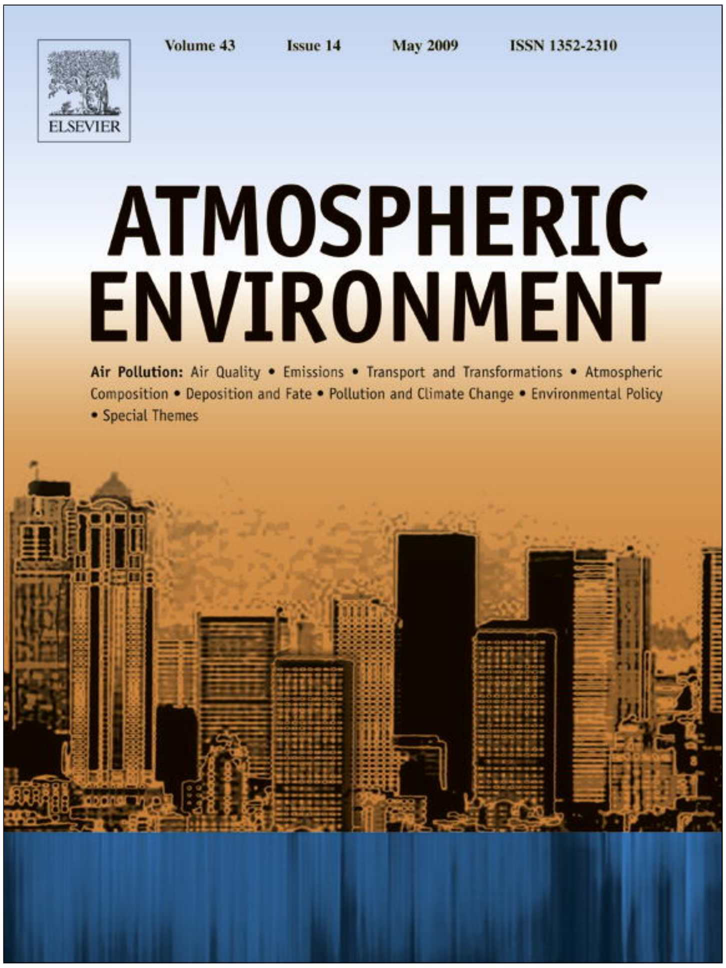
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Short communication

Lung cancer mortality and exposure to atmospheric aerosol particles in Guangzhou, China

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ABSTRACT

In recent years, China and other emerging countries have been experiencing severe air pollution problems with high concentrations of atmospheric aerosol particles. Satellite measurements indicate that the aerosol loading of the atmosphere in highly populated regions of China is about 10 times higher than, for example, in Europe and in the Eastern United States. The exposure to extremely high aerosol concentrations might lead to important human health effects, including respiratory and cardiovascular diseases as well as lung cancers. Here, we analyze 52-year historical surface measurements of haze data in the Chinese city of Guangzhou, and show that the dramatic increase in the occurrence of air pollution events between 1954 and 2006 has been followed by a large enhancement in the incidence of lung cancer.

1. Introduction

Since 1980s, air pollution has become a major problem in areas affected by rapid population growth and economic development. The economic development of China, for example, has been accompanied by the emergence of several megacities with enhanced consumption of energy, increased emissions of air pollutants, and dramatic degradation of air quality. In 2005, the urban population in China represented 40.5% of the total Chinese population, compared to 19.6% in 1980 (Chan and Yao, 2008). In 2004, 170 cities had more than 1 million permanent residents. In the Chinese city of Guangzhou (population of about 10 million), for example, the usage of fossil fuel (coal and crude oil), which represented 263 Mtons (million tons) in 1973, has reached a value of 823 Mtons (IEA, 2004) in 2002. This rapid increase in fossil fuel usage in the urban area has led to enhanced emissions of pollutants (e.g., CO_2 ozone precursors), as well as increased atmospheric concentrations of aerosol particles. Satellite observations show that the concentrations of aerosols and gaseous pollutants have become extremely high in Central and Southern China during the last decades (Richter et al., 2005; Tie et al., 2006; Wu et al., 2006; Zhang et al., 2006). These high concentrations of aerosol particles are believed to induce oxidative damage to human DNA, resulting in significant effects for human health (Lave and Seskin, 1970; Vineis and Husgafvel-Pursiainen, 2005; Peluso et al., 2005). High levels of ozone that usually occur together with high aerosol pollution events generate additional health problems (e.g., Jerrett et al., 2005; Abbey et al., 1999). Although the biological mechanisms involved may not be fully understood, there is statistical evidence that air pollution provides a considerable risk for respiratory morbidity and cardio-pulmonary mortality (Cohen et al., 1997). It is also associated with the incidence of lung cancers (Nesnow and Lewtas, 1981) since the particles released by diesel engines, for example, are believed to have mutagenic and carcinogenic properties (Pope et al., 1995).

2. Method and results

Here, we examine long-term records of aerosol particles and lung cancer incidence in the city of Guangzhou to infer a statistical relationship between the abundance of atmospheric aerosol particles and the incidence of lung cancers in this particular megacity. Such statistical relationship does not provide conclusive evidence that the presence of atmospheric aerosols is the leading factor responsible for lung cancer occurrence, but suggests that some causal relationship is possible. Lung cancer is known to be a leading cause of deaths, resulting to a large extent from cigarette smoking by individuals (Forastiere, 2004; Pope et al., 2004). Medical studies show that the exposure to high concentrations of fine particles produced, for example, by vehicles, industry, and power plants, can also raise the likelihood of developing lung cancers by individuals (Parent et al., 2007; Pope et al., 2002). To assess the possible impact of urban pollution on the incidence of

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lung cancers, we examine a long-term (1954–2005) series of aerosol optical extinction coefficients (AEC) in the city of Guangzhou derived from routine observations of atmospheric visibility at the city station. Since the concentrations of particle matter (PM) are not available, we derive the AEC ($Mm^{-1} = 10^{-6}\ m^{-1}$) from observations of visibility after having filtered out the observations during fog days. Deng et al. (2008) find goof correlation between visibility and AEC under these conditions (see also Seinfeld and Pandis, 1998). We assume therefore that AEC is a good indicator of the PM concentration.

Recent field measurements suggest that about three quarters of the optical depth is caused by particles with a radius of less than 1.0 μm (Deng et al., 2008). Fine particles penetrate in the lungs more easily than the larger particles, and are therefore believed to more easily generate lung cancer tumors (Forastiere, 2004). As shown by Fig. 1 (upper panel), the evolution of the AEC during the 1954–2005 timeframe is characterized by three successive periods. Between 1954 and 1972, the AEC is very low and is generally smaller than 150 Mm^{-1}. Between 1972 and 1980, the AEC rapidly increases, with values reaching about 300 Mm^{-1} in 1980. Finally, between 1980 and 2005, the AEC values remain high, and are characterized by small annual variations. Fig. 1a also shows that the rate of cigarette smoking (defined by total consumption of cigarettes per person per year) in Guangzhou does not exhibit any significant long-term trend from 1954 to 2006 (Hu et al., 1988).

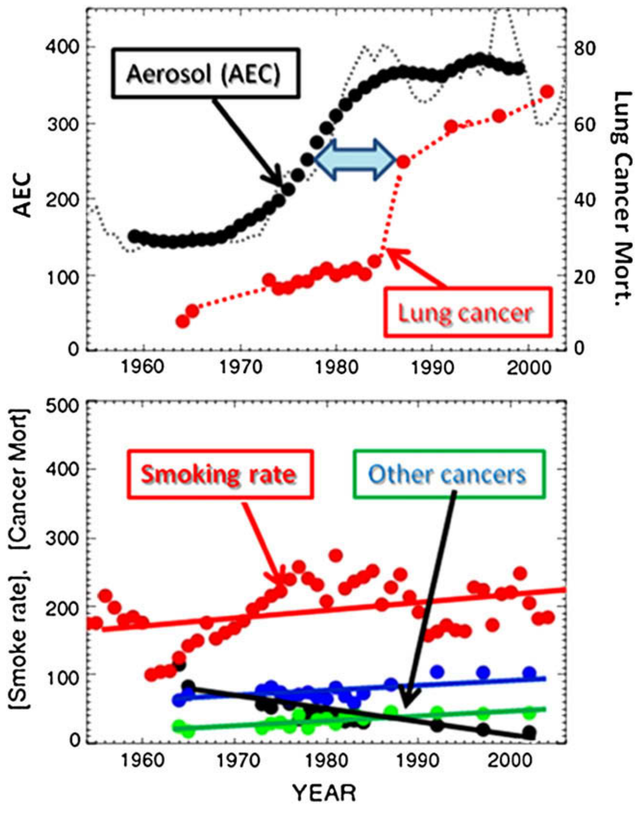

Fig. 1. Upper panel: time evolution (1954–2006) of aerosol extinction coefficient (AEC (Mm^{-1}) (red dotted-line)), and its 10-year running mean values (black dots). The AEC can be categorized by three successive periods; (1) Between 1954 and 1972, the AEC is very low; (2) between 1972 and 1980, it increases rapidly; and (3) between 1980 and 2005, its value remains high and is characterized by some annual variations. Time series (1964–2002) of mortality of lung cancer (red dots; deaths/100,000 people). The double arrow indicates the time lag (year) between the trend of aerosol and mortality of lung cancer. Lower panel: time series (1964–2002) of mortality due to other cancers (deaths/million people); i.e., nasopharyngeal (blue dots-line), leucocythemia (green dots-line), and cervical cancers (black dots-line). The rate of cigarettes smoking (number/people/year) for the period 1954–2006 is shown by the red dots-line. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A long-term statistical record from 1964 to 2006 suggests that the mortality due to lung cancer in Guangzhou is closely correlated with the levels of aerosol particles present in the atmosphere near the surface (He and Liu, 2006; Guangzhou Statistic Bureau, 2006). As highlighted by Fig. 1, the incidence of lung cancer is low between 1954 and 1972 with 10 (deaths/100,000), but increases to 20 (deaths/100,000) between 1972 and 1980 and at beginning of the 1980s. After 1980, it reaches values as high as 50–70 (deaths/100,000). No similar relationship is found in the case of other cancers such as nasopharyngeal, leucocythemia, and cervical cancers (as highlighted in Fig. 1). Note that the rate of cigarette smoking in Guangzhou remains relatively constant from 1954 to 2006, so that the observed increase in the number of incidences resulting from lung cancers since 1980 cannot be associated with changing smoker's behavior. Moreover, the starting point for the rapid increase in lung cancer mortality takes place in 1986–1987, and lags by about 6–7 years the rapid increase in the concentration of atmospheric aerosol particles. Chen et al. (2003) reported a statistical analysis of lung cancers induced by air pollution in the city of Hangzhou, China (H-city). They derived that the latent periods of lung cancers induced by total suspended particles are 7 years. Because the occurrence of lung cancer requires a long time of exposure to the fine particles (Pope et al., 2004), the rapid variations in aerosol level do not have significant effects on the illness. Therefore, in the following analysis, we filter out the small time scales in the aerosol concentration, and use a smoothed value of the AEC (10-year moving average) in correlation to the yearly averaged value of cancer mortality. In order to better quantify the statistical relationship between lung cancer mortality and aerosol abundance (AEC), we derive the correlation coefficient between mortality and AEC for different time lags (years), and calculate the sensitivity ($A = \Delta[\text{mortality}]/\Delta[\text{AEC}]$), which ranges from 0.17 to 0.22 for different cases. The result (in Table 1) shows that the highest correlation coefficient is found for a time lag of about 7–8 years. Thus, this time lag is similar to the value derived by Chen et al. (2003). The correlation between the smoothed AEC and lung cancer mortality is shown in Fig. 2 with no time lag and when for a 7-year time lag is considered. This figure clearly shows that lung cancer mortality and AEC are better correlated when a time lag of 7 year is adopted.

3. Summary

In summary, there is good statistical evidence for a relationship between the degradation of air quality and the mortality associated with lung cancers in a highly polluted megacity such as Guangzhou in Southern China. We should emphasize, however, that substantial errors could be associated with the data that have

Table 1
Statistical relationship (correlation coefficient) between AEC (Mm^{-1}) and the mortality by lung cancer for different time-lags (year).

Lag (year)	Correlation coefficient
0	0.72
1	0.77
2	0.80
3	0.88
4	0.91
5	0.94
6	0.96
7	0.97
8	0.97
9	0.96

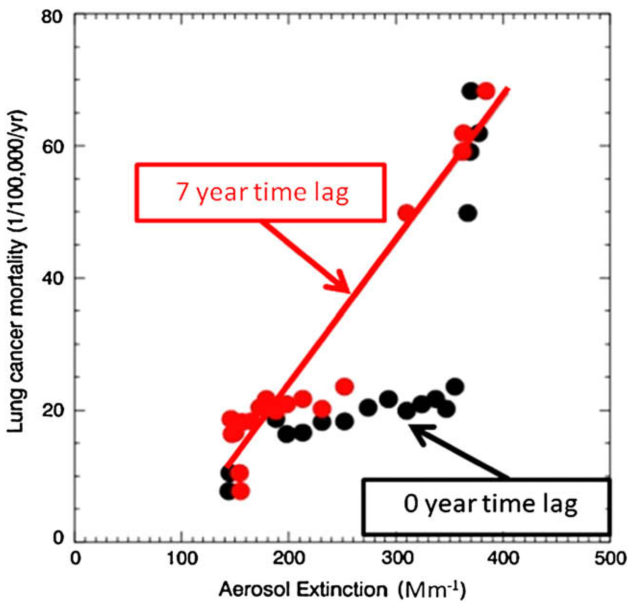

Fig. 2. Correlation between the 10-year running mean AEC (Mm^{-1}) and the mortality (#/100,000/year) by lung cancer with 7-year lag (red dots-line), and with no-time lag (black dots). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

been collected during periods characterized by rapid changes in the economy and the medical conditions. Therefore our study cannot be fully conclusive due to the limited amount of reliable data and the lack of information on other risk factors that could affect our conclusions. We were not able, for example, to adjust our results for factors such as age, education, occupation groups, population migration, indoor conditions, smoking factors, etc. Only a slight increase in the rate of smokers was noticed during the period under consideration. Additional information is therefore needed and more sophisticated analyses of air pollution and medical records in different highly polluted cities of the world should be performed since several studies suggest that the death rate due to lung cancer appears to increase under polluted conditions. Finally, the possible association between air pollution and lung cancers in less polluted regions such as the urban areas of Europe and North America (Vineis and Husgafvel-Pursiainen, 2005) also needs further studies.

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References

Abbey, D.E., Nishino, N., McDonnell, W.F., Burchett, R.J., Knutsen, S.F., Beeson, W.L., Yang, J.X., 1999. Long-term inhalable particles and other air pollutants related to mortality in nonsmokers. Am. J. Respir. Crit. Care Med. 159 (2), 373–382.

Chan, C.K., Yao, X., 2008. Air pollution in mega cities in China. Atmos. Environ. 42, 1–42.

Chen, S.X., Li, L., Zhou, L., 2003. Quantitative study by grey system on the latent period of lung cancer induced by air pollutants. Chin J. Epidemiol. Chin. 24, 233–235.

Cohen, A.J., Pope III, C.A., Speizer, F.E., 1997. Ambient air pollution as a risk factor for lung cancer. Salud Publica Mex. 39. doi:10.1590/S0036-36341997000400012.

Deng, X.J., Tie, X., Wu, D., Zhou, X.J., Tan, H.B., Li, F., Jiang, C., 2008. Long-term trend of visibility and its characterizations in the Pearl River Delta Region (PRD), China. Atmos. Environ. 42, 1424–1435.

Forastiere, F., 2004. Fine particles and lung cancer. Occup. Environ. Med. 61, 797–798.

Guangzhou Statistic Bureau (GSB), 2006. Year-Book of Statistics in the City of Guangzhou. Chinese Statistic Publisher (in Chinese).

He, T.H., Liu, Q., 2006. Statistics and trends of major cancers from 1980–2004 in Liwan, of Guangzhou. Chin. Cancer 15, 650–652 (in Chinese).

Hu, M.X., Gou, H.R., Huang, X.L., 1988. Statistics and trends of major cancers from 1964–1984 in Guangzhou. Chin. Health Stat. 5, 12–16 (in Chinese).

IEA, 2004. Key World Energy Statistics. International Energy Agency.

Jerrett, M., Burnett, R.T., Ma, R.J., Pope, C.A., Krewski, D., Newbold, K.B., Thurston, G., Shi, Y.L., Finkelstein, N., Calle, E.E., Thun, M.J., 2005. Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology 16 (6), 727–736.

Lave, L.B., Seskin, E.P., 1970. Air pollution and human health. Science 169, 723–733.

Nesnow, S., Lewtas, J., 1981. Mutagenic and carcinogenic potency of extracts of diesel and related environmental emissions: summary and discussion results. Environ. Int. 5, 393–401.

Parent, M., Rousseau, M., Boffetta, P., Cohen, A., Siemiatycki, J., 2007. Exposure to diesel and gasoline engine emissions and the risk of lung cancer. Am. J. Epidemiol. 165 (1), 53–62. doi:10.1093/aje/kwj343.

Peluso, M., et al., 2005. DNA adducts and lung cancer risk: a prospective study. Cancer Res. 65, 8042–8048.

Pope III, C.A., Dockery, D.W., Schwartz, J., 1995. Review of epidemiological evidence of health effects of particulate air pollution. Inhal. Toxicol. 7, 1–18.

Pope III, C.A., Burnett, R.T., Thun, M.J., et al., 2002. Lung cancer, cardiopulmonary ortality, and long-term exposure to fine particulate air pollution. JAMA 287, 1132–1141.

Pope III, C.A., Burnett, R.T., Thurston, G.D., et al., 2004. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. Circulation 109, 71–77.

Richter, A., Burrows, J.P., Nüß, H., Granier, C., Niemeier, U., 2005. Significant increase in tropospheric nitrogen dioxide over China observed from space. Nature 437, 129–132.

Seinfeld, J., Pandis, S., 1998. Atmospheric Chemistry and Physics. John Wiley & Sons, Inc., NewYork.

Tie, X., Brasseur, G., Zhao, C., Granier, C., Massie, S., Qin, Y., Wang, P.C., Wang, G.L., Yang, P.C., 2006. Chemical characterization of air pollution in Eastern China and the Eastern United States. Atmos. Environ. 40, 2607–2625.

Vineis, P., Husgafvel-Pursiainen, K., 2005. Air pollution and cancer: biomarker studies in human populations. Carcinogenesis 26, 1846–1855. doi:10.1093/carcin/bgi216.

Wu, D., Tie, X., Deng, X., 2006. Physical and chemical characterizations of soluble aerosols in southern China. Chemosphere 64, 749–757.

Zhang, Q., Zhao, C., Tie, X., Wei, Q., Li, G., Li, C., 2006. Characterizations of aerosols over the Beijing Region: a case study of aircraft measurements. Atmos. Environ. 40, 4513–4527.