Air Pollutants Emitted by Coal Resources City: Health Risks for the Population Living in the Neighborhood

Abstract: The air pollution that can lead to the health risks for human beings is a hot issue in environmental science research. By investigating the changes of air pollution spatiotemporally caused by human activities in a coal resource based city in Heilongjiang province, one systemic research on long-term residents about health risk was studied with the health risk assessment model. The results showed that, BaP were the main factor of regional health risks, rather than noncancerogenic risk. The region health risk probability changes along with time which is mainly related to the development and utilization of coal resources in the region. Health risks differed in different areas because of the distance to the coking plant.

Keywords: Coking plant; Environmental sensitive; Health risks; Pollution factor; BaP

1 Introduction

Studies on the potential impact on health risk associated with the coal resources development activities have mainly focused on two classes of compounds: (1) criterion pollutants such as carbon monoxide (CO), nitrogen and sulfur oxides (SOx and NOx), total suspended particulate matter (TSP), sulfur compounds of hydrogen (H2S), hydrogen and nitrogen compounds (NHx) and (2) noncriterion pollutants such as benzo pyrene (BaP), etc.

In recent years, quantitative risk assessment tools have been used to evaluate various site development activities caused by local as well as the pollution of the environment of the area around. Characterization of environmental risk assessment for one or more physical, chemical or biological agents to human health (or possible) effect probability.

Marta Schuhmacher study on the human health risk for long-term living in cement plant, set up the mathematical model for personal health risk and the health
risks of cancer research through by SO$_2$, NO$_x$ and dioxins from cement production, although the research results shows that the cement plant nearby residents affected by cement plant emissions of pollutants is lower, the paper has made valuable exploration from the methodology [1]. Bingheng Chen use the “four steps” to assess NO$_x$ more than ten years of monitoring data in the urban atmosphere residents, the results show that NO$_x$ pollution in the atmosphere caused some losses to residents’ health, and with the increase of NO$_x$, the health risk is on the rise [2]. Zhenyuan Zang assess the abandoned chemical crowd also with “four steps”, the results show that the venue cancer risk and non–cancer risk over the acceptable values, the chemical plant site for adults and children have risks, so the government need to make urban plan reasonably [3]. Ping Li use mainly adopts domestic health risk assessment of soil health risk model to evaluate heavy metal pollution in atmospheric dust, the results show that the heavy metal pollution of atmospheric dust in October to March of next year is relatively serious, the risk of no cancer in children are bigger than adults, and the maximum has most risk in no carcinogenic risks [4].

Unfortunately at the moment, the monitoring data and the study of population environmental health risk of coking plant is less. Therefore study around the crowd of coking plant health risk is very necessary. This article will divide a develop long–term production release of air pollutants into the carcinogenic risk and no carcinogenic risks, use “four steps” to make assessing system of the health risk of the residents around the coking plant, in order to providing scientific basis for avoiding potential health risk factors and planning the coal resources city development.

2 The Research Object

2.1 The City of Coal Resources General Situation and Coking Industry Development Situation

The coal resource city is a city with coking industry mainly and multi–industry simultaneously. The city has proven recoverable reserves of 400 million tons of coal resources, with the main coking coal, fat coal, gas coal, anthracite coal, especially the main coking coal, accounts for 82 % of total reserves, has a very low sulfur, low phosphorus, high calorific value, high ash melting point, etc., known as “industrial powder”, is one of the rare coalfields state in three protective mining. Therefore, the development and production of coke will lead industry of the city’s economic development.

Until 1996, the coal resource city set up the first coking plant, the region is given priority to with “small primitive coke”. After 2002, coke market demand soared with developing smoothly mutations leading to the city coking plant quantity spurt. The city had 27 coking plant, with production capacity between 1 million tons/year.
Beginning in 2003, the central government began to control small coking plant. By the end of June 2004, more than 60 “small primitive coke” have been shut down, banned and destroyed, but large-scale coking plant has built, its coking capacity reach 7 million tons/year. However, the coking severe overcapacity by the steel industry downturn. Beginning in 2011, several coking enterprises had entered coke unsalable, falling prices, operating loss serious trouble, the region is the production of coking enterprises are to extend industrial chain continuously, at present only the four coking plant in the region to avoid the risk of the furnace, capacity only retain the ability of 4 million tons/year. Since May 2016, the prices of coke began to rise, so the coking plant management situation improved markedly. Coking enterprise production operation is worth to pay close attention to the health risks of pollution emissions.

### 2.2 Pollutant Profile Distributions of Meteorological Conditions and Population Distribution Characteristics

The level of pollutant concentration distribution in environment particularly around coking enterprise is closely related to meteorological conditions in the region. According to the meteorological statistical data of 20 years in the region, the primary wind direction was WSW, with a frequency of 18 %, while the secondary wind direction was W, with a frequency of 14 %. The percentage of calms was more or less constant throughout the year around 7 %.

The city coking enterprises is relatively concentrated, focused on the west of the city. The region main pollutants come from major industrial pollution sources in coking enterprises and its industry chain emissions.

In the present study, the concentration distribution around 1 km in coking enterprises outside the scope, mainly in the east of #3 village, with a population of more than 3600 people. Fig. 1 shows location of sampling points.
2.3 The Source of the Monitoring Data

This study collected the study area from 1999 to 2011. Shown from table 1 to table 4.

Tab. 1: The region’s monitoring data in 1999 (mg/m³)

<table>
<thead>
<tr>
<th></th>
<th>BaP</th>
<th>TSP</th>
<th>SO₂</th>
<th>NO₂</th>
<th>CO</th>
<th>H₂S</th>
<th>NH₃</th>
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<td>#1</td>
<td>0.0009</td>
<td>0.2540</td>
<td>0.0334</td>
<td>0.0241</td>
<td>1.7400</td>
<td>0.0005</td>
<td>0.0070</td>
</tr>
<tr>
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<td>0.9750</td>
<td>0.0005</td>
<td>0.0070</td>
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<tr>
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<td>0.0263</td>
<td>0.1980</td>
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</table>

Tab. 2: The region’s monitoring data in 2003 (mg/m³)

<table>
<thead>
<tr>
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<th>BaP</th>
<th>TSP</th>
<th>SO₂</th>
<th>NO₂</th>
<th>CO</th>
<th>H₂S</th>
<th>NH₃</th>
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<td>0.0005</td>
<td>0.1574</td>
<td>0.0324</td>
<td>0.0288</td>
<td>1.4000</td>
<td>0.0010</td>
<td>0.0150</td>
</tr>
<tr>
<td>#2</td>
<td>0.0010</td>
<td>0.2538</td>
<td>0.0442</td>
<td>0.0318</td>
<td>2.3333</td>
<td>0.0010</td>
<td>0.0150</td>
</tr>
<tr>
<td>#3</td>
<td>0.0005</td>
<td>0.2588</td>
<td>0.0488</td>
<td>0.0340</td>
<td>2.3333</td>
<td>0.0017</td>
<td>0.0150</td>
</tr>
</tbody>
</table>
Air Pollutants Emitted by Coal Resources City

Tab. 3: The region’s monitoring data in 2007 (mg/m³)

<table>
<thead>
<tr>
<th></th>
<th>BaP</th>
<th>TSP</th>
<th>SO₂</th>
<th>NO₂</th>
<th>CO</th>
<th>H₂S</th>
<th>NH₃</th>
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<td>0.0050</td>
<td>0.0900</td>
</tr>
<tr>
<td>#4</td>
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<td>1.0000</td>
<td>0.0010</td>
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<tr>
<td>#5</td>
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<td>0.0020</td>
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<td>0.0368</td>
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<td>1.0000</td>
<td>0.0010</td>
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</tbody>
</table>

Tab. 4: The region’s monitoring data in 2011 (mg/m³)

<table>
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<tr>
<th></th>
<th>BaP</th>
<th>TSP</th>
<th>SO₂</th>
<th>NO₂</th>
<th>CO</th>
<th>H₂S</th>
<th>NH₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>0.0005</td>
<td>0.1574</td>
<td>0.0324</td>
<td>0.0288</td>
<td>1.4000</td>
<td>0.0010</td>
<td>0.0150</td>
</tr>
<tr>
<td>#2</td>
<td>0.0010</td>
<td>0.2538</td>
<td>0.0442</td>
<td>0.0318</td>
<td>2.3333</td>
<td>0.0010</td>
<td>0.0150</td>
</tr>
<tr>
<td>#3</td>
<td>0.0005</td>
<td>0.2588</td>
<td>0.0482</td>
<td>0.0340</td>
<td>2.3333</td>
<td>0.0017</td>
<td>0.0150</td>
</tr>
</tbody>
</table>

3 Method of Study

Health risk assessment have many methods such as four steps from the National Academy of Sciences (NAS), life cycle analysis, method of MES and beta – Possion model assessment of viral infection, etc. In these methods, four steps has the most common of the national academy of sciences to use includes Hazard Identification, Toxicological Evaluation, Exposure Assessment, and Risk Characterization. The method is widely used in environmental medium such as air, water and soil in the human health risk assessment of pollutants in the toxic chemical [5]. This article will use the “four steps” health risk assessment on the city.

3.1 Hazard Identification

In fact, as the coal resource development activities of coking enterprises, the main harmful substances released into the atmosphere are poison and dust, belongs to the chemical hazard factors, chemicals directly inhaled into the body through the air from the pollution emissions to the atmosphere [6]. In dozens of chemical toxicants of coking enterprise, the largest amount of emissions and the most harmful substances mainly are BaP, benzene soluble matter, sulfur dioxide, carbon monoxide, nitrogen dioxide and ammonia. They all are high toxic substances except the
sulfur dioxide. Environmental chemical damage to the human body is mainly poisoning effect. According to the course of disease development speed and characteristics, they can be divided into acute, chronic and chronic poisoning. Chronic special poisoning is embodied in: the body's basic genetic material DNA is induced by poison making its sequence and structure change down to genetic code changes, eventually cause cancer and birth defects. And the follow dust's harm to human body: contacting or inhalation of dust will make cornea, skin mucous membrane on the local stimulation first and cause a series of pathological changes. Long – term inhalation of high concentrations of dust can cause lung diffuse, progressive fibrosis of systemic disease, namely pneumoconiosis. Due to long – term inhalation of productive dust of pneumoconiosis, it is a common occupational disease which has more destructive [7].

As mentioned earlier, the main harmful substances in coking enterprises released into the atmosphere are poison and dust, belongs to the chemical hazard factors. This study, CO, SOx, NOx, TSP, NH₃, H₂S and BaP will be to evaluated.

### 3.2 Toxicological Evaluation

Air pollutants caused people to disease and death in the related research reports earlier. The EPA of China provides some reference dose of pollutants, table 5, table 6 discussed for the reference value of pollutants [8].

<table>
<thead>
<tr>
<th>Tab. 5: Cancer – causing pollutants reference dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pollutants</strong></td>
</tr>
<tr>
<td>qₘₐₚₑₜ (mg/(kg·d)⁻¹)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tab. 6: Noncancer – causing pollutants reference dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pollutants</strong></td>
</tr>
<tr>
<td>Dₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₑₚ (mg/(kg·d))</td>
</tr>
</tbody>
</table>

### 3.3 Exposure Assessment

Coking enterprise have land for homes, schools and so on, the main sensitive crowd is people around, including the adult and the child. Therefore, residents living
around the coking enterprise may cause adverse health effects through direct contact with air pollutants in daily life breathing.

### 3.4 Risk Characterization

Coking enterprises have various kinds of pollutants. However according to the influence on population health risk can be divided into carcinogenic effect (BaP) and carcinogenic effect (SO₂, NOₓ, TSP, CO, H₂S and NH₃). This paper carried out in accordance with the carcinogenic effect and noncarcinogenic effect of health risk assessment, and assess health risk on the basis of the comprehensive.

#### 3.4.1 Carcinogenic Risks

Cancer risk expresses the likelihood of occurring cancer due to a definite daily intake of a pollutant [1]. Cancer risk use URFᵢ to estimate. URFᵢ is defined as the air pollutant concentration of 1μg. m⁻³ when the carcinogenic risk of cap.

\[
R^{c} = \sum_{i=1}^{k} R^{c}_{i} \tag{1}
\]

\[
R^{c}_{i} = \frac{1 - \exp (-D_{i} q_{i})}{70} \tag{2}
\]

\[
D_{i} = C \times M / 70 \tag{3}
\]

Where \( R^{c} \) is genes toxic substances i through breath way for the average individual in risk of cancer, a⁻¹; \( D_{i} \) is genetic toxic substances i through breath way units daily exposure dose, mg/(kg·d); \( q_{i} \) is genetic toxic substances i through breath way carcinogenic factor, mg/(kg·d)⁻¹; \( M \) take 20 m³/d by breathing; 70 a is human life expectancy.

#### 3.4.2 Noncarcinogenic Risks

In the risk of noncancer, all not carcinogenic chemicals are related to noncarcinogenic effect. As a result, noncarcinogenic risk attribute has always been a dose–response analysis, are calculated by calculation, hazard index of the human body to accept the exposure dose and the ratio of reference dose (DᵢRF) of pollutants, DᵢRF defined as not because health risks of dose of pollutants in the atmosphere.

\[
R^{n} = \sum_{i=1}^{k} R^{n}_{i} \tag{4}
\]
R^n = (D_i / D_{ref}) \times 10^{-6} / 70 \tag{5}

R^n is noncarcinogen i personal average annual risk through breathing, a^{-1}; D_i is noncarcinogen i through breath way units daily exposure dose, mg/(kg \cdot d); D_{ref} is noncarcinogens i through breath way reference dose, mg/(kg \cdot d); 70a is human life expectancy.

3.4.3 Total Risk Characterization

Assuming all the toxic effects of toxic substances harmful to human body health relationship are not antagonism relationship, we characterize the total risk as:

R^T = R^c + R^n \tag{6}

International Commission on Radiation protection (ICR) recommends maximum acceptable risk is 5\times10^{-5}/a [9].

4 Results and Discussion

4.1 The Analyses of Main Factors which Influence the Health Risk Probability in the Region

Using monitoring data of coking enterprise sensitive area around 1999, 2003, 2007, 2011years, for each sensitive crowd , we assess the overall health risk on the basis of the risk of cancer and noncancer according to the the health risk assessment method. Figure 2 shows the probability of the risk of cancer and noncancer, the blue part of the figure is carcinogenic effect probability, the yellow part is noncarcinogenic effects probability. Table 7 shows the percentage of carcinogenic effect probability and noncarcinogenic effect probability.
Fig. 2: The probability of the risk of cancer and noncancer

Through the monitoring data of different years about all sensitive evaluation results in Fig.2, the probability of causing cancer by BaP is much higher than that of SO₂, NOₓ, TSP, CO and H₂S, NH₃.

**Tab. 7: The percentage of carcinogenic effect probability and noncarcinogenic effect probability**

<table>
<thead>
<tr>
<th>Time</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>noncancer</td>
<td>cancer</td>
<td>noncancer</td>
</tr>
<tr>
<td>1999</td>
<td>0.738</td>
<td>99.262</td>
<td>0.666</td>
</tr>
<tr>
<td>2003</td>
<td>1.019</td>
<td>98.981</td>
<td>1.666</td>
</tr>
<tr>
<td>2007</td>
<td>0.057</td>
<td>99.943</td>
<td>0.081</td>
</tr>
<tr>
<td>2011</td>
<td>0.155</td>
<td>99.845</td>
<td>0.136</td>
</tr>
</tbody>
</table>

It can be seen from Table 7 that the percentage of the probability of the risk of cancer are over 98 %, explaining that BaP pollutant is the main factor of regional health risk, rather than noncarcinogenic risk.

### 4.2 The Region Health Risk Probability Analysis in the Region Through Time

Fig. 3 shows the regional vibration of health risk probability along with time. The blue part of the figure represents #1 location, the red part of the figure represents #2 locations, and the green part of the figure represents #3 locations.
From Fig. 3, the regional health risk probability goes flatly or slightly down from 1999 to 2003. This is because the region is given priority to be with “small primitive coke”, which changes after the birth of first 50000 Ton/Year in 2000. It includes a complete set of the corresponding pollution control engineering measures. From 2003, the government began to control small coking enterprises, “Small primitive coke” was shut down, banned and destroyed, as well large-scale coking enterprises were gradually built. Thus during the period in 2003, the concentrations of pollutants in air distribution are basically flat or slightly down due to construction of a complete set of environmental protection facilities. Sensitive health risk probability was not changed too much. However from 2003 to 2007, its coking capacity reach 7 million tons/year. Pollutant emissions increases in the atmosphere also showed a trend of increase. Its health risk evaluation results in 2007 #1, #2, #3 are even more than the maximum acceptable risk recommended by the ICR. After 2011, several coking enterprises had entered coke unsalable, falling prices, operating loss serious trouble, the region is the production of coking enterprises are to extend industrial chain continuously, to 2016 only the four coking plant in the region to avoid the risk of the furnace, capacity only retain the ability of 4 million tons/year, so health risk probability fell down in 2011.

4.3 The Regional Health Risk Probability Analysis of Characteristics of Different Regions

Since the health risk probability which coking enterprise environment caused changing with the time very consistent on the whole, this section only take an example in coking enterprises around the health risk probability analysis of the research in different areas in 2007.
Fig. 4 shows the characteristic figure of regional health risk probability in 2007. The yellow part of the graph represents the size of human settlement’s health risk probability.

![Graph showing regional health risk probability](image)

**Fig. 4:** The regional health risk probability characteristic figure in 2007

From Fig. 4, #1, #2, #3, the health risk probability is much higher than human settlement, they are $0.000258203 \text{ a}^{-1}$, $0.000156882 \text{ a}^{-1}$, $0.000106201 \text{ a}^{-1}$ respectively, the distance #1, #2, #3 to the coking plant are 1.03 km, 1.17 km, 1.28 km. Since #4, #5, #6 is far away from coking plant, health risk probability is not big because of pollutant concentration are lower than #1, #2 #3, and the farthest #4 is only 0.134 of #1. As the coking enterprise has the low pollution origin, which leads to spread of the pollutant, it always causes the higher concentrations of atmospheric pollutants near by the coking plant. Therefore the probability of close place is greater than the probability of distant location.

5 Conclusion

Results of Environmental sensitive health risk assessment around coking clusters are follows:

The major air pollutants causing the regional health risks is BaP, whose health risk probability is more than 98 % of the total health risk probability;

The coking production has much influence for the atmosphere pollution in the region. The regional health risk probability is well linked to the changes of the coking capacity and the different methods of coking production. During the period
around 2007, the health risk probability in the region of environment sensitive which close around the coking enterprises are even more than the maximum acceptable risk recommended by the ICR. So measures must be taken to reduce the emissions of pollutants to reduce health risk probability in that region.

Finally, the probability of close place is greater than the probability of distant place. Thus the coking enterprise has the low pollution origin, which leads to spread of the pollutant making higher concentrations of atmospheric pollutants. Full consideration must be given in the urban planning, and development, because coking enterprises should not be within the scope of people live for a long time.

References


