

# A Quantitative Evaluation of Severity of Disease Index due to Consumption of Arsenic contaminated Groundwater in Assam, India

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**Abstract:** *The study endeavour sought to undertake an economic evaluation of groundwater contamination by arsenic in the districts of Jorhat and Nalbari, situated in the state of Assam. The research encompassed a total of twelve remote villages spanning across two districts of Assam viz. Jorhat and Nalbari. A comprehensive sampling strategy was employed to select a total of 175 households from the Titabor block in the esteemed Jorhat district, and an additional 180 households from the Paschim Nalbari block in the illustrious Nalbari district. These particular blocks were chosen due to their notable prevalence of elevated arsenic concentrations, which in turn resulted in a significant impact on the local population within the respective districts. The comprehensive assessment of the socio-economic landscape encompassed various factors, including educational achievement, household size, occupational categorization, and monthly expenditure patterns. The assessment of the household's overall economic status was based on the economic wellbeing as a fundamental indicator. The Severity Incidence Index (SII) quantifies the gravity of the occurrence resulting from the ingestion of potentially arsenic-contaminated water. It has been observed that there exists a positive correlation between the concentration of arsenic in water and the corresponding SII values. This elucidates the direct correlation between the escalating levels of arsenic in water and the escalating magnitude of individuals susceptible to potential ailments associated with arsenic contamination. The present index exhibits a diminished numerical representation for the region afflicted by a relatively modest concentration of arsenic.*

**Keywords:** Arsenic poisoning, Groundwater, Severity Incidence Index, Health stock index

## INTRODUCTION

In Assam and the rest of India, groundwater is relied on more than any other source for human consumption, agriculture, and industry. In third-world countries, people typically prefer groundwater for consumption. Humans have an inherent need for safe drinking water, and providing access to sufficient supplies is a proven method of improving health. Reduced productivity at work, fewer students enrolled in school, and other negative outcomes may stem from a lack of potable water. Therefore, access to safe drinking water is an important part of preventative medicine (Ahmed et al, 2010). The issue of arsenic poisoning through groundwater has emerged as a widespread global concern, especially due to its substantial toxicity as a pollutant in drinking water and groundwater (Pearson et al., 2011; Jain and Singh, 2012; Mohan and Pittman, 2007). There exists a discernible correlation between the concentration of arsenic within water sources and the severity of the disease. The ramifications stemming from the contamination of groundwater with arsenic proved to be of significant economic magnitude (Chakraborti et al. 2018). In a seminal study conducted by Nickson et al. (2007), meticulously examined the regions nestled within the Ganges-Brahmaputra River basin in India, where the insidious presence of groundwater arsenic contamination has left an indelible mark. The investigation of the duration and severity of skin lesions, the level of arsenic exposure, and the nutritional status of individuals has shed light on the health consequences linked to arsenic poisoning among hospital patients in Southern Bangladesh (Mitra et al. 2002). Assam, with the Brahmaputra and the Barak rivers, is one of India's eight northeastern states. Rain, streams, and rivers continue to supply the majority of Assam's population with their drinking water and other household needs. Groundwater contamination is a major issue in Assam due to the occurrence of excess fluoride, arsenic, and nitrate in varied concentrations across the state (Singh, 2004). Earlier, we have reported the health cost estimation of arsenic contamination of drinking water in Assam (Mahanta et al. 2016). In the present study, we have assessed the severity incidence index (SII) associated with consumption of probable arsenic contaminated water in two districts of Assam viz. Nalbari and Jorhat districts.

## REVIEW OF LITERATURE

At present, there are significant worries about the distribution of arsenic (As) and its compounds, as well as their related toxicity. Millions of individuals around the world have been affected by the harmful effects of arsenic from consuming contaminated groundwater (Chetia et al., 2010). Arsenic (As) in groundwater represents a serious public health concern around the world. A large share of the world's

drinking water comes from underground sources, especially in developing nations like India, where over two-thirds of the population relies on this essential resource (Mahanta et al., 2016; Saha et al., 2020; Thakur et al., 2021). Research indicated that arsenic was the main factor associated with the risks related to both cancer and non-cancer effects. Given the pressing concern of groundwater pollution, recent studies have concentrated on assessing the quality of groundwater sources, examining the level of heavy metal contamination, including arsenic, and the related risks to human health (Mahanta et al., 2016; Thakur and Gupta, 2025).

Research by Kibria et al. (2010) shows that the skin of individuals can alter in color and texture after consuming food and water that contain arsenic contamination. Melanosis, which may present in various shades from white to darker tones, keratosis, marked by thickened skin on the palms and feet, skin lesions, and, in more severe instances, skin cancer, are common symptoms associated with chronic arsenicosis. The occurrence of these health disorders significantly impacts the productivity and wellbeing of individuals, particularly those living in rural areas and economically disadvantaged communities who depend on untreated groundwater for their daily needs.

Chakraborti et al. (2018) highlighted that the presence of arsenic in groundwater within the Ganga-Brahmaputra basin poses significant health risks and represents a growing socio-economic challenge. This is particularly significant for Assam, a state situated in the Brahmaputra valley, where several districts have indicated arsenic levels surpassing the permissible limits set by WHO and BIS. Research conducted by Nickson et al. (2007) has shown that arsenic contamination significantly impacts five Indian states, including Assam, leading to lasting consequences for public health policy and the safety of drinking water.

In Bangladesh and certain regions of Eastern India, such as Assam, exposure to arsenic has been associated with higher mortality rates, hindered cognitive development in children, and lasting organ toxicity (Mitra et al., 2002; Mohan and Pittman, 2007). The toxicokinetics of arsenic, particularly in its inorganic forms, enable it to readily cross biological membranes and accumulate in vital tissues, leading to carcinogenic and mutagenic effects.

Mahanta et al. (2016) carried out one of the initial evaluations regarding the health costs linked to arsenic exposure in Assam, focusing on the economic implications. Their findings highlight significant financial challenges faced by impacted households, stemming from both direct medical costs and lost productivity. A structured risk assessment and indexing approach is essential for evaluating the severity of impact. This includes the development of tools like the Severity Incidence Index (SII) and Health Stock Index (HSI), which are utilized in the current study.

Additionally, Pearson et al. (2011) highlighted the urgent requirement for effective interventions in areas impacted by arsenic contamination, particularly in developing countries. Even with several mitigation efforts in place, the ongoing reliance on contaminated groundwater sources often driven by economic limitations or a lack of awareness still puts rural communities at risk of enduring arsenic toxicity.

The Public Health Engineering Department of Assam has recorded numerous habitations affected by arsenic in districts such as Nalbari and Jorhat. The reports highlight

the presence of arsenic and reveal that there are insufficient and sustainable mitigation strategies in place at the community level. Therefore, thorough scientific assessments that measure the health impacts and their relationship with arsenic levels, like the current study, are crucial for developing policies based on solid evidence. This study utilizes a theoretical framework based on the dummy variable regression model to analyze and understand the severity of disease conditions in areas with high, medium, and low arsenic exposure. This research connects arsenic levels with health outcome indices, enhancing previous findings and offering new perspectives on regional arsenic exposure dynamics in Assam.

## METHODOLOGY

### Theoretical Model

#### Determination of Severity Incidence Index (SII)

The quantification of the magnitude of occurrence resulting from the consumption of potentially arsenic-contaminated water has been established as an index and denoted as the Severity Incidence Index (SII). This metric has been estimated across varying levels of arsenic concentration in water, namely high, medium, and low, encompassing the entirety of the dataset. Additionally, it has been analysed separately for the specific regions of Jorhat district and Nalbari district. The variable in question is of a continuous nature, exhibiting a range that spans from 0 to 1. The higher the value, the greater is the severity.

Thus,

$$\text{Severity Incidence Index} = \frac{\text{Sum of persons infected with probable arsenic affected diseases}}{\text{Total population affected with arsenic contaminated water}}$$

#### Effect of Degree of Arsenic concentration on the Health Stock Index

The Health Stock Index (HSI) served as a quantifiable metric that assessed the overall health capital possessed by a given household. It epitomised the amalgamation of the quantified summation of the plausible afflictions of arsenic that have befallen the family members during the designated span of six lunar cycles. The allocation of weights is predicated upon the hierarchical assignment of ranks, serving to elucidate the comparative costliness of the ailment. As the numerical value increases, the corresponding health stock exhibits a progressively deteriorating state.

To ascertain the consequences of varying concentrations of Arsenic (high, medium, and low) on the HSI, the ensuing dummy variable linear regression model has been employed (Gujarati, 1995).

$$HSI_i = \alpha + \alpha_1 D_{HG_i} + \alpha_2 D_{MG_i} + u_i$$

Where,  $HSI_i$  = Health Stock Index

$D_{HG_i} = 1$ , if arsenic concentration is high  
 $= 0$ , if otherwise

$D_{MG_i} = 1$ , if arsenic concentration is medium  
 $= 0$ , if otherwise

$\alpha$ ,  $\alpha_1$ , and  $\alpha_2$  are parameters

$u$  = the error term

and,  $i$  = the number of households

### Empirical Model

#### Study Area

The study encompassed both an upper and a lower

Assam district characterized by elevated levels of arsenic contamination. In the course of this investigation, we employed a sophisticated and progressive multistage sampling methodology. The urban center of Jorhat, situated in the upper Assam, was found to harbour a significant populace afflicted by the pernicious effects of arsenic contamination. The region of Nalbari, situated in the lower Assam region, experienced a significant prevalence of arsenic poisoning, as documented in the GOA report of 2010. Consequently, a comprehensive survey was undertaken within the two districts of Assam, namely Jorhat and Nalbari, as designated for the purpose of this study. Again, the regions exhibiting the most pronounced aggregations of affected individuals were deliberately selected. The Titabor block of the Jorhat district exhibited the highest prevalence of homes afflicted by the presence of arsenic, as documented by the Public Health Engineering Department (PHED), Government of Assam (GOA) in the year 2011 (Supplementary File 1). The region under consideration boasts a populace of 7,1543 individuals, cohabiting within a remarkable assemblage of 227 residential abodes. In a striking parallel, it is worth noting that a staggering 18,887 habitations, constituting a significant portion of the overall 47 habitations, were profoundly affected within the Paschim Nalbari block of the esteemed Belsor division, situated in the illustrious Nalbari district. Consequently, the meticulous selection process led to the identification of the Paschim Nalbari and Titabor blocks within the Nalbari and Jorhat regions, respectively, as the optimal areas for our groundbreaking research endeavour. Out of the vast expanse encompassing these two distinct regions, a meticulous selection process was undertaken to identify a total of twelve villages, with an equitable distribution of six villages in the Titabor region and an equivalent number in the Paschim Nalbari region. Every established community is required to allocate a single dwelling for the purpose of scientific inquiry and exploration. Further, the rural settlements were meticulously categorized into distinct strata based on the levels of arsenic concentration, namely high, medium, or low. A fortuitous sampling methodology was employed, wherein precisely fifty percent of the domiciles within every settlement were chosen at random to partake in the survey.

#### Data Source

The analysis utilized a combination of primary and secondary sources. The arsenic concentration data for various regions in Jorhat and Nalbari district were obtained from the Public Health Engineering Department, which is under the Government of Assam. These data were collected from secondary sources. The compilation of socioeconomic features and demographic patterns was accomplished by utilizing data from various sources, including the Census of India (2011), the Assam Health Service, the Assam Fishery Department, the Assam Directorate of Panchayat and Rural Development, and the Assam Directorate of Health Service.

#### Sampling Design

For the primary data, we used a multi-stage sampling approach. The study focused on the districts of Jorhat and Nalbari, specifically the blocks with the highest concentrations of arsenic impacted residents. Different ranges of Arsenic concentration were used to choose communities from among the affected population. In total, 12 communities in Titabor and Paschim Nalbari were surveyed. Again, the villages were classified as either high, medium, or low for arsenic concentration. Two villages were

chosen with varying concentrations of arsenic (high, medium, and low). Each settlement has to contribute one home for the research. Table 4.1 provides data on the number of people living in each affected dwelling and the total number of dwellings impacted by arsenic. The households chosen were selected at random. A random sample of 175 homes in Titabor, Jorhat, was taken. Similarly, 180 homes in Paschim Nalbari, Nalbari district, were chosen. As a result, 355 families in the Jorhat and Nalbari areas were surveyed. This research relies on data collected from a survey of 355 homes in the Assam districts of Jorhat and Nalbari.

## RESULTS

### Severity Incident Index (SII)

Upon careful examination of the data collected within the encompassing survey region, it has been discerned that there exists a positive correlation between the concentration of arsenic in water and the corresponding Severity Incident Index (SII). This elucidates the correlation between the escalating levels of arsenic in water and the escalating magnitude of individuals susceptible to potential ailments associated with arsenic contamination. The presented index exhibits a diminished numerical representation for the region afflicted by a relatively minimal extent of arsenic concentration, as depicted in Table 1.

**Table 1: Severity Incident Index (SII) across the different degrees of arsenic in water**

| Degree of Arsenic | Overall | Jorhat | Nalbari |
|-------------------|---------|--------|---------|
| High              | 0.46    | 0.58   | 0.38    |
| Medium            | 0.39    | 0.45   | 0.34    |
| Low               | 0.30    | 0.32   | 0.27    |

Source: *Author's Estimates*

### Health Stock Index (HSI) of probable arsenic affected diseases in the overall study area

Table 2 shows the parameter estimates of the dummy variable linear regression as discussed in section 4.6 of chapter 4. The parameter estimates of HSI indicate that the coefficient of high and medium concentration of arsenic is significant at 1% level of significance. This implies that both high and medium concentration has effect on HSI. Again, the coefficient of high concentration is greater than the coefficient of medium concentration. Therefore, it can be inferred that high concentration of arsenic has more impact on HSI than medium concentration. This clearly shows that people are more exposed to sickness from probable arsenic related diseases in high concentration area.

**Table 2: Estimation parameters of Health Stock Index (HSI)**

| Variables                       | Coefficients | T         |
|---------------------------------|--------------|-----------|
| Constant                        | 6.073        | 23.980*** |
| High concentration of arsenic   | 17.034       | 48.783*** |
| Medium concentration of arsenic | 8.604        | 24.783*** |

Source: *Author's Estimates*

\*\*\*significant at 1% level

## DISCUSSION

In this study, we assessed the SII in two severely affected regions of Assam, where residents have been drinking water that may contain arsenic. An individual's SII is evaluated after they drink potentially arsenic-tainted water. We observed that the SII rises in tandem with rising arsenic concentrations in water. This makes it quite evident that when arsenic levels in drinking water grow, so too will the severity

and number of people who are likely to contract diseases linked to arsenic. When arsenic contamination is low, the value of this index drops.

In order to discern the ramifications of varying concentrations of arsenic, namely high, medium, and low, upon the HSI (Health Stock Index), we have conducted to derive the parameter estimates. The findings suggest that the coefficient pertaining to the elevated concentration of arsenic and the moderate concentration of arsenic exhibit a noteworthy significance at a level of significance of 1%. This postulation posits that the influence of both elevated and moderate concentrations exerts a discernible impact on the HSI. Again, it is worth noting that the coefficient pertaining to a state of heightened concentration surpasses the coefficient associated with a state of moderate concentration. Henceforth, one may deduce that a heightened concentration of arsenic exerts a more pronounced influence on the Hazard Severity Index (HSI) when compared to a moderate concentration. This unequivocally demonstrates that individuals are rendered increasingly vulnerable to afflictions stemming from potential arsenic-induced maladies within regions characterized by elevated concentrations thereof.

## CONCLUSION

The issue of groundwater arsenic contamination has been ascribed to a multitude of enigmatic factors, encompassing both the local and regional dimensions. Henceforth, the inquiry arises as to the extent to which the remedial actions and strategies implemented by the Government prove efficacious in terms of reinstating, resolving, and obliterating the predicament, while concurrently achieving sustainability in combating this pernicious threat. A comprehensive evaluation is imperative to ascertain the efficacy of its implementation in regions afflicted by arsenic contamination. In the present study we have considered only two districts of Assam, reported to have high concentration of arsenic in its groundwater. It indicates that further work is still required to show the severity of this incidence in the entire state of Assam. A thorough comprehension of the aforementioned facets may prove more efficacious in formulating expeditious, provisional, and enduring strategies to effectively tackle the issue at hand.

## REFERENCES

1. Ahmad, I., Haq, M. and Sattar, A. (2010). Factors Determining Public Demand for Safe Drinking Water (A Case Study of District Peshawar) PIDE Working Papers.
2. Census (2011). Census of India, *Economic Survey of Assam*, 2011-12, Govt. of Assam. p7.
3. Chakraborty, D., Singh, S.K., Rahman, M.M., Dutta, R.N., Mukherjee, S.C., Pati, S., Kar, P.B. (2018). Groundwater Arsenic Contamination in the Ganga River Basin: A future Health Danger. *Int J Environ Res Public Health*, 15(2): 180.
4. Chetia, M., Chatterjee, S., Banerjee, S., Nath, M. J., Singh, L., & Srivastava, R. B. (2010). Groundwater arsenic contamination in Brahmaputra River Basin: A water quality assessment in Golaghat (Assam), India. *Environmental Monitoring and Assessment*, 173(1-4): 371-385.
5. GOA (2010). Public Health Engineering Department, Govt. of Assam data on number quality affected habitations and population in Assam.
6. GOA (2011). Annual report. Public Health Engineering Department, Government of Assam.
7. Gujarati, D.N. (1995). Regression on dummy variables, In, Basic Econometrics 3<sup>rd</sup> Edition, McGraw-Hill International Editions, New Delhi, Pp 499-539.
8. Jain, C.K. and Singh, R.D. (2012). Technological options for the removal of arsenic with special reference to South East Asia. *J. Environ. Manage.*, 107: 1-18.
9. Kibria, G., Haroon, A. K. Y., Nuggeoda, D., Rose, G. (2010). Health hazards of arsenic in drinking water and the environment. In: *Health Effects of Arsenic Contamination* (pp. 1-25). Global Science Books.
10. Mahanta, R., Chowdhury, J, Nath, K.K. (2016). Health costs of arsenic contamination of drinking water in Assam India. *Economic Analysis and Policy.*, 49: 30-42.
11. Mohan, D., and Pittmann C.U. Jr. (2007). Arsenic removal from water/wastewater using adsorbents – A critical review, *Journal of Hazardous material*, 142:1-53.
12. Mitra, A.K., Bose, B. K., Kabir, H., Das, B.K. and Hussain, M. (2002). Arsenic-related health problems among hospital patients in Southern Bangladesh. *Journal of Health, Population and Nutrition*, 20(3):198-204.
13. Nickson, R., Sengupta, C., Mitra, P., Dave S. N., Banerjee, A.K., Bhattacharya, A., Basu, S., Kakoti, N., Moorthy, N.S., Wasuja, M., Kumar, M., Mishra, D.S., Ghosh, A., Vaish, D.P., Srivastava, A.K., Tripathi, R.M., Singh, S.N., Prasad, R., Bhattacharya S, and Deverill, P. (2007). Current knowledge on the distribution of arsenic in groundwater in five states of India. *J. Environ. Sci. Health. A Tox Hazard Subst. Environ. Eng*, 42(12): 1707-18.
14. Pearson, M., Jones-Hughes, T., Whear, R., Cooper, C., Peters, J., Evans E.H., and Depledge, M. (2011). Are interventions to reduce the impact of arsenic contamination of groundwater on human health in developing countries effective?: a systematic review protocol. *Environmental Evidence*, 1:1-7.
15. Saha, D., Sahu, S., Saxena, R., Kumar, M., & Dewandel, B. (2020). Occurrence and origin of arsenic in groundwater in parts of northeast India: A multidisciplinary review. *Environmental Earth Sciences*, 79, 72.
16. Thakur, B.K., Gupta, V., Bhattacharya, P., Jakariya, M., Islam, M.T. (2021). Arsenic in drinking water sources in the Middle Gangetic Plains in Bihar: An assessment of the depth of wells to ensure safe water supply. *Groundwater for Sustainable Development*, 12: 100504.
17. Thakur, B.K., Gupta, V. (2025). Welfare estimation of groundwater arsenic contamination in India: Insights for water policy. *Journal of Cleaner production*, 497: 145107.