A preliminary study on the characteristics of fogwater in the masson pine forest in Chongqing, China

Liu Houtian[1] and Du Xiaoming[1]

(Received September 27, 1989)

Abstract— The masson pine (*Pinus massoniana* Lamb.) forest of 2000 ha situated on Nanshan, the south bank of the Yangtze River near Chongqing, China. From 1982, some trees began to die. Since then, half of the trees have died and the whole forest is in danger. From November 1986 to January 1987, a study dealt with the characteristics of fogwater in that area was carried out, in order to explain the relationship between acid fog and masson pine decline. The results of our study showed that the acid fog might be responsible in part for the decline of the masson pine forest.

Keywords: acid fog; masson pine forest; particulate matter.

INTRODUCTION

Some reports on acid fog in Northern America and Europe have been published (Waldman, 1982; Wisniewski, 1982; Hileman, 1983; Hofman, 1984). Recently, acid fog was found in Chongqing, China (Peng, 1986), situated near the confluence of Yangtze River and Jialing River, is well known for its fog. In this city the fog days were more than 90 each year. Over 80 percent of fog samples were acidic. The coal smoke is the main source of acid fog.

There is a masson pine forest in Nanshan, faced central district of this city across the Yangtze River. In 1982, some trees of the forest began declining and dying (Liu, 1988). It seems that acid rain was an important cause of the decline (Liu, 1988), and acid fog might relate to the forest decline.

In 1986 and 1987, we researched the characteristics of fogwater in the forest region and the relationship between acid fog and forest decline. The fogwater analysis in the forest region for three months showed that the average pH of fogwater was 4.5, the major ionic components were SO_4^{2-}, Ca^{2+} and NH_4^+, the total ionic concentration in fogwater was 9.3 times the amount

---

[1]Institute of Ecology, Chinese Research Academy of Environmental Sciences, Beijing 100012, China.

in rainwater, and the fogwater contained a great quantity of particulate matter. The pH value of fogwater condensed on needles was rather low (even below 3.0). Such acidic fogwater could result in leaching of Ca^{2+}, Mg^{2+} and NO_3^- and so on from the needles, and destroying of chlorophyll in the needles.

METHODS

Sampling sites

The sites for collecting fogwater samples were selected from different areas of the forest according to the decline degree of trees. One sampling site was in the serious disaster area (Zhenwushan). One was in the light disaster area (Nanshan Park), and the other was in the normal area (Dayandong).

Collection of fogwater

The fogwater was collected with a passive fogwater collector, condensing on nylon threads, flowing down and pouring into the bottle through a funnel bottom. The duration of fogwater collection was at 6:00—10:00 A.M..

Collection of fogwater condensed on needles

When the air was filled with dense fog, the fogwater drops condensed on needles were collected with a dropper.

Determination of content of particulate matter in fogwater

Fogwater was filtered through a filter paper. The filter paper with particulate matter was dried and weighted.

pH determination of fogwater

The pH value of filtered fogwater determined by a pH meter.

Analysis of ion component in fogwater

The fogwater was analyzed for ion component, using DIONES Ion Chromatograph for SO_4^{2-}, NO_3^-, K^+ and NH_4^+ and Model 180-70 Atomic Absorption Spectrophotometer for Ca^{2+} and Mg^{2+}. The concentration of H^+ was calculated from pH value.

RESULTS

pH of fogwater

The pH of fogwater sampled from 6 events of dense fog in December 1986 at every site were shown in Table 1. Generally, the acidity of fogwater and frequency of acid fog (pH<5.6) in the forest were consistent with the decline degree of masson pine at the same site. At Zhenwushan, where the masson pine decline was very serious, the acidity of fogwater was the highest, averaged pH 4.0, and the frequency of acid fog was the highest (100%). At Dayandong, where the masson pine forest grew normally, the average pH was 5.87 and the acid fog frequency

was 33%. In comparison with the rainwater fell in the same month at Zhenwushan, the H^+ concentration of fogwater was 5.3 times higher than that of rainwater.

Table 1   The pH value of fogwater and the frequency
of acid fog in Nanshan (Dec. 1986)

Site	pH							Acid fog freq., %
	14th	15th	16th	17th	26th	27th	Mean	
Zhenwushan	4.78	3.95	4.07	4.05	3.90	3.55	4.00	100
Nanshan park	5.62	5.00	4.25	4.31	5.20	4.20	4.76	88
Dayandong	5.82	6.40	5.70	5.47	6.20	5.40	5.87	33

Ion component of fogwater

The results of ion component analysis of fogwater were shown in Table 2 and Fig. 1. Among the anions, SO_4^{2-} was the most, making up 50 percent of the total anion. The ratio of SO_4^{2-} to NO_3^- was about 32. Thus the fog of Nanshan should belong to sulphuric acid fog. Among the cations, Ca^{2+} was the dominant, amounting to 60 percent of the total cation. There was an order of ion content among the fogwater samples from 3 sites: Zhenwushan > Nanshan Park > Dayandong, identically with the decline degree of the masson pine forest.

Table 2   The ion content of fogwater in Nanshan

Site	Ion concentration, μeq/L						
	H^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	SO_4^{2-} 7	NO_3^-
Zhenwushan	100	1180	6684	912	130	15897	342
Nanshan Park	17	1016	4456	1043	1439	9561	384
Dayandong	2	808	1710	351	978	6466	176

Amount of particulate matter in fogwater

The fogwater samples taken at Zhenwushan showed black in color. It was found microscopically that there where a lot of particle in fogwater, the major part being coal dust. The content of particulate matter was showed in Table 3. The most of particles existed in samples were taken at Zhenwushán, where the most serious decline of the forest had occurred. The particulate

Table 3   The content of particulate matter in fogwater
(Dec. 1986, g/L)

Site	14th	15th	16th	17th	26th	27th	Mean
Zhenwushan	6.08	2.98	0.24	–	0.76	1.10	2.19
Nanshan Park	2.48	–	0.18	0.18	0.56	0.34	0.75
Dayandong	0.04	0.10	0.04	0.05	–	0.08	0.06

matter in the samples taken at the light disaster area (Nanshan Park) was less than that at the serious disaster area. However, few of particles were found in the normal area (Dayandong). The particulate matter in the fogwater of the serious disaster area was 36.5 times of the content in the normal area.
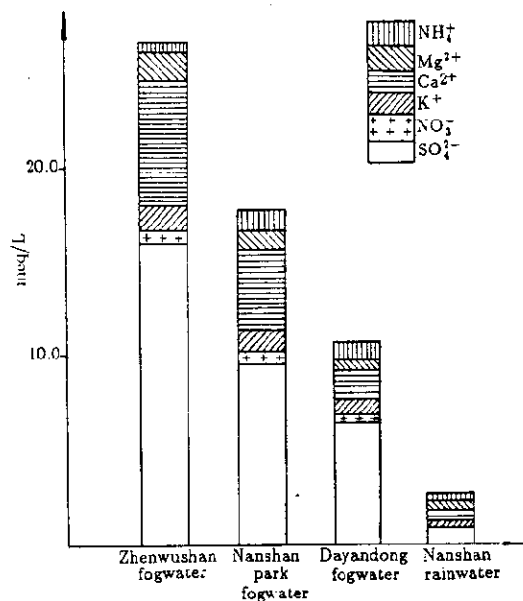

Fig. 1 The ions content in fogwater of different sites compared with rainwater

pH of fogwater condensed on needles

The pH value of fogwater condensed of needles on December 27, 1986, were showed in Table 4. In the normal area, the pH values of condensed fogwater were lower than that of fogwater. The lowest pH value of condensed fogwater was found on Zhenwushan, so far as to be 2.62.

Table 4   The change of pH in fogwater condensed on needles

Sample	Zhenwushan	Nanshan Park	Dayandong
Fogwater	3.55	4.20	5.40
Condensed fogwater	2.62	3.36	5.33

DISCUSSION

The results of this study showed some characteristics of fogwater in the disaster region of the masson pine forest in Nanshan: lower pH value, higher acid fog frequency, dominant content of SO_4^{2-} and a large quantity of particulate matter. All characteristics related closely to the

heavy coal smoke pollution. It was well known that coal has been the major energy source of the city, and the sulphur content in the coal was over 5 percent. The industrial emission and domestic smoke in the city included considerable amount of SO_2 and particulate matter. The SO_2 concentration in the air of the city was about 0.4 mg/m^3, four times as much as the average level in Chinese southern cities.

In Chongqing, there is a high humidity of the air, over 80 percent all the year round. In addition, the wind speed is very low (about 1 m/s) and calm frequency was quite high (about 40%). So that the fog formation in the city is easily, especially in winter. The particulate matter in the air could become the condensation nucleus of vapour forming fog. SO_2 is the major source of the acidity of fog.

We also found that the fog acidity in Nanshan was increased with the duration of fog event, similar to the "smoke-fog-smoke" phenomenon observed by Hofman (1984) in Southern California, US. At night, in moist and stagnant air, water aerosol and smoke bind and became fog. In next morning, when fog had dispersed and disappeared, aerosol and smoke reformed again. So repeatedly, more and more pollutants would be accumulated in fog.

The fogwater condensed on needles might dissolved a part of the acidic substance adhered to needles and became even more acidity. In the serious disaster area, the pH value of condensed fogwater on needles could decrease to below 3.0. Such acidic fogwater was enough to injure needles.

We had studied the leaching effect of acid fog to the needles of masson pine. It was shown that fogwater could leach some ions, such as Ca^{2+}, Mg^{2+} and NO_3^-, and the leaching amount of ions was positively related to the concentration of H^+ in fogwater.

Acid fog could damage needles directly. We carried out an experiment about the effect of acid fog on the chlorophyll content of needles. The results showed that acid fog could lower the level of chlorophyll.

The particulate matter in fog could be easily adhered on the needles. They might shade sunlight, hindering photosynthesis, and block stomata, affecting gaseous exchange and tran-spiration. Some dissolved substances in fogwater might injure needles. On the needles, when removed particulate matter, some tiny greensick spots appeared at the same place of particles.

Acid fog spread all over the forest would contact with the needles for longer time than raindrop. As it were the more fog duration prolonged, the more pollutants content in fog, and the more pH of fogwater decreased, the more fog damaged to needles. Therefore, in the damage effect of masson pine, acid fog contribution might be more serious than acid rain.

From the above mentioned facts, we could come to the conclusion, that because the pollu-tants content in fog, the acidity of condensed fogwater on needles, the leaching effect on nutrient elements in needles and the destroying effect on chlorophyll were consistent with the decline

degree of the masson pine forest, it seemed that the acid fog might be responsible in part for decline of the masson pine forest.

REFERENCES

Hileman, B., Environ. Sci. & Technol., 1983, 17:117

Hoffmann, M. R., Environ. Sci. & Technol., 1984, 18:61

Liu, H. T. Acta Botanica Sinica, 1988, 30: 318

Liu, H. T. Acta Scientiae Circumstantiae, 1988, 8:331

Peng, Z. G., Chongqing Environ. Protec., 1986, (12):1

Waldman, J. M., Science, 1982, 218:677

Wisniewski, J., Water, Air & Soil Pollution, 1982, 17:361