C-4.1 Studies to Estimate the Projection of Emission and its Distribution of Acid Rain Precursors in East Asia

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Abstract In order to prevent the damage with acid precipitation in Asia, the evaluation of status and future emission amount of SO_2, NOx and CO which diminish the oxidation of SO_2 and NOx, and also neutralizing chemicals such as NH_3 are necessary. The anthropogenic emissions of SO_2 and NOx with 1 x 1 longitude latitude resolution for Asian countries have been calculated for 1975, 1980, 1985, 1986 and 1987 based on fuel consumption, sulfur content in fuels and emission factors for used fuels in each emission category. Locations of major power plants, iron and steal industry, chemical and petrochemical industry, oil refineries and others have been identified for improving accuracy of the allocation of emissions to each grid. Emission from transport, residential and commercial sectors were allocated according to population. Grided NH_3 emission flux of cattle, pig and fertilizer is obtained as 10.6, 4.4, 4.9 ton/year, respectively. Taking the consumption amount of coal at each sector in the literature, total CO emissions in China due to fuel combustion were estimated. The results showed that most CO emission(89%) due to coal combustion came from commercial and domestic uses which occupied ca.22% of total consumption of coal in 1988.

Key Words East Asia, Emission Inventory, SO_2, NOx, Ammonia

1. Introduction

A large amount of SO_2 and NOx which are the precursor of acid rain is emitted in East Asia followed by European continent and Norhern America continent. It was forecasted that the emission of SO_2 and NOx may increase in the near future by the development of industry and increment of population. In order to prevent the damage with acid precipitation in Asia, the evaluation of status and future emission amount of SO_2, NOx and CO which diminish the oxidation of SO_2 and NOx, and also neutralizing chemicals such as NH_3 are necessary.

2. Research Objectives

The final objectives of this research is to estimate the regional emission amount of SO_2 and NOx in East Asia. The forecasted data is accurate enough to use it to the simulation study for to prevent damage of acid precipitation in East Asia.

The procedure of research is as follows:

(1) Estimation of emission amount of SO_2 and NOx in East Asia.
(2) Conversion of emission amount of SO_2 and NOx to grided data to use simulation study.
(3) Grided data of NH_3 emission in our country.
(4) Estimation of CO emission amount from coal used in China.

3. Research Method, Results and Discussion

[1] The status for SO_2 and NOx emissions in China and Korea

Through the economic growth, industrialization achieved rapidly in Korea since 1965, the energy consumption in 1989 was more than six times of the energy consumption in 1965. SO_2 and NOx emissions in Korea by oil and coal consumptions were surveyed. Using emission factor of the United States E.P.A., SO_2 and NOx emission amounts in Korean large cities and provinces are obtained as fuel type and different sectors. The government promoted the use of lower sulfur content oil and begun to supply low sulfur fuel to large cities and industrial facilities in 1981, and strengthened the vehicles emission standard in 1987. Increasing rates for SO_2 and NOx emission amounts were fairly supressed due to this series of countermeasures. However, the recent accelerations of economic growth and industrialization in Korea are increasing the emissions of atmospheric pollutants, especially SO_2 emissions by industry and transportation sectors and NOx emissions by industry and power generation sectors.

Total SO_2 emission, of which more than 90% came from coal combustion, in China was estimated to be 18 (in 1989) (Shen and Zhao, 1992), 20 (in 1987) (Akimoto and Kato, 1992), 16 (in 1989) (Annual Reports of Chinese Environmental Statistics, 1989), and 15 (in 1990) (Wang et al., 1992) million tons by several groups. However, these data were not in accordance with each. SO_2 emission as well as NOx emission for large cities and provinces are obtained. there are much discrepancies and they were induced mainly by assumption of sulfur content for standard coal; 1.12% and sulfur discharge by its combustion; 64% in the estimated values by Annual Reports of Chinese Environmental Statistics (1989) and Wang et al.(1992).

[2] Grided emission inventory of SO_2 and NOx

The anthropogenic emissions of SO_2 and NOx for 25 Asian countries east of Afghanistan and Pakistan except exUSSR have been calculated for 1975, 1980, 1985, 1986 and 1987 based on fuel consumption, sulfur content in fuels and emission factors for used fuels in each emission category. The provincial and regional basis calculations have also been made for China and India. The total emission of SO_2 in the covered area of Asia is 9.1 and 14.5 TgS/yr, in 1975 and 1987, respectively. Also, the total emission of NOx is 2.9 and 4.7 TgN/yr in 1975 and 1987, respectively. Thus, the increasing rates of SO_2 and NOx emissions during the period are 3.8 %/yr and 4.1 %/yr, and the increasing factors during the same period are 1.59 and 1.65, respectively. The emissions of SO_2 and NOx in "East Asia" including China, Taiwan, Hong Kong, North and South Korea and Japan amount 11.7 TgS/yr and 3.3 TgN/yr in 1987, and thus their contribution to the covered area of Asia are 81 and 70 %, respectively.

Spatial distribution of SO_2 and NOx from fuel combustion and industrial activities in Asia was obtained with 1 x 1 longitude latitude resolution for 1975, 1980 and 1987 based on the country basis data described above. Locations of major power plants, iron and steal industry, chemical and petrochemical industry, oil refineries, airports and harbors have been identified for improving accuracy of the allocation of emissions to each grid. Emission from transport, residential and commercial sectors were allocated according to population. Figure 1 and 2 shows the SO_2 and NOx emission flux with 1 x 1 resolution in 1987, respectively. Intensive emissions are observed in the Pacific rim region of Asia including Japan, North and South Korea, the coastal are of China, Taiwan and Hong Kong. High emission flux of SO_2 is also observed for several grids in the inland area of China including Sichuan and Guizhou.

In order to obtain the distributions of SO_2 and NOx emissions in the Asian part of exUSSR, energy balance tables for Far East, East Siberia, West

Siberia of Russia, Usbekstan, Turkmenistan, Kirgizstan, Tajikstan and Kasakhstan have been obtained. The calculation of emissions by using the same methodology as has been described above could provide harmonized data for Asian exUSSR with the other part of Asia. The study is underway.

[3] Ammonia emission inventory

A large amount of NH_3 is emitted in Europe by its intense cattle breeding activity. In Europe detailed map of NH_3 emission flux has been obtained, for NH_4^+ deposited on the ground easily change to NO_3^- and concurrently released H^+ bring a soil acidification. The data obtained in Europe indicate that the major contributors are cattle, pig and fertilizer in our country. We conducted an estimation of NH_3 emission flux from cattle, pig and fertilizer. The prefcture basis data were converted to 1 x 1 grid basis data, depending upon the land area ratio. We adapted emission factor of cattle and pig of European's for example cattle and pig 23.04 and 5.36 $kgNH_3$/animal/year, respectively. As far as fertilizers concerned, we used 10% evaporation of NH_3 for ammonium sulfate, urea and other nitrogen containing fertilizer. Grided NH_3 emission flux of cattle, pig and fertilizer is obtained as 10.6, 4.4, 4.9 ton/year, respectively. The grided emission of beef cattle is shown in Fig. 3. The contribution with the western part of Japan(Kyushu Is.) and in Kanto area are bigger compared to other areas.

The NH_3 emission with agricultural activity are mentioned above, however, the NH_3 emission possibility still exist on industrial activity. We had taken into account the automobile, desulflization and denitrification equipment and sewage treatment as a candidate. The three way catalyst system was explained to purify the exhaust gas from the tale pipe including HC, CO and NOx, which is adopted by many corporations. NH_3 emission may not be included in the exhaust gas because of the fine controll of this system. Electric power company referred to the mechanism of the flue gas denitration facility to examine the possibility of the NH_3 emission from steam power plants. A widely used method is the selection catalistic NOx reduction using NH_3 gas as reducing agents. Because the amount of poured NH_3 is controlled according to the amount of NOx, so there is no leak of NH_3.

[4] The status for CO emission by coal combustion in China

In order to estimate CO emissions from coal combustion in China, firstly the percentages of coal used for different purposes were investigated and secondly, CO emission factors were looked over the literatures and some data were obtained experimentally using combustion furnace for pulverized coal. Taking the consumption amount of coal at each sector in the literature, total CO emissions in China due to fuel combustion were estimated as shown in Table 1. The results showed that most CO emission(89%) due to coal combustion came from commercial and domestic uses which occupied ca.22% of total consumption of coal in 1988. This fact indicates that in order to control CO emission from coal combustion in China, the improvement of combustion efficiency for commercial/domestic and transportation is very important.

Publication

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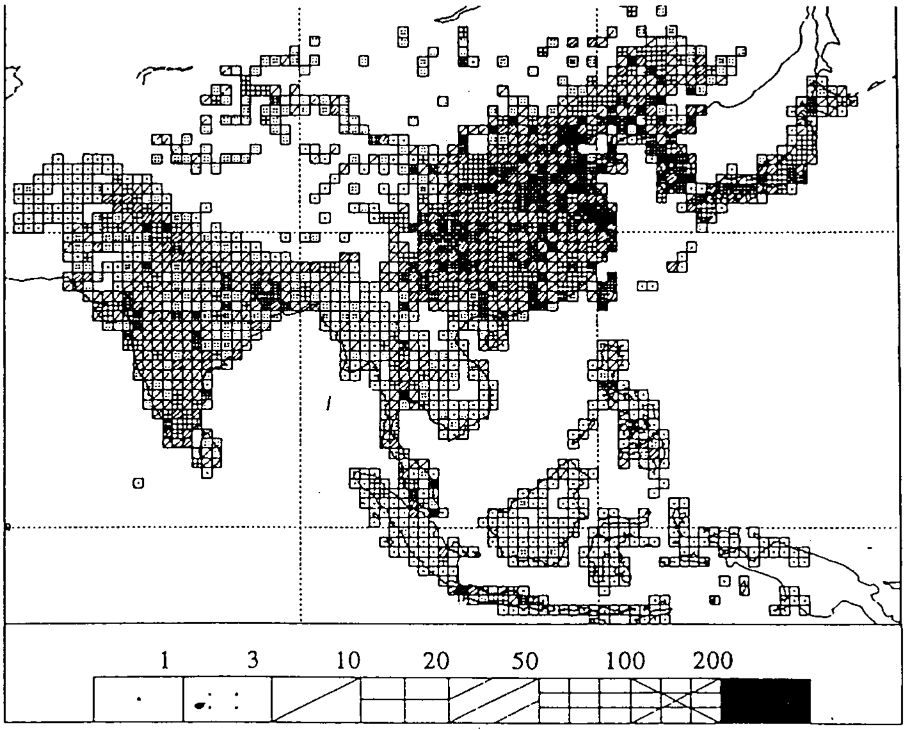

Fig. 1 Annual SO_2 emission in 1987

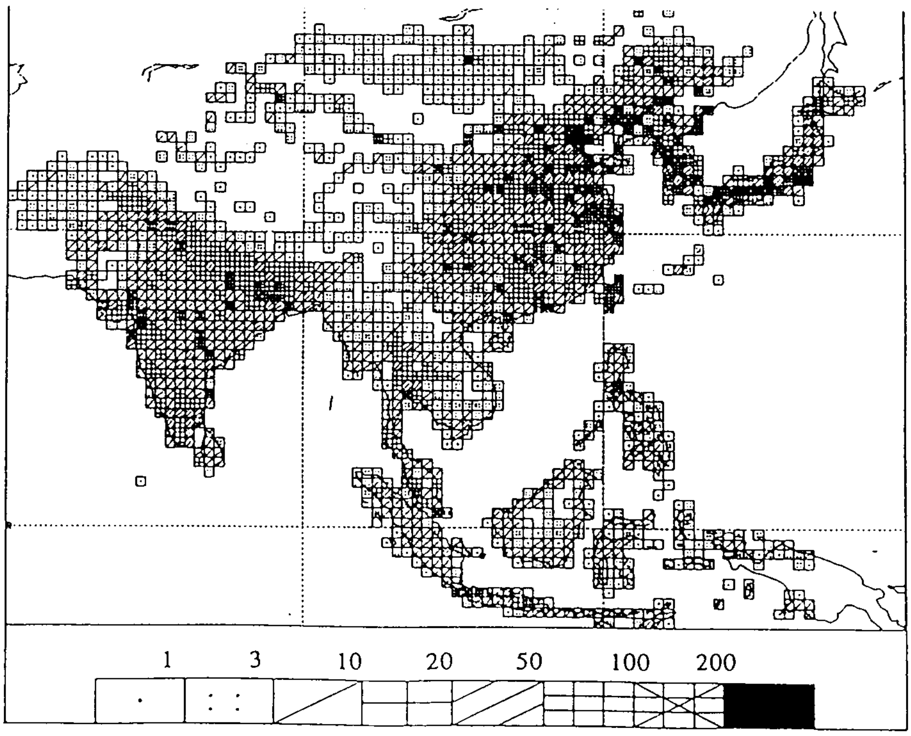

Fig. 2 Anual NOx emission in 1987

	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76	68	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	530	265	22	57
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	197	781	1541	761	379
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	384	325	655	1184	39	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	324	176	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	1063	952	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	1092	1803	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	432	2350	1231	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	33	29	239	1065	1770	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	42	0	0	212	560	1416	3028	1539	0	0	0	0	0
35	0	0	0	0	0	0	0	0	278	650	871	395	972	1145	806	751	942	0	0	0	0	0
34	0	0	0	0	0	227	44	521	770	969	1134	518	671	606	188	64	0	0	0	0	0	0
33	0	0	0	0	0	1011	1738	943	530	411	548	163	38	0	0	0	0	0	0	0	0	0
32	0	0	0	0	178	303	3199	3218	44	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	4544	1587	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	240	149	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	686	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	191	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	390	245	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	136	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 3 Grided emission of NH_3 by beef cattle(ton/year)

Table 1 Coal consumption for four consumption sectors[a] and estimation of CO emission[b] from each sector in China

(Unit for coal consumption: 10^6 ton/year, CO emission: 10^3ton/year)

	1980		1985		1988	
Sector	Consumn.	CO emisn.	Consumn.	CO emisn.	Consumn.	CO emisn.
Industry	334	334	425	425	495	495
Power	123	62	175	88	252	126
Transporn.	24	552	26	598	24	552
Comml/dom.	126	5,670	191	8,910	212	9,540
Total	607	6,618	815	10,021	983	10,713

a) Coal consumptions for four consumption sectors were obtained from the literature (Using efficiency of coal and its environmental effects in China, Vol. 1, 1990).

b) CO emission factors for each use used in this estimation were indicated in the reference (Cullis and Hirscher, Atmos. Environ., 24A, 1153(1990)).