Unbearable Burden

Health Impact of Coal Combustion in China

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Beijing, China
February 2014

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Acknowledgment

Among the policy research activities sponsored by Health Care Without Harm (HCWH), this paper is to push the continued discussion on health impact of coal combustion in China. Working with HCWH, Rock Environment and Energy Institute look forward to raising the voice of public health experts in the decision making of energy policy in China.

We also want to give thanks to people who have provided insightful ideas during the process. They are Prof. Xinbiao Guo and Prof. Xiaochuan Pan, both from the Public Health School of Peking University, and Prof. Qi Shang from the China National Center for Disease Control and Prevention.

Abbreviations and Acronyms

AHC Adjusted Human Capital
CO Carbon Monoxide
EU European Union
GBD the Global Burden of Disease
GDP Gross Domestic Product
Hg Mercury
NO_x Nitrogen Oxides
O_3 Ozone
PAHs Polycyclic Aromatic Hydrocarbons
Pb Lead
PM Particulate Matter
$PM_{2.5}$ Particulate Matter of Less than 2.5 μm in diameter
PM_{10} Particulate Matter of Less than 10 μm in diameter
SEPA State Environmental Protection Administration of China
SO_2 Sulfur Dioxide
TSP Total Suspended Particulates
VOLY Value of a Life Year
VSL Value of Statistical Life
WTP Willingness to Pay

Introduction

This paper is to review the previous studies on health impact of coal combustion in China and briefly discuss the association between change of health impact of coal combustion and coal consumption flow of coal power fleet. The cost of health impact is monetized mainly based on economic assessment of health burden. Value of Statistical Life (VSL)[1] is applied by willingness to pay (WTP) approach. Of a range of health impacts from coal use, the paper is focused on mortality[2], which accounts for vast majority of health cost of coal use.

A number of studies demonstrate that the use of coal, from mining, transporting, processing, to burning, has tremendous and terrible health impacts on human being.(Falk and Jurgelski 1979, Pope III, et al. 1995, Epstein, et al. 2011). In comparison to extraction and transportation, coal combustion in coal-fired power plants emit the most toxic pollutants, including sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter(PM), carbon dioxide (CO_2), ozone (O_3), polycyclic aromatic hydrocarbons (PAHs)[3], mercury (Hg), lead (Pb) and others. Thus the paper concentrates on the health impact from coal combustion.

Coal consumption is the major factor to both outdoor air pollution in developing and developed countries(Huscher and Smith 2013) and indoor air pollution mainly in developing countries(Finkelman, Belkin and Zheng 1999). The causal association between coal consumption and air pollution varies in different countries, where coal may play a different role in energy mix. In China, coal has been the dominant energy source for decades. The percentage of coal in the annual national primary energy consumption has been at very high level, approximately three fourths. In 2012, 3.65 billion tons of coal was extracted, equal to 78% of annual primary energy production[4]. Nearly all extracted coal was consumed in the country. Most are fed into thousands of coal power plants to generate electricity. In China, assessing the public health impact of coal combustion can largely contribute to the understanding of the health cost of air pollution.

The paper examines the health impact of outdoor air pollution rather than of indoor air pollution. It is well known that long exposure to coal-driven air pollution may cause respiratory (asthma and chronic bronchitis), cardiovascular (heart attack), cerebrovascular, cancers (lung cancer), premature death and lifespan loss(Lockwood

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[1] VSL is a controversial economic approach to assess the value of human life. The paper is not to address the moral aspect of the debate, but to discuss the health impact burden or cost based on the existing literature. VSL means the sum of people's willingness to pay for mortality risk reductions. If each of 10,000 people are willing to pay 300 Chinese Yuan to reduce each person's risk of dying by 1 in 10,000, the VSL = 10,000 * 300 Chinese Yuan = 3 million Chinese Yuan.

[2] Its definition in the paper is the number of premature deaths.

[3] More information about PAHs and their health impacts, please check the webpage of U.S. EPA, link: http://www.epa.gov/waste/hazard/wastemin/minimize/factshts/pahs.pdf.

[4] The number is calculated based on the national statistical report 2012 by the National Bureau of Statistics of China. Link: http://www.stats.gov.cn/tjsj/tjgb/ndtjgb/qgndtjgb/201302/t20130221_30027.html. Accessed on 2nd February 2014.

2012). Outdoor air pollution from coal combustion has much more severe influences on public health than the indoor air pollution caused by domestic coal use, although in China the domestic coal use (for heating and cooking) also causes disastrous health burden for many rural communities(Finkelman, Belkin and Zheng 1999). While the contribution from household cook-fuels to anthropogenic primary $PM_{2.5}$(particulate matter of less than 2.5 µm in diameter) is undeniable(Smith 2013), the outdoor air pollution from coal combustion is still the overwhelmingly dominant threat to public health.

Mortality: unbearable health burden of outdoor air pollution

$PM_{2.5}$ is the most representative factor to study the health impact of air pollution as $PM_{2.5}$ has the worst impact on human health(United States Environmental Protection Agency 2012). Global Burden of Disease Study 2010 (The Lancet 2012), the most sophisticated analysis of global distribution and causes of a range of major diseases, injuries, and health risk factors, suggests that mortality from PM2.5 in China is 1.2 million in 2010(Smith 2013). After Beijing residents and environmental groups campaigned for the disclosure of air quality data in 2011 and 2012, the Ministry of Environmental Protection began to disclose the data of air quality index, including $PM_{2.5}$ and PM_{10} (particulate matter of less than 10 µm in diameter), in Beijing and other cities in 2013 onwards.

That mortality accounts for the vast majority of monetized cost of health impact from outdoor air pollution has been demonstrated in the studies from the United States (U.S.) and European Union (EU). A Clean Air Task Force study (Schneider and Banks 2010) estimates that PM air pollution from existing coal power plants in U.S. caused about 13,200 deaths in 2010 and 24,000 deaths in 2004, respectively. The decrease of death number is largely attributed to the decline of SO_2 emitted by coal power plants overall from 10.3 million tons in 2004 to 5.7 million tons in 2009. The monetized mortality cost is US$ 96.3 billion, accounting for 94% of total monetized health impact cost. Based on this study, VSL in U.S. is approximately US$ 7.3 million in 2010.

An EU study suggests that in 2009 coal power plants in the union caused chronic mortality in great: 196,218 life years lost, or 18,247 premature deaths. The attributed costs are 10,596 million Euro or 37,954 million Euro, respectively(Huscher and Smith 2013). In another word, on average, in 2009, the value of a life year (VOLY) was 54,000 Euro and VSL was about 2 million Euro. Of the health impact, the mortality accounts for the majority of monetized value. In term of VOLY, the share is 69%, and in term of VSL the share 89%.

The same result can be found in a research about China(The World Bank and SEPA 2007a). According to the study, the share of mortality cost in the overall health cost is 71% in 2003 under the adjusted human capital approach (AHC)[5], or 76% under VSL

[5] AHC approach assigns "the same value – per capita GDP- to a year of life lost by all persons, regardless of age, and can be viewed as a social statement of the value of avoiding premature mortality." (The World Bank and China EPA 2007, p71.)

approach[6]. With AHC approach, the mortality cost from outdoor air pollution in 2003 is 110.9 billion Chinese Yuan. With VSL approach, the cost is 394 billion Chinese Yuan in 2003, which was about 2.9% of 2003 Gross Domestic Product (GDP).

As a study(The World Bank and SEPA 2007a) demonstrates, the large-sample epidemiological cohort studies had not been carried out before 2006 in China. Most researches are cross-sectional ecological studies(Xu, Liu and Yu 1996, Jin, Qin and Xu 1999, Wang, Lin and Pan 2003). These studies are based on site-specific characteristics and don't consider such significant factors as socioeconomic conditions, which also affect mortality. Therefore, the study applies the results of cohort studies from U.S. (Dockery 1993, Pope III, et al. 1995, Pope III, et al. 2002) while discussing the issue in China context.

Life expectancy lost is another perspective to understand the deteriorating health burden from outdoor air pollution. A study (Chen, et al. 2013) compares the health risk of air pollution exposure between population of North China and of South China[7]. The different health risk, say, life expectancy, is attributed to the long-term arbitrary energy policy that provides free winter heating supply for the north rather than the south. The policy has significant impact on life expectancy of 500 million people living in North China, as the air quality of south is better than that of north. The economic modeling suggests that on average the life expectancy of northern population is 5.5 years shorter than that of southern fellow citizens.

Averted mortality: the benefits of addressing outdoor air pollution

Making air clean can bring huge health benefits. Studies show that a large number of premature deaths could be avoided even if moderate measures could be undertaken. A study(Mead and Brajer 2006) projects that if China's clean air standards (200 $\mu g/m^3$ (micrograms per cubic meter) of total suspended particulates (TSP), 60 $\mu g/m^3$ of SO_2 and 80 $\mu g/m^3$ of NO_2) were met, more than 138,000 deaths could be averted by 2012, which is valued at US$ 57 billion.

A study on health impact of air pollution under different energy mix scenarios in Shanghai, China's most developed urban area, estimates that 608-5144 and 1189-10462 PM_{10}-related deaths can be avoided in 2010 and 2020, respectively(Kan, et al. 2004). A similar study(Chen, Chen and Wang 2007) projects that under various low-carbon energy scenarios the PM_{10}-realted averted mortality in Shanghai could be 2804-8249 in 2010 and 9870 - 23,100 in 2020. Correspondingly, the economic benefits could reach US$0.5-1.5 billion in 2010 and US$2.6 - 6.2 billion in 2020.

Clean Air: phasing out coal

[6] VSL in 2003 is 1 million Chinese Yuan, approximately US$120,000 with exchange rate of 1:8.267 on 1st August 2003.
[7] China is divided into two parts by Huai River - Qinling Mountain Range Line. The upside of the line is North China, and the downside of the line South China.

The strong association of the health lost and coal consumption in China also indicates a very straightforward solution to win clean air back. That means China has to reduce coal consumption quickly and greatly.

However, China has to cope with the lock-in of coal consumption in energy system. It is not easy to get rid of coal addition in a short run. China's economic booming in 2005-2010 and weak environmental regulation explain why the air quality in most urban areas has been getting worse. China increased its thermal-power generation (nearly all of them coal power) by 63%, pig iron and cement production by 74% and 76%; national emission of SO2, mainly from coal combustion, only declined from 32.3 million tones in 2005 to 28.7 million tones in 2010(Zhang, He and Huo 2012). In another word, between 2005 and 2010, while coal production increased by 48%, from 2.19[8] billion tons in 2005 to 3.24 billion tons in 2010, the national SO_2 emission declined only by 11%.

In the World Bank study, which is based on PM_{10} –related air quality data, suggests that mortality from air pollution in China is approximately 700,000(the World Bank and SEPA 2007b). According to GBD 2010, which is based on $PM_{2.5}$ –related air quality data, the mortality reaches up to 1.2 million in 2010. In contrast, from 2003 to 2010, China annual coal production grew up by 94%, from 1.67 billion tons to 3.24 billion tons.

Capping the total national coal consumption has been discussed, especially since Chinese government took a range of policy measures to fight air pollution in September of 2013. For example, Hebei Province, has been requested to reduce coal consumption from 389 million tons in 2012 to 250 million tons in 2017.

Conclusion

By highlighting the mortality caused by outdoor air pollution, this literature review shows that air pollution largely driven by coal combustion has brought great public health burden to Chinese population. To large extent, the burden would be unbearable if coal consumption were not to decline significantly and rapidly. The seriousness of unbearable health burden can be better comprehended in new researches, for instance, societal distribution of air pollution-related mortality and its impact on well-being of marginal groups in the society. From this perspective, public health concern should be the most important factor in realizing a coal-exit strategy and pursuing a low-carbon energy system.

[8] All data of coal consumption come from the Annual Statistical Report of China Economy and Development. The series report can be checked out at http://www.stats.gov.cn/tjsj/tjgb/ndtjgb/qgndtjgb/.

Bibliography

Chen, C., B. Chen, and B. Wang. “Low-carbon energy policy and ambient air pollution in Shanghai, China: A health-based economic assessment.” *Science of the Total Environment* 373 (2007): 13-21.

Chen, Yuyu., Avraham. Ebenstein, Michael. Greenstone, and Hongbin. Li. “Evidence on the impact of sustained exposure to air pollution on life expentancy from China's Huai River Policy.” *Proceedings of the National Academy of Sciences* 110, no. 32 (August 2013): 12936-12941.

China, National Bureau of Statistics of. "China Statistical Annual Report." Beijing, 2003 & 2010.

Dockery, D.W., et al. “An association between air pollution and mortality in six U.S. cities.” *New England Journal of Medicine* 329, no. 24 (1993): 1753-9.

Epstein, R. P., et al. “Full cost accounting for the life cycle of coal.” *Annals of the New York Academy of Sciences* 1219 (February 2011): 73-98.

Falk, Hans L., and Jr. , William Jurgelski. “Health Effects of Coal Mining and Combustion: Carcinogens and Cofactors.” *Environmental Health Perspectives* 33 (1979): 203-226.

Finkelman, Robert B., Harvey E. Belkin, and Baoshan Zheng. “Health Impacts of Domestic Coal Use in China .” *Proceedings of the National Academy of Science of the United States of America* 96, no. 7 (March 1999): 3427-3431.

Goenka, Debi, and Sarath Guttikunda. *Coal Kills: An Assessment of Death and Disease Caused by India’s Dirtiest Energy Source.* Report, Conservation Action Trust, Urban Emissions, Greenpeace India, 2013.

Greenpeace. *The True Cost of Coal: Air Pollution and Public Health (in Chinese).* report, Beijing: Greenpeace, 2010.

Huscher, Julia, and Diana Smith. *The Unpaid Health Bill: How Coal Power Plants Make Us Sick.* Report, Brussels: The Health and Environment Alliance, 2013.

Jin, LB., Y. Qin, and Z. Xu. “Association between air pollution and mortality in Benxi.” *Chinese Journal of Public Health* 15, no. 3 (1999): 211-12.

Kan, Haidong, Bingheng Chen, Changhong Chen, Qingyan Fu, and Minghua Chen. “An evaluation of public health impact of ambient air pollution udner various energy scenarios in Shanghai, China.” *Atmospheric Environment* 38 (2004): 95-102.

Lockwood, Alan H. *The Silent Epidemic: Coal and the Hidden Threat to Health.* Cambridge: MIT Press, 2012.

Mead, RW., and V. Brajer. “Valuing the adult health effects of air pollution in Chinese cities.” *Annals of the New York Academy of Sciences* 1076 (2006): 882-892.

National Bureau of Statistics of China . *China Statistical Yearbook.* Beijing , 2006 & 2011.

Pope III, C. Arden, et al. “Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution.” *Journal of the American Medical Association* 287, no. 9 (2002): 1132-41.

Pope III, C. Arden., et al. “Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults.” *American Journal of Respiratory and Critical Care Medicine* 151 (1995): 669-74.

Schneider, Conrad, and Jonathan Banks. *The Toll from Coal.* assessment report, Boston: Clean Air Task Force, 2010.

Smith, Kirk R. “Kirk Smith's homepage .” *the school of public health at UC Berkeley.* 2013 йил 28-March .

http://ehs.sph.berkeley.edu/krsmith/Presentations/2013/CRAES%20Mar%2013.pdf (accessed 2014 йил 1-February).
The Lancet . *Global burden of disease* . 2012 йил 13-December . http://www.thelancet.com/themed/global-burden-of-disease (accessed 2014 йил 30-January).
the World Bank and SEPA. *Cost of Pollution in China: economic estimates of physical damages .* Report , Washington D.C.: The Word Bank , 2007b, 77.
The World Bank and SEPA. *Cost of Pollution in China: Economic Estimates of Physical Damages.* Report, Washington, D.C.: The World Bank, 2007a.
United States Environmental Protection Agency. *Provisional Assessment of Recent Studies on Health Effects of Particulate Matter Exposure.* Report , Research Triangle Park: US EPA, 2012.
Wang, H., G. Lin, and X. Pan. "Association between total suspended particles and cardiovascular disease mortality in Shenyang(in Chinese)." *Journal of Environment and Health* 20, no. 1 (2003): 13-15.
Xu, ZY., Y. Liu, and D. Yu. "Effect of air pollution on mortality in Shenyang City." *Chinese Journal of Public Health* 15, no. 1 (1996): 61-64.
Zhang, Qiang., Kebin. He, and Hong. Huo. "Policy: Cleaning China's Air." *Nature* , 2012 йил 11-April : 161-162.