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# Industrial water pollution, water environment treatment, and health risks in China☆

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ABSTRACT

The negative health effects of water pollution remain a major source of morbidity and mortality in China. The Chinese government is making great efforts to strengthen water environment treatment; however, no studies have evaluated the effects of water treatment on human health by water pollution in China. This study evaluated the association between water pollution and health outcomes, and determined the extent to which environmental regulations on water pollution may lead to health benefits. Data were extracted from the 2011 and 2013 China Health and Retirement Longitudinal Study (CHARLS). Random effects model and random effects Logit model were applied to study the relationship between health and water pollution, while a Mediator model was used to estimate the effects of environmental water treatment on health outcomes by the intensity of water pollution. Unsurprisingly, water pollution was negatively associated with health outcomes, and the common pollutants in industrial wastewater had differential impacts on health outcomes. The effects were stronger for low-income respondents. Water environment treatment led to improved health outcomes among Chinese people. Reduced water pollution mediated the associations between water environment treatment and health outcomes. The results of this study offer compelling evidence to support treatment of water pollution in China.



## 1. Introduction

Since the 1970s, China has experienced dramatic environmental degradation, including water pollution, as a by-product of rapid economic development and industrialization (Ministry of Environmental Protection, 2015). Pollutant discharge causes widespread organic pollution, toxic pollution, and eutrophication, along with severe ecological destruction (Miao et al., 2012). For example, the latest review showed that the Tonghui River and Guanting Reservoir of Beijing, Minjiang River Estuary and Wuchuan River in China had comparatively higher ranges and mean values of dichlorodiphenyltrichloroethanes (DDTs) and hexachlorocyclohexanes (HCHs) in water (Ahmed et al., 2015). Concurrent with the water pollution, the country has also experienced an increase in health risks (Lu et al., 2015). Approximately 190 million people fall ill and 60,000 people die from a range of other diseases and injuries associated with water pollution each year (Tao and Xin, 2014).

The health impacts of water pollution are of increasing concern for Chinese citizens and policymakers, and the unaddressed health consequences at regional and global levels pose major policy challenges (Lu et al., 2008; Miao et al., 2015). Over 70 percent of Chinese people feel threatened by water pollution (China Youth Daily, 2013). The country has stepped up its efforts to tackle the problem (Zhang et al., 2012, 2013). Generally, increasing environmental awareness coupled with more stringent regulation standards has triggered various industries to challenge themselves in seeking appropriate wastewater treatment technologies (Teh et al., 2016a).

Researchers have reported connections between water pollution and acute water-borne diseases which include hepatitis, cholera, dysentery, cryptosporidiosis, giardiasis, diarrhea and typhoid (WB-SCEA, 2006; Cutler and Miller, 2005; Jalan and Ravallion, 2003; Roushdy et al., 2012), and also, the increasing negative effects of water pollution have put more people at risk of carcinogenic diseases, potentially contributing to cancer villages (Lu et al., 2015; Lin et al., 2000; Morales-Suarez-Varela et al., 1995;

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Ebenstein, 2012). Much of what we know about the marginal effects of pollution on health is derived from data reported in developed countries, where pollution levels are relatively low. Compared to developed countries, health risks related to water pollution in developing countries are more serious. About 2.3 billion peoples in the whole world are suffering from water related diseases. Among them, 2.2 billion people live in developing countries (e.g. India, Pakistan) (Jalan and Ravallion, 2003; Azizullah et al., 2011). Given the low levels of water pollution in developed countries, these estimates may not be valid in developing countries if there is a nonlinear dose relationship between pollution and health. Moreover, to our best knowledge, no other study has analyzed the health effects of environmental treatment in China.

Using nationally representative data, this study examined the effects of industrial water pollution and related environmental regulations pertaining to water pollution on individual health outcomes in China. To be specific, this study makes three major contributions to the existing literature. First, by exploiting treatment-induced changes in water pollution, it addresses a policy-relevant question: to what extent does environmental treatment in developing countries lead to improved health outcomes? This is the first study to evaluate the effects of water pollution treatment on human health in China. Second, this study contributes to our understanding of the relationship between water pollution and health outcomes in a developing country with high water pollution levels using nationally representative individual data. According to the 2012 Environmental Performance Index from Yale University, China is one of the worst performers (ranked 116th of 132 countries). Thus, findings in China provide compelling evidence applicable to the unique context of developing countries where water pollution levels are relatively high. Third, although previous research in other countries has linked health disparities to socioeconomic status, much less is known about differences in health outcomes due to exposure to water pollution (Zhang et al., 2010). Diseases related to pollution remain a major source of health problems, especially among people of low socioeconomic status in China; the significant income-related health disparities in China may partly result from different exposures to polluted water (Zhang et al., 2010). Thus, the present study aims to identify vulnerable populations, which may be useful for policy design.

## 2. Data and methods

### 2.1. Water pollution data

This study investigated 51 sample cities that (a) were distributed nationwide and representative of China's various geographical locations and climatic conditions; (b) varied in population and economic scales; and (c) were part of China's collection of environmental protection pilot cities, from which data on environmental pollution is collected yearly by the Chinese Ministry of Environment Protection; thus the data from these 51 cities have strong reliability and robustness.

Pollution intensity refers to the indicator of pollution emission per industrial gross domestic product. Per industrial gross domestic product represents industrial economic output and eliminates the effects of population scale. In accordance with previous environmental research, pollution intensity was selected as a pollution indicator to measure the effects of pollution on health outcomes (Tang and Mudd, 2015). Concentrations of lead (Pb), arsenic (As), mercury (Hg), chemical oxygen demand (COD), ammonia nitrogen ($NH_3$-N), and volatile phenol (Fn) per industrial gross domestic product were also used to measure water pollution. These indicators of the liquid phases of pollutants can be used to map a city's industrial water pollution. Moreover, these types of pollutants are consistent with official statistical indicators. Sequential data on the emissions of such pollutants in 51 cities were obtained from the 2011 and 2013 China Environment Yearbook. Industrial gross domestic product and populations within the same time sequence were obtained from the China City Statistical Yearbook.

According to the method described by Managi and Kaneko (2009), the efficiency in terms of water pollution treatment at the city level was calculated as:

$$TFP(L) = TFP_B(L) - TFP_A(L) \quad (1)$$

Where *TFP(L)* is the environmental management productivity, $TFP_A(L)$ is calculated based on the Luenberger productivity index (the Luenberger productivity index is $TFP(L) = (1/2) \times \{[D^t_i(t) - D^t_i(t+1)] + [D^{t+1}_i(t) - D^{t+1}_i(t+1)]\}$, where $D^t_i(t)$ denotes the total factor productivity measured by a sequential slack-based directional distance function (SSDDF)), which includes only market inputs and outputs,[2] and $TFP_B(L)$ is calculated based on the Luenberger productivity index, which includes environmental inputs and outputs in addition to the market inputs and outputs.[3] $TFP(L) > 0$ represents productivity progress in terms of environmental management. The environmental management productivity, which describes the relationship between the outputs and inputs of environmental management, is widely considered to be cost-effective environmental economic instrument for pollution control (Lannelongue et al., 2015). Such a continuous measure could capture the difference in intensity of water pollution treatment among cities.

### 2.2. Health outcomes and demographic data

This study used data from the 2011 and 2013 China Health and Retirement Longitudinal Study (CHARLS). The CHARLS is a nationally representative sample of Chinese residents aged 45 years and above. The baseline national wave of CHARLS was fielded in 2011 and contained approximately 10,000 households in 150 counties/districts (a total of 450 villages/resident communities). The overall response rate was 85%. These individuals will be followed up every two years. The CHARLS uses a multi-stage stratified probability-proportionate-to-size (PPS) sampling framework. The CHARLS is similar to the Health and Retirement Study (HRS) in the United States, the English Longitudinal Study of Aging (ELSA) in the United Kingdom, and the Survey of Health, Aging and Retirement in Europe (SHARE). The CHARLS questionnaire includes the following modules: demographics, family structure/transfer, health status and functioning, biomarkers, health care and insurance, work, retirement and pension, income and consumption, assets (individual and household), and community-level information. More information about the CHARLS data can be found at http://charls.ccer.edu.cn/en.

#### 2.2.1. Mental health

Mental health was measured by a seven-item modification of

[2] Labor, physical capital and water withdraw as inputs, and gross industrial output value as desirable output. The gross industrial output is deflated by producer price index in 2011, and the value of physical capital is deflated by price index of investment in fixed assets.

[3] Labor, physical capital and water withdraw, costs of waste water treatment facilities as input indicators. Gross industrial output value as desirable output; industrial waste water discharged, COD in industrial waste water, and $NH_3$-N discharge in industrial waste water were added as a set of undesirable outputs. The gross industrial output is deflated by producer price index in 2011, and the value of physical capital is deflated by price index of investment in fixed assets.