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“Haze in China”: an overlook of urban PM 2.5 pollution impacts and control benefits[①]

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Introduction

Along with the rapid process of urbanization, industrialization, and regional economic integration, air pollution in China is changing from be a local, single city phenomenon to be a complex, heavy regional one. Some areas such as the Beijing-Tianjin-Hebei region, the Yangtze River delta, the Pearl River delta and other group of cities have shown obvious regional air pollution characteristics, and the increasing spread of this trend, seriously restricted the sustainable socioeconomic development of the region, threatening their population health. In these regions, the air pollution has changed from be a traditional smog to a more complex pollution formed by the mix of soot and vehicle exhaust, also becoming a regional problem with broader impacts more difficult to control and governance.

By the end of 2011, a debate about air quality started on the Internet, which overnight turned the term PM2.5, from being an academic specialized vocabulary to a "common sense" one. Thus, from the early stages of the

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discussion, the PM2.5 term became synonymous with all the environmental issues. In January 2013 another particular event occurred, named by the Chinese media “Haze China”, which was a long duration, high concentration and long range pollution episode, affecting Beijing, Tianjin, Hebei, Henan, Shandong, Jiangsu, Anhui, Hubei, Hunan and other cities, overall impacted about 20 provinces nationwide, with varying degrees of heavy air pollution and extreme low visibility. It was estimated that the scope reached by the pollution was more than 140 square kilometers. This incident has widespread a broader concern of the society about the environmental quality.

After these incidents several changes on the behavior of the society were perceived, from the initial online debates and arguments, to the questioning of the accuracy of the data, from the explosion on the demand of facial dust masks on the biggest online market “Taobao”, to the major shopping malls selling air purifiers like “hot cakes”; likewise an increasing number of the most followed bloggers were loudly calling for a daily release of information, and the citizens took actions to avoid some risk by the use of portable tools for measuring the air quality. This actions triggered by individual citizens quickly were attended by the government, the results were: the establishment of a regional monitoring system, the data disclosure, the set-up of new atmospheric quality standards all together with other measures and strategies of pollution control.

The pollution debate, not only turn the technical PM2.5 term into a "common sense" vocabulary but also build "consensus" around it. But more importantly, it increased the public concern to the fast growing air pollution problems, and directly lead to the design and implementation of government control strategies, measures and actions, also triggering great amount of investments on R&D related to technology and capabilities.

Various official forums and mass media reports suggested that as long as the government is determined to set goals and strategies to improve the air quality standards, then the urban air pollution problems will get solved in the near future. However, the reality may not be consistent with the good will, especially with the regional air pollution PM2.5 problem mainly because its complexity, its cumulative characteristic and the vast widespread socio economic impacts that it causes. Therefore, in order to solve the PM2.5 pollution problem, not only a strong political will is needed but also the development and effective implementation of long-term pollution control strategies.

This article explores the regional and local PM2.5 pollution control strategies taking into account the socio economic loses and the benefits of the PM 2.5 pollution control.

A short review on PM 2.5 and its impacts on air pollution

The term Particulate Matter (PM) refers to solid or liquid particles suspended in the atmosphere, it is not a particular compound but a complex mixture of chemicals. These particles can stay suspended in the air for prolonged periods of time forming a relatively stable suspension, called the atmospheric aerosol. Another characteristic of these particles is related with its extremely irregular shape that makes difficult to use the geometric diameter to measure their size. Hence it is necessary to calculate their aerodynamic diameter which represent their size.

The particles with aerodynamic diameter between 10 to 100 microns stay suspended in the air for a short period of time, then gradually fall down, they are called dust; but the ones with aerodynamic diameter under 10 microns not only can stay suspended in the air for a long time, but also can enter the human respiratory tract, this part of the particles called respirable suspended particles or inhalable coarse particles. Recently the sort of particles that is attracting most of the attention are the ones with aerodynamic diameter less than 2.5 microns, often mentioned in the literature as fine particulate matter (also known as fine particles).

PM2.5 particles are so small, that they can enter the respiratory tract and be deposit anywhere within it, even reaching the lungs causing respiratory inflammation. Furthermore, some ultrafine particles can enter the bloodstream and through the blood circulation affect the whole body. Secondly, the fine particles are emitted by a variety of direct sources and also generated by secondary sources such as chemical reactions so are a complex compounds with varied composition, including heavy metals, polycyclic aromatic hydrocarbons organic matter and others which may contribute to their health effect. Many epidemiological studies have confirmed that the atmospheric particulate matter, especially the fine particulate matter is one of the most harmful air pollutants to human health (Wilson, Spengler, 1996 [2]; KanHaiDong, Chen Bingheng, 2002 [3]; Li Yangong, Yuan Dong, 2003[4]). A World Health Organization (WHO) study, conducted in 3211 cities around the world, showed that in the year 2000 the global outdoor air particulate matter pollution caused 79.9 million premature deaths, of which 48.7 correspond to the Asia-pacific region (Cohen, et al., 2005)[5]. In addition, particulate matter pollution is a major cause of respiratory and cardiovascular diseases.

Other studies have shown that particulate matter, especially fine particulate matter is closely related to the reduction of visibility, representing until 99% of this impact (usually anthropogenic emissions of PM2.5). Visibility reduction has directly impacts on driving on highways, marine and air transportation. It

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[2] Wilson, R. and J.D. Spengler, Particles in our air: concentrations and health effects. 1996: Harvard School of Public Health Cambridge, MA.

[3] KanHaiDong, Chen Bingheng, 2002. Relationship of air particulates exposure and human health effects in China. Journal of Environment and Health. 2002. 19(6), pp422-424

[4] Li Yangong, Yuan Dong, 2003. Development of epidemiology study on Air particulates pollution and mortality changes , Environment and Occupational Medicine. 2003. 20(1)， pp47-49

[5] Cohen, A.J., et al., The global burden of disease due to outdoor air pollution. Journal of Toxicology and Environmental Health, Part A, 2005. 68(13-14): p. 1301-1307

can cause severe flight delays, expressway closure, traffic accidents and other problems. Low visibility caused by fine particulate matter also has negative impact affecting people's mood and inducing mental illness. Low atmospheric visibility is also detrimental to public health affecting people’s mood inducing the appearance of mental illnesses. Lately also impacts people’s comfort, which is an important component of people’s quality of life.

The direct economic losses from fine particulate matter pollution

Studies generated in different years and from different countries showed that the economic losses and health damage caused by air pollution is enormous. The earliest research on economic losses caused by air pollution, is Ridker’s research on 1967 which is considered to be the precursor of the following studies that tried to calculate and evaluate the economic damages of this phenomenon. Ridker’s study applied the human capital method to calculate the 1958 economic losses due to the diseases caused by air pollution in America, his results showed that the health benefits for the US on that year for controlling air pollution were around 80.2 billion dollars.

Subsequently other countries, the World Bank, the World Health Organization and other international organizations have performed a series of studies considering the relationship between air pollution and human health as a basis for assessing the losses due to air pollution. Also the results of these studies were used to support environmental protection investments, improve the governance and the implementation and evaluation of environmental policies. In 1985, a study from the American lung association measuring the losses due to the impact of air pollution on health have found that the direct medical cost was up to 16 billion dollars in the United States, and the productivity reduction due to illnesses related with this problem caused economic losses for about 24 billion dollars.

Moreover, Quaha et al. (2003) using the damage function and a dose-response method studied the losses due to health damages caused by PM10 in Singapore, the final calculation showed that the losses for 1999 reached the amount of 3.662 billion dollars, accounting for 4.31% of Singapore's GDP that year.

In China many studies on fine particulate matter pollution damage were performed, all showing that this factor generates great economic losses. Due to the use of different estimation methods to calculate the economic losses, they ranged from more than 1% of the Chinese GDP to even more than 7% of it.

In the early 90's, many scholars and researchers (including Liu Wen, Guo Xiaomin, Qu GePing, Xu Shoubo, Xia Guang etc) studied the welfare losses because of air pollution at the national level, the estimated minimal loss was 4.4 billion Yuan, accounting for 1.2% of the national GDP and the maximum was 98.6 billion Yuan, accounting for 4.04% of the GDP. In 1997, the World Bank in their publication 'Blue sky: in the 21st century China's environment' estimated that the cost of China's air and water pollution was more than 54 billion dollars per year, which means about 8% of its GDP. Lately in 2007, the World Bank, considering PM10 as an air pollution indicator, estimated China's air pollution losses in 2003. They found that the average for Chinese cities total health loss due to air pollution was between 1570—52900 billion Yuan, about 1.2—3.8% of the GNP of that year.

Since the year 2000, Chinese researchers used the population attributable risk fraction to assess the value of health damages. Focused on the whole country, Yu Fang et al. (2007) using city, province, and national level data, bottom up approach, estimated that the economic losses caused by air pollution for China account 170.3 billion Yuan for 2004. In 2008, Zhang Minsi studied 111 Chinese large and medium-sized cities and obtained an estimate for the economic losses caused by the atmospheric particulate matter pollution of 29.2 billion dollars also in 2004.

In the case of individual city studies, Xu Zhaoling et al. (1996), used the ecological and time series analysis, considering the multi factor analysis and local and international studies related with the relative risk of contracting diseases due to air pollution; their results showed that in Shenyang the heavy polluted areas experiment an increase of 3000 deaths per year compare with light polluted areas, this is equivalent to a loss of 2,469,421 working days or loss of 173,303 years of life. The total economic losses were around 233 million Yuan per year. Also Xu Yihong et al. (2001), applied the human capital method, to estimate the economic impact of air pollution in human health for Dalian in 1996, arriving to a value of 157.34 million yuan/year. Zhou Anguo et al. (1998) preliminary estimations for the total economic losses caused by air pollution in Zhejiang province was around 1.27 billion Yuan, of which health losses accounted for one third; Later Xu Zhaoling et al. (2003) used different valuation methods to estimate the economic value of health losses due to atmospheric particulate matter pollution in Fushun city in Liaoning province in the year 2000; their results range from 140 million to 340 million Yuan, representing 0.75% to 1.95% of the GDP;

Other studies like Xu Yan, Zhao Shanlun (2004) estimated economic loss caused by the air pollution in Shandong province for the year 2002. The results showed that the total economic loss was about 12.6 billion Yuan which is about 1.2% of the GDP, of which 8.7 billion Yuan were related to health losses. Wang Yan et al. (2006), using the human capital method estimated that the economic losses due to human health impacts, agricultural impacts and the increase of the cleaning costs in Shandong province for the period from 2000 to 2002, accounted for more than 15 billion Yuan per year, around 1.85%-1.92% of the GDP in that period.

In addition, there are recent studies using dose response models to to determine pollution the health impacts. Han Guifeng et al. (2001) studied, in Xian, the loss of wages due to premature death, wages loss due to work delays and the cost of medical treatments; they found that in the year 1995 the economic losses of human health caused by the Total Suspended Particles (TSP) were around 201 million Yuan. Song Zhen et al. based on that study calculation method estimated that the economic value of the health losses due to air pollution in Xi’an for the year 2002 reached 251.6 million Yuan.

In the case of China’s main cities studies, other researchers like Kan Haidong et al. (2004) studied the health economic losses resulted from the exposure to urban atmospheric particulate matter pollution in Shanghai in 2004, and found that the loss was around 5.15 billion Yuan, accounting for 1.03% of that city annual GDP. Zhang Minsi et al. (2007) combined GIS and remote sensing methods to match the particle matter concentration and the population exposure, finding that the economic health loss caused by Beijing’s PM10 during the 2000-2004 period ranged between 1.67 to 3.65 billion Yuan per year, accounting for 5.58% to 7.06% of this city annual GDP; moreover Zou Wenbo, Zhang Shiqiu et al. (2010) calculated the economic costs losses of premature deaths caused by the exposure to atmospheric particulates in Beijing during the 2001-2006 period, the final values obtained were from 3.03 to 9.3 billion Yuan per year, representing 0.8% to 1.2% of Beijing's annual GDP. Additionally Huang Desheng and Zhang Shiqiu studied the economic burden from health losses due to particulate matter pollution in the pearl river delta in 2006, their results showed that the total loss was rounding 22.3 billion Yuan, accounting for 1.04% of this region annual GDP (Desheng Huang, Shiqiu Zhang, 2012)

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[⑥] Desheng Huang, Jianhua Xu, Shiqiu Zhang. Valuing the health risks of particulate air pollution in the Pearl River Delta, China. Environmental Science and Policy 15 (2012), pp. 38-47

Our research team have recently completed a study on the direct economic losses on transportation and health due to the national haze episode occurred in January 2013. The lowest estimated loss was 23 billion Yuan, where people visiting the emergency room and outpatients accounted for 98% of the total loss. The largest losses were accounted within the Beijing-Tianjin-Hebei region and China's east region, including several provinces and cities such as Zhejiang, Jiangsu, Shandong, Hebei, Shanghai, Beijing and others. In respect to the economic losses due to acute health impacts caused by PM2.5 pollution, it was found that during the haze episode they reached twice the value of the same under normal pollution conditions; So, if we assume that haze episode is the normal condition, considering the effects on the appearance of chronic disease and premature deaths, the potential total economic health impact value can be as high as 200 billion Yuan per year, equivalent to 5.2 % of 2012 China's monthly gross domestic product (this value may be overestimated, because the air quality during a year is not necessarily the same as the situation in January 2013) (MuQuan, Zhang Shiqiu 2013)[⑦].

<u>Controlling PM2.5 can bring significant benefits</u>

The reduction of PM2.5 concentrations and other pollution hazards will bring many benefits including the improvement of the population health and visibility, reduction in building's corrosion and others. Thus, controlling PM2.5 will improve substantially the economic and social welfare. As it was mentioned before, recently epidemiological studies have confirmed the harmful relation between the atmospheric particulate matter (especially PM2.5) and the human health. Overseas studies also revealed that economic health losses caused by the atmospheric particulate matter and the economic losses of low visibility due to urban haze are a large proportion of the total economic losses caused

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⑦ Mu Quan, Zhang Shiqiu. An Evaluation of the Economic Loss due to the Heavy Haze During January 2013 in China. China Environmental Science, Vol 33, No 11, 2013 P2087-2095 by air pollution. Therefore, to control atmospheric particulate matter, especially fine particulate pollution, is not only good to improve air quality, but more importantly is helpful to avoid harmful impacts on human health and to reduce the corresponding social and economic losses, which impacts positively people's quality of life.

Starting in 2010, we conducted a study on the benefits of controlling PM2.5 in the Beijing-Tianjin-Hebei region. Based on a comprehensive epidemiological study, using environmental health risk assessment techniques and several environmental valuation methods, we estimated the health benefits after the new fine particulate matter (PM2.5) concentration standards (2012 air quality standards) in the Beijing-Tianjin-Hebei region were reached to later perform and intercity comparative analysis. The results showed that the total health benefit will range between 61.2 to 256 billion Yuan per year (average 172.9 billion), which is equivalent to 1.66% to 6.94% (average 4.68%) of the 2009 GDP in the Beijing-Tianjin-Hebei region. Among the beneficiaries, Hebei province is the one obtaining the highest health benefits, while the health improvement and the economic benefits of Beijing, Tianjin and Shijiazhuang are also significant. The reduction of premature deaths and the incidence of chronic bronchitis accounts for over 90% of the economic health benefits achieved by the implementation of the PM2.5 pollution control strategy in the Beijing-Tianjin-Hebei region [⑧].

Additionally, within the Beijing-Tianjin-Hebei region there are large differences in respect to their PM2.5 pollution and population characteristics, thereby the health benefits due to PM2.5 pollution control are also different, which should be taken in full consideration for the implementation of the regional air quality management program with efficient cooperation.

[⑧] Huang Desehng, Zhang Shiqiu. Health Benefit Evaluation for PM2.5 Pollution Control in Beijng-Tainjin-Hebei Region of China. China Environmental Science, Vol 33, No 1, 2013 pp166-174

Conclusions

Atmospheric particulate matter, especially fine particulate matter (PM2.5), has great potential to cause health problems, thus influences the increase of disease treatment costs, decrease the people's welfare and quality of life, even can cause deaths; PM2.5 is also an important factor causing low atmospheric visibility, which always brings great negative impact on transportation and residents comfort. Some studies results show that PM2.5 pollution decrease the social welfare, so that to control the pollution not only can improve people's health but also can have direct significant environmental and economic benefits in that way improving the population welfare.

The damage assessment of atmospheric pollution in different enterprises, industries and regions along with the benefit assessment of different pollution control measures are important factor to be consider in order to support decision related with air pollution control. Considering that one of the fundamental responsibility of modern governments is to achieve the implementation of cost-effective policies, rather than to achieve goals at any cost. Hence in China the PM2.5 pollution control measures should be prioritize by their cost effectiveness (considering individual pollutant emissions control measures), finally choosing the most cost effective strategies, which are the ones presenting the minimum costs of implementation and prove to be effective . Unfortunately by now, in China there are still difficulties to discern and formulate pollution control strategies with the lowest cost, although all the efforts already performed by our scientist. So, still there is an urgent need for solid, reliable and realistic studies.

In addition, regional joint control and governance have gained more important practical significance and urgency, this mainly because of the regional and complex characteristics of the atmospheric fine particulate matter pollution. A basic premise of the regional joint control and governance is to establish a regional common objectives, then the region may control and reduce PM2.5 concentration effectively. The regional control is not only a supplement but a complement to the current air quality management system and policies, is also helpful to reduce the PM2.5 concentrations which has significant negative effect to the public health, thus improving the air quality control and management system.