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Assessment of Human Health Risks from Arsenic Contamination in Groundwater-Soil-Crop System of a Humid Sub-Tropical Region in India

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Arsenic Contamination: Background

- Arsenic contamination in groundwater-soil-crop system: Highly toxic and widespread occurrence, worldwide epidemic.
- Argentina, Chile, Mexico, China, Hungary, ***India***, Bangladesh, and Vietnam.
- Sources of arsenic: **Geogenic** (aquifer sediments), **Anthropogenic** (agricultural waste, industrial waste), and **Biogenic** mobilization into groundwater, enter the food chain via. irrigation.
- Arsenic exists in the following forms in groundwater, soil, and plants: Arsenite **[As(III)]**, Arsenate **[As(V)]**, Monomethylarsonous acid **[MMA(III)]**, Monomethylarsonic acid **[MMA(V)]**, Dimethylarsinous acid **[DMA(III)]** and Dimethylarsinic acid **[DMA(V)]**.
- Arsenic is **tasteless** and **odorless** and toxicity symptoms are delayed.
- Arsenite ***[As (III)]*** is the most toxic form of arsenic and causes acute toxicity. Forms of arsenic such as As (III) and As (V) lead to chronic toxicity.

Objectives

- *To assess the human health risks from arsenic toxicity on the basis of the international risk framework.*
- *Statistical assessment of cancerous and non-cancerous human health risks from arsenic toxicity.*

Study Area

There are a few reasons behind selecting the study area: a ***humid sub-tropical*** region in India encompassing Ballia, Deoria, and Mau districts in the state of Uttar Pradesh.

- ➢ They lie in the vicinity of the main stem of the ***Ganga River***.
- ➢ They are agriculturally fertile and substantially irrigated by arsenic-contaminated groundwater.
- ➢ They are densely populated and hence provides better understanding of arsenic exposure among all age groups.

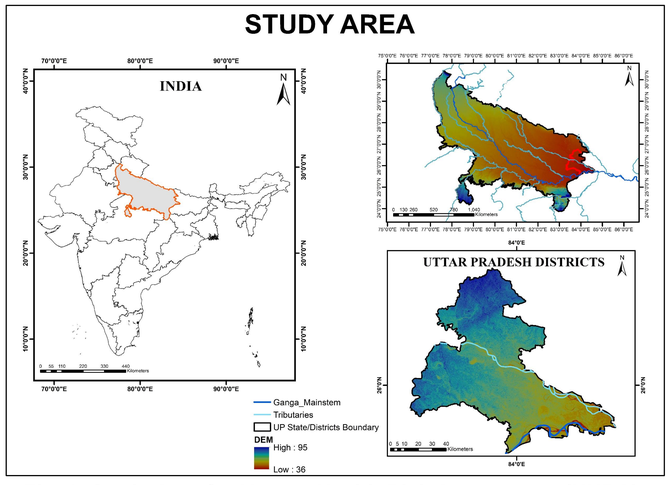


Fig. 1: Study Area for Human Health Risk Assessment (HHRA).

Human Health Risk Assessment (HHRA): Approach

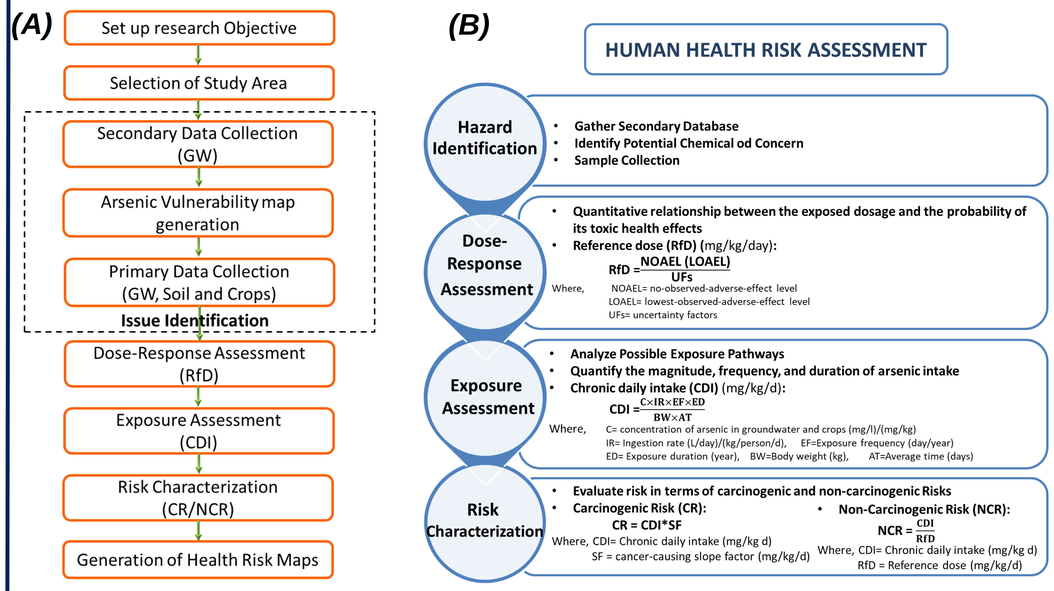
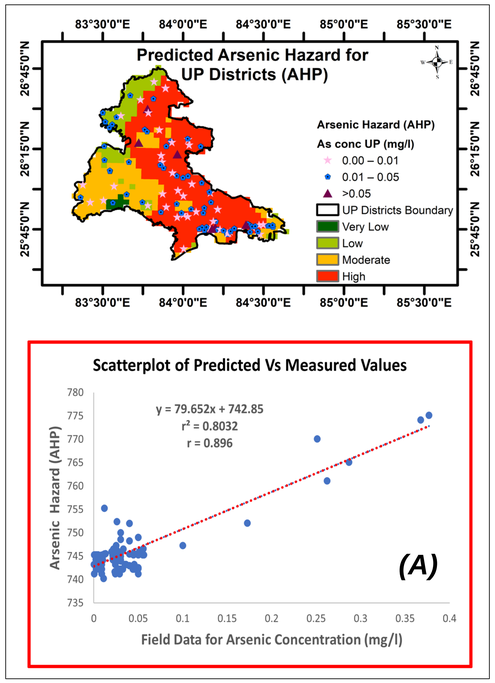


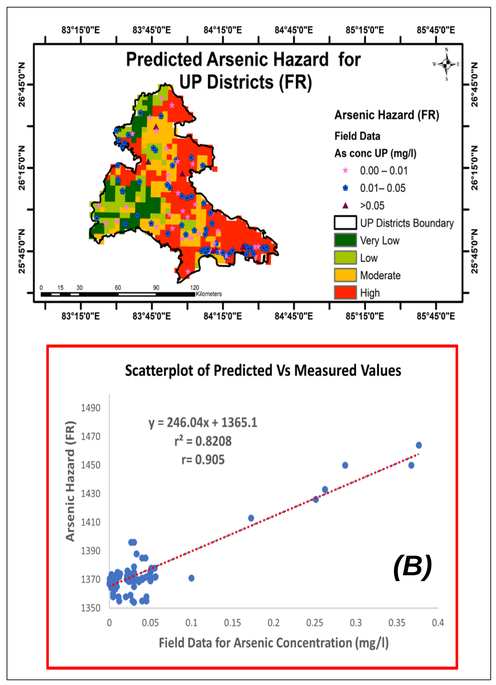
Figure 2: (A) Overall Approach (B) Approach for Human Health Risk Assessment (HHRA).

Results and Discussion

Hazard identification

- Predicted Groundwater Arsenic Vulnerability from Secondary Data (CGWB, 2015) employing Analytical Hierarchy Process (AHP) and Frequency Ratio (FR) methods.





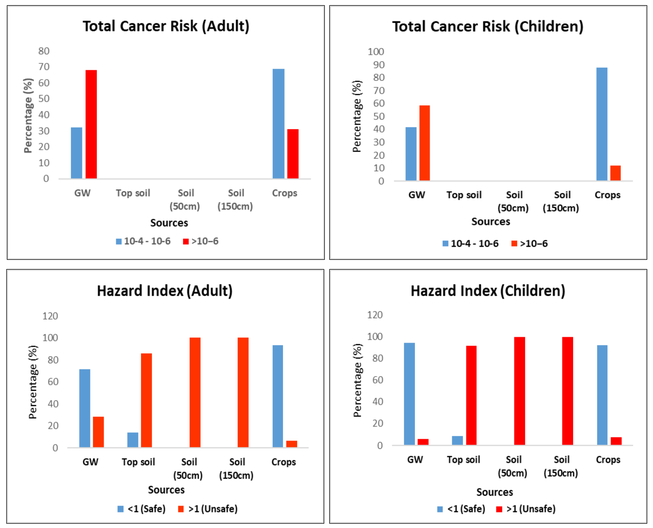
Dose-Response Assessment

- Dose estimates from the experimental and observational impacts data is referred as the point of departure.
- Point of departures for cancer and non-cancer effects are near the lower observed range without any extrapolation and no-observed-adverse-effect level (NOAEL)/lowest-observed-adverse-effect level (LOAEL), respectively (EPA 2005a).
- During the non-availability or lack of data, EPA's Integrated Risk Information System (IRIS) database is used as a reference for human health risk assessment i.e. RfD for Arsenic= 3.0 x 10^{-4} mg/kg/day (USEPA, 2005).

Exposure Assessment

- Possible Exposure Pathways :
  - ➢ Inhalation ✗
  - ➢ **Ingestion** ✓
  - ➢ Dermal ✗
- Quantification of Exposure (CDI)

Risk Characterization



- Targeted Reference Range for Total Cancer Risk is 10^{-6} and < 10^{-4}
- If HI >1 (High Non-Cancerous Risk); HI <1 (Low Non-cancerous Risk) (USEPA 2015)

Conclusions

- 66% (AHP) and 61% (FR) of the study area is at risk of arsenic contamination with arsenic from soil as the route source to groundwater and further to crops (Food chain).
- 68% of Adults and 58% of Children are at high cancer risk from groundwater along with 31% Adult and 12% Children at risk from contaminated crops.
- TCR (Adults >Children); HI (Children > Adults)

Acknowledgments

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