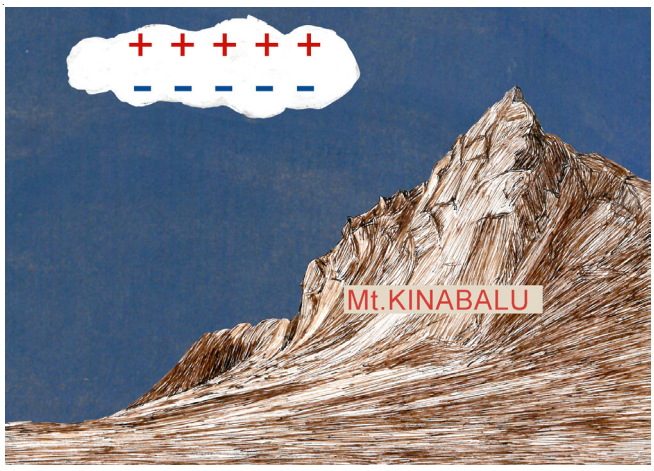

Fig. 1. Mt. Kinabalu

The cloud should function as an electrolyser or as electrophoretic equipment for the aerosols, especially when dealing with an electrically charged aerosol or an ionized aerosol[12-15]. In addition, the electric charge should have an effect on the electrically charged and ionized aerosols outside of the cloud.

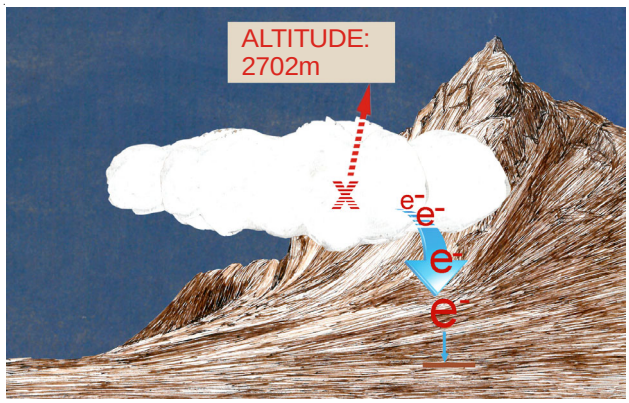

Fig. 2. Sampling at altitude 2702 m at Mt. Kinabalu (The cloud-shrouded mountain)

Thus, the positively charged layer of the cloud should have the ability to attract anion aerosols from outside of the cloud and the negative electrically charged layer of the cloud should have the ability to attract cation aerosols[16-18].

At Mt. Kinabalu, Sabah, Malaysia, if the cloud had the electrically charged layer of a typical cloud, it could produce an anion concentration in aerosols between that of the under-the-cloud case and that of the above-the-cloud case, excluding the anion concentration of NO^{3-}. Because all of anion concentrations excluding NO^{3-} at the atmosphere under the cloud were higher than those above the cloud, if the cloud top was positively charged, then the anion aerosols excluding NO^{3-} gather to the cloud top; therefore, the concentration of anion aerosols in the atmosphere at the upper part of the cloud decreases because the layer of the cloud top concentrated these anion aerosols from the upper cloud atmosphere (Figs. 3 and 4).

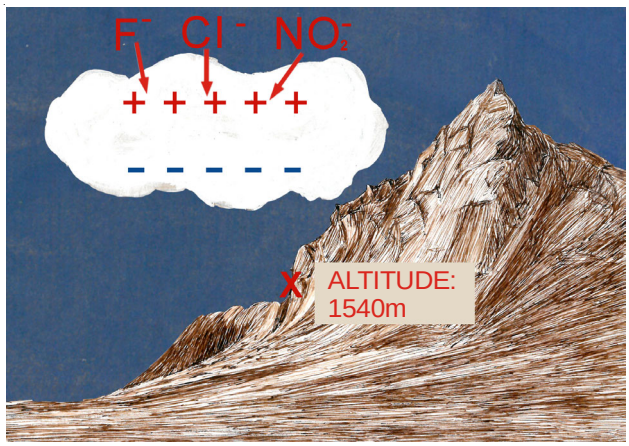

Fig. 3. Sampling at altitude 1540 m at Mt. Kinabalu

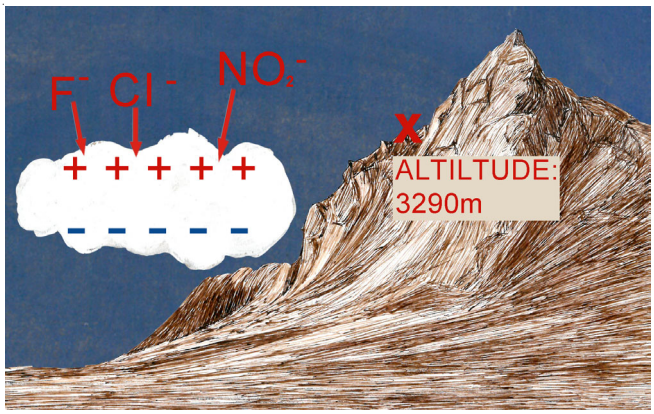

Fig. 4. Sampling at altitude 3290 m at Mt. Kinabalu

The trend of the concentration of anion aerosol NO^{3-} was reversed for F^-, Cl^- and NO^{2-} in September 2009. The formula weight of NO^{3-} is 62.00. This formula weight of 62.00 is much higher than the formula weight for F^- (19.0), Cl^- (35.5) and NO^{2-} (46.0). The following relationship between the electric potential or the electric field E and the electrostatic force F is known:

$$F = qE \quad (1)$$

where q is the electric charge. The following relationship between the acceleration (a) and force (F) is also known:

$$F = ma \quad (2)$$

where m is the mass.

$$a = \frac{qE}{m} \quad (3)$$

Therefore, if the electric charge q and the electric potential or the electric field E were not changed but m was increased (*i.e.*, the formula weight was increased), the acceleration a was decreased. Hence, the acceleration a for NO^{3-} was lower than that for NO^{2-}. Thus, the above-described results were observed.

Conclusion

Prior to this work, the relationship between the electric charge of the clouds or the atmosphere and the fate of the aerosols has not been explored. Present investigation indicated that the past models addressing the fate or transformation of cloud aerosols are not based on the actual details of the situation. This study demonstrated that the fate of the electrically charged aerosols or ionized aerosols was affected by the electric charge of the cloud. The electric charge of clouds or the atmosphere will vary with the weather conditions. In the future, investigations of cloud aerosols should consider the effect of clouds.

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