STUDIES ON INDOOR AIR POLLUTION FROM DOMESTIC FUEL IN CHINA

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ABSTRACT
Coal is used in most of homes as domestic fuel in China. Many Chinese scientists conducted investigations on indoor air pollution and adverse effects on human health. The paper reviewed the major findings. The concentrations of pollutants in indoor air in households where coal is used as domestic fuel for cooking and heating are much higher than those in households where piped gas or liquefied petroleum gas are used. The levels of nearly all pollutants measured in kitchens are higher than those in bedrooms in different seasons. The concentrations of pollutants in indoor air are higher than those in atmosphere. Studies also showed that coal burning induced higher incidence of respiratory illness. Particularly, the study in Xian wei revealed that the concentrations of PAHs in homes using smoky coal were higher than those in homes using wood and a strong relationship between concentrations of PAHs and incidence of lung cancer was found.

INDEX TERMS
Indoor air pollution, Coal combustion, Health effects, Lung cancer

INTRODUCTION
In general, people spend more than 90% of their time indoors. Indoor air quality is increasingly concerned and is recognized the importance for human health. Coal is the main source of energy in both of industries and households. The major domestic fuel in households in China is coal, liquefied petroleum gas (LPG) and piped gas (natural gas or water gas ). Recently, the piped gas and LPG are commonly used in big citied, but in the whole country coal is used in most of homes. Therefore, indoor air pollution is very heavy and mainly from domestic fuel combustion, particularly from coal burning for cooking and heating. Many studies showed that indoor air pollution caused adverse effects on human health. This paper reviewed Chinese studies on indoor air pollution and health effects from coal combustion.

INDOOR AIR POLLUTION FROM DOMESTIC FUEL
Indoor air pollution from coal burning is much heavier than that from gas burning
The main pollutants from coal burning are sulfur dioxide (SO₂), carbon monoxide (CO), total suspended particulates (TSP), nitrogen oxide(NOₓ), and polycyclic aromatic hydrocarbons (PAHs) etc. Concentrations of pollutants from coal and gas combustion in indoor air of bedrooms and kitchens in winter and summer were measured and Table 1 showed the data in bedrooms in winter (Qin, Zhang, Jin et al, 1991; Zhang, Zhang, Shang et al, 1992; Zhou, Zhang, Pang et al, 1985; Dept of Environmental Health 1986; Guo, Shi, Xi et al, 1994; Wu, 1984). The data clearly indicated that the concentrations of SO₂, CO, TSP in indoor air in homes using coal were much higher than those in homes using gas. Indeed, coal burning caused very heavy indoor air pollution whatever in winter and summer or in bedrooms and kitchens.

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**Table 1.** Concentrations of pollutants in indoor air, mg/m$^3$

<table>
<thead>
<tr>
<th>Cities</th>
<th>SO$_2$ (Coal)</th>
<th>CO (Coal)</th>
<th>TSP (Coal)</th>
<th>NO$_x$ (Coal)</th>
<th>SO$_2$ (Gas)</th>
<th>CO (Gas)</th>
<th>TSP (Gas)</th>
<th>NO$_x$ (Gas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chengde</td>
<td>0.274</td>
<td>0.140</td>
<td>7.11</td>
<td>0.270</td>
<td>0.052</td>
<td>0.054</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chengde</td>
<td>0.397</td>
<td>0.154</td>
<td>7.96</td>
<td>0.286</td>
<td>0.107</td>
<td>0.053</td>
<td>0.127</td>
<td>0.055</td>
</tr>
<tr>
<td>Shenyang</td>
<td>--</td>
<td>--</td>
<td>6.25</td>
<td>0.221</td>
<td>--</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shanghai</td>
<td>0.502</td>
<td>0.037</td>
<td>13.46</td>
<td>0.184</td>
<td>0.082</td>
<td>0.046</td>
<td>0.082</td>
<td>0.040</td>
</tr>
<tr>
<td>Wuhan</td>
<td>0.087</td>
<td>0.041</td>
<td>9.91</td>
<td>0.163</td>
<td>0.150</td>
<td>0.071</td>
<td>0.077</td>
<td></td>
</tr>
<tr>
<td>Baoding</td>
<td>0.30</td>
<td>0.05</td>
<td>9.60</td>
<td>0.50</td>
<td>0.26</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Hefei</td>
<td>1.10</td>
<td>0.42</td>
<td>--</td>
<td>0.48</td>
<td>0.38</td>
<td>0.50</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Taiyuan</td>
<td>0.168</td>
<td>0.097</td>
<td>5.69</td>
<td>0.716</td>
<td>0.236</td>
<td>0.085</td>
<td>0.206</td>
<td></td>
</tr>
<tr>
<td>Changzhou</td>
<td>0.14</td>
<td>0.04</td>
<td>5.26</td>
<td>--</td>
<td>--</td>
<td>0.05</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

**Indoor air pollution in kitchens is much heavier than that in bedrooms**

Kitchens are pollution source from domestic fuel. The concentrations of nearly all pollutants from domestic fuel in kitchens in winter and summer are much higher than those in bedrooms (Qin, Zhang, Jin et al, 1991; Zhang, Zhang, Shang et al, 1992; Xue, Chen, Wu et al, 1990). Figure 1 showed the concentrations of SO$_2$ and CO from coal burning.

![Figure 1. Comparison of concentrations of SO$_2$ and CO in kitchens and bedrooms](image)

**Indoor air pollution in winter is more serious than that in summer**

In northern part of China, heating is needed in winter because of the cold weather. People use coal in households not only for cooking, but also for heating in winter. Also, the windows and doors are tightly closed and the ventilation inside houses is poor. Studies showed that indoor air pollution in winter is more serious than that in summer (Qin, Zhang, Jin et al, 1991; Xue, Chen, Wu et al, 1990). Based on the survey in Chengde, the ratio of concentrations of SO$_2$, CO, TSP and NO$_x$ between winter and summer was 5.02, 3.5, 5.01 and 1.79, respectively (Zhang, Zhang, Shang et al, 1992).

In addition, investigations found that the concentrations of SO$_2$, CO, TSP and NO$_x$ in indoor air were usually higher than those in outdoor air.
PAHs CONCENTRATIONS IN INDOOR AIR FROM SMOKY COAL
Smoky coal, smokeless coal and wood are used as domestic fuel in Xuan Wei county of Yunnan Province in southern China. Studies showed that heavy indoor air pollution was caused by smoky coal burning in households (Cao, Zhao, Chen et al., 1994; Xian, Chen, Wang et al., 1986). The measurements of PAHs and benzo (a) pyrene (BaP) in indoor air and outdoor air were summarized in Table 2.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>PAHs µg/m³</th>
<th>BaP µg/100m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indoor</td>
<td>Outdoor</td>
</tr>
<tr>
<td>Smoky coal</td>
<td>150</td>
<td>2.0</td>
</tr>
<tr>
<td>Wood</td>
<td>36</td>
<td>--</td>
</tr>
</tbody>
</table>

The concentrations of PAHs and BaP in indoor air were much higher than those in outdoor air. The pollution source was certainly from indoors by domestic fuel combustion. Particularly, during cooking time the concentrations of PAHs can reach 555 µg/m³ in indoor air in homes where smoky coal was used as domestic fuel and 115 µg/m³ in homes using wood. BaP concentration was up to 23 µg/m³ in homes using smoky coal and it was 7 times of the concentration in homes using wood.

EFFECTS OF POLLUTANTS FROM COAL COMBUSTION ON HUMAN HEALTH

Personal exposure to indoor air pollutants
Time weighted average exposure to pollutants emitted from coal combustion was measured in several studies. In one study, 750 school children with age of 10-15 were investigated and the results are showed in Table 3 (Qin, Fu, Pei et al., 1990).

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Personal exposure µg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coal group</td>
</tr>
<tr>
<td>PM 10</td>
<td>708</td>
</tr>
<tr>
<td>SO₂</td>
<td>436</td>
</tr>
<tr>
<td>CO</td>
<td>6550</td>
</tr>
<tr>
<td>NOx</td>
<td>63</td>
</tr>
</tbody>
</table>

Xian reported that personal exposure to PAHs in households with smoky coal was 25.32 µg/m³ and 5.72 µg/m³ in households with wood in Xuan Wei and BaP exposure was 0.11 and 0.025 µg/m³, respectively (Xian, Qiao and Wang).

Effects of indoor air pollution on pulmonary function and respiratory illness
Several studies found that coal combustion can cause high prevalence of respiratory illness. 750 school children of 10-15 years old were investigated and the results showed higher prevalence of respiratory illness in children in homes using coal, if compared with that in homes using gas (Qin, Fu, Pei et al., 1990). 624 young children in age of 12-36 months and 598 children of 7-8 years old were investigated as subjects and the results indicated that prevalence of cough and pneumonia in subjects in coal group was higher than that in gas group (Zhou, Hong and Tao, 1992, 1994). Mortality of respiratory diseases was investigated in observed area where 92% of households using coal as domestic fuel and in control area where 95% of households using gas and the data showed that mortality rate of chronic bronchitis and pulmonary emphysema in the observed area was much higher than that in control area (Xia, 1984).
Effects of indoor air pollution from coal combustion on immunological functions and pulmonary functions were also studied and the data revealed that both of functions were affected (Shen, Yin, He et al, 1991; Wang and Chen, 1989; Tao, Hong and Yu 1991; Wang, Qian, Qi et al, 1993).

INDOOR AIR POLLUTION AND LUNG CANCER
A study on risk of male lung cancer attributed to coal combustion indoors in Shanghai revealed that 10-year lung cancer mortality rate in communities using coal was 1.48 times as much as that in communities using gas and 32.5% of total lung cancer death in coal group were possibly attributed to coal combustion (Tao, Hong, Yu et al, 1992).

A series of studies have focused on the etiologic link between lung cancer and indoor air pollution from smoky coal combustion in Xuan Wei County of Yunnan Province (He and Liu, 1989; He and Lan, 1993; Lan, Chen, Chen et al, 1993; Liu, He, Chapman, 1991; Chen and He, 1994). The results showed a strong association of lung cancer mortality with indoor air pollution from smoky coal combustion. A population–based case-control study was conducted and risk assessment was made (He, Tian, Lan et al, 2000). The data suggested the incremental lifetime lung cancer risk over background due to continuous exposure to the concentration of 1 µg/m$^3$ of PAHs (BaP as index) was estimated to be 0.087.

IMPROVEMENT OF INDOOR AIR QUALITY BY ENVIRONMENTAL INTERVENTION MEASURES
In order to improve indoor air quality, the centralized heating system was built up in Chengde city. The investigation indicated that concentrations of pollutants in indoor air and mortality rate of respiratory diseases were decreased (Zhang, Pei, Wang et al 2000). The indoor air quality is significantly improved.

Indoor air pollution from smoky coal combustion was very heavy in Xuan Wei. Previously people there used unvented firepits. Since 1979, the primary prevention strategy, of replacing unvented firepits with vented stoves, has been gradually put into practice. The investigation showed that the concentrations of pollutants, including SO$_2$, PAHs, BaP, TSP were dramatically decreased (Yang, Jiang, Wang et al, 1994). Also, it is very important measure for reducing incidence of lung cancer (Lan, Tian, He et al, 1999).

CONCLUSION
Coal combustion can cause very heavy indoor air pollution and adverse effects on human health. Higher incidence of respiratory illness was found in households using coal. Studies in Xuan Wei showed a strong association between PAHs concentrations in indoor air and mortality rate of lung cancer. Indoor air quality can be improved by environmental intervention measures.

REFERENCES


