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# Making waves: Public health risks from arsenic in Mexico's water extraction practices

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ABSTRACT

In response to water scarcity in Mexicoś urban areas, authorities have implemented significant measures to increase water access, primarily by overexploiting groundwater resources. However, this approach has unintentionally worsened human exposure to groundwater arsenic consumption, which is part of a broader phenomenon known as environmental problem shifting. This paper examines the public health implications of arsenic contamination in Mexico's groundwater. We particularly focus our analysis on urban areas to demonstrate the policy gap that leaves the issue of arsenic contamination caused by over-pumping, and its associated widespread health risks, largely unaddressed. We draw on evidence from Mexico, but also Bangladesh, to define and describe the issue of such problem-shifting and how it underlies the urgent need to develop integrative water management strategies that balance the demands of water access with the necessity of maintaining water quality. By analysing water data from Mexico, the paper calls for a reconsideration of water policies to prevent further health crises.

## Introduction

The global water crisis has already offered glimpses into how water scarcity can lead to large-scale human migration, transborder conflicts, and deaths (IPCC, 2023; Rockström et al., 2023; van Thienen et al., 2023). In countries like Mexico, water stress has caused significant, harmful impacts. Short-term droughts have repeatedly forced the government to shut off water access for human consumption, risked the collapse of major cities' water supply systems, and triggered violent, sometimes fatal, conflicts over water access (Figueroa-Oropeza et al., 2023; Martinez-Canales, 2023; Merino-Ayala and Aguilar-Antonio, 2022; Zamora Saenz, Itzkuauhtli Benedicto, 2024). Naturally, the situation is expected to worsen with the increasing combined effects of climate change, land degradation, and water demand, adding more pressure to Mexico's urban areas as the population concentration amplifies the challenges of water management and public health challenges.

Like in most regions globally, the primary strategy of Mexico's National Water Programme to address water stress and meet demands is to increase water exploitation (SEMARNAT, 2020). However, evidence shows that this approach overlooks, or inadequately addresses, a crucial issue: increasing pressure on water resources by over-pumping groundwater to meet human demand significantly degrades water quality by increasing water contamination, especially with arsenic (Shaji et al., 2021). This is known as environmental problem shifting: decisions or actions to address one environmental problem which create or worsen another (Wood Hansen and Van Den Bergh, 2023). In this perspective, we focus on the problem-shifting inherent to current efforts to ensure water security due to increasing water stress in Mexico causing a rise in arsenic contamination and its associated public health concerns.

## Why should we care about, and discuss problem-shifting?

Arsenic is the most ubiquitous naturally occurring toxic substance in the environment (Shaji et al., 2021; WHO, 2019). Arsenic water contamination affects an estimated 140 million people in 50 countries with inorganic arsenic levels far above the World Health Organization (WHO) guideline value of 10 ug/L (WHO, 2019). The source of arsenic contamination is plural and besides its natural occurrence in the soil, also includes industrial activities, agricultural practices, and geogenic factors (Nordstrom, 2002; Smedley and Kinniburgh, 2002). In Mexico, for example, volcanic sediments and mining activities are significant

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contributors to arsenic levels in groundwater (Nordstrom, 2002). However, aquifer overexploitation is also a major contributor to rising arsenic levels in Mexican waters (Armienta and Segovia, 2008; Fisher et al., 2017). Indeed, the over-pumping of groundwater increases arsenic levels in water by favouring the release of arsenic from sulphide and oxyhydroxide minerals (Shaji et al., 2021). As a result, human exposure to arsenic through purported "safe" drinking water, intended to meet increasing water demand, has led to countless public health problems (Shaji et al., 2021). Thus, we focus our attention on groundwater overexploitation as an increasingly concerning practice that requires critical attention.

Between 2012 and 2018, the number of Mexican states reporting unsafe arsenic concentrations in urbanised areas rose from 17 to 24 (out of 32 (Curiel and Mena, 2021)). In addition, reports show that between 2018–2019, on average, almost five water-pumping groundwater wells in the main cities and/or capitals of each state in Mexico exceeded the risk levels for arsenic (Curiel and Mena, 2021).[1] Thus, over 70% of the 170 municipalities monitored in Mexico states have unsafe levels of arsenic, above the established regulatory level of 25 μg/L and much above the 10 ug/L WHO's guideline value (Alarcón-Herrera et al., 2020). These high arsenic levels are estimated to affect 1.5 million people in Mexico (Munguía-Lara et al., 2023). The cause of arsenic water contamination has been debated, but a detailed analysis of the geochemical factors at play in some regions of Mexico has confirmed that groundwater over-extraction is a major contributor to arsenic contamination (Mahlknecht et al., 2023).

This arsenic-related problem shifting has an obvious precedent: the tragic water-contamination event in Bangladesh. In the 1970s, the United Nations Children's Fund (UNICEF) initiated a well-drilling program in Bangladesh to provide groundwater and prevent the spread of cholera and other diarrheal diseases from surface water consumption. (Smith et al., 2000) By the end of this initiative, around 1997, UNICEF proudly announced that Bangladesh had surpassed its goal of providing 80% of the population with access to "safe" drinking water through tube wells and ring wells (Smith et al., 2000). However, due to an absence of requirement for arsenic water testing, it was not immediately realised that ~20 million people were drinking arsenic-contaminated water at aberrantly high levels, leading to a health disaster of unprecedented proportions, far worse than Chernobyl and Bhopal combined, and sometimes referred to as the largest mass poisoning in history (Smith et al., 2000). Thus, in two of the world's most affected areas, Bangladesh and West India, groundwater arsenic levels are detected as high as 3400 μg/L which is associated with an annual death toll of 43,000 people (Ratnaike, 2003; WHO, 2019). However, the morbidity associated with arsenic exposure is much greater. This is because, besides the immediate symptoms of acute arsenic poisoning (e.g., vomiting or diarrhoea), arsenic also triggers a constellation of long-term health effects involving all major organs, including cancer, cardiovascular and pulmonary diseases and neurological disorders (Farzan et al., 2013; Smith et al., 2000). While there are obvious differences in the causes and stakeholders involved in the arsenic water contamination between Bangladesh and Mexico, it nonetheless highlights the need to carefully balance water access, sanitation, and contamination to avoid problem shifting and extensive negative impact on populations.

Unfortunately, as expected from widespread arsenic exposure in Mexico, health problems have started to be documented. For instance, research on five communities in northern Mexico linked the consumption of arsenic-contaminated groundwater with cognitive, lung, and kidney problems, among other health issues in children aged 3 to 12 (Del Razo et al., 2021). This issue is further compounded by the fact that efforts to combat arsenic in drinking water are insufficient and clearly ineffective. The research collective Data Crítica, along with the think-tank Quinto Elemento Lab, reported that out of Mexico's 1256 water treatment plants, only 173 could remove arsenic, and an analysis of 30 of these plants revealed that 6 out of 10 failed to reduce arsenic concentrations to safe drinking levels (Curiel and Mena, 2021). In fact, the regions with the highest arsenic concentrations in groundwater lack water purifiers capable of removing it.

### Increasing water access is not synonymous with water security

As described above, the increased extraction and exploitation of contaminated groundwater correlates with a rise in arsenic exposure through water consumption. However, ensuring the human right to water access within Mexico's demographic growth, especially in major cities where the rural population is also migrating, undeniably requires more water extraction. Although it is not in the scope of this paper, it is worth mentioning that in 1975, México had 32 overexploited aquifers; in 2023, this number rose to 114, an increase of 256% in 50 years (CONAGUA, 2023). Highlighting this issue as a wicked problem is paramount if we want to circumvent such problem-shifting (Fig. 1).

The problem is not only that increasing arsenic levels have been observed when an aquifer system is over-pumped (Shaji et al., 2021) but also that many groundwater sources with naturally high arsenic concentrations are being used to supply water to communities in Mexico (Del Razo et al., 2021). The Mexican government's official data confirms this situation, stating that out of 775 monitored water quality sites in 2022, 155 did not meet the "drinking" quality standards solely based on arsenic concentrations, while 120 sites had no available data (CONAGUA, 2024).

We must emphasise that the data presented focuses only on arsenic concentration, excluding other chemical components such as nitrates or fluoride, which are also present in Mexican groundwater. Remarkably, as shown in Fig. 2, many areas lack water quality monitoring, suggesting that the actual number of groundwater sites with high arsenic concentrations may be higher.

Even if the exact magnitude of the issue of arsenic water contamination remains unknown, the case for the urgent need to address this problem-shifting is evident, especially in urban areas which have been supplied with arsenic-contaminated water for years (Armienta and Segovia, 2008). Alarcón-Herrera and colleagues estimated that around 1.5 million people in Mexico consumed water with unsafe arsenic concentrations, predicting a related increase of 13,070 new arsenic-induced cancer cases in the arid states of central and northern Mexico (Alarcón-Herrera et al., 2020). Detailed case-studies are needed but are starting to emerge. For example, after conducting a water quality analysis of 36 wells in the city of Colima, Mexico, Mendoza-Cano and colleagues estimated that 446 people were at risk of developing cancer due to chronic arsenic consumption (Mendoza-Cano et al., 2017). Furthermore, a connection between metabolic diseases and arsenic in drinking water in north-central Mexico has been identified (Sánchez-Rodríguez et al., 2023). Thus, current Mexican efforts to guarantee the human right to water access by over-pumping groundwater have led to a significant trade-off with its quality and the notion of water security (Del Razo et al., 2021).

### Policy implications of problem-shifting

Mexican efforts to address water insecurity have focused on strengthening supply and availability infrastructure indicators, neglecting other critical dimensions such as quality and reliability (Del Razo et al., 2021). This oversight has serious public health implications in cities with high water demand and contamination risks (Armienta and Segovia, 2008). However, this failure is not due to a lack of regulation. Mexico has an official standard, "NOM-127-SSA1–2021," which sets permissible water quality limits for human use, including a maximum

[1] According to the authors, not all municipalities and capital cities provided information on arsenic concentrations in groundwater. When data was unavailable for the capital city, we used information from another major city in the state.

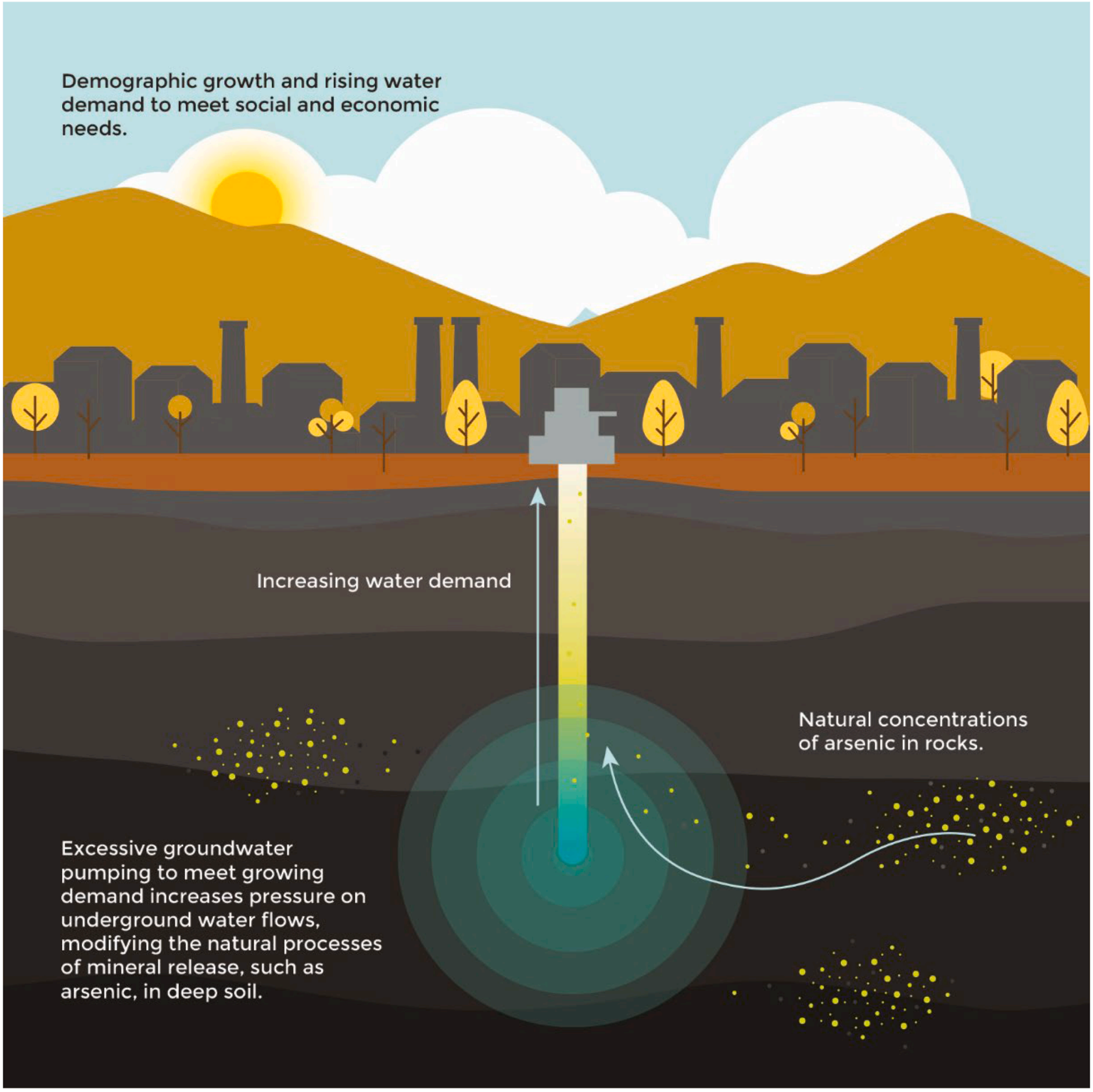


**Fig. 1.** Problem-shifting - Increasing water demand and access lead to over-pumping and the supply of groundwater with high arsenic concentrations.

arsenic limit of 10 μg/L (DOF, 2021).

Mexico's human right to water access also includes water sanitation; however, achieving both access and quality simultaneously has proven difficult. The National Water Programme acknowledges that Mexico's institutional incapacity, due to a lack of resources and infrastructure to ensure water quality, has severely impacted public health, especially for children (SEMARNAT, 2020); and this problem is not new. In the 1980s, it was discovered that 90% of the rural communities and municipal capitals in the 'Comarca Lagunera' region consumed groundwater with arsenic levels 20 times higher than the WHO's guideline (Del Razo et al., 2021). Despite local and federal efforts and strategies like using ferric sulfate to flocculate arsenic, these measures have been insufficient, and the area continues to report serious arsenic poisoning cases (Del Razo et al., 2021). Similar challenges persist in other regions, such as the Zimapán Valley in Hidalgo (Del Razo et al., 2021). In all these cases, the root problem has been the reliance on over-pumping groundwater to meet rising demand, causing arsenic contamination.

If the government is aware of the magnitude of the arsenic contamination problem, why have public policy and remediation efforts been insufficient? We argue that policies tackling water shortages cannot fail to address arsenic contamination and vice versa. This dual focus is essential yet often overlooked in discussions of water access strategies where arsenic contamination is not adequately considered (Garcia et al., 2022; Gilabert-Alarcón et al., 2018). As difficult as it is, the dual focus on water conservation and arsenic-decontaminated water should, at the very least, be at the forefront of the actions from all stakeholders involved.

Several strategies have been proposed in the literature, including systematic arsenic testing, enforcement of arsenic standards, improved infrastructure maintenance, and better coordination between regulatory, market, and local entities to reduce water overuse and encourage water reuse (Fisher et al., 2017; Mahlknecht et al., 2023). However, one major challenge remains the fragmentation of water governance across federal, state, and municipal levels, as well as among private companies and NGOs, which makes policy implementation complex and often ineffective (Mahlknecht et al., 2023). Future policies should prioritise treated water reuse to relieve pressure on over-pumped aquifers. This is especially important as urban areas face increasingly severe water stress in a hotter climate. However, caution is needed with water reuse practices, such as aquifer recharge, as improperly managed initiatives can increase arsenic leaching (Fakhreddine et al., 2015). Therefore, future water reuse projects must focus on strategies that minimise arsenic

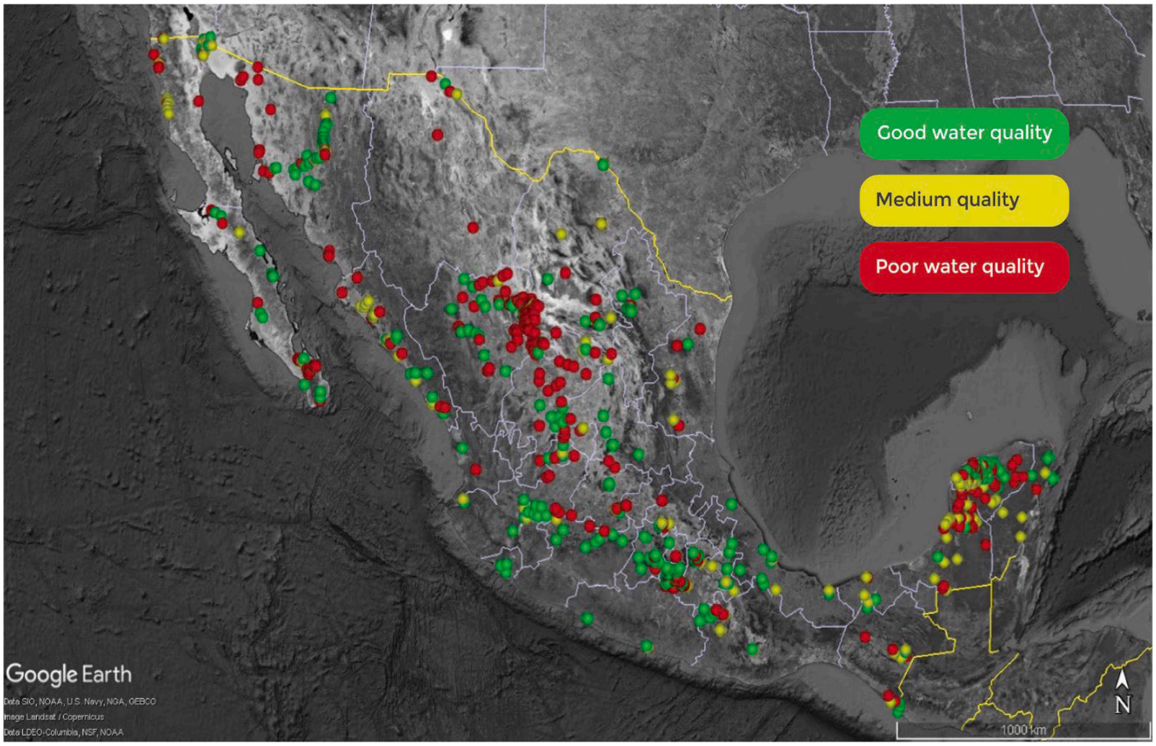


**Fig. 2.** Water quality monitored sites on arsenic concentration. Red points indicate poor water quality (it has an arsenic concentration greater than 0.25 μg/L, requiring further treatment before it can be used). Yellow points represent medium quality (it has an arsenic concentration greater than 10 μg/L and less than or equal to 25 μg/L, so water is only suitable, e.g., for irrigation but not for human consumption). Green points represent good water quality (it has an arsenic concentration less than or equal to 10 μg/L, so it is suitable for human consumption). Monitored extraction sites were collected from the Mexican National Water Commission database and uploaded to Google Earth for their visualisation (CONAGUA, 2024).

leaching risks, paired with systematic arsenic testing to monitor efficacy and prevent problem-shifting (Silva et al., 2024).

## Conclusion

- Recognising and addressing problem-shifting, particularly in urban areas, is paramount to preventing public health risks from arsenic contamination due to groundwater overexploitation in Mexico.
- Mexico must adopt integrated water management strategies that balance water access with maintaining water quality for suitable water security.
- Addressing problem-shifting requires a dual focus on water conservation and arsenic mitigation, supported by strengthened policies and coordinated stakeholder actions to ensure safe, sustainable water resources.

## CRediT authorship contribution statement

**Gabriel López Porras:** Writing – original draft, Investigation, Conceptualization. **Patrick Allard:** Writing – review & editing, Investigation, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Patrick Allard reports financial support was provided by National Institutes of Health. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

No data was used for the research described in the article.

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