

**Air Pollution Shortens Life Expectancy and Health Expectancies
for Older Adults: The Case of China.**

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BACKGROUND

Recent three decades have witnessed China's magnificent economic development in the reform era. While rapid industrialization and urbanization improved many of the country's citizens' standards of living, the ensuing unwelcomed environmental effects have led to a legitimate public health and environmental justice concern. Among a variety of environmental risks in China, outdoor air pollution is one of the most worrying and is among the worst in the world. It is estimated that outdoor air pollution led to about 470,000 premature deaths in China in 2000. Despite frequent media coverage and increasing scholarly writings on China's environmental threats, little comprehensive analysis of the environment and health link is available. A handful of studies relied on ecological data which are inevitably subject to ecological fallacy considering the key interest is to quantify a causal effect of environmental risks on individual health outcomes. Multilevel study designs and multilevel statistic methods are thus appropriate to address this type of research questions.

STUDY PURPOSE

Using a nationally representative longitudinal data of older adults in China, this study examined how exposure to outdoor air pollution contextually affects individuals' life expectancy and health expectancy net of socio-demographic factors including age, gender, urban or rural residential location, education, financial independence, marital status, and community economic resources.

METHODS

Study population

This study used data from the third and fourth waves of the Chinese Longitudinal Health Longevity Survey (CLHLS) in 2002 and 2005. The CLHLS, which initiated in 1998, only included seniors aged 80 or above for the first two waves, covered 22 provinces in China where more than 85% of the national population resided. Starting from 2002, the third wave of the CLHLS added younger elders aged 65-79 in addition to those followed-up respondents, resulting in a sample size of 15,940. All information was obtained through in-home interviews. Systematic assessments of the CLHLS indicate that the data quality is high (Gu, 2008; Gu, & Dupre, 2008; Zeng & Gu, 2008).

Measurement

Death rates

In order to calculate life expectancies, we need to estimate the age-sex-specific death rate first. The death rates were estimated from proportional Cox hazard models after treating age and air pollution as covariates stratified by gender. The CLHLS collected the interview date of the follow-up wave in 2005 for those survivors and the date at death for those died before the follow-up wave, which enables us to use the classic hazard regression to estimate the death rates.

Life expectancies and health expectancies

With sex-age-specific death rates calculated, we constructed a life table and estimated the life expectancies. The sex-age-specific death rates and life expectancies in the CLHLS datasets from 2002 to 2005 are close to those in the 2000 census (see Figure 1). Thus, we did not make any adjustment for mortality in the CLHLS.

Based on previous research (Hayward & Warner, 2005; Robine et al., 2003), we employed Sullivan's method to estimate IADL-disability-free life expectancy, ADL-disability-free life expectancies (a.k.a, ALE), cognitive impairment-free life expectancy, healthy life expectancy (HLE, measured by SRH), and disease-free life expectancy (DFLE). The common formula to calculate health expectancy is

$$HE_x = \frac{x \sum_{\omega} L_x^h}{l_x} = \frac{x \sum_{\omega} L_x h_x}{l_x},$$

(see Lamb & Siegel, 2004), where HE_x represents health expectancy; l_x the number of living persons in the life table at age x ; L_x is person-years lived at age x ; h_x is the prevalence of a healthy state (e.g., ADL active) at age x ; Lh_x is person-years lived in a healthy state at age x . Using the Sullivan method, expected years in

IADL or ADL disability-free, cognitive impairment-free, good or excellent SRH, and disease-free states were calculated by applying the corresponding cross-sectional age–sex specific prevalence rates in 2002 to the person-years lived in different age categories derived from period life tables from 2002 to 2005.

Health conditions

Health conditions were measured by five variables capturing several key dimensions of health: Activities of Daily Living (ADL), Instrumental Activities of Daily Living (IADL), cognitive impairment, self-rated health, and chronic disease conditions.

ADL refers to ability to perform any of the following basic personal-care activities: (a) bathing, (b) dressing, (c) eating, (d) indoor transferring, (e) toileting, and (f) continence. Since its distribution was highly skewed in this sample, with 66% reporting no difficulty performing any of these activities, we dichotomized it into “disabled” (having at least one ADL limitation) and “no limitation,” with the latter as the reference category).

IADL refers to ability to perform any of the following items: (a) visiting neighbors, (b) shopping, (c) cooking, (d) washing clothes, (e) walking one kilometer, (f) lifting five-kilograms, (g) crouching and standing up three times, and (h) taking public transportation. Choices for each item were: “able to do without help,” “need some help,” and “need full help.” In a similar vein, we dichotomized IADL into disabled (having at least one IADL limitation) and non-disabled.

Cognitive impairment was measured by the Mini-Mental Status Examination (MMSE) (Foldstein et al., 1975), which covers the following aspects of cognitive functioning: orientation, registration, duplication and design, calculation, recall, naming, and language, with a total score ranging from 0 to 30. It was adapted to the cultural and socioeconomic conditions in China (Zeng & Vaupel, 2002). Following the criterion of Foldstein et al (1975) and classification by previous Chinese study (Zhang, 2006), we classified the respondents into cognitive impaired (score less than 18) and cognitive unimpaired.

Self-rated health (SRH) has been shown to be an effective measure of individual health status and has a strong predictive power of comorbidity and mortality (Idler & Benyamini, 1997). It is assessed by a general question: “In general, would you say your health is: (1) very good, (2) good, (3) so so, (4) bad, or (5) very bad?” Because the distribution is skewed (choices of (4) and (5) account for less than 15% of the whole sample), we combine the responses into the following two categories: “poor” (combining (3) to (5)) and “good” (combining (1) and (2)), with the latter as the reference category.

The CLHLS collected information on more than 20 chronic disease conditions (including but not limited to hypertension, stroke, heart diseases, cerebrovascular disease, pneumonia, and arthritis). For this analysis, we operationalized chronic disease as having at least one disease (coded 1) compared to no diseases. Comparisons of prevalence rates in the CLHLS with other external nation-wide surveys indicated that data on chronic conditions were valid and reliable (Zeng et al., 2008).

Air pollution measures

Air pollution was measured by the Air Pollution Index (API) at the prefecture or city level, shared by districts within the same prefecture or city. API is widely used in environmental research as a measure of the general air pollution (Cui et al., 2003; WHO, 2003). It assesses the concentration of three pollutants: sulfur dioxide (SO₂), nitrogen dioxide (NO₂), and inhalable particulates (consisting of particulate matter less than 10 microns in diameter (PM₁₀), carbon monoxide (CO), and ozone (O₃)) (see Appendix A for details). They are among the most common air pollutants found in China as well as other developing countries (Krzyzanowski & Schwela, 1999; Tseo et al., 1991; Xu, 1998). APIs in this analysis were obtained from the Chinese Natural Resources Database (<http://www.naturalresources.csdb.cn/zy/english/database.asp>), which is managed by the Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences. Given that the health outcome variables examined in this study reflect general health status rather than immediate, specific health responses, we used APIs for the year of 1995 to take into account the chronic or lagged response to air pollution. Research has shown that air pollution could yield significant mid- or long-term effects on health or mortality, but this time lag has been largely overlooked in the literature (Schikowski et al., 2007). API is graded from 1 to 7 with lower scores indicating better quality.

Statistical analysis

Two multilevel models were fit for all the dependent variables including mortality and five health outcomes. Model I only controlled for age and API stratified by sex; and Model II controlled for individual's socioeconomic status measured by whether living in an urban area, financial independence, years of education, marital status and per capita GDP at the contextual level (i.e., county or city district). In the survival analysis where death was the outcome variable, we coded age into seven five-year groups and treated it as a categorical variable because the continuous form will distort the established age pattern at very old ages. For the five health outcomes, we used multilevel logistic regression to estimate the prevalence of disability, impairment, and disease conditions. These prevalence rates of un-healthy condition were finally converted to prevalence of health condition when we estimated health. All analyses were conducted using STATA 10.0.

RESULTS

Table 2 shows air pollution is a significant risk factor of mortality for women and its impact is not due to individual socio-demographic factors or community economic resources. Air pollution did not appear relevant for men. Table 3 shows coefficients of multilevel logistic models of health conditions. For both men and women, air pollution strongly increases risks of health problems and these effects are over and above individual characteristics and community economic resources.

Table 4 illustrates life expectancies estimated by the survival analyses for each age stratum stratified by gender. Two areas of different pollution levels are illustrated, with an API of 2 representing much less populated areas compared to an area of API of 6. Recall the range of API is from 1 (least polluted) to 7 (most polluted). We picked areas of API of 2 versus API of 6 to avoid extreme cases. For each age stratum, for men and women, life expectancies in areas of API of 2 were greater than those of API of 6. In absolute value, the reduction in life expectancy corresponding to air pollution decreased for older groups (see the third column of Table 4). However, proportionally speaking, the detrimental effects of air pollution were actually greater for older groups in general. The air pollution effect was considerably greater for women compared to men although men's life expectancies were also negatively affected by air pollution. These patterns continued to hold after individual socio-demographic factors and community economic resources were accounted for. The largest gap in health expectancy between lightly polluted and heavily polluted areas was 3.78 years for women of age 65. Table 5 shows the contributions of air pollution to reductions in health expectancies. This time, the patterns were even clearer. Air pollution negatively corresponded to health expectancy for each of the five health conditions and the reductions in health expectancy were monolithically increasing for older groups. And again, the pollution effects were greater for women's health expectancies than men's. The largest gap in health expectancy between lightly polluted and heavily polluted areas was 5.26 years based on ADL for women of age 65.

Figure 2 graphically shows the pollution effects on mortality. The survival curve was obviously better in lightly polluted areas (API2) compared to that in heavily polluted areas (API6). Although the pattern is consistent across genders, the gap between the heavily polluted versus lightly polluted areas was more remarkable for women, which is consistent with the analytical result where for men the pollution effect was not statistically significant. Lastly, Figure 3 illustrates the pollution effects on health expectancies. The general patterns that air pollution corresponded to reductions in health expectancy were consistent across the specific health outcomes and there were no apparent gender differences detected for these conditions. That said, the largest impact of air pollution seemed to be on ADL. Nuanced age differences in the pollution effects were observed for IADL, ADL, and cognitive impairment, where health expectancies were most affected somewhere between 80 and 90 years old. No apparent age patterns in the pollution effects on health expectancy were found for self-rated health and chronic conditions.

CONCLUSION

This study is among the first to quantify the contribution of air pollution to reduced life expectancy and health expectancy in China, using a nationally representative sample of older adults recently collected. Net of

the impacts of individual socio-demographic factors and community economic resources, exposure to outdoor air pollution directly corresponded to a reduction of life expectancy and greater reductions of health expectancies based on IADL, ADL, self-rated health, cognitive impairment, and chronic conditions. These detrimental pollution effects seemed to be stronger for women than men although for men the pollution effect on life expectancy was in the same direction and the pollution effects on health expectancies were statistically significant. The largest gap in health expectancy between lightly polluted and heavily polluted areas was 3.78 years for women of age 65. And the largest gap in health expectancy between lightly polluted and heavily polluted areas was 5.26 years based on ADL for women of age 65. Adding up to the population level, these human and health costs are tremendous posing serious threats to human and economic development in China. The detrimental health effects of environmental pollutions in China need to be urgently addressed.

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APPENDIX

Appendix A: API definition and classification

The National Environmental Monitoring Center, China, collects information to construct API based on the following pollutant concentrations: SO₂, NO₂, and inhalable particulates (including PM₁₀, CO, and O₃). A sub-API is calculated daily for each pollutant concentration according to the criteria shown in Table A. Then the maximum of all sub-APIs is taken as the daily API of the city. The yearly API, which is the average of daily APIs for a given year, is released by the Ministry of Environmental Protection of China, which classifies air quality into seven categories based on the yearly API with a score from 1 to 7: Excellent (API 0-50), good (API 51-100), slightly polluted (API 101-150), light polluted (API 151-200), moderately polluted (API 201-250), moderately heavily polluted (API 251-300), and heavily polluted (API>300). Please refer <http://www.sepa.gov.cn/english/airqualityinfo.htm> for more information.

Table A. The API value and corresponding pollutant concentrations

Pollution Index	Pollutant Concentrations (mg/cubic meter)				
	SO ₂ (daily average)	NO ₂ (daily average)	PM ₁₀ (daily average)	CO (hourly average)	O ₃ (hourly average)
50	0.050	0.080	0.050	5	0.120
100	0.150	0.120	0.150	10	0.200
200	0.800	0.280	0.350	60	0.400
300	1.600	0.565	0.420	90	0.800
400	2.100	0.750	0.500	120	1.000
500	2.620	0.940	0.600	150	1.200