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Elixir of Adversity: Unearthing the Alchemical Link between Groundwater Arsenic Contamination and Socio-Economic Metamorphosis through a Systematic Review

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ABSTRACT

Although arsenic contamination of groundwater was identified late in the 20th century but research on this topic gained significant attention in the early 21st century. Most of the study primarily focused on sources, health effects, removal methods, and mitigation in a particular area. Overall, research on the socioeconomic repercussions remained limited. The geological structure, demographics, and infrastructure of the Bengal Delta Plain region, though not exclusively, led to its selection as the study's focal point. We conducted a comprehensive analysis of 41 pieces of literature using Google Scholar, Web of Science, and Scopus—three extensively used databases, revealing a skewed emphasis on the Bengal Delta Plain (70.73%), with fewer studies focusing on other Indian regions (17.07%) and international contexts (12.20%). Analysis revealed that lower socioeconomic status is associated with increased susceptibility and was exacerbated by factors such as prolonged exposure, lack of education, and malnutrition. The effects of the consumption of arsenic-contaminated water and food were manifested in compromised health, decreased agricultural output, limited access to potable water, financial strains, and stunted development. The study, thus, emphasised the urgency of attention to the welfare of arsenic-affected communities globally, particularly in underdeveloped regions through a comprehensive understanding of the very complicated socioeconomic effects of arsenic contamination. However, the focus should be on empowering the community through awareness, education, and engagement in combating the deleterious impacts of arsenic contamination on various facets of human development. Further, it proposed a holistic approach to health interventions with socioeconomic empowerment that breaks underdevelopment cycles and promotes inclusive and sustainable progress through interdisciplinary research and collaborative approaches.

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INTRODUCTION

One of the nation's most precious natural assets is groundwater, which contributes roughly 40% of the public water supply (Alley et al., 1999), facilitates 43% of irrigation-dependent agriculture (Siebert et al., 2010), and functions as a crucial emergency reservoir during climatic disasters. However, various natural and human-induced actions lead to groundwater contamination through the mingling of minerals in diverse regions around the globe (Onodera et al., 2008). Hence, the lack of access to clean water continues to be a problem for billions of people worldwide (Payen, 2011; Ghoul et. al, 2021), and nowadays, providing safe drinking

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water is acknowledged as a worldwide concern and policy issue. However, it is also true that minerals present in groundwater are essential for human health but that to be within a certain limit and it may cause health problems if consumed in excess of the permitted limit. Among these minerals, arsenic is one of the most significant and deadly. High levels of inorganic arsenic in drinking water are posing a risk to human health in many parts of the world, as they can harm the skin, lungs, liver, and other essential organs (Saha et. al, 1999; Chakraborti et. al, 2017; Sinha and Prasad, 2020). Therefore, in recent times, arsenic poisoning has emerged as one of the most significant issues with groundwater contamination and is referred to as a silent disaster because it is imparting a painful lesson to society, especially to those who have been dealing with arsenicosis. (Nasreen, 2004). According to the World Health Organization, the largest population poisoning by a single substance in history has been caused by arsenic (Smith et. al, 2000; Jones 2007). It is projected that arsenic pollution of groundwater might be a problem in roughly 108 different nations and over 230 million people are at risk due to consuming too much arsenic-polluted water globally; among them 180 million from Asian nations (Shaji et. al, 2021). While reports of groundwater arsenic contamination have emerged from numerous countries globally, it is the South Asian nations, particularly the Indo-Ganga-Brahmaputra region, that bear the brunt of this issue to the greatest extent (Pinchoff et. al, 2022; Samuel et. al, 2022; Bhowmick et. al, 2013) which could be the cause of arsenic-bearing minerals are brought down by the river from the Himalayan region and deposited into deltaic flood plain region (Nickson et al., 2000; Chatterjee et. al, 2005; Stuckey et. al, 2016).

In this regard, to combat groundwater disasters and to provide polluted-free drinking water, the United Nations launched the Millennium Development Campaign in 2002 with one of its environmental objectives being the mitigation of groundwater-related disasters and the provision of uncontaminated drinking water. The essential human right to clean drinking water was successfully upheld by this campaign. As a key determinant of health and socioeconomic progress, as well as fundamental sanitation and hygiene considerations, the Millennium Development Goals (MDGs) Target 7c aimed to cut in half the population without sustainable access to a safe water supply. In order to achieve this goal, the World Health Organization (WHO, 2007) specifies a maximum permissible threshold for drinking water arsenic content of 10 μg/L. However, many nations find it difficult to achieve this goal because of the complex nature of arsenic pollution and the high cost of arsenic removal methods. For instance, India has defined its highest acceptable level for arsenic in drinking water as 50 μg/L, and the Food and Agriculture Organization (FAO) designates a permissible threshold of 0.10 mg/L for irrigation water (Bhattacharya et al., 2009; Ahsan and Del Valls, 2011).

Groundwater arsenic can result in severe skin conditions including Melanosis and Keratosis in the early stages, and if unchecked, it can progress to skin cancer in the later stages (Thakur et. al, 2013). However, drinking arsenic-contaminated water for an extended period of time puts your health in danger and harms all of your body's systems and organs (Saha et. al, 1999; Ahmad et. al, 2001). To examine the effects of groundwater arsenic on human health, several research projects have been conducted. (Saha et. al, 1999; Karim, 2000; Shrestha et. al, 2003; Kapaj et. al, 2006; Sing et. al, 2014; Chakraborti et. al, 2017; Bhowmick et. al, 2018; Sinha and Prasad, 2020; Pinchoff et. al, 2022; Chowdhury, 2022). Some studies discuss about the consumption of arsenic-contaminated water can cause of cancer (Morris, 1995; Canter, 1997; Karim, 2000; Smith et. al, 2000; Chakraborti et. al, 2017 Sinha and Prasad, 2020). Studies demonstrate that groundwater arsenic also contributes to difficulties with cardiovascular illness, respiratory issues, gastrointestinal tract troubles, disorders of the skin, kidney and bladder problems, infertility, etc. (Singh et al, 2007; Sinha & Prasad, 2020; Prakash & Verma, 2021), Pregnancy Outcomes, Infant Mortality can be adversely affected by consuming arsenic during pregnant (Ahmad et. al, 2001; Milton et. al, 2005; Quansah et. al, 2015). Arsenic exerts its impact not solely on physical well-being but also on the psychological and behavioural aspects

of individuals residing within areas afflicted by arsenic contamination (Brinkel et. al, 2009; Syed et. al, 2012; Chowdhury et. al, 2016;). Some studies calculated the financial burdens caused by health issues associated with arsenic (Maddison et.al, 2005; Khan, 2007; Roy, 2008; Mahanta et. al, 2016). While other studies tried to establish the link between the socioeconomic status of households and arsenicosis diseases (Hadi & Parveen, 2004; Brinkel et. al, 2009; Thakur et. al, 2013; Muehe & Kappler, 2014). Literature also exhibited that the impact of prolonged exposure of arsenic contamination on cognitive and psychological development in terms of learning outcomes of school-going children in rural Bangladesh (Asadullah & Chaudhury, 2011). However, the impacts of arsenic toxicity on physical and mental health have been extensively documented, but its connection with social well-being and its role in impeding economic development have not received comprehensive coverage in studies. Hence, there is a noticeable need for increased attention and investigation in these domains. Since consumption of arsenic-contaminated water deteriorates the health condition which in turn worsens the socioeconomic position of individuals either directly or indirectly. Thus, the present study was carried out to fulfil three major objectives, i.e., (i) to assess the impact of prolonged exposure to arsenic on physical health and associated societal repercussions of arsenicosis victims, (ii) to analyse the implications of economic progress caused by groundwater arsenic poisoning in light of health risks and agriculture., and (iii) to highlight the overall quality of life and well-being of the poisoning victims in the context of socioeconomic degradation.

METHODOLOGY

This systematic review adheres to the widely acknowledged quality assessment methodology outlined in the PRISMA guidelines, developed by a panel of international experts, designed to enhance the transparency, precision, comprehensiveness, and regularity of documented systematic reviews (Fig. 1). The review procedure has undergone the subsequent three sequential stages. These stages further improve the systematic review's reliability as well as credibility by guaranteeing a methodologically sound approach to evidence synthesis and academic communication.

Review Planning (Design): This phase establishes the framework for a systematic and targeted review process that includes defining the specific objectives and scope of the study; developing search strategies; and creating a structured review protocol to direct the following stages.

Assessment of the Review (Determination): The information gathered was meticulously and carefully examined at this step. This phase encompasses the identification and collection of studies that satisfy predetermined criteria, followed by the extraction of relevant data, in-depth analysis, and synthesis of findings.

Portraying the Review (Reporting): The dissemination of the review's outcome is the last stage. In this stage, a comprehensive report is compiled to present the findings in a structured and transparent manner, communicating the results of the analysis, highlighting key trends or patterns identified, and enabling academics, Planners, and policymakers to get benefit from the synthesized knowledge.

This study was undertaken to investigate the social and economic challenges encountered by individuals residing in arsenic-contaminated regions, guided by specific objectives outlined earlier. The objectives serve as the driving force for the entire research endeavour. It is kind of like what Xiao and Watson (2017) pointed out; how research questions or objectives act as the backbone of a study. According to them, research inquiries are prompted by research questions or objectives that operate as the very basis for the exhaustive process of literary review, thereafter followed by the recommendation.

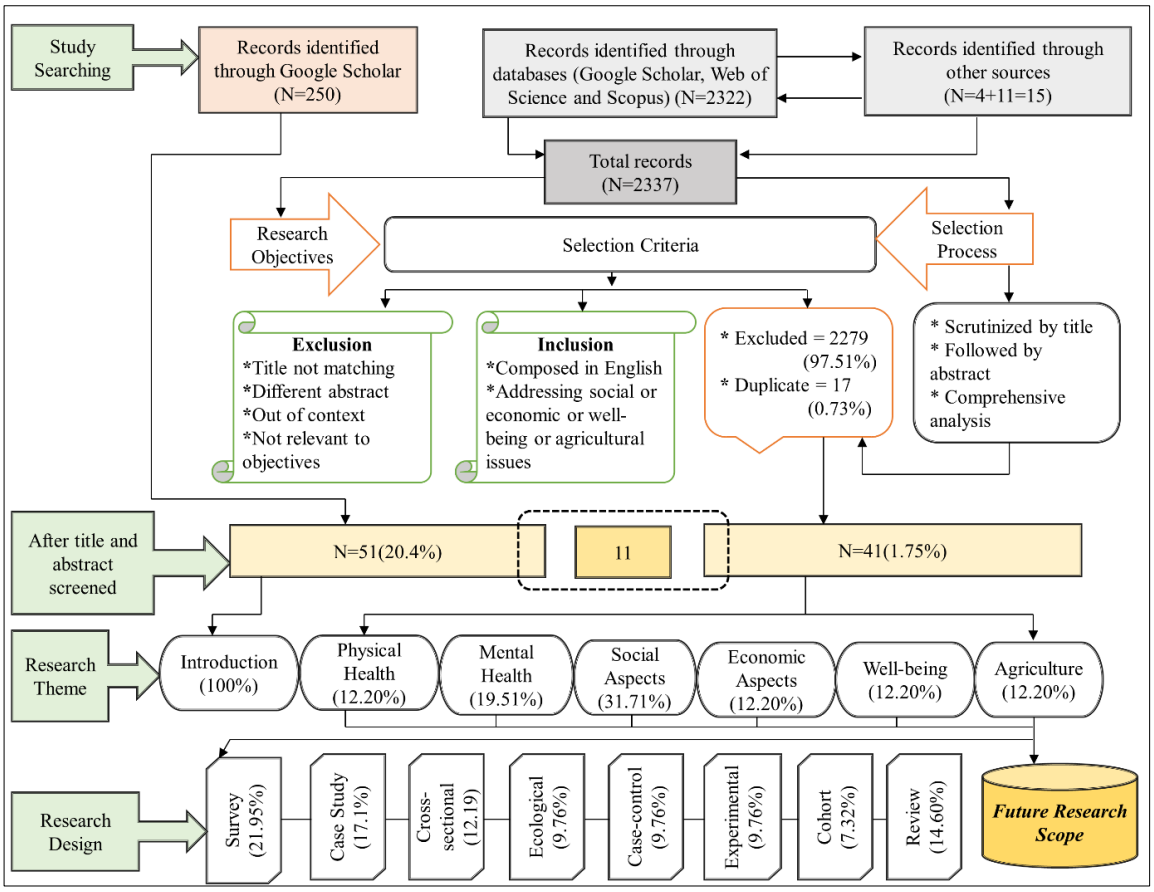

Fig. 1. Visual representation of PRISMA flow diagram for literature mapping in the review

Search strategy of literature and identification criteria

The search strategy involves finding relevant databases and journals and generating systematic search keywords to retrieve potentially relevant research aligned with the research objectives. The identification criteria are precise guidelines used to determine whether a study is eligible for review inclusion. We searched the literature for this study using Google Scholar, Web of Science, and Scopus, three extensively used databases by academics in a variety of disciplines (Fig. 2). Further sources from articles discovered in these searches were also explored. Again, a simple Google search using the Chrome browser was performed as part of the study's research strategy. To find relevant literature, a variety of following keywords, thesaurus, and occasionally Boolean operators were utilised to reduce the possibility of missing pertinent studies:

Using single words: 'arsenic', 'arsenicosis', 'endemic', 'contamination', 'poisoning', and 'toxicity'.

Using multiple words: 'groundwater arsenic contamination', 'arsenic-induced problems', 'socio-economic consequence of arsenic', 'arsenic poisoning on quality of life', and 'dynamics of arsenicosis victim'.

Using Boolean operators: 'arsenic' OR 'arsenicosis' OR 'toxicity' OR 'poisoning' AND 'social implication' OR 'social hazards' OR 'ostracism' OR 'economic repercussion' OR 'agriculture' OR 'health effect' OR 'psychological effect' OR 'well-being' OR 'QOL'.

Inclusion and exclusion criteria

In order to reduce redundant content and produce data that best matches the objectives of the research, it is essential to create exclusion criteria for certain articles within the search

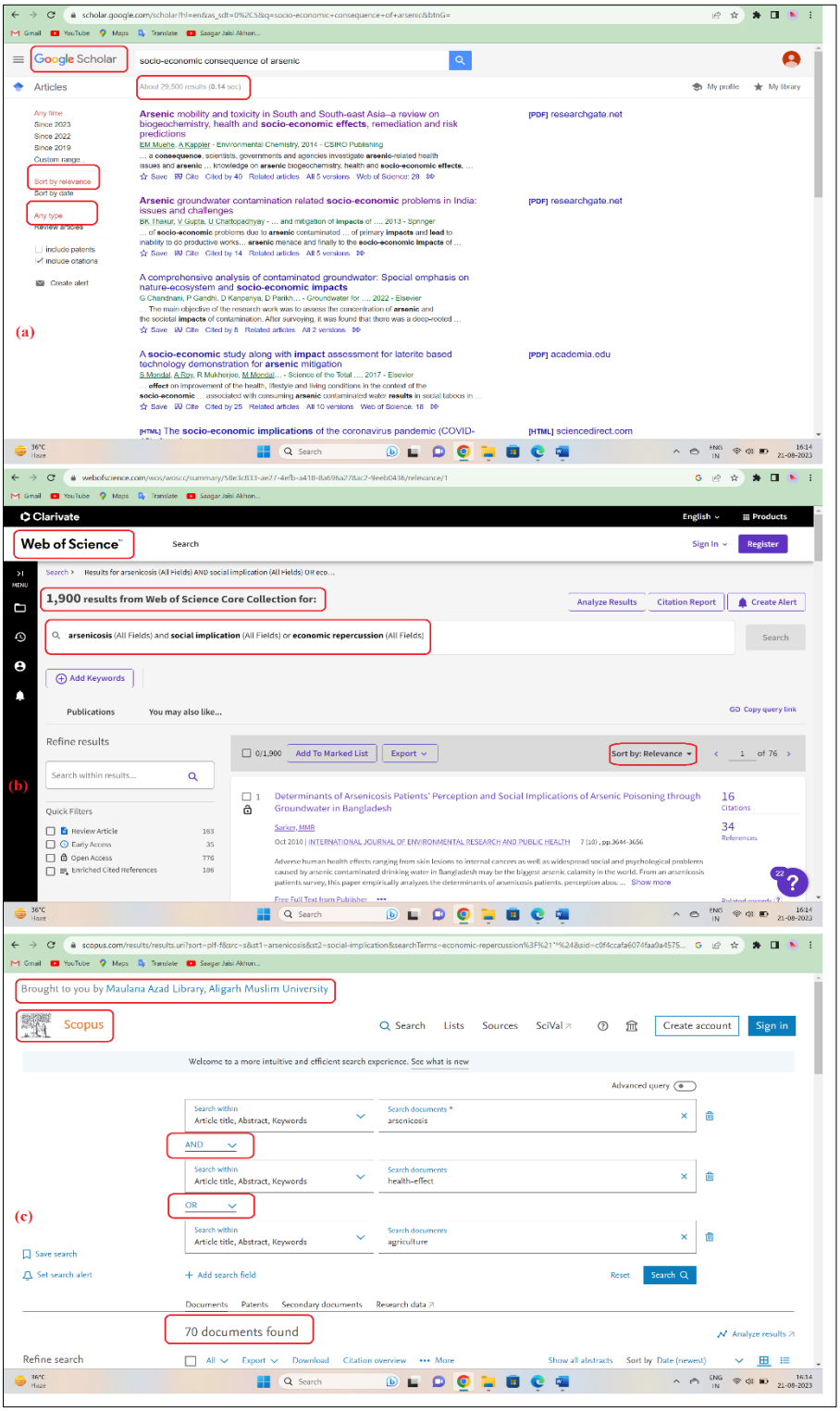

Fig. 2. Databases used for searching scientific documents (a) Google Scholar, (b) Web of Science and (c) Scopus

database results. Therefore, for the introduction section, this review includes articles that address diverse dimensions of groundwater contamination, with a specific emphasis on arsenic contamination, as a vital approach to comprehensively establish the foundational context of groundwater contamination and enhance the understanding of arsenic contamination dynamics

of the reader. But for the discussion section, we exclusively incorporate articles that address social issues, economic challenges, and agricultural repercussions (at least one of the problems) attributed to arsenic contamination. We integrated studies from diverse disciplines, ranging from engineering to medical and health science, geology, biology, sociology and environmental science. Furthermore, considering the scarcity of relevant material within our domain of focus, our study encompasses a diverse range of book chapters, reports, and news articles with the selection criterion stipulating that published manuscripts must be exclusively composed in the English language. The details of different studies included in this systematic review is shown in Table 1.

Review procedure

At first, a Google Scholar inquiry employing the keywords "arsenic" was undertaken to comprehend the multifaceted dimensions and consequences associated with it. After an assessment of the first 25 result pages which had about 250 scholarly works, we carefully examined the titles and abstracts; as a result, 51 relevant articles were selected, serving as the foundational content for the introduction of our article. Notably, 11 of these articles met the criteria for inclusion in the discussion segment as well. Subsequently, an additional inquiry on Google Scholar has been done using the aforementioned multiple keywords, extending across 20 pages, yielding approximately 200 studies, of which 56 articles emerged as potentially relevant upon screening title. A search on Web of Science and Scopus using Boolean operators generated 2034 and 88 studies respectively. Following an initial title screening, 138 and 54 records respectively, aligning with our study's inclusion criteria, were identified. In the next step, we proceeded to meticulously review abstracts of relevant articles from the combined sources (56+138+54 = 248), identifying 43 aligned with our research objective. Consolidating the initial 11 eligible studies with the 43 from the combined sources yielded 17 duplicates (i.e., an article exists in more than one database). Later on, after a comprehensive study of (43+11-17=37) relevant articles, 4 new articles were added from the cited references of existing articles, the detailed procedure is shown in Fig. 1. The publication of the paper over time is illustrated in Fig. 3.

RESULTS

The occurrence of arsenic contamination in groundwater is not a recent development, as it was first documented in the latter portion of the twentieth century in the West Bengal region. Nevertheless, a comprehensive study into its implications for human health and societal well-being gained substantial momentum in the early years of the twenty-first century and is still being vigorously pursued today Fig. 3. Following a thorough analysis of the available research on groundwater arsenic contamination, it comes to light that most of the studies mainly focused on the sources, mobilization, health impact, arsenic removal technology and mitigation strategy of arsenic contamination. Only a few studies have specifically addressed socioeconomic ramifications and the majority of these studies were conducted in the Bengal Delta Plain, which spans parts of Bangladesh and West Bengal, India; one of the well-known regions with a high prevalence of arsenic contamination in groundwater. This is because of the geological composition, redox conditions, groundwater dynamics, high population density and water dependency, illiteracy, poor economic conditions and lack of awareness and infrastructure in this region. While arsenic-related issues are not exclusive to specific regions and extend to various parts of the world, including developed countries like the USA, Mexico, Argentina, Vietnam etc. Nevertheless, a conspicuous contrast emerges between developed and underdeveloped countries concerning the consequences of arsenic toxicity. In developed nations such as the USA, where analogous challenges emerge within alluvial areas, the resultant impact

Table 1. Attributes of different studies included in this systematic review

Author/Authors	Methodology	Year	Study Location	Journal	Key Findings
Hassan et al.	Survey	2005	Bangladesh	Social Science & Medicine	Patients' interactions reveal significant adverse social consequences and a marked difference in opinions about arsenic and social issues between those who have arsenicosis and those who are not.
Ahmed et al.	Survey	2011	Bangladesh	Journal of Toxicology and Environmental Health Sciences	The social fall-out and exclusion prompted by arsenic contamination were exacerbated by insufficient awareness, ultimately leading to hindrances in medical access and causing challenges for family's dependent on affected earners
Morton and Caron	Cohort	1989	USA	American Journal of Industrial Medicine	Two cases of occupational arsenic exposure led to cognitive impairment, validated by increased urine levels with symptoms alleviating post-exposure cessation
Thakur et al.	Review	2013	India	Knowledge systems of societies for adaptation and mitigation of impacts of climate change	Economically disadvantaged households bear the brunt of arsenic contamination, as current mitigation efforts prove ineffective in supplying accessible clean water, resulting in the expansion of affected regions.
Nurun Nahar	Case Study	2009	Bangladesh	Environment, development and sustainability	Male arsenicosis prevalence surpasses females at equal income levels, correlating with poverty-related escalation, inadequate mitigation awareness, and discernible NGO-driven behavioural changes.
Das et al.	Experimental	2013	West Bengal, India	Chemical Speciation & Bioavailability	Applying arsenic above 100 mg/kg triggered rapid damage in rice plants within 5-7 days, causing complete death at 150 mg/kg within 45 days, and initiating yield decline from 15 mg/kg onwards, with a significant economic impact surpassing 60 mg/kg (80.8% yield reduction)
Syed et al.	Case-Control	2012	Bangladesh	Journal Of Health, Population, And Nutrition	In comparison to non-patients of both sexes, arsenic-affected patients experienced significantly lower quality of life (QOL) and greater mental health disturbances.
Pinchoff et al.	Ecological	2022	India	International Journal of Hygiene and Environmental Health	Each 1% increase in predicted arsenic exceeding 10 µg/L correlated with 4.5% higher stillbirths, 4.2% higher recurrent pregnancy losses and 4.4% higher infertility rates.
Asadullah and Chaudhury	Cross-Sectional	2011	Rural Bangladesh	Economics of Education Review	A clear negative association was identified between home arsenicosis and students' mathematical scores with a stronger effect observed in boys compared to girls; comparable patterns are seen in social well-being, life satisfaction, and health status.
Rahman et al.	Review	2018	Bangladesh	Ecotoxicology and Environmental Safety	Individuals impacted by arsenic experience social isolation, job loss, divorce, and reduced living standards, straining Bangladesh's fragile public health system with numerous arsenicosis cases.
Ranjan and Kumari	Survey	2022	Bihar, India	Problemy Ekorozwoju	Low education promotes superstition in arsenic-affected regions, with poor awareness leading to untreated water consumption, particularly affecting economically vulnerable populations.
Roy et al.	Cross-Sectional	2011	Mexico	Environmental Research	Urinary arsenic levels' connection with behaviour is influenced through arsenic's effect on cognitive function, with significant consequences for future outcomes, as early behaviour can mould social interactions, teacher relationships, and academic progress.
Joyashree Roy	Case Study	2008	West Bengal, India	Science of The Total Environment	The monthly household benefit of lowering arsenic concentrations to 50 µg/l is Rs 297 ($7), while the monthly cost of KMC-filtered piped water is Rs 127 ($3), demonstrating the financial sustainability of making an investment in safe drinking water.

Continued Table 1. Attributes of different studies included in this systematic review

Author/Authors	Methodology	Year	Study Location	Journal	Key Findings
Chowdhury et al.	Survey	2006	Bangladesh	Pakistan Journal of Biological Sciences	Lack of awareness breeds superstitions around arsenicosis, which leads to treatment avoidance, exclusion from social activity, economic strain, and escalating violence against women, intensifying the arsenic-related crisis.
Singh et al.	Survey	2022	Rural India	Emerging Contaminants	Factors like caste, education, awareness, occupation, social capital, housing condition, sanitation, interpersonal trust, and participation of NGOs substantially influenced the social resilience toward arsenicosis patients.
Nath et al.	Review	2021	West Bengal, India	SN Applied Sciences	Elevated arsenic levels in the Holocene aquifers are mobilized through irrigation, depositing onto fields and causing bioaccumulation in food, amplifying health concerns among the local population
Chowdhury et al.	Case-Control	2016	Bangladesh	DEF-Discussion Papers on Development Policy	Compared to individuals with other illnesses, the impact of arsenicosis symptoms on mental health is notably pronounced, resulting in a substantial compensation requirement equivalent to the average annual household income.
Nahar et al.	Survey	2008	Bangladesh	Journal Of Environmental Health	Men are more vulnerable to drinking water arsenic, with increased arsenicosis risk tied to lower per capita income; yet a substantial proportion of villagers express eagerness to pay extra (around 60%) for safe water provision.
Sukha Ranjan Samadder	Ecological	2011	West Bengal, India	KSCE Journal of Civil Engineering	A notable fall in HDI was witnessed of up to 25% in six blocks of Murshidabad district, which was mostly attributable to the decline in life expectancy brought on by the groundwater arsenic contamination
Farhana Sultana	Case Study	2012	Bangladesh	Annals of the Association of American Geographers	In instances of slow poisoning arising from a blend of developmental endeavours and environmental factors intertwines health complexities, with evolving implications for individuals and communities over time
Chatterjee et al.	Survey	2010	West Bengal, India	Environment and Ecology	Poor living conditions, unsafe water, inadequate medical care, and a lack of education cause social instability and people of the region are drawn into the gloom of depression, which has serious socioeconomic repercussions.
Majumdar et al.	Case Study	2018	West Bengal, India	International Journal of Research and Review	Chronic arsenic exposure yields diverse psycho-social, behavioural, and financial repercussions. Prompt awareness initiatives, psychosocial aid, job prospects, and health information are imperative for the affected.
Mahmood and Halder	Review	2011	Bangladesh	Journal of Toxicology and Environmental Health Sciences	Impoverished families face a greater arsenic issue, with limited safe water access leading to heightened exposure worsened by poverty-related malnutrition
Laskar et al.	Case-Control	2010	Bangladesh	Archives of Environmental & Occupational Health	Arsenicosis patients showed notably lower quality of life scores across domains than controls, with a clear link between higher arsenic exposure and poorer quality of life.
M. Mizanur Rahman Sarker	Survey	2010	Bangladesh	International Journal of Environmental Research and Public Health	Females were less vulnerable to social issues but more to psychological problems from arsenicosis than males, while the Education and household income of respondents correlated with perceptions about arsenicosis.
Hadi and Parveen	Cross-Sectional	2004	Bangladesh	Public Health	The prevalence of arsenicosis is inversely correlated with economic status, while the factors of sex and education didn't demonstrate statistical significance
Chakraborti et al.	Cohort	2016	India	Journal of Trace Elements in Medicine and Biology	Arsenicosis yields health risks, strained families, mental stress, and social exclusion, leading to income loss and burdening families and society, impacting the overall economy of the region
Abedin et al.	Experimental	2002	Bangladesh	Plant and soil	Irrigating with arsenate-containing water decreased plant height, lowered rice yield, and impaired root growth development

Continued Table 1. Attributes of different studies included in this systematic review

Author/Authors	Methodology	Year	Study Location	Journal	Key Findings
Sukha Ranjan Samadder	Ecological	2010	West Bengal, India	KSCE Journal of Civil Engineering	Continuous exposure to groundwater arsenic contamination could substantially reduce the life expectancy of residents in over 26% of the area across six blocks in the Murshidabad district
Chakraborti et al.	Cohort	2017	India	Hydrogeology Journal	Individuals with severe arsenical skin lesions could face long-term risks of multiple Bowens/cancers, alongside experiencing unique symptoms like skin itching, burning sensations, and sunlight-induced eye-watering in arsenicosis patients.
M. Zakir Hossain Khan	Case Study	2007	Bangladesh	South Asian Network for Development and Environmental Economics	The annual costs associated with illnesses brought on by exposure to arsenic range from Tk 557 (US$ 9 million) to Tk 994 (US$ 17 million), or an average of roughly 0.6% of the affected people's annual income.
Muehe and Kappler	Review	2014	South and Southeast Asia	Environmental Chemistry	Arsenicosis sparks social instability and affects vulnerable people, while arsenic-contaminated irrigation threatens agriculture, economies, and food security, intensifying crises
Mahbuba Nasreen	Case Study	2004	Bangladesh	Bangladesh e-journal of Sociology	The harmful consequences of arsenic, particularly in Bangladesh, demonstrate how water has changed from being a lifesaver to a threat to survival because of its delayed effects and lack of quick disease diagnosis.
Ahmad et al.	Case-Control	2001	Bangladesh	Environmental Health Perspective	In comparison to the non-exposed group, the exposed group showed a noticeably increased incidence of unfavourable pregnancy outcomes, such as spontaneous abortion, stillbirth, and premature birth.
Ahmad et al.	Case Study	2005	Bangladesh	Journal of Environmental Management	Rural inhabitants in Bangladesh are ready to invest in piped water stands at approximately 10–14% of their expenditure and merely 0.2–0.3% of the mean household income.
Norra et al.	Experimental	2005	West Bengal, India	Applied Geochemistry	Arsenic deposition in plants and hazardous soil may result from prolonged irrigation with arsenic-contaminated water, demonstrating the critical importance of soil monitoring.
Mahbuba Nasreen	Ecological	2005	Bangladesh	Sociological Bulletin	Successful strategies demand prioritizing policies, education, community involvement, and gender sensitivity, coupled with collaboration, monitoring, and psychological assistance for sustainable arsenicosis mitigation
Nahar et al.	Cross-Sectional	2014	Bangladesh	Environmental health and preventive medicine	Even after socioeconomic status control, a correlation existed between arsenic concentration in water and urine arsenic levels, which in turn related to diminished intelligence quotient or social competence.
Saha et al.	Review	1999	Global	Critical reviews in environmental science and technology	Arsenicosis treatment is ineffective despite repeated attempts; once the problem has arisen, utilizing medicine may not be able to avoid it
Sujeet Kumar Dubey	Cross-Sectional	2022	Bihar, India	India Centre for Policy Research and Development	Mental development in arsenic-affected districts of Bihar deviated from standardized levels, with prevalent mental retardation and developmental disabilities observed in affected children
Haq et al.	Survey	2012	Pakistan	Sustainable Agriculture Research	Around 42% of patients suffering from arsenicosis, exacerbated by income decline and limited awareness, with 60% of poor earnings allocated to hospitalization.

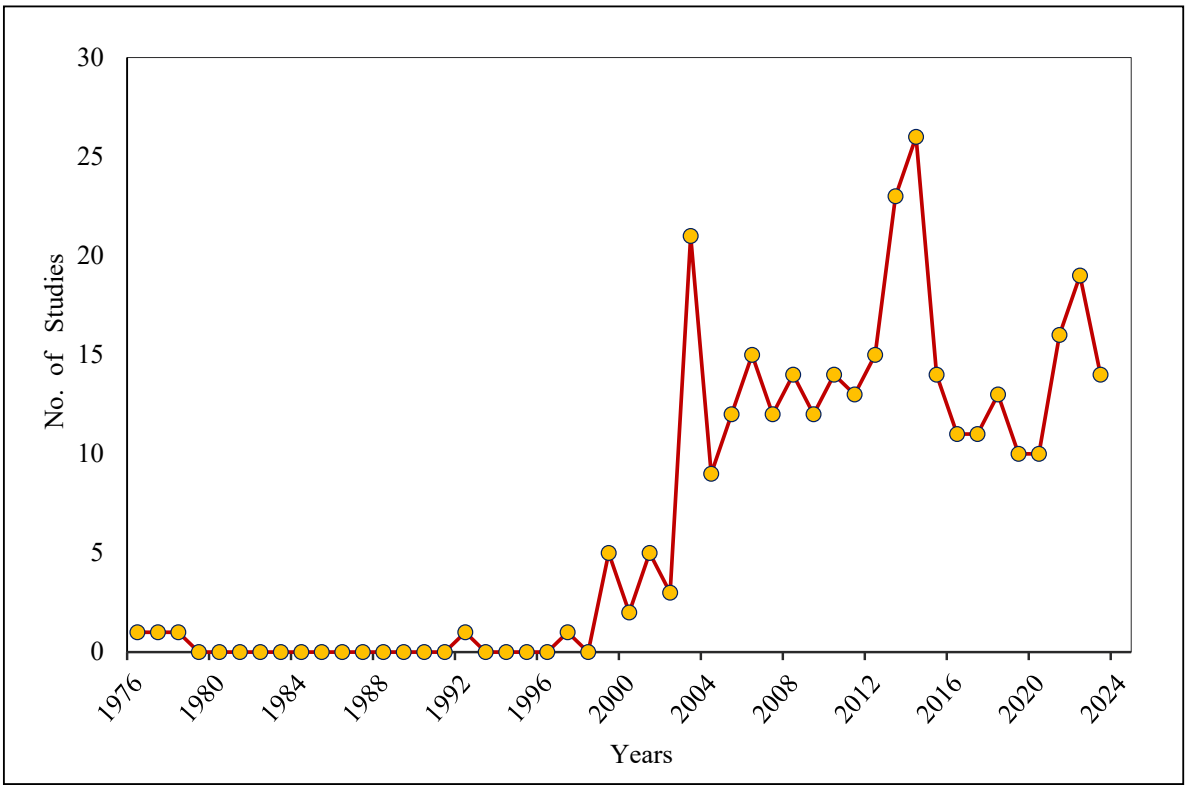

Fig. 3. Distribution of published papers frequency over the years (Data source: Scopus, obtained using keywords "arsenicosis" AND "health" OR "Psychological" OR "socio-economic" OR "agriculture")

notably differs from the consequences observed in underdeveloped and developing countries. This phenomenon can be attributed to the socioeconomic disparities prevalent between developed and underdeveloped or developing countries. This is supported by some studies in which a correlation has been established between individuals with lower socioeconomic status and consequently elevated dietary insufficiencies, leading to a heightened susceptibility to arsenicosis and factors such as malnutrition, disadvantaged socio-economic conditions, lack of education, dietary patterns, and prolonged consumption of arsenic-contaminated water over numerous years which are more common in underdeveloped and developing countries, have collectively exacerbated the impact of arsenic toxicity on this population (Rahman et al., 2018; Chakraborti et al., 2002). The accuracy of this claim is further corroborated by our careful analysis which shows that approximately 70.73% of the total works (comprising 29 out of 41) are conducted within the geographical expanse of the Bengal Delta Plain region; an extensive area that spans both Bangladesh and West Bengal province of India; thereby making it a highly significant area of focus. Subsequently, a notable proportion of 17.07% of the studies (7 articles) is situated within diverse regions across India, with the exception of West Bengal. The remaining corpus of scholarly endeavours (5 articles), comprising 12.20% is disseminated across various international contexts, thereby exemplifying a limited international perspective in research distribution, extending its scope beyond national boundaries, and underscoring the global relevance and consideration of the socio-economic ramifications associated with arsenic contamination in groundwater.

Focused theme analysis

The primary goal of the study theme analysis was to carefully analyze the core themes of the various research publications. The systematic review conducted within this study was also

methodically structured in alignment with the delineated research themes. The outcomes of this investigation unveiled a spectrum of research themes. Notably, among the total of 41 studies, 13 studies (31.71%) were dedicated to the investigation of arsenic contamination and its intricate interplay with diverse societal concerns. Subsequent to this, a notable emphasis emerged on the psychological ramifications, encompassing 8 articles (19.51%). Furthermore, a cluster of research delved into the economic challenges and health-related costs engendered by arsenic contamination, yielding 5 articles (12.20%). Similarly, an equivalent number of studies were aligned with the themes revolving around the impact on physical health, overall well-being, and the agricultural predicaments associated with arsenic contamination, each category comprising 5 articles (equivalent to 12.20%).

Analysis of research methodology

In order to ensure the author's comprehensive analysis and to increase the review's overall quality, reliability, and validity, in a systematic literature review it is essential to analyse of research design of collected studies (Okoli, 2015). Our evaluated outcomes have demonstrated that within a broad framework, the corpus of scientific manuscripts predominantly falls into two categories: qualitative studies, predominantly centred around sociocultural dimensions (e.g., Nasreen, 2004; Hassan et al., 2005; Chowdhury et al., 2006, etc.), and quantitative studies (e.g., Ahmad et al., 2005; Das et al., 2013; Khan, 2007; Roy, 2008, etc.), primarily concerning economic aspects or physical health. Notably, a few articles have also adopted a mixed-methods research approach to elucidating the psychological implications of arsenic contamination (e.g., Hadi and Parvin, 2004; Sultana, 2012; Majumdar et al., 2018, etc.). Given that our study focuses on different aspects of the effects of arsenic contamination, the collection of carefully examined scientific papers can be divided into the following categories (Fig. 1): survey investigations (9 articles= 21.95%), case studies (7 articles= 17.1%), review articles (6 articles= 14.6%), cross-sectional inquiries (5 articles= 12.19%), ecological studies (4 articles= 9.76%), cohort analyses (3 articles= 7.32%) and experimental research (3 articles= 7.32%). It is noteworthy that among the six review papers, three pertain to the realm of physical health impact (e.g., Saha et al., 1999), agricultural ramifications with associated health outcomes (e.g., Nath et al., 2021), and Mahood and Halder (2011) who attempted to propose a methodological framework for assessing health effects and diverse mitigation strategies respectively. The remaining three review articles (e.g., Thakur et al. 2013; Rahman et al. 2018; Muehe and Kappler, 2014) gave a brief overview of the socioeconomic effects of arsenic contamination, including its causes, mobilization, and effects on physical health. Interestingly, none of the review articles provides a thorough connection between arsenicosis, its socioeconomic effects, and how these effects all work together to affect the overall holistic well-being of individuals as well as affected regions. In this context, the present study stands out as a unique and groundbreaking contribution, addressing a junction that had not been examined before.

Research trends analysis (emerging foci) using bibliometric metrics

Keyword analysis serves as a valuable approach for discerning the research inclinations of authors concerning a particular subject matter (Ellegaard and Wallin, 2015). Fig. 4 portrays a network analysis of the co-occurrence patterns within the most frequently employed author keywords across publications addressing the socio-economic ramifications of arsenic contamination. In the analysis, a total of 3313 keywords were acquired. In order to establish and ensure robust co-occurrence connections between these keywords a minimum occurrence criterion of 5 was applied. Out of the total, 330 items met this criterion, and after careful screening eliminated irrelevant terms like "review," "article," and "questionnaire," as well as similar terms such as "human" vs. "humans," "groundwater" vs. "ground water," a final selection of 324 keywords was chosen for visualization. Among the 3313 distinct keywords

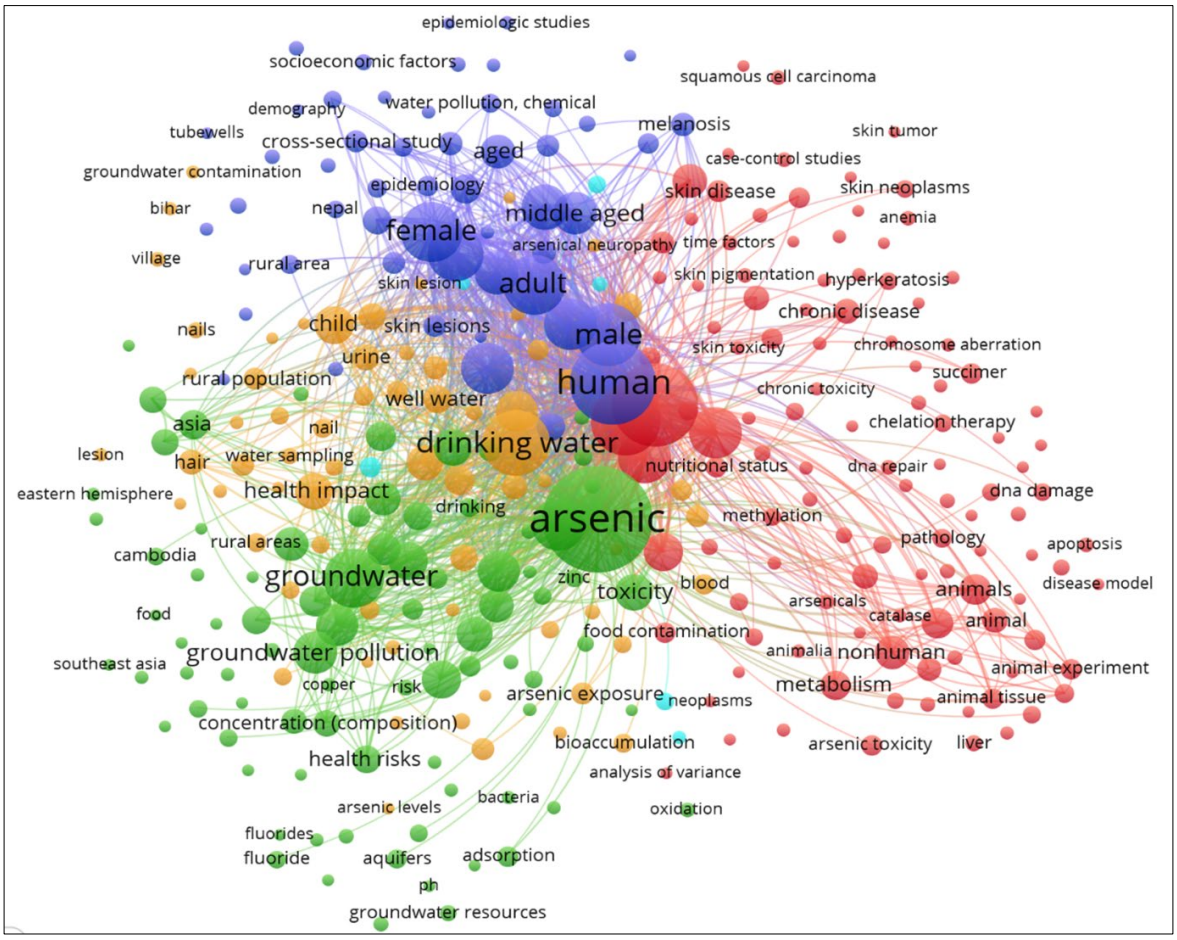

Fig. 4. Global Keyword Co-occurrence Network Analysis in Scholarly Literature using VOSviewer (data source: Scopus, obtained using keywords "arsenicosis" AND "health" OR "Psychological" OR "socio-economic" OR agriculture")

present in the published articles (390 were excluded due to irrelevance or similarity), "arsenic" emerged as the most frequently utilized keyword accounting for 9.03% (264 instances) of the dataset. Other prominent keywords within the top 10 included "human," "arsenic poisoning," "arsenicosis," "drinking water," "male," "female," "adult," "groundwater," and "environmental exposure," reflecting their significance within the domain.

DISCUSSION

Arsenic contamination in drinking water has severely negative impacts on the socioeconomic development of arsenicosis households (Fig. 5). This includes lower productive hours, increased medical costs, social instability, social unfairness, social isolation, and challenging family dynamics.

Social problems

Arsenicosis is not only a physical health problem but also a social phenomenon (Khan et.al, 2014). Despite the fact that arsenic is a proven carcinogen, the impact of the poisoning extends to the patients' social spheres, compounding the already distressing challenges they face. The arsenic contamination in drinking water has resulted in numerous social and societal problems for individuals afflicted by arsenicosis and their families in the afflicted regions. However,

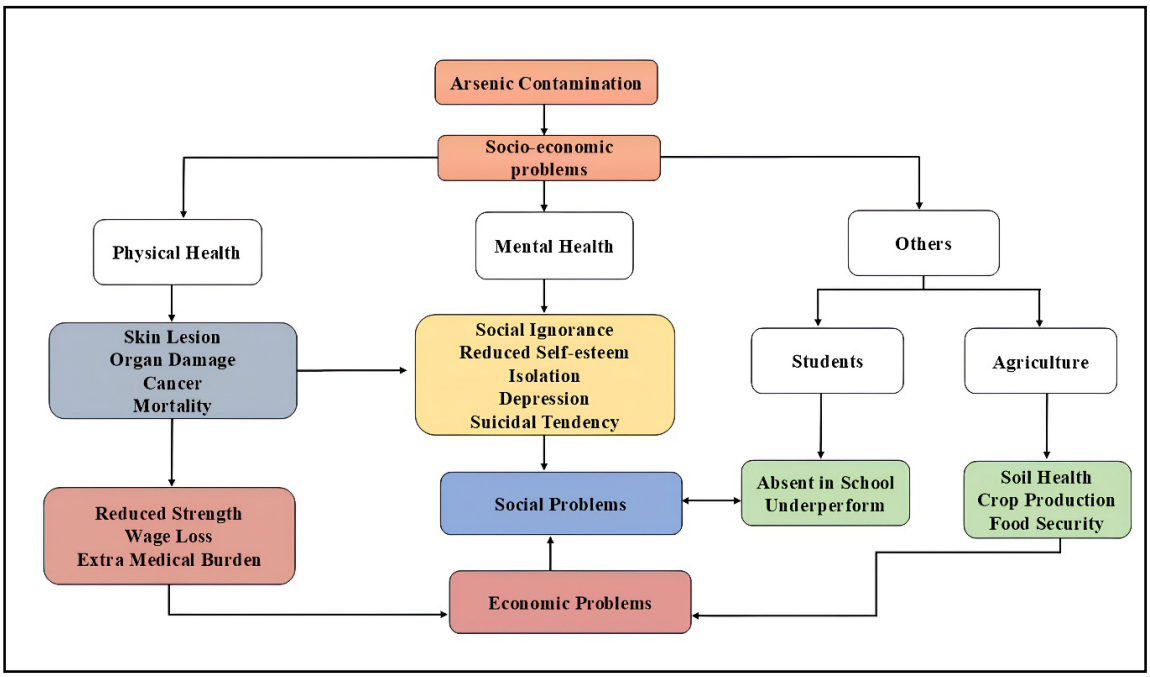

Fig. 5. Socio-economic problems of groundwater arsenic contamination (Source: adapted and modified from Thakur et. al, 2013)

many of these are still not fully recognized. However, various social issues have been discussed in different studies are discussed below:

Social instability

Nasreen (2005) and Chatterjee, et al. (2010) described that arsenicosis is the cause of extreme instability in the social life of arsenicosis victims in West Bengal and Bangladesh. People are dwindling under the condition of what to do and not to do, where they should go, how they would get rid of the situation, and how they would get arsenic-free water (Chatterjee, et. al, 2010). Such type of situation is witnessed due to illiteracy, lack of awareness about arsenic contamination in drinking water, improper treatment, and even not at the time. Besides these, arsenic is the cause of societal embarrassment and discrimination. (Ahmed et. al, 2011). The unaffected people try to avoid and isolate, even sometimes angry and aggressive toward arsenic victims as they are afraid that if arsenicosis attacked them and they would experience the same health and social issue as arsenicosis victims facing (Nasreen, 2005; Hassan et. al, 2005; Chowdhury et.al, 2006; Muehe & Kappler, 2014). Case study demonstrated that arsenicosis patients experienced negligence from local leaders and local authorities' incompetence also. For instance, local officials don't cooperate with arsenic victims in their attempts to receive financial aid from the community and medical care from the proper physician (Hassan et. al, 2005). Affected people are frequently excluded from social events. Arsenic-affected children are frequently denied the opportunity to play with other kids and avoided by their peers at school, which pushes them into a severe state of depression (Ahmed et.al, 2011). Children of arsenicosis sufferers are prohibited from participating in social and religious gatherings (Ahmed et al. 2011; Nasreen, 2005) and they also face restrictions when attempting to access water from neighbouring tube wells (Rahman et.al, 2018), even this barrier is created by the local people in government-owned tube wells also (Hassan et. al, 2005). Even, the victims are not allowed to offer their worship in mosques or in the temple (Ahmed et.al, 2011), and in rural Bangladesh,

when an arsenicosis sufferer passed away, some local religious leaders refused to bury him according to Muslim customs. (Hassan et. al, 2005). A study conducted by Singh et. al, (2022) highlighted that 60% of respondents agreed to invite an arsenicosis family to a social gathering and 54% allow their children to play with the children of an arsenicosis family. This is clearly revealed the pathetic situation of arsenicosis victims for their survival in our society where still nearly half of the population avoids or tried to not come into close contact with the victims.

Ostracism

Even though arsenicosis patients may not appear sick or feel sick in the early stages of the disease, they are nevertheless viewed as "dangerous individuals" and degraded their status in society; even, some unaffected individuals exhibit antagonistic behaviour and argued that sufferers should either remain in their houses or leave the community (Hassan et. al, 2005). For example, Singh et. al, (2022) in their study highlighted that within the surveyed population, 57% of respondents hold the belief that an individual afflicted with arsenicosis would be allowed to continue residing within their locality and only 50% of the communities demonstrated a degree of resilience towards arsenicosis patients. However, these findings vary when taking into account education, occupation, housing conditions, caste, social capital, personal hygiene practises, interpersonal trust, NGOs, and awareness. In another instance, Jhilam, a patient with arsenic poisoning, recalled one of his intimate friends telling her, "Please don't come near me; if I touch you then the disease you have got will infect me"(Hassan et. al, 2005). There is evidence that sometimes people tried to avoid the area which is contaminated by arsenic. For instance, Tandra Sarkar, an inhabitant of the Merudandi area in North 24 Parganas District, West Bengal, said that she wishes to sell her house and move to another "safe village" but "Nobody is ready to purchase my property even if I agree to sell it at rates lower than the market price," (The Hindu, April 29, 2013). Due to fear of such type of ostracism at the initial stage of arsenicosis patients conceal their symptoms (Rahaman et.al, 2018) and families made an effort to discourage their own members from interacting with society, which had negative effects on families over generations (Arsenic Primer, 2018).

Difficulties within the family

Arsenicosis sufferers find themselves forsaken not only by society but also encounter challenges within their immediate family circles. Within families, they are indirectly neglected and isolated (Hassan et.al, 2005), and sometimes they even emerge as a source of burden for both their families and the broader society (Hadi and Parveen, 2004; Chowdhury et al., 2006; Ahmad et. al, 2007). Parents exhibit reluctance to maintain proximity with their offspring, and conversely, children display a reluctance to approach their parents closely (Hassan et.al, 2005; Sarkar, 2010). It is a terrible situation for a family of victims of arsenic contamination. A case study revealed that Parvin, a 17-year-old female who has manifested black spots on her palms and skin lesions across her body and within her family, she encounters challenges, and in a moment of desperation, she disclosed, my parents' demeanour has grown harsh towards me which she never witnessed prior to the emergence of these lesions, leading her to feel burdensome within the household (Hassan et.al, 2005). In many cases, husbands abandoned their wives or remarried and wives temporarily left their husbands to avoid arsenicosis risks (Chowdhury et. al, 2006). A study indicated that around 32% of respondents observed marital and familial distress among arsenic-affected couples (Sarker, 2010).

Arsenic is the curse of God

Public awareness or special education/training programs to target individuals may play a vital role in against increasing social crisis due to arsenicosis (Chowdhury et. al, 2006; Sarker, 2010). But, unfortunately, the majority of the population attacked by arsenicosis are poor, live-in rural

areas and have a lower level of educational achievement (Mahmood and Halder, 2011). Hence, due to a lack of knowledge about arsenicosis people wrongly recognized arsenic problems as contagious, hereditary or a curse of God (Hassan et al. 2000; Sarkar, 2010; Ahmed et al. 2011). However, existing beliefs and superstitious notions regarding illnesses stemming from arsenic exposure exacerbate the circumstances. People with arsenic contamination also experience some social stigma because the illness result of arsenicosis is mistakenly blamed on sins committed in previous or present lives, which causes social strife and ruins social harmony and network relationships (Ahmed et. al, 2011). Some people believe that it is the result of malevolent forces, demons, or polluted air, leading them to distance themselves and their families from the affected individuals, sometimes they neglect or become scared of arsenic patients. Additionally, there is also evidence that many people think that a poisoned well is a sign that a snake was struck while the digging was going on (The New York Times, Nov. 10, 1998). Due to a lack of knowledge, superstitious beliefs, and prejudices the majority of patients remained untreated, enduring lives marked by profound suffering (Nasreen, 2004; Chowdhury et. al, 2006). But fortunately, literature cited evidence that these prejudices are limited among illiterate people. For instance, In Samta, Jessore, Bangladesh, with an illiteracy rate exceeding 70%, superstitious inclinations peak at 80% while, in Courtpara and Kushtia, where approximately 65% are literate, only 30% of arsenic sufferers remain untreated due to superstitious beliefs, while 70% attribute their lack of treatment to financial constraints. (Chowdhury et. al, 2006).

Arsenicosis issues in relationships or seeking marriage

One of the most important social problems of arsenic contamination is people avoid getting married to members of families who have arsenicosis (Chowdhury et.al, 2006; Ahmed et. al, 2011) and it breeds unrelenting anxiety in both parents and unmarried adult children. Many mothers were concerned that their daughters might not find husbands, and younger women worried that if they showed signs of arsenicosis, their value or desirability as wives would be diminished (Sultana, 2012). Not just girls, adult boys are equally worried about it too. For example, as per a study, 64% of participants held the belief that girls might encounter challenges in securing marriage due to arsenicosis, while 12% perceived those men displaying signs of arsenic exposure on their bodies exhibited reduced confidence in pursuing marriage (Sarkar, 2010). Adult male arsenic victims are not able to find a spouse and sometimes, young men and women are advised to remain unmarried (Chowdhury et. al, 2006). Even, after marriage, problems are also notable. There are several cases where arsenicosis causes the breakdown of marriages. Literature cited evidence that couples are separated or many women were divorced or abandoned by their husbands (Hassan et. al, 2005; Chowdhury et. al, 2006; Sarker, 2010, Chatterjee et. al, 2010); impacted wives, occasionally accompanied by their children, are sent back to their parental homes for treatment (Hassan et. al, 2005; Thakur et. al, 2015); and wives also left their husbands due to the concerned of being attacked by arsenicosis (Nasreen, 2005; Ahmed et. al, 2011).

Impact on women

A prevalent notion exists that women symbolize misfortune, and an ailing woman might bring a curse upon the family (Sultana, 2012). Paradoxically, amidst the arsenicosis predicament, women often assume pivotal roles, not only by procuring arsenic-free drinking water but also by provisioning nourishing sustenance to the afflicted, utilizing their personal savings, liquidating assets, and leveraging their social networks (Chowdhury et al. 2006). Women exhibit greater vulnerability due to their comparatively less robust physiological composition in comparison to males (Thakur et al., 2016; Nahar, 2016). As their bodies are more susceptible to arsenic poisoning, rural inhabitants, particularly women, experience the most pronounced impacts (Ahmed et.al, 2011). Study revealed that approximately 53% of females, in contrast to 34% of

males, pinpointed marriageability concerns as the foremost social challenge for women, along with overarching social ostracism, stigmatization, and the exclusion of ailing women (Sultana, 2012). Certain literature cites evidence that women exhibiting symptoms of arsenicosis often experience neglect from their husbands (Hassan et al., 2005), hated by others (Ahmed et. al, 2007), and some suffered housewives' husbands file for divorce (Chowdhury et al., 2006; Ahmad et al., 2007; Chatterjee et. al, 2010; Sarker, 2010), even sometimes they are avoided by their immediate family member and friends (Hassan et.al, 2005; Ahmad et al., 2007).

Considering the patriarchal characteristics of societies and the socio-cultural position of women within society particularly in South Asian nations, unmarried and divorced women grappling with arsenicosis are confronted with harsh and dehumanizing conditions (Rahaman et.al, 2018). They constitute the most marginalized group within the spectrum of disease victims (Chatterjee et, al, 2010; Rahaman et.al, 2018). For instance, Upon the occurrence of arsenicosis within a household, the notable focus is directed towards the primary earners or allocating a considerable portion of treatment expenses to enhance the well-being of the male members, occasionally overshadowing the needs of women (Ahmed et. al, 2011). Even, during times of marital negotiation, the bridegroom's family emphasises physical attractiveness and complexion. Hence, arsenic-affected unmarried girls are the worst victims of the situation as they lose their beauty and complexion due to the toxic effect of arsenic (Chatterjee et, al, 2010). Again, arsenicosis incidents in poor households forced children to drop out of school to support their families, and girls are most deprived in this regard (Nahar, 2008). Furthermore, it is also clear that men (53%) were less aware than women (91%) about the psychological effects of arsenicosis. (Sarkar, 2010).

In daily life activities

The arsenic crisis has a profound impact on the socioeconomic framework of households (Thakur et. al, 2016) exerting a substantial threat to the societal standing, way of life, and economic stability of both sufferers and their families (Rahaman et. al, 2018). Consequently, those affected encounter substantial challenges in upholding their routine social interactions (Chatterjee et. al, 2010). This situation might prompt difficulties in maintaining customary emotional expressions, affection, and interpersonal dynamics in daily life (Sarkar, 2010). Social deterioration, inequity, and social isolation emerge as prevalent occurrences among the affected individuals. (Rahaman et. al, 2018; Chowdhury et. al, 2006). Most of the arsenicosis patients thought the way of looking of society towards them had changed as a result of their illness (Majumdar et. al, 2018) even though the simplest social interaction becomes impossible; sometimes, victims skip social interaction to avoid harassment by others (Thakur et. al, 2016; Hassan et. al, 2005). For example, an arsenic-affected person in Bangladesh described that within the Hatkhola periodic market, some people adopt an indirect avoidance stance towards him. Whenever they engage in routine shopping at various stores or visit a tea stall for refreshments, certain individuals purposefully distance themselves or make attempts to leave the vicinity (Hassan et. al, 2005). Social discrimination is also associated with this disease in terms of employment opportunity. Since the untouchable stigma attached to arsenic sufferers prevents them from being hired, even after the appointment if the employee displayed signs of arsenicosis then they have been forced to quit the job (Chowdhury et. al, 2006). Not only the adult population, but school-going children also encounter hindrances in their daily life, such as former classmates keep distance, refused to share books, pencils, and even, teachers who may restrict their access to the classroom (Hassan et. al, 2005). Within the family, the partner lost his/her interest to other partner as they sought his/her partner was unsuitable or weaknesses during physical relations or losing their beauty due to arsenic toxicity (Majumdar et.al, 2018; The New York Times, Nov. 10, 1998). The aforementioned description of social issues paints a picture of the social hazards experienced by arsenic-affected people on a daily basis, which

results in isolation, social injustice, and harm to social ties. Consequently, the victims suffer from mental health issues on a regular basis and may even attempt suicide (Thakur et. al, 2016; Rahman et.al, 2018). Some victims and their families believe they can escape societal injustice if they can establish a relationship with prominent locals like political figures, social activists, and elected officials (Hassan et.al, 2005), which is further proof of to what extent an arsenicosis patient witnessed social injustice in their daily life.

Economic problems

World Health Organization (2000) points out that the social challenges stemming from arsenic pollution impose strains on the economies of the regions impacted by this issue. Apart from these health issues and social problems, arsenic poisoning in water creates economic problems in a variety of ways and subsequently reduces the chances of economic development for both the individual and households. Medical costs, income loss, decreased crop output, and a poor quality of life are all factors in the economic impact of arsenic toxicity. However, all these factors are interlinked to each other. For example, the consumption of arsenic-contaminated water leads to physical illness, gradually decreasing their work capability and early retirement from work. As a result, they fall into debt and due to limited physical strain self-cultivators solely depend on hired agricultural labourers which raises costs and significantly drops agricultural output. As a result, they fall into debt which exacerbates the preexisting economic condition. Consequently, they are unable to secure access to nourishing dietary provisions, compounding the decline in their overall health status. Additionally, they are forced to drink contaminated water since they cannot afford to buy arsenic-free water, which exacerbates the already dire situation (Chakraborti et. al, 2016). From the above discussion, it is clear that people affected by arsenicosis and their family passes through a vicious cycle of economic problems, which is illustrated in Fig. 6.

Poverty induced by arsenic contamination

There is a significant correlation exists between arsenicosis problems and poverty (Brinkel et al., 2009; Ahmed et al. 2011; Haq et. al, 2012). Ahmed et.al, (2011) revealed that 58.6% of the 140 respondents who had an arsenicosis patient in their family reported experiencing financial issues as a result of the disease. Since government support is insufficient to fund treatment facilities for the patients, poverty is the main driving force behind arsenicosis treatments and related measures. Various studies have reported that a significant proportion of the population experiencing arsenicosis issues comes from a low socioeconomic background (WHO, 2000: Hadi and Parveen, 2004; Nasreen, 2004; Chowdhury et.al, 2006; Thakur et.al, 2016; Chatterjee et.al, 2010; Ahmed et.al, 2011; Haq et. al, 2012). Consequently, people are unable to purchase nutrient-rich food, which exacerbates the deadly effect of arsenic on humans or their higher dietary deficiencies lead to more often struck by arsenicosis (Chowdhury et.al, 2006; Muehe and Kappler, 2014). For instance, out of 3 villages in Bangladesh, one village (Ranihati) higher percentage of arsenicosis patients was found due to receiving less share of nutrition than others (Nahar, 2009). The presence of arsenicosis, coupled with an increased dietary deficiency, progressively diminishes the working capacity of the afflicted individuals. Studies found that people with arsenic poisoning struggle to deal for more than 3 hours per day in contrast to a healthy individual who can work 8 hours per day (Ranjan et.al, 2022). Therefore, the afflicted person may sometimes quit their job early or a self-producer may begin using hired agricultural labour, which comes at a cost and results in a significant decrease in output (Chakraborti et. al, 2016) and these losses in crop yield would further negatively affect the nutritional status of the farmers (Ranjan et.al, 2022).

Therefore, over an extended duration, this exacerbates the pre-existing economic conditions of the families of the victims. In addition, arsenicosis-related increased medical expenses are

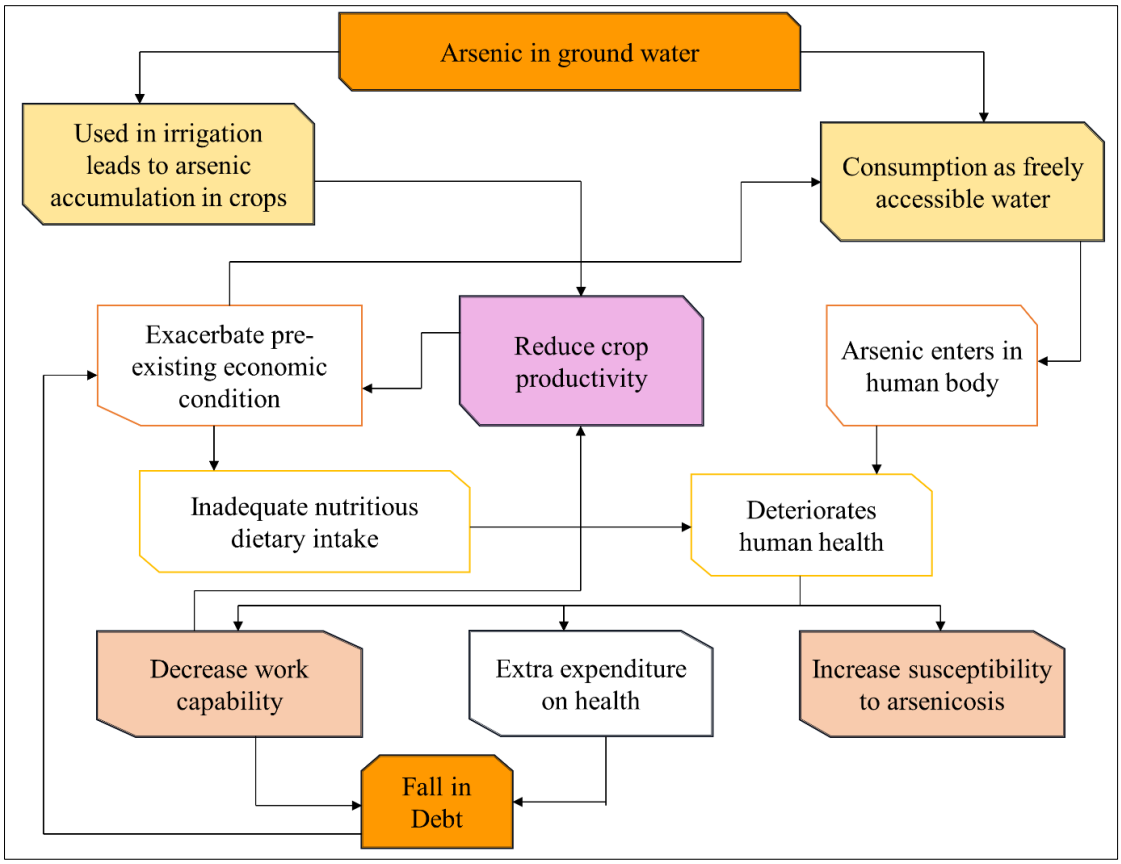

Fig. 6. Vicious cycle of economic repercussion induced by arsenic contamination (prepared by authors)

another factor that is damaging the economy. In one study done in Pakistan by Haq et al. (2012), noted that an average of four persons per household suffer from diseases (mostly arsenicosis), with the poor spending almost 60% of their incomes on hospitalization. Studies across South Asia (Khan, 2007; Roy, 2008; Mahanta et al., 2016; Nahar, 2008) reveal that arsenic exposure incurs substantial economic losses, including millions in healthcare costs and lost productivity ith projected monthly benefits ranging from $14 to 84 per year if arsenic level reduced to safe limit. Hence, it can be concluded that excessive arsenic in drinking water as well as accessing arsenic-free water, diminishes household income.

Arsenic, a poor man's disease

Since it is confirmed that the poorest members of society experience the worst arsenic-related issues, chronic groundwater arsenic poisoning is referred to as the poor man's disease or an orphan disease (Chakraborti et al, 2016). Studies showed that those who are poor have a 1.87 times higher probability of developing arsenic lesions than people who are not poor (Hadi and Parveen, 2004). Hence, the majority of individuals affected by arsenicosis are of low socioeconomic status and belong to rural areas, subjecting them to experiences of malnutrition. (Mahmood and Halder, 2011) which often pushed them toward the path of being assailed by arsenicosis (Chowdhury et. al, 2006). In this context, one expert in the field of arsenic contamination Mr. Dipankar Chakraborti noted that if the affected population had better nutrition facilities, approximately 80% of them may be saved from arsenic toxicity (The Hindu, April 29, 2013). Due to the fact that the majority of victims are from rural areas, therefore they work in informal settings, and if they get sick and can't work, they don't get paid for that

day and sometimes they become incapable of doing hard labour which further deteriorates their overall economic condition (Hassan et. al, 2005). Consequently, most of the poor victims remain untreated (Brinkel et. al, 2009), or to cover the cost of medical expenses all of these households sold off assets, and as soon as earnings from the sale of the last asset had been used, no more expensive medical expenses were incurred (Pryer, 1989). Studies cited evidence that the effect of arsenicosis symptoms on mental well-being warrants a considerable compensation request, equivalent to the average annual household income (Chowdhury et al. 2016). In a few cases, families lost their heads of the household or primary earners due to this disease which break down the economic structure of the household and affected orphans and widows forced to find alternative livelihood options (Chowdhury et. al, 2006). In addition, literature also cited evidence that social issues were encountered substantially more frequently by the lower-income group than by the higher-income income groups (Mahmood and Halder, 2011).

Agriculture

A matter of substantial public health concern encompasses not solely the intake of arsenic-contaminated drinking water, but also the absorption of arsenic via the food chain. Studies indicate that subsequent to the direct ingestion of arsenic-contaminated drinking water, the second principal route of arsenic exposure occurs through the food chain (Thakur et al.,2013). At the time of irrigation, an elevated level of arsenic is released during the process and gets deposited in agricultural fields leading to the accumulation of arsenic in food products (Dutta and Bandyopadhyay, 2016; Shrivastava et al. 2020; Nath et al. 2021). In addition, this cycle of arsenic contamination from water to crops is extended by the prolonged use of arsenic-contaminated water from shallow aquifers. In this process arsenic concentrations in surface soils especially in paddy fields are enhanced (Norra et al., 2005). Therefore, using water contaminated with arsenic for irrigation has a negative impact on soil quality and reduces food production. Several studies highlighted that this contaminated irrigation water could have a direct negative impact on plant growth and yield by causing early damage and even complete death of rice plants at high arsenic levels (Abedin et al., 2022; Senanayake and Mukherji, 2014; Singh et al., 2022). Consequently, arsenic-contaminated groundwater irrigation pollutes agricultural soils, posing a rising threat to food security and human health. In many cases, residents in arsenic-endemic regions often suffer from severe malnutrition or undernutrition due to the intake of arsenic-contaminated food, rendering them susceptible to various health issues (Swain et al., 2021). The negative effects of consuming arsenic-contaminated food, coupled with reduced crop production, further contribute to the economic struggles of affected farmers. It is compounded by the fact that areas affected by arsenic-contaminated water may witness heightened poverty levels as a result of market refusal to accept agricultural goods from these locales (Pandey and Rathore, 2020; The Tribune, 2015). Therefore, it would not be wrong to say that the interplay between arsenic contamination, agricultural practices, and economic repercussions creates complex challenges that have a substantial impact on food security, public health, and socioeconomic stability.

Impact on well-being

Two key dimensions are examined in order to conduct a thorough well-being assessment. The first is quality-of-life (QOL), which quantifies the level of holistic satisfaction across the various domains of an individual's life. The second is the Human Development Index (HDI) as an indicator of regional progress. Through these lenses, we explore the nuanced landscape of how the ubiquitous threat of arsenic poisoning combines with the unique fabric of each person's well-being, inspiring reflection on a wide range of topics.

Degraded overall quality of life

Quality of life is a multidimensional concept since it considers the personal evaluation of health conditions, psychosocial well-being, and several life domains. Different research studies regarding arsenic contamination reported that all these domains are severely affected by arsenicosis problems. For example, studies documented arsenicosis induced multisystemic health impacts, including physical weakness (Ahmed et al., 2011; Chatterjee et al., 2010), carcinogenic effects (Smith et al., 2000; Chakraborti et al., 2017), neurological and organ damage (Saha et al., 1999; Ahmad et al., 2001), reproductive complications (Pinchoff et al., 2022; Chakraborti et al., 2016), and impaired physical-cognitive development in children (Chakraborti et al., 2017). Other studies shown that arsenic exposure is linked to a wide range of psychological impairments, including attention deficits, hyperactivity, learning disabilities, mood disorders, memory deterioration, and reduced IQ (Nahar et al., 2014; Dubey, 2022), with school-aged children particularly vulnerable to cognitive and behavioral impacts that adversely affect academic performance and social competence (Roy et al., 2011). It is also evident that cognitive abilities may recover once arsenic exposure is removed (Morton et al., 1989). In addition, the implications of contaminated water are felt most acutely in the areas of physical health and overall well-being, social isolation and exclusion, and socioeconomic constraints (Sultana, 2012) which further creates environmental hazards in the affected region. As a result of a lion's share of govt spending to mitigate this problem, no or little positive development is shown compared to other free or less hazardous-prone areas (Chatterjee et. al, 2010). Because of these issues of arsenic exposure in different aspects of life, studies noted that individuals affected with arsenicosis consistently exhibit notably lower quality of life scores in each specific domain, when compared to both control groups and non-patient populations. (Syed et. al, 2012; Laskar et. al, 2010).

Decreased Human Development Index

According to Roser (2014), the Human Development Index (HDI) is a metric used to measure fundamental aspects of human development such as life expectancy, educational accessibility, and the level of living standards. But arsenic contamination and its toxicity hamper the general human development in the affected area, thus indicators of HDI have shown a downward trend (Chatterjee et. al, 2010). For example, the HDI in the six blocks of West Bengal's Murshidabad district decreased by 15% to 20% as a result of arsenic pollution in the groundwater (Samadder, 2010). Arsenic poisoning has detrimental effects on human health and lowers productive hours (Mahmood and Halder, 2011) which in turn limits their access to medical treatment (Sultana, 2012). The health impacts thus increase government spending on health infrastructure leads to public deficits and a rise in the national debt resulting negative impact on the country's overall economic development trajectory (Nahar, 2009). In addition, persons suffering from arsenicosis must pay extra money for ongoing medical care, which drives up local living costs, reduces their purchasing power, and ultimately lowers their standard of living in the affected area. (Chatterjee et. al, 2010). Further, arsenic exposure over a long period of time has been associated with severe skin disorders, cancer, and non-cancer diseases that cause premature death, thereby lowering the life expectancy of affected people in a region. For instance, it is estimated that if people in a 26% region of six blocks in the Murshidabad district of West Bengal are continuously exposed to arsenic poisoning, their life expectancy will be significantly reduced and among these blocks, three are at higher risk as the reduction in life expectancy expected to be more than 23% (Samadder, 2010). This unpredictable death of bread earners or cash constrained of poor arsenicosis households forced them to early drop-out of their children from school (Nahar, 2008). Again, Asadullah and Chaudhury (2011) pointed out that there is a negative correlation between children's academic performance and arsenic poisoning in household drinking water wells. Hence, children from arsenicosis families are sometimes deprived of the highest educational attainment.

CONCLUSION

The presence of arsenic in groundwater in a contaminant state is not a recent occurrence; however, a prevailing perspective suggests that global public health efforts tend to overlook the health and socio-economic welfare of economically disadvantaged communities. This assertion has been reinforced by the limited attention given to investigating the socio-economic dimensions of arsenic poisoning. Though there are multiple researches on the various facets of arsenic contamination but limited to socio-economic and well-being aspects and among these limited studies only the psychological aspect has been evaluated in developed nations and all the socioeconomic aspects that further effect on social well-being are primarily concentrated in South Asian underdeveloped countries. Therefore, this study fervently argues that the global focus must be shifted to embrace the welfare of individuals suffering from arsenicosis while situating the issue in the larger framework of arsenic contamination, specifically in socioeconomically backwards regions of the world. Through a comprehensive analysis, it becomes evident that the implications of groundwater arsenic contamination are not simply environmental but also penetrate a multitude of socio-economic dimensions, tying into a complex and multidimensional relationship between arsenic contamination and different aspects of socioeconomic development. The review further highlighted the significant detrimental effects of groundwater arsenic contamination on communities: social instability, ostracism, social injustice, social exclusion and problematic family issues; compromised health outcomes; poor living standards; reduced agricultural productivity; impediments to clean water access; and increased economic burdens. These reverberate across the three domains of human development in the areas of the physical, social, and economic. Agricultural productivity seemed to suffer through the availing of contaminated irrigation water, leading to reduced crop yields and income disparities. Moreover, the reviewed research consistently demonstrated how the presence of arsenic could deter investment, limit educational opportunities, and hamper local economic growth, thereby keeping the locality perennially in a state of underdevelopment. Awareness, education, and community engagement issues presented for discussion in this paper must therefore be shed more light on addressing groundwater arsenic contamination. In this manner, the strategies would help empower communities to recognize, reduce, and adapt to contamination threats and can contribute to enhanced resilience and improved socio-economic conditions. A holistic approach that combines targeted health interventions with socio-economic empowerment has the potential to break the cycle of arsenic-induced underdevelopment brought on by arsenic and promote long-term development in impacted areas. In order to significantly improve the lives of people dealing with the effects of groundwater arsenic poisoning, this study emphasizes the significance of interdisciplinary research and cooperative efforts. By acknowledging the profound interconnectedness between environmental health, economic stability, and social harmony, societies can pave the way for sustainable progress that leaves no community behind.

LIMITATIONS OF THE STUDY

This study has some limitations which encompass the lack of adherence to a specific timeline or consideration of political and geographical boundaries. Only English-language scientific sources were included. The intentional omission of specific subject areas and study design restrictions was intended in order to capture the diversity and variability within the data pool.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

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