EVALUATION OF GROUNDWATER ARSENIC CONTAMINATION AND REMEDIAL INTERVENTIONS

Synopsis of the Thesis
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Sanjana Chakraborty

Department of Economics
Jadavpur University
Kolkata-700032, India

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Access to safe drinking water being a basic human need as well as a right. During the later half of the twentieth century millions of hand tubewells were installed by the governments for providing drinking water. For overcoming the problem of drinking microbiologically unsafe and untreated surface water, more emphasis was given on groundwater use and the use of treated surface water was ignored. The accessibility of hand-pumps / tubewells to the households had increased substantially, whereas the use of the dugwells or any surface water source declined significantly. With increasing population, the demand for drinking, cooking and irrigation water had increased, which was fulfilled by increasing withdrawal of groundwater by tube-wells. Besides domestic use, to meet the food demands of the growing population, agriculture too had shifted to use of groundwater to supplement the rainwater supplies for the purpose of irrigation. As a result, groundwater exploitation was rampant. The absence of regulation on the part of the government intensified the use. This was more of a feature of the rural areas than of the urban areas. Over the years, this limitless and reckless human attack on the nature's sub-soil water-table eventually caused so far dormant geogenic poison arsenic to erupt and being leached out, to exert finally its chronic toxic impact via groundwater contamination. Consumption of arsenic contaminated water beyond permissible limit (WHO guideline value of 10 µg / L) has very serious health implications. The arsenicosis is a health hazard, caused by direct consumption of contaminated drinking water and indirect consumption of such water through the food chain as it is used in agricultural production. The people affected by arsenic poisoning suffer from skin lesions, gradual loss of energy, physical weakness, loss of appetite, lethargy, sleeplessness, diminishing work ability, uneasiness in the stomach, burning sensation over the body and gradually progressive debilitation etc. which lead to loss in the working hours and their income. It also creates unhealthy and strained within-family relations and stress at the social front. With the symptoms of arsenicosis becoming evident more often various agonizing social issues arise, such as, affected persons are often sacked from their jobs, arsenic affected children are sometimes debarred from their schools, the affected girls are denied of marriage and often married women face problems in their marital life and even divorce ensues. Affected people are quite often ostracized from social functions. The arsenic affected persons are often boycotted socially as they are mistakenly considered as the patients infected with contagious diseases. The social barriers create economic barriers as well (Becker, 1971). It may create inequality in the rural society and may perpetuate poverty. The World Health Organization (WHO) points out that social problems arising from groundwater arsenic contamination create pressure on the economy of the affected areas (WHO, 2000). The present thesis draws its motivation in measurement of economic loss both contemporaneous and over the time of the arsenic affected households vis-à-vis the arsenic unaffected households. It also studies adoption of piped drinking water by the households in an arsenic affected area as a mitigation strategy against the arsenic-related hazards.

'Arsenic' is a shiny metalloid which is the 20th element in the nature. It is found throughout the Earth's crust, soil, sediments, water, air and living organisms. In different countries, arsenic has been used as a drug as well as a poison**.** The estimated global average level of arsenic in soil is 5µg / kg (microgram per kilogram), but the concentrations may vary considerably in different geological regions. The variation can be in the range of 0.1 to 4000 µg / kg. While arsenic contamination has been reported from 38 countries in the world (Chakraborti et al. 2009), Asian countries seem to be more affected than the others. The magnitude of arsenic contamination is considered as the highest in the following four Asian countries: India, Bangladesh, China and Taiwan; India having the highest and Taiwan having the lowest incidence. The Ganga-Meghna-Brahmaputra (GMB) plain of India and Bangladesh is the worst affected among the world arsenic scenario raising a severely alarming note. More than 500 million people of the GMB plain may be potentially at risk from groundwater arsenic contamination (Nahar et al. 2008, BGS; DPHE, 2001).

The thesis draws its sample households from the severely affected North 24 Parganas district. Among the strategies for fighting the arsenic menace / hazards, the use of arsenic-safe water sources like treated dugwell, arsenic-safe deep-tubewells (often coloured green for easy identification while unsafe are coloured red), treated piped water etc. and improvement of nutritional status are considered as the most important strategies[1]. The spread of awareness complements such strategies. Since dugwells and tubewells are more vulnerable to contamination, the piped water supply is considered as the safest source of arsenic-free water. The provision of piped water being costly as it is network dependent, in developing countries like India, the government in recent times has arranged for free-access, intermittent-supply of piped water at some locations at the arsenic affected villages lived mainly by the poor. Apart from the behavioural trait and bounded rationality, the adoption decision of piped water source can also be affected by the costs of adoption and economic-demographic characteristics like education, religion, percentage of female at the household and the household income. The present thesis studies the adoption of this source of safe-water among arsenic affected and unaffected households in an arsenic affected village of West Bengal, India.

While several studies have investigated the issue of arsenic contamination before, most of them have explored its geological aspects, health problems related to arsenic and technologies for arsenic removal. Though studies evaluating the economic cost of arsenic contamination are few, designing of any arsenic mitigation program would require such a cost estimate. The present thesis investigates the economic cost of arsenicosis on the per

[1]People having poor nutrition were found to be affected more from arsenic toxicity than the people having an adequate nutrition rich food. Intake of nutritious diet especially with vitamins such as A, C and E is essential for arsenic mitigation (Quamruzzaman et al. 2003; Milton, 2003).

capita monthly household income of the arsenic affected households at a particular time period as well as over the years by applying two different kinds of impact evaluation methods: (i) PSM [for Chapter 2] and (ii) DID [for Chapter 4]. This thesis also studies the probability of adoption of arsenic-safe piped water supply projects as mitigation strategy among the households when piped water supply project was freely provided by the government during 2011-2012 [for Chapter 3]. Chapter 2 shows that the loss from labor market participation is not the only source from which an arsenic affected household suffers but the additional loss comes from the social discrimination it faces. The 'social discrimination' being an unobserved factor, has been captured indirectly and found out to lead to significant income loss. To refine our estimation of relative economic loss of the arsenic affected households over the years, in chapter 4, we derive the income loss due to arsenicosis that arises purely from the time-dependent unobserved factors that differentiates the treatment (arsenic-affected) and control (arsenic-unaffected) group households. It shows that the arsenic affected households adapt to their situation over time to reduce their income gap vis-à-vis the arsenic unaffected households[2]. In chapter 3, to check the nature of adoption decision among the households we empirically seek answer to the following research questions: (a) Whether the arsenic-affected households show higher probability of adoption of arsenic-safe piped water source than the arsenic-unaffected households? (b) How the spread, intensity and years of experience with arsenicosis in the households matter in adoption decision? We found affirmative to the first question and for the second, we found the years of illness matters the most in the adoption decision.

The thesis is divided in three core chapters: Chapter 2, 3 and 4. Chapter 1 introduces the thesis and chapter 5 concludes it.

[2]Earlier studies like Khan (2007), Roy (2008), Mahanta et al. (2016) and Thakur et al. (2019) estimate the income loss from arsenicosis counting only the loss from labor market participation. The dynamic aspect of estimating income loss is completely absent in the existing literature.

BIBLIOGRAPHY

Becker, Gary S. (1971): "The Economics of Discrimination", *Second edition*, London, The University of Chicago Press.

BGS and **DPHE (**2001): "Arsenic Contamination of Groundwater in Bangladesh", *Summary. British Geological Survey WC/00/19*; Kinniburgh, D.G., Smedley, P.L., Editors; British Geological Survey: Keyworth, UK, Vol. 1, 1-15.

Chakraborti, Dipankar; Das, Bhaskar; Rahman, Mohammad M.; Chowdhury, Uttam K.; Biswas, Bhajan; Goswami, Arunasis B.; Nayak, Bishwajit; Pal, Arup; Sengupta, Mrinal K. and **Ahamed, Sad** (2009): "Status of Ground Water Arsenic Contamination in the State of West Bengal, India: A 20 Year Study Report", *Molecular Nutrition and Food Research*, 53(5), 542-551. https://doi.org/10.1002/mnfr.200700517.

Khan, M. Zakir Hossain (2007): "Managing the Arsenic Disaster in Water Supply: Risk Measurement, Costs of Illness and Policy Choices for Bangladesh," *Working Paper No. 27–07. Kathmandu: South Asian Network for Development and Environmental Economics (SANDEE)*.
http://www.sandeeonline.org/uploads/documents/publication/749_PUB_working_paper_27.pdf.

Mahanta, Ratul; Chowdhury, Jayashree and **Nath, Hiranya K.** (2016): "Health Costs of Arsenic Contamination of Drinking Water in Assam, India." *Economic Analysis and Policy* 49 (March), 30–42. https://doi.org/10.1016/j.eap.2015.11.013.

Milton, A. H. (2003): "Health Effects of Arsenic Toxicity, Clinical Manifestation and Health Management in Arsenic Contamination: Bangladesh Perspective", *edited by* **M. Feroz Ahmed**, *ITN Bangladesh, Centre for Water Supply and Waste Management, BUET, Dhaka, Bangladesh*, 281-297.

Nahar, Nurun; Hossain, Faisal and **Hossain, M. Delawer** (2008): "Health and Socioeconomic Effects of Groundwater Arsenic Contamination in Rural Bangladesh: New Evidence from Field Surveys", *Journal of Environmental Health*, 70(9), 42-47. https://www.ncbi.nlm.nih.gov/pubmed/18517153.

Quamruzzaman, Q.; Mahmuder, R. and **Khordekar A.** (2003): “Effects of Arsenic on Health in Arsenic Contamination: Bangladesh Perspective”, *edited by BUET, Dhaka, Bangladesh*, 257-267.

Roy, Joyashree (2008): “Economic Benefits of Arsenic Removal from Ground Water - A Case Study from West Bengal, India”, *Science of the Total Environment*, 397 (1-3), 1-12. doi: 10.1016/j.scitotenv.2008.02.007.

Thakur, Barun Kumar and **Gupta, Vijaya** (2019): “Valuing Health Damages due to Groundwater Arsenic Contamination in Bihar, India”, *Economics and Human Biology*, 35, 123-132. Doi: 10.1016/j.ehb.2019.06.005.

World Health Organization (2000): “Towards an Assessment of the Socio-Economic Impact of Arsenic Poisoning in Bangladesh”, Sustainable Development and Healthy Environments, Geneva, *prepared in cooperation with the Department of Health in Sustainable Development*, Protection of the Human Environment Water, Sanitation and Health, WHO/SDE/WSH/00.4.