STUDIES ON THE EFFECTS OF AIR POLLUTION AND THE ENVIRONMENTAL INTERVENTION

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ABSTRACT

The monitoring of air pollution and health levels was carried out in coal burning districts and the districts with central heating in Chengde City. The air pollution levels in winter and summer were compared in coal burning districts and the districts with central heating, indoors and outdoors, in kitchens and bedrooms, before and after the central heating system was used. The health levels of residents who lived in coal burning districts and in the districts with central heating were compared. The effects of environmental intervention of central heating were demonstrated preliminarily through the analysis of the environmental quality, the evaluation of health effects and the estimation of economic benefits.

Chengde City is located in the northern part of Hebei Province, and the urban air pollution is serious. The city government has planned to develope the central heating in phases, in order to clean the air. The effects of the environmental intervention of central heating on the environment and human health will be discussed in this article by using experimental epidemiological analysis of the air pollution.

METHODS

Using the method of comparing coal burning with central heating, the air pollution level and its health effects were monitored and contrasted in coal burning districts and in the districts with central heating. Air monitoring was carried out in these two districts, respectively. Two kinds of households were selected: the coal burning households in which coal is burned for cooking and heating; and the households with central heating in which liquefied gas is used for cooking and central heating is used for heating. The environments, structures of the houses, the economic and educational levels, and the sizes of residences are basically identical for these two kinds of households, except for the factor of coal burning. The school children of ages from 11 to 13 in the same grades, in these two districts, were selected to carry out the health investigation, and the air of classrooms was monitored. The indexes of the environmental monitoring include SO_2, NO_2, CO, TSP, IP and Bap. The air sampling was conducted in winter and summer, in bedrooms, kitchens, and outdoors, respectively, 3 days for each season and 4 times for each day on each site. The contents of health investigation were as follows:

(1) investigation on the personal exposure of 800 school children;
(2) cohort study on the respiratory diseases during 3 months in winter;
(3) pulmonary function test (CHEST HI-298 pulmonary function meter);
(4) determination of lysozyme and secretory IgA(SIgA) in saliva;

(5) examination of nasopharynx;
(6) determining the content of alveolar carbon monoxide;
(7) determining the content of carboxyhemoglobin (COHB) of blood from earlobe.

The toxicological studies included:
(1) the toxic effects of particles on microphage;
(2) the pulmonary damages of rats caused by the inhalation of coal burning smoke in situs.

The following quality control methods for laboratory examination and field investigation were adopted:
(1) calibration of instruments; (2) personnel training; (3) the unified sampling methods, standardized questionnaires and inquires were adopted, and the preliminary test was carried out according to the design; (4) the figure of quality control for each item was drawn up 3 days before investigation.

RESULTS

General situation

Chengde is a city in a river valley basin. The frequency of temperature inversion occurrence in winter is 93.3%. The total coal consumption in the whole city is about 1,400,000 tons. The ash content of the coal burned is about 24.5% to 45.25%. The sulphur content is about 0.9-2,5%. Coal burning was spread over the whole city before 1986. By 1990, about one-half of households were connected to the central heating. On January 6, in 1986, SO_2 concentration in the air was 3.86 mg/m^3 and TSP was 3.09 mg/m^3 in Chengde City, similar to the level of "London Smog" in 1952.

The pollution level

Outdoor air

In winter, the pollution level was significantly higher than in summer, and all of the pollutants were on an ultra high level, except NO_2. The SO_2 concentration was 11 times as high as that in summer and the daily average concentration was 5.1 times beyond the standard in the coal burning districts. The pollution level of residential area was higher in coal burning districts than in the districts with central heating, and the ratio of SO_2 concentration in coal burning and central heating districts was 1.8:1(p 0.01). The concentration of air pollutants were highest in coal burning districts, next were the districts with central heating, and lowest in the summer resort mountain villas, and the gradient of air pollution was obvious in the city.

Indoor air

The indoor air pollution is more serious in winter than in summer in Chengde City. For example, in the bedrooms of coal burning households, the concentrations in winter were 5.02 times for SO_2, and 5.01 times for IP, as high as those in summer. 80% of the values of indoor air SO_2 concentrations were below 0.15mg/m^3 in summer, and more than 80% of the values were above 0.15mg/m^3 in winter. All of the indoor air pollutants were on ultra high levels, except for NO_2, in winter. The pollution level was higher in coal burning households than in the households with central heating, the ratio of SO_2 concentration in these two kinds of households was 3.69:1(p 0.01). In one residential area of Xiaoxigou district of Chengde City, before the central heating was used (January, 1986), the indoor air concentrations were 1.96 mg/m^3 for SO_2 and 2.03mg/m^3 for TSP. After the central heating was used (January, 1988), the indoor air concentrations were 0.15mg/m^3 for SO_2 and 0.13mg/m^3 for TSP, and the concentrations went down to 1/12 for SO_2, 1/15 for TSP and 1/13 for B(a)P. The concentrations of air pollutants were higher in kitchens than in bedrooms; and in the coal burning households, they were 1.67 times for SO_2 and 2.38 times for IP as high as that in bedrooms in winter. The pollutant concentrations of indoor air were close to that of outdoor air in summer because the doors and windows were open ($p>0.05$); and because of the coal burning and high frequency of temperature inversion, the winter concentrations of SO_2, NO_2 and IP were higher in outdoor air than in indoor air. The results of the air monitoring in classrooms made it clear that the air pollutant concentrations in the classrooms of preliminary schools were much lower in the districts with central heating than in coal burning districts. For SO_2, it was 0.15 mg/m^3 and 0.46 mg/m^3 in the two districts, respectively (p/0.01).

Health effects

The results of the study of personal exposure

The pollutional loads of residents were higher in coal burning districts than in the districts with central heating. The time distribution of children was almost the same in these two districts, 6 hours in school, 2 hours in the open and 16 hours at home, for winter days. The time weighted personal exposure of the school children in these two districts was compared, and calculated by the following formula:

$$E=(Ci \cdot Ti+Cc \cdot Tc+Co \cdot To)/24$$

(E-personal exposure; Ci-daily average concentration of indoor air pollutant; Ti-time, staying indoors; Cc-daily average concentration of air pollutant in classroom; Tc-time, staying in classroom; Co-daily average concentration of outdoor air pollutant; To-time, staying outdoors.

In coal burning district, the personal exposure to SO_2 by school children was 0.47 and 2.76 times as high as that in the district with central heating (0.17). To TSP, it was 0.79 and 4.16 times as high as that in the district with central heating (0.19).

The prevalence rates of asthma chronic bronchitis pharyngitis, and tonsillitis, were higher in coal burning district than those in the district with central heating. The results of cohort study also made it clear that the prevalence of respiratory diseases of the coal burning group (77.78%) was higher than that of central heating group (50.0%), and the difference was significant ($p<0.05$), compared to the central heating group. The relative risk was 1.55 and attributed pollution risk was 27.78%.

The average content of lysozyme in saliva of residents who lived in the coal burning households was 99.02 μg/ml, and lower than that of residents in the households with central heating (135.59μg/ml) ($p<0.001$). The average content of SIgA in saliva of the coal burning group was 61.7μg/ml and lower than that of the central heating group (91.4 μg/ml) ($t=5.01$ $p<0.001$).

The results of the synchronous studies of aii CO concentration in bedroom, alveolar CO concentration and blood COHb level:

Coal burning made the air CO concentration, the accumulation of alveolar CO concentration, and the content of blood COHb level all higher than those in the district with central heating. The concentration of these three items were 8.15, 9.80, and 7.61, respectively in the coal burning group, and 4.75, 7.16, 6.28 in the districts with central heating.

Pulmonary function results

The total vital capacity (FVC2474.88) and its mid-terminal velocity (V75=4.23, V50=2.65, V25=1.11), etc., of the school children in the district with central heating were better than those of the children in the coal burning district (FVC=2303.16, V75=3.88, V50=2.45, V25=1) ($P<0.05$).

The results of toxicity tests

Microphages were exposed to toxicant in vitro for 2 hours. The survival rate was 78.4% and significantly lower than the control's (95.6%). The TSP concentration was 0.1 mg/ml, and it dropped to 35.5%. Most of the cells died when TSP concentration was 0.5 mg/ml, so it was believed that TSP was quite toxic to microphages. The endoenzyme (LDH) and lysosome enzyme (ACP) were released when cells died. When the cells were exposed for 24 hours, LDH activity in culture liquid was 1.2 times as high as the control's when TSP concentration was 0.05 mg/ml, and it was 1.5 times as high as the control's when TSP was 0.1mg/ml. The positive correlation was shown between LDH, ACP activity and exposed dose (LDH:$r=0.91$, p/0.05; ACP:$r=0.97$, $p<0.01$). The cells' damages became serious as TSP dose increased.

The results of animal tests

The animals were exposed to the coal burning smoke in situs (daily average concentration: SO_2 1.91mg/m^3; TSP 1.87mg/m^3) for 15 days, the cell content of lung perfusate showed acute inflammatory change (neutrophils increased to 53%) and the chronic inflammatory character was shown after 28 days (lymphocyte increased to 32%). The free cells of lung tissue which contain dust, increased when rats were exposed for 5 days. After 15 days' exposure, pulmonary interstitial cells hyperplasia, focal emphysema and inflammation were shown. Up to 28 days, the widespread emphysema, infiltration of lymphocyte and pulmonary abscess could be observed.

DISCUSSIONS

The concentrations of indoor and outdoor air pollutants were higher in winter than in summer. This showed that coal burning was the main cause to aggravate air pollution in northern cities. The concentrations of indoor and outdoor air pollutants were lower in the districts with central heating than in coal burning districts, and the air pollution level dropped in the same residential area when central heating was started. The active effects of central heating on air quality were shown. Through the study of personal exposure, it was believed that there were lower pollution loads, lower prevalence rates of respiratory diseases and better pulmonary function in the districts with central heating. The damages to respiratory systems caused by the pollution from coal burning were also reflected. This was also confirmed by the cytotoxicological test and pathological study of animal lungs. The decrease of lysosome and SIgA in saliva of residents who lived in coal burning districts also shows the inhibitory effects of coal burning on immunity. To sum up, the effects of the environmental intervention of central heating to reduce the pollution and pollution load could be accessed preliminarily from each phase of studies of "pollution, load, and the effects".

The economic benefits of central heating in Chengde City:

According to the equation: $Y=64.7+0.86X$ (Y:total mortality, X:yearly average air SO_2 concentration), the total mortality would be dropped by 11.9 (1/100,000) with every $10\mu g/m^3$ decrease of SO_2 concentration. The yearly average SO_2 concentration was reduced by $238\mu g/m^3$ after central heating was used (501.5 in coal burning districts, 263.5 in the districts with central heating). In Chengde City, in which there were 340,000 people, the total number of deaths per annum would be reduced by 952, theoretically, and the deaths due to respiratory diseases would be reduced by 178 as the respiratory diseases account is 18.65% of all death causes. The economic loss of 53,400 labor days and about 700,000 yuan could be avoided in a year.

In Chengde City, the prevalence rate of respiratory diseases was 13.25%. If central heating could reduce the prevalence rate by 27.8% (attributed risk), the number of respiratory patients could be reduced by 12,515 in the whole city, per annum. If we suppose that the loss was 5 working days per person, the economic loss of 62,575 labor days and about 1,400,000 yuan could be eliminated. If we suppose the yearly medical fee is 45 yuan per person, total about 560,000 yuan of medical fee could be saved. The loss of working days to look after patients was computed at 50% of the loss of a patient corresponded to 700,000 yuan. Total of 2,660,000 yuan of economic loss could be avoided.

The total consumption for scattered warming is 300,000 tons in winter in Chengde City. The yearly coal consumption per square meter will be reduced from 90kg to 30kg as central heating is used and 200,000 tons of coal and 24,000,000 yuan could be saved. By decreasing economic loss by death and respiratory diseases, a total of 27,360,000 yuan would be saved because of the central heating, and this matches the total wages of 10,000 staff members and workers in one year.

CONCLUSION

Coal burning is the main cause to aggravate the outdoor and indoor air pollution and serious health damages have been caused by the air pollution in northern cities in China. The environmental intervention of central heating will be fully beneficial to saving energy, improving air quality and protecting human health and should be widely and actively developed.