



Assessing Groundwater Arsenic Exposure and Household Coping Strategies in a Gangetic Floodplain Village: A Proposed Mixed-Methods Protocol

Mateo Haddad^{1*}, Beatriz Do², Thao Lindo³

¹Department of Fashion Designing, Yangtze Research Institute of Fashion Designing, Cote d'Ivoire

²Department of Fashion Designing, Tagus Institute for Advanced Fashion Designing, Barbados

³Department of Fashion Designing, Netravati School of Fashion Designing, Poland

Article Info

Volume 1, Issue 1, 2026

doi: [10.62715/ijesr.2026.v1.i1.pp15-20](https://doi.org/10.62715/ijesr.2026.v1.i1.pp15-20)

Received: 15 February 2026

Accepted: 21 April 2026

Published: 27 June 2026

Abstract

Naturally occurring arsenic in the shallow aquifers of the Ganges floodplain exposes rural households to a recognised carcinogen through the hand-pumped tube wells on which they depend. The geochemistry and the health effects are well described at regional scale. Much less is recorded about how exposure is distributed within a single village and how households respond once they learn that their well is unsafe. This article proposes a protocol for a village-level study that joins the two questions. It combines a census and testing of every well, a household survey of water use, optional biomarker sampling, and qualitative interviews on coping strategies such as well switching, deeper wells and household filters, within a convergent mixed-methods design. Seven steps are described, from site selection and ethical review to the return of results to the community, with the purpose of each, the decisions it requires and the output it should produce. The protocol is assembled from published methods and guidance. It is a proposal that has not been applied or validated here, and the article sets out the limitations that a first application would need to examine.

Keywords: Arsenic, Groundwater, Ganges floodplain, Household water choice, Mixed methods, Exposure assessment

© 2026 Mateo Haddad et al. This is an open access article under the CC BY license (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

1. Introduction

The discovery that groundwater drawn from the alluvial aquifers of the Bengal Basin contains arsenic at concentrations harmful to health changed the meaning of the hand-pumped tube well. Wells that had been promoted as a safe alternative to polluted surface water turned out, in many places, to deliver a slow poison (Nickson *et al.*, 1998). The affected region is not confined to the delta. Arsenic was subsequently documented upstream in the middle Ganga plain of Bihar, in villages where it had not been suspected (Chakraborti *et al.*, 2003), and the same geological setting recurs along much of the river's floodplain.

Regional surveys have mapped the problem, and the geochemical processes behind it are understood

* Corresponding author: Mateo Haddad, Department of Fashion Designing, Yangtze Research Institute of Fashion Designing, Cote d'Ivoire.
E-mail: mateo.haddad@yangtze.edu

© 2026 Mateo Haddad et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

in outline. What happens inside a village is less well recorded. Arsenic concentrations vary sharply over short distances, so that one family's well may be safe and its neighbour's not. Exposure is therefore decided well by well and household by household, and so is the response. A family that learns its water is contaminated may walk to another well, sink a deeper one, buy a filter, turn to a pond, or do nothing, and each choice has its own costs and risks.

This article proposes a protocol for studying exposure and coping together in one village. It is intended for researchers, public health departments and non-governmental organisations planning such work. The article describes a design and the reasoning behind it. It does not report an application, and no findings are presented.

2. Background

The design rests on three bodies of knowledge: how arsenic comes to be in the water, what it does to health and how exposure is measured, and what earlier work has shown about household behaviour.

2.1. Arsenic in floodplain aquifers

The arsenic is geogenic. It is carried into the basin on iron oxyhydroxide coatings of Himalayan sediment and released to groundwater when those coatings dissolve under the reducing conditions that develop in young, organic-rich alluvium (Nickson *et al.*, 1998; Smedley and Kinniburgh, 2002). High concentrations are typical of shallow wells in Holocene deposits, the depth range tapped by most private hand pumps, while older and deeper sediments are more often low in arsenic. Within the affected depth range the distribution is patchy at the scale of tens to hundreds of metres, and it cannot be predicted for an individual well without testing it (Fendorf *et al.*, 2010).

2.2. Health effects, standards and markers of exposure

Arsenic in drinking water is classified as carcinogenic to humans, with sufficient evidence for cancers of the skin, lung and urinary bladder (IARC, 2012). Long-term exposure also produces characteristic skin lesions and is associated with cardiovascular, respiratory and developmental effects (Naujokas *et al.*, 2013). The World Health Organization's provisional guideline value is 10 micrograms per litre (WHO, 2017), and the Indian drinking water standard sets its acceptable limit at the same level (Bureau of Indian Standards, 2012). Effects appear after years of exposure, and the risk at concentrations near the guideline value is less certain than at the high concentrations where most of the evidence was gathered.

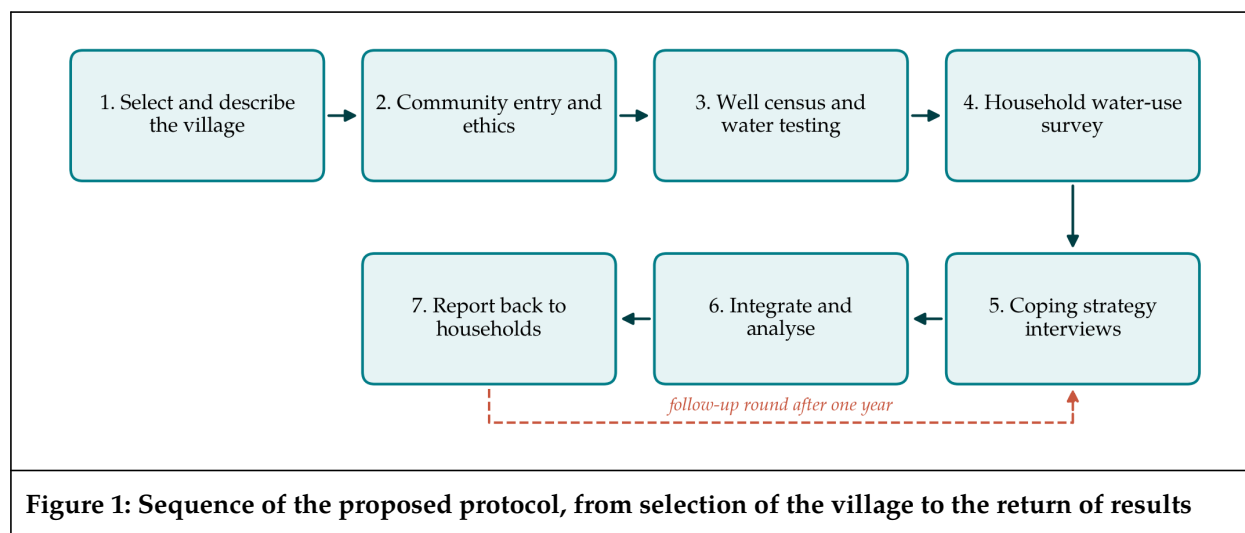
Water is the main route of exposure but not the only one. Rice irrigated with contaminated groundwater and cooked in it contributes as well (Meharg and Rahman, 2003). Individual exposure can be assessed through biomarkers: arsenic in urine reflects intake over the preceding days, while hair and nails integrate over months, each with known limitations (Hughes, 2006).

2.3. What is known about household responses

Experience in Bangladesh shows that information changes behaviour. When households were told the arsenic status of their well, a majority of those with unsafe wells changed to another source within a year (Madajewicz *et al.*, 2007). Switching to a nearby safe well and installing deeper wells have been the most widely adopted responses, ahead of treatment technologies (Flanagan *et al.*, 2012). Alternatives can introduce new hazards: a comparative risk assessment found that options such as dug wells and pond sand filters may replace arsenic risk with microbial risk (Howard *et al.*, 2006). Why households adopt or reject an option depends on perceived risk, cost, social norms, confidence and habit, the factors organised in the behaviour change model of Mosler (2012).

3. The Proposed Protocol

The protocol treats the village as a single case studied in depth, combining quantitative measurement of exposure with qualitative enquiry into coping. The two strands are collected in the same period, analysed separately and then brought together, which is the convergent form of mixed-methods design (Creswell and Plano Clark, 2018). Figure 1 shows the seven steps in sequence. Each is described below.



3.1. Step 1: Select and describe the village

A suitable village lies on the Holocene floodplain in a district where arsenic has been documented, relies mainly on private hand-pumped wells, and is small enough for every well and household to be enumerated. A single case supports analytic generalisation, meaning that it tests and refines explanations, and not statistical generalisation to other villages (Yin, 2018). The choice should therefore be made and reported for stated reasons. A baseline description records the layout of hamlets, the social and economic composition of the population, landholding, existing water infrastructure and any previous testing or mitigation programme.

3.2. Step 2: Community entry, consent and ethical review

Before fieldwork the protocol is submitted to an ethics committee constituted under the national guidelines (ICMR, 2017). Three matters need particular care. Consent is sought in the local language from each well owner and each household, with separate consent for any biological sample. The study commits in advance to telling every owner the result for their well, since withholding a result that bears on health cannot be justified. And the team agrees with local health services how people with suspected arsenic-related illness will be referred. Marking wells and discussing skin lesions can stigmatise families, so the way results are made public is settled with the community at the start.

3.3. Step 3: Well census and water testing

Every well is located by satellite positioning and recorded with its owner, reported depth, year of installation and the households that use it. Each is tested on site with a field kit of the kind that converts arsenic to arsine gas and reads the stain it leaves on a test strip. Such kits are semi-quantitative and least reliable near the thresholds that matter, so a subset of wells, chosen to span the range of kit readings, is sampled in duplicate, acidified and sent for laboratory analysis by hydride generation atomic absorption spectrometry or inductively coupled plasma mass spectrometry. Field blanks, duplicates and a certified reference material accompany each batch. Results are classified against the guideline value (WHO, 2017). Testing is repeated in a second season, because water tables on the floodplain rise and fall with the monsoon.

3.4. Step 4: Household water-use survey

A structured questionnaire, administered to an adult who manages water in each household, records all sources used for drinking and for cooking in each season, how long the present well has been used, wells used previously, who fetches water, and what the household already knows about the status of its well. Rice consumption and the source of cooking water are included because of the dietary route. Linking each household to the tested wells it uses gives an exposure classification for every household. Where laboratory capacity and ethical approval allow, urine or nail samples from consenting adults add an

individual measure; this component is optional and should not be attempted without a laboratory able to analyse the samples properly.

3.5. Step 5: Coping strategy interviews

Semi-structured interviews explore what households have done about their water and why. Interviewees are chosen purposively to cover households with high and low arsenic, different strategies, different economic positions and both women and men, since women usually carry the water and men often control spending on wells. Key informants such as well drillers, health workers and elected village representatives are interviewed as well. Table 1 lists the strategies the interview guide should cover and what to record for each. Recordings are transcribed and analysed thematically following the phases set out by [Braun and Clarke \(2006\)](#), with the factors in the model of [Mosler \(2012\)](#) used as sensitising concepts and not as a fixed coding frame.

Table 1: Household coping strategies to be covered in the interview guide, with points to record and known concerns			
Strategy	What the household does	Points to record	Known concern
Well switching	Fetches water from a nearby well tested as low in arsenic	Distance, ownership of the well, who fetches	Depends on access and on relations with the owner
Deeper tube well	Installs or shares a well drawing from a deeper aquifer	Depth, cost, who paid, test result	Cost; deep water must still be tested
Household filter	Treats well water in an arsenic removal unit	Type, age, upkeep, test of treated water	Performance falls without maintenance
Surface or rain water	Uses a pond, river, dug well or stored rain	Season of use, treatment before drinking	Microbial contamination (Howard et al., 2006)
Purchased or piped water	Buys water or draws on a public supply	Cost, reliability, origin of the supply	Affordability and continuity
No change	Continues to drink from the tested well	Reasons given and constraints faced	Exposure continues

3.6. Step 6: Integrate and analyse

The quantitative strand yields the distribution of arsenic across wells, maps of its spatial pattern, and the proportion of households whose main drinking source exceeds the guideline value. The qualitative strand yields an account of strategies and the reasoning behind them. Integration takes place in a joint display: a table that sets each household's exposure class beside its strategy and its stated reasons, so that patterns and exceptions can be read across ([Creswell and Plano Clark, 2018](#)). Households that remain on a contaminated well despite knowing its status deserve the closest reading, since they show where mitigation fails.

3.7. Step 7: Report back

Each owner receives the result for their well in writing and in person, with an explanation of what it means and what the options are. A village meeting presents the overall picture without identifying households. With the community's agreement, wells are marked as safe or unsafe for drinking, and the anonymised dataset is shared with the district authority responsible for rural water supply. A follow-up round a year later, repeating the survey of sources, would show whether disclosure changed behaviour.

4. Fitting the Protocol to Field Conditions

Floodplain villages impose their own timetable. Roads and some wells are under water during the monsoon, households migrate seasonally for work, and agricultural peaks leave little time for interviews. The two rounds of testing are best placed before and after the rains. The field team needs women

enumerators, because conversations about water are conversations with women and in many households will not otherwise take place. Field kits generate a toxic gas and contain reagents that require care, so training in their safe use and disposal is part of preparation. Where laboratory confirmation is distant or costly, the size of the confirmation subset can be reduced, but it should not be dropped.

5. Limitations and What Remains to Be Shown

This protocol has not been applied or validated here, and several of its assumptions need testing in use. It is not yet shown that a complete census is feasible in larger villages within a single season, or how far the exposure classification based on reported water sources agrees with biomarkers where both are collected. Reported depth and age of wells depend on the owner's memory. Self-reported coping behaviour may be shaped by what interviewees believe the team wishes to hear, particularly after results have been disclosed.

The design also has inherent limits. One village cannot represent a floodplain, and a cross-sectional study cannot attribute illness to exposure. The protocol does not include clinical examination, which requires trained clinicians and a different ethical framework. Its purpose is narrower: to describe who is exposed, what they do about it and why, in enough detail to inform mitigation in that place and to generate propositions that studies elsewhere can test.

6. Conclusion

Arsenic exposure on the Ganges floodplain is determined at the level of the well and the household, and that is the level at which this protocol proposes to study it. By testing every well, recording how each household actually obtains its water, and asking why families respond as they do, a single village study can link the chemistry of the aquifer to the decisions that govern exposure. The seven steps are offered as a starting point for adaptation. Their practicality and the quality of the evidence they produce can be judged only when the protocol is put to use.

Conflict of interest

To be declared by the author(s) before publication.

Funding

To be declared by the author(s) before publication.

References

- Braun, V. and Clarke, V. (2006). [Using thematic analysis in psychology](#). *Qualitative Research in Psychology*, 3(2): 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Bureau of Indian Standards (2012). [IS 10500: 2012, Drinking Water: Specification \(Second Revision\)](#). Bureau of Indian Standards, New Delhi.
- Chakraborti, D., Mukherjee, S.C., Pati, S., Sengupta, M.K., Rahman, M.M., Chowdhury, U.K., Lodh, D., Chanda, C.R., Chakraborti, A.K. and Basu, G.K. (2003). [Arsenic groundwater contamination in Middle Ganga Plain, Bihar, India: A future danger?](#) *Environmental Health Perspectives*, 111(9): 1194-1201. <https://doi.org/10.1289/ehp.5966>
- Creswell, J.W. and Plano Clark, V.L. (2018). [Designing and Conducting Mixed Methods Research, 3rd edition](#). SAGE Publications, Thousand Oaks, CA.
- Fendorf, S., Michael, H.A. and van Geen, A. (2010). [Spatial and temporal variations of groundwater arsenic in South and Southeast Asia](#). *Science*, 328(5982): 1123-1127. <https://doi.org/10.1126/science.1172974>
- Flanagan, S.V., Johnston, R.B. and Zheng, Y. (2012). [Arsenic in tube well water in Bangladesh: Health and economic impacts and implications for arsenic mitigation](#). *Bulletin of the World Health Organization*, 90(11): 839-846. <https://doi.org/10.2471/BLT.11.101253>

- Howard, G., Ahmed, M.F., Shamsuddin, A.J., Mahmud, S.G. and Deere, D. (2006). [Risk assessment of arsenic mitigation options in Bangladesh](#). *Journal of Health, Population and Nutrition*, 24(3): 346-355.
- Hughes, M.F. (2006). [Biomarkers of exposure: A case study with inorganic arsenic](#). *Environmental Health Perspectives*, 114(11): 1790-1796. <https://doi.org/10.1289/ehp.9058>
- IARC (2012). [Arsenic, Metals, Fibres, and Dusts](#). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 100C. International Agency for Research on Cancer, Lyon.
- ICMR (2017). [National Ethical Guidelines for Biomedical and Health Research Involving Human Participants](#). Indian Council of Medical Research, New Delhi.
- Madajewicz, M., Pfaff, A., van Geen, A., Graziano, J., Hussein, I., Momotaj, H., Sylvi, R. and Ahsan, H. (2007). [Can information alone change behavior? Response to arsenic contamination of groundwater in Bangladesh](#). *Journal of Development Economics*, 84(2): 731-754. <https://doi.org/10.1016/j.jdeveco.2006.12.002>
- Meharg, A.A. and Rahman, M.M. (2003). [Arsenic contamination of Bangladesh paddy field soils: Implications for rice contribution to arsenic consumption](#). *Environmental Science & Technology*, 37(2): 229-234. <https://doi.org/10.1021/es0259842>
- Mosler, H.-J. (2012). [A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: A conceptual model, a review, and a guideline](#). *International Journal of Environmental Health Research*, 22(5): 431-449. <https://doi.org/10.1080/09603123.2011.650156>
- Naujokas, M.F., Anderson, B., Ahsan, H., Aposhian, H.V., Graziano, J.H., Thompson, C. and Suk, W.A. (2013). [The broad scope of health effects from chronic arsenic exposure: Update on a worldwide public health problem](#). *Environmental Health Perspectives*, 121(3): 295-302. <https://doi.org/10.1289/ehp.1205875>
- Nickson, R., McArthur, J., Burgess, W., Ahmed, K.M., Ravenscroft, P. and Rahman, M. (1998). [Arsenic poisoning of Bangladesh groundwater](#). *Nature*, 395: 338. <https://doi.org/10.1038/26387>
- Smedley, P.L. and Kinniburgh, D.G. (2002). [A review of the source, behaviour and distribution of arsenic in natural waters](#). *Applied Geochemistry*, 17(5): 517-568. [https://doi.org/10.1016/S0883-2927\(02\)00018-5](https://doi.org/10.1016/S0883-2927(02)00018-5)
- WHO (2017). [Guidelines for Drinking-water Quality, 4th edition, incorporating the 1st addendum](#). World Health Organization, Geneva.
- Yin, R.K. (2018). [Case Study Research and Applications: Design and Methods, 6th edition](#). SAGE Publications, Thousand Oaks, CA.