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GRANTS/AWARDS:

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2010:	**Erasmus Mundus Doctoral Scholarship**, European Commission
2010:	Offered **DAAD Doctoral Scholarship**, DAAD, Germany
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PUBLICATIONS (Citations are based on Google Scholar, last accessed 19.12.19):
Total Citations: 319; Cumulative IF: 53.398; Average IF: 4.449; h-index: 8; i10-index: 8

***Peer reviewed*:**

1. Neidhardt H., Schöckle D., Schleinitz A., Eiche E., Berner Z., Tram P.T.K., Lan V.M., Viet P.H., Biswas A., **Majumder S.**, Chatterjee D., Oelmann Y., Berg M. (**2018**) Towards a better understanding of Biogeochemical Phosphorus cycling in Aquifer Ecosystems – Insights from South East Asian Floodplain and Delta Aquifers. ***Science of the Total Environment,*** 644, 1357-1370. **IF – 5.589**. **Citation – 2.**
2. Kundu A.K., *__Majumder S.__, Biswas A., Bhowmick S., Pal C., Mukherjee A., Majumder M., Chatterjee D. Optimization of laboratory arsenic analysis for groundwaters of West Bengal, India and possible water testing strategy. (**2018**) ***International Journal of Environmental Analytical Chemistry***, DOI: 10.1080/03067319.2018.1477136, 440-452. **IF – 1.267.**
3. Biswas J.K., Bera B., Chanda R., Sarkar S.K., Majumdar J., **Majumder S.**, Hazra S. (**2017**) Nutrient modeling of an urban lake using best subset method. ***International Journal of Environmental Science & Technology***, DOI: 10.1007/s13762-017-1540-7. **IF – 2.031.**
4. Biswas J.K., Banerjee A., **Majumder S.**, Bolan N., Seshadri B., Dash M.C. (**2017**) New Extracellular Polymeric Substance Producing Enteric Bacterium from Earthworm, *Metaphire posthuma*: Modulation through Culture Conditions. ***Proceedings of Zoological Society***, DOI: 10.1007/s13762-017-1540-7. **Citation – 2.**
5. *__Majumder S.__, Nath B., Datta S., Sarkar S., Neidhardt H., Berner Z., Hidalgo M., Chatterjee D., Chatterjee D. (**2016**) Monsoonal influence on variation of hydrochemistry and isotopic signatures: implications for associated arsenic release in groundwater. ***Journal of Hydrology***, 535, 407-417. **IF – 4.405**. **Citation – 15.**
6. *__Majumder S.__, Nath B., Sarkar S., Chatterjee D., Roman-Ross G., Hidalgo M. (**2014**) Size-fractionation of groundwater arsenic in alluvial aquifers of West Bengal, India: the role of organic and inorganic colloids. ***Science of the Total Environment,*** 468-469, 804-812. **IF – 5.589**. **Citation – 29.**
7. Neidhardt H., Berner Z. A., Freikowski D., Biswas A., **Majumder S.**, Winter J., Gallert C., Chatterjee D., Norra S. (**2014**) Organic carbon induced mobilization of iron and manganese in a West Bengal aquifer and the muted response of groundwater arsenic concentrations. ***Chemical Geology***, 367, 51-62. **IF – 3.618**. **Citation – 50.**
8. Bhowmick S., Nath B., Halder D., Biswas A., **Majumder S.**, Kundu A. K., Saha D., Mondal P., Chakraborty S., Nriagu J., Bhattacharya P., Roman-Ross G., Guha Mazumder D., Chatterjee D., Chatterjee D. (**2013**) Arsenic mobilization in the aquifers of three physiographic settings of West Bengal, India: understanding geogenic and anthropogenic influences. ***Journal of Hazardous Materials***. 262, 915-923. **IF – 7.650**. **Citation – 38.**

9. *__Majumder S.__, Nath B., Sarkar S., Islam S.M., Bundschuh J., Chatterjee D., Hidalgo M. (**2013**) Application of natural citric acid sources and their role on removal of arsenic from drinking water: a green chemistry approach. ***Journal of Hazardous Materials***. 262, 1167-1175. **IF – 7.650. Citation – 5.**
10. Neidhardt H., Biswas A., Freikowski D., **Majumder S.**, Chatterjee D., Berner Z. (**2013**) Reconstructing the sedimentation history of the Bengal Delta Plain by means of geochemical and stable isotopic data. ***Applied Geochemistry***, 36, 70-82. **IF – 2.894. Citation – 18.**
11. Chatterjee D., **Majumder S.**, Biswas A., Halder D., Bhowmick S., Chatterjee D., Mukherjee- Goswami A., Jana J., Saha D., Kundu A. K., Sarkar S. (**2012**) Arsenic in Groundwater of Young Bengal Delta Plain of India: It's Distribution and Geochemistry. ***Indian Society of Applied Geochemists***, 170-185.
12. Biswas A., **Majumder S.**, Neidhardt H., Halder D., Bhowmick S., Mukherjee – Goswami A., Kundu A., Saha D., Berner, Z., Chatterjee, D. (**2011**) Groundwater chemistry and redox processes: depth dependent arsenic release mechanism. ***Applied Geochemistry***, 26, 516-525. **IF – 2.894. Citation – 47.**
13. Chatterjee D., Halder D., **Majumder S.**, Biswas A., Nath B., Bhattacharya P., Bhowmick S., Mukherjee-Goswami A., Saha D., Hazra R., Maity P. B., Chatterjee D., Mukherjee A., Bundschuh J. (**2010**) Assessment of arsenic exposure from groundwater and rice in Bengal Delta region, West Bengal, India. ***Water Research***, 44, 5803-5812. **IF – 7.913. Citation – 91.**
14. Lawson M., Ballentine C. J., Polya D. A., Boyce A. J., Mondal D., Chatterjee D., **Majumder, S.**, Biswas A. (**2008**) The geochemical and isotopic composition of ground waters in West Bengal: tracing ground–surface water interaction and its role in arsenic release. ***Mineralogical Magazine***, 72, 441-444. **IF – 1.898. Citation – 18.**

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***Conference Proceedings*:**

1. **Majumder S.**, Sarkar, S., Chatterjee, D., Roman-Ross, G., Hidalgo, M. (**2013**) Role of colloidal particles as scavengers of groundwater arsenic: a case study from rural Bengal. ***Procedia Earth and Planetary Science***, 7, 546–549. **Citation – 2.**
2. Chatterjee D., Nath B., Chakraborty S., **Majumder S.**, Biswas A., Bhowmick S., Halder D., Mondal P., Kundu A., Saha D., Barman S., Biswas U., Saha I., Das A., Sarkar S., Chatterjee D. (**2013**) Groundwater arsenic in the fluvial Bengal plains: geochemistry and mitigation. ***Procedia Earth and Planetary Science***, 7, 143–146. **Citation – 1.**

***Book Chapters*:**

1. **Majumder S.**, Biswas A., Neidhardt H., Sarkar S., Berner Z., Bhowmick S., Mukherjee A., Chatterjee D., Chakraborty S., Nath B., Chatterjee D. (**2015**) An Insight into the Spatio-vertical Heterogeneity of Dissolved Arsenic in part of the Bengal Delta Plain Aquifer in West Bengal (India). In: ***Safe and Sustainable Use of Arsenic-Contaminated Aquifers in the Gangetic Plain: A Multidisciplinary***

Approach. Edited by AL. Ramanathan, Scott Johnston, Abhijit Mukherjee and Bibhash Nath. **Capital Publishing Company**, New Delhi (India) and **Springer International Publishing**, Cham, Switzerland; pp. 175-192. **Citation – 1.**

2. Bhattacharya P., Jacks G., Nath B., Chatterjee D., Biswas A., Halder D., **Majumder S.**, Bhowmick S., Ramanathan A. L. (**2010**) Natural arsenic in coastal groundwaters in the Bengal Delta region in West Bengal, India. In ***Management and Sustainable Development of Coastal Zone Environment;*** Ramanathan, A.L., Bhattacharya, P., Dittmar, T., Prasad, M.B.K. Neupane, B.R. Eds.; **Capital Publishing Company**, New Delhi (India) and **Springer International Publishing**, Cham, Switzerland; pp. 146-160.

***Papers in Pipeline*:**

1. Knappett P., Li Y., Loza I., Hernandez H., Aviles M., Pina V., Lynch B., Huang Y., Majumder S., Wang J., Mahlknecht J., Datta S., Thurston B., Terrell D., Nordstrom D.K. Processes driving rising arsenic concentrations in an intensively pumped agricultural basin in central Mexico. Submitted to ***Science of the Total Environment*** *(under review)*.
2. **Majumder S.**, Margui E., Roman-Ross G., Chatterjee D., Hidalgo M. Hollow Fiber Liquid Phase Microextraction (HF-LPME) combined with Total Reflection X-ray Spectrometry (TXRF) for the determination of trace level inorganic arsenic species in waters. Submitted to ***Talanta***.

Conference Abstracts:

1. **Majumder S.**, Vega M., Datta S. (2018) Oxyanion-forming trace elements and associated geochemical processes in high As aquifers. *Goldschmidt 2018*, August 12-17, 2018, Boston, USA.
2. **Majumder S.,** Nath B., Datta S., Sarkar S., Neidhardt H., Berner Z., Hidalgo M., Chatterjee D., Chatterjee D. (2017) Effect of Monsoon on spatio-temporal variation of groundwater chemistry and stable isotopic signatures: insights for concomitant arsenic mobilization in West Bengal, India. *American Geophysical Union (AGU) Fall Meeting 2017*, December 11-15, 2017, New Orleans, USA.
3. **Majumder S.**, Chatterjee D. (2015) Groundwater arsenic – a threat for the rural population of Bengal Delta Plain and possible mitigation approaches. *47th Indian Water Works Association Annual Convention*, January 30-31, 2015, Kolkata, India.
4. **Majumder S.**, Chatterjee D. (2014) Geochemistry of arsenic in groundwater and mitigation approches. *National Seminar on Interdisciplinary Approaches in Science, Humanities and Culture*, May 28-29, KURSA, University of Kalyani, Kalyani, West Bengal, India.
5. **Majumder S.**, Margui E., Roman-Ross G., Chatterjee D., Hidalgo M. (2014) Detecting trace levels of labile arsenic in water: key to biomonitoring and risk assessment. *International Seminar on Groundwater Issues and Challenges of the 21st Century*, December 29-30, 2014, Murshidabad, India.

6. **Majumder S.**, Margui E., Roman-Ross G., Chatterjee D., Hidalgo M. (2013). Hollow Fiber Liquid Phase Microextraction (HF-LPME) combined with Total Reflection X-ray Spectrometry (TXRF) for the determination of trace level arsenic species in waters. *14th EuCheMS International Conference on Chemistry and Environment (ICCE 2013)*, June 25-18, 2013, Barcelona, Spain.
7. **Majumder S.**, Datta S., Nath B., Berner Z., Sarkar S., Chatterjee D. (2012). Monsoonal influence on stable isotope signature and arsenic distribution in groundwaters of rural West Bengal: a spatio-temporal study. In: J.C. Ng, B. N. Noller, R. Naidu, J. Bundschuh & P. Bhattacharya (eds.) *"Understanding the Geological and Medical Interface of Arsenic, As 2012". Interdisciplinary Book Series: "Arsenic in the Environment—Proceedings"*. Series Editors: Jochen Bundschuh and Prosun Bhattacharya, CRC Press/Taylor and Francis (ISBN-13: 978-0-415-63763-3), pp. 69-70.
8. **Majumder S.**, Nath B., Sarkar S., Islam S.M., Chatterjee D. (2012). Removal of arsenic from drinking groundwater using non-hazardous natural citrate sources. In: J.C. Ng, B. N. Noller, R. Naidu, J. Bundschuh & P. Bhattacharya (eds.) *"Understanding the Geological and Medical Interface of Arsenic, As 2012". Interdisciplinary Book Series: "Arsenic in the Environment—Proceedings"*. Series Editors: Jochen Bundschuh and Prosun Bhattacharya, CRC Press/Taylor and Francis (ISBN-13: 978-0-415-63763-3), pp. 312-313.
9. **Majumder S.**, Chatterjee D., Biswas A., Neidhardt H., Berner Z. (2011) Multivariate analysis to explain arsenic mobilization in rural West Bengal, India. *Proc. 11th International Conference on the Biogeochemistry of Trace Elements (ICOBTE)*, July 3-7, 2011, Florence, Italy, Part I.
10. **Majumder S.**, Neidhardt H., Roman-Ross G., Datta S., Sarkar S., Berner Z., Chatterjee D. (2011). Monsoonal influence on stable isotope signature and Arsenic distribution in groundwaters: a case study from West Bengal, India. *Geol. Soc. Amer., Abstracts with Programs,* 43(5): p. 339.
11. **Majumder S.**, Chatterjee D., Biswas A., Berner Z., Neidhardt H. (2010) Characterization of factors affecting arsenic distribution in groundwater. In: P. Birkle & I.S. Torres-Alvarado (eds.) *Proceedings of the 13th Water-Rock Interaction Symposium, WRI-13, Guanajuato, Mexico, 16–20 August, 2010.* Balkema, CRC Press/Taylor & Francis, pp. 403-406.

SELECTED/INVITED TALKS:

2017: Texas Water Observatory – NEON Meeting, Texas A&M University, College Station, **USA**
2017: 2nd Annual Post-Doctoral Research Symposium, Texas A&M University, College Station, **USA**
2015: 47th Indian Water Works Association Annual Convention, Kolkata, **India**
2013: Water-Rock Interaction 14 (WRI 14) International Symposium, Avignon, **France**
2012: 4th International Congress on Arsenic in the Environment (As2012) in Cairns, **Australia**

SELECTED CONFERENCE CONTRIBUTIONS:

2018 Goldschmidt 2018, August 12-17, 2018, Boston, **USA** (Poster).

2017: American Geophyscial Union (AGU) Fall Meeting, New Orleans, **USA** (Poster)

2017: 2nd Annual Post-Doctoral Research Symposium, Texas A&M University, College Station, **USA** (Oral)

2015: 47th Indian Water Works Association Annual Convention, Kolkata, **India** (Oral)

2013: Water-Rock Interaction 14 (WRI 14) International Symposium, Avignon, **France** (Oral)

2012: 4th International Congress on Arsenic in the Environment (As2012), Cairns, **Australia** (Poster)

2012: 4th International Congress on Arsenic in the Environment (As2012), Cairns, **Australia** (Oral)

2011: 11th International Conference on the Biogeochemistry of Trace Elements (ICOBTE), Florence, **Italy** (Poster)

MEMBERSHIPS/AFFILIATIONS:

1. International Society for Trace Element Biogeochemistry (**ISTEB**)
2. International Association of Geochemists (**IAGC**)
3. American Geophysical Union (**AGU**)

OTHER PROFESSIONAL ACTIVITES:

Post-graduate Supervision/co-Supervision:

- M.Sc. Thesis – *Four* (2014 – 2016)
- M.Tech. Thesis – *Two* (2014 – 2016)

Review Panels:

1) Journal of Hazardous Materials, 2) Water, Air & Soil Pollution, 3) Journal of Hydrology, 4) Achieves of Agronomy and Soil Science, 5) Chemical Engineering Journal, 6) Water Resources Research, 7) Geosciences Frontiers

Conference Organized:

1. **Conference Coordinator**, *International Seminar on Groundwater Issues and Challenges of the 21st Century*, December 29-30, 2014, Murshidabad, India.

Academic Panels:

1. Member: Departmental Committee (D.C.), Department of Ecological Engineering & Environmental Management, University of Kalyani.
2. Member: Syllabus Modification Committee, Department of Ecological Engineering & Environmental Management, University of Kalyani.

Resource Person:

Invited talk as a Resource Person at the Pre-departure Orientation Programme for the Outgoing Fulbright Post-Doctoral Fellows, Organized by the United States-India Educational Foundation, Hotel Oberoi Grand, Kolkata, June, 2019.

AQUIRED SKILLS/TRAININGS:

- Extensive experience on state-of-the-art laboratory techniques for environmental/geochemical/analytical research, e.g., HR-ICP-MS, ICP-OES, HPLC, IC, TXRF, XRF, AAS, TOC-Analyzer.
- Filed sampling experience on water, soil/sediment and stable isotopes (δ^2H and δ^{18}O).
- Digital Mapping & Geographical Information System (DMGIS)

OUTREACH ACTIVITIES:

- The Fulbright Orientation Program Community Service (Plantation), 2017, Audubon, Los Angeles, USA.
- The Big Event, 2017, Bryn-College Station, USA.
- Soft Skill Development workshops for Post-graduate students, 2014-2016, University of Kalyani, India.
- World Environment Day community service with students, 2014-2016, University of Kalyani, India.

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Google Scholar:	https://scholar.google.com/citations?user=-nXpBoIAAAAJ&hl=en
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INTERNATIONAL JOURNAL OF ENVIRONMENTAL ANALYTICAL CHEMISTRY
2018, VOL. 98, NO. 5, 440–452
https://doi.org/10.1080/03067319.2018.1477136

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Taylor & Francis Group

ARTICLE

Check for updates

Optimisation of laboratory arsenic analysis for groundwaters of West Bengal, India and possible water testing strategy

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ABSTRACT

Regular monitoring of arsenic (As) in groundwater is crucial from public health perspectives as millions of people are suffering due to use of contaminated aquifer water for drinking purposes. The routine analyses, especially in developing nations, are mostly done in localised government/non-government laboratories with limited resources, having the target of analysing large number of samples in each run. Thus apart from analytical sensitivity, cost-effectiveness of the method and eco-friendliness of the experimental operation are key surreptitious factors. This demands optimisation of total As measurement methods and finding a method that gives 'optimum benefit' considering all these factors together. The present study therefore evaluates four common As (total) measurement methods [iodometric-colorimetric method, silver diethyl dithiocarbamate method, molybdenum blue method and hydride generation atomic absorption spectrophotometric (HG-AAS) method] practised in the Bengal Delta Plain, in view of their analytical sensitivity, related environmental hazard and experimental costs. It was found that the HG-AAS method is analytically more sensitive, whereas the iodometric-colorimetric method and the molybdenum blue method are better choices in terms of eco-friendliness and cost-effectiveness, respectively. However, when all three factors (analytical reliability, environmental hazard and cost) are considered simultaneously, the molybdenum blue method was found to be placed first in the 'optimum performance rank' list. It was also found that both environmental hazard and cost play a more crucial role than analytical reliability, although this is case specific and would differ from place to place around the globe. Finally based on the results, we have hypothesised a water testing strategy for developing countries such as India where the molybdenum blue method can be adapted as a screening method and later the HG-AAS method can be used to precisely identify the groundwater samples with As concentration below the WHO drinking water guideline value of 10 µg/L.

ARTICLE HISTORY
Received 22 December 2017
Accepted 11 May 2018

KEYWORDS
Groundwater; arsenic; spectrophotometric methods; HG-AAS; Spearman's rank correlation coefficient

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Supplemental data for this article can be accessed here.

Int. J. Environ. Sci. Technol.
DOI 10.1007/s13762-017-1540-7

ORIGINAL PAPER

Nutrient modeling of an urban lake using best subset method

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Received: 17 May 2016 / Revised: 28 July 2017 / Accepted: 6 September 2017

Abstract Lakes are functionally integral and biologically complex freshwater ecosystems which provide a vast array of ecosystem goods and services to society. Nowadays aquatic ecosystems are being used, misused and abused by diverse anthropogenic activities at an unprecedented rate. The management of lake water quality is usually directed to resolution of conflicts between maintenance of desirable water quality and human-induced degradation of aquatic environment. Nutrients play a decisive role in determining lake's environmental state through regulation of its primary production. The present study on Saheb Bundh Lake located in Purulia District, West Bengal, India, was undertaken to assess the status of nutrients (nitrogen and phosphorus) subject to certain anthropogenic activities, and to construct models using best subset method which could be adopted as a nutrient management tool. The water samples were monitored for different physicochemical parameters adopting standard methods. It was found that the set of variables including turbidity, temperature, pH, redox potential and total hardness has been championed as the best subset of water quality explaining the dynamics of total phosphorus concentration of freshwater Saheb Bundh Lake. The suite of factors comprising dissolved oxygen, pH, temperature, turbidity and total hardness has been proved as the best subset for estimating total nitrogen concentration. The models developed have been validated for total phosphorus and total nitrogen concentration. For total phosphorus, the model values were found to be very close to the measured values but the values varied widely for total nitrogen, championing the former as a very potent down-to-earth model.

Keywords Nutrient modeling · Saheb Bundh Lake · Phosphorus · Nitrogen · Productivity · Best subset method · Cultural eutrophication

Editorial responsibility: An-Lei Wei.

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Introduction

There is rising recognition that lakes inclusive of their biological diversity are functionally intact and biologically complex freshwater ecosystems which provide a vast array of ecosystem goods and services to society including flood control, transportation, recreation, purification of human and industrial wastes, habitat for plants and animals, and production of fish and other foods and marketable goods (Schallenberg et al. 2013). They also play active role in controlling water cycling and cleaning the environment. Ecological services are costly and often impossible to replace when aquatic

Published online: 13 September 2017

Journal of Hydrology 535 (2016) 407–417

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Monsoonal influence on variation of hydrochemistry and isotopic signatures: Implications for associated arsenic release in groundwater

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ARTICLE INFO

Article history:
Received 12 August 2015
Received in revised form 25 December 2015
Accepted 21 January 2016
Available online 29 January 2016
This manuscript was handled by Laurent Charlet, Editor-in-Chief, with the assistance of Rafael Pérez-López, Associate Editor

Keywords:
Arsenic
West Bengal
Monsoon
Stable isotopes
Dissolved organic carbon (DOC)

SUMMARY

The present study examines the groundwater and surface water geochemistry of two different geomorphic domains within the Chakdaha block, West Bengal, in an attempt to decipher potential influences of groundwater abstraction on the hydrochemical evolution of the aquifer, the effect of different water inputs (monsoon rain, irrigation and downward percolation from surface water impoundments) to the groundwater system and concomitant As release. A low-land flood plain and a natural levee have been selected for this purpose. Although the stable isotopic signatures of oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) are largely controlled by local precipitation, the isotopic composition falls sub-parallel to the Global Meteoric Water Line (GMWL). The Cl/Br molar ratio indicates vertical recharge into the wells within the flood plain area, especially during the post-monsoon season, while influences of both evaporation and vertical mixing are visible within the natural levee wells. Increase in mean DOC concentrations (from 1.33 to 6.29 mg/L), from pre- to post-monsoon season, indicates possible inflow of organic carbon to the aquifer during the monsoonal recharge. Concomitant increase in As_T, Fe(II) and HCO_3^- highlights a possible initial episode of reductive dissolution of As-rich Fe-oxyhydroxides. The subsequent sharp increase in the mean As(III) proportions (by 223%), particularly in the flood plain samples during the post-monsoon season, which is accompanied by a slight increase in mean As_T (7%) may refer to anaerobic microbial degradation of DOC coupled with the reduction of As(V) to As(III) without triggering additional As release from the aquifer sediments.

1. Introduction

In the Bengal Delta Plain (BDP), groundwater arsenic (As) concentrations have been found to frequently exceed the WHO drinking water guideline of 10 μg/L (WHO, 2011). Amongst other countries worldwide, parts of SE Asia including India and Bangladesh are facing severe threats of limited As safe drinking water sources (Nath et al., 2008a; van Geen et al., 2008; Fendorf et al., 2010; Datta et al., 2011). Toxic inorganic forms, arsenite [As(III)] and arsenate [As(V)], are the most dominant species of As in groundwater (Majumder et al., 2014). The concentration of organic As species are negligible throughout the BDP aquifers (Sharim et al., 2002; Gault et al., 2005). This situation is currently affecting the health of millions of people and has become one of the world's worst health catastrophes (Smith et al., 2000; Nriagu et al., 2007).

It has been proposed that the local groundwater pumping for irrigation and/or community drinking water supply may draw young, organic-rich water into the shallow aquifers (Neumann et al., 2010), accelerating the release of As to groundwater

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http://dx.doi.org/10.1016/j.jhydrol.2016.01.052
0022-1694/

Science of the Total Environment 468–469 (2014) 804–812

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Size-fractionation of groundwater arsenic in alluvial aquifers of West Bengal, India: The role of organic and inorganic colloids

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HIGHLIGHTS

- We study the role of colloidal particles on groundwater arsenic in West Bengal (India).
- Arsenic concentration decreases with sequential micro- and ultra-filtration steps.
- Majority of As_T remain in the 'truly dissolved' phase (i.e., pass through 0.05 μm).
- Larger Fe-rich inorganic colloids (>0.05 μm) scavenge As(III).
- Smaller organic/organometallic colloids (<0.05 μm) scavenge As(V).

ARTICLE INFO

Article history:
Received 3 July 2013
Received in revised form 26 August 2013
Accepted 26 August 2013
Available online xxxx

Editor: Damia Barcelo

Keywords:
Size-fractionation
Groundwater
Arsenic
Dissolved organic carbon (DOC)
Organometallic colloids

ABSTRACT

Dissolved organic carbon (DOC) and Fe mineral phases are known to influence the mobility of arsenic (As) in groundwater. Arsenic can be associated with colloidal particles containing organic matter and Fe. Currently, no data is available on the dissolved phase/colloidal association of As in groundwater of alluvial aquifers in West Bengal, India. This study investigated the fractional distribution of As (and other metals/metalloids) among the particulate, colloidal and dissolved phases in groundwater to decipher controlling behavior of organic and inorganic colloids on As mobility. The result shows that 83–94% of As remained in the 'truly dissolved' phases (i.e., <0.05 μm size). Strong positive correlation between Fe and As (r^2 between 0.65 and 0.94) is mainly observed in the larger (i.e., >0.05 μm size) colloidal particles, which indicates the close association of As with larger Fe-rich inorganic colloids. In smaller (i.e., <0.05 μm size) colloidal particles strong positive correlation is observed between As and DOC ($r^2 = 0.85$), which highlights the close association of As with smaller organic colloids. As(III) is mainly associated with larger inorganic colloids, whereas, As(V) is associated with smaller organic/organometallic colloids. Scanning Electron Microscopy and Energy Dispersive X-ray spectroscopy confirm the association of As with DOC and Fe mineral phases suggesting the formation of dissolved organo-Fe complexes and colloidal organo-Fe oxide phases. Attenuated total reflectance-Fourier transform infrared spectroscopy further confirms the formation of As–Fe–NOM organometallic colloids, however, a detailed study of these types of colloids in natural waters is necessary to underpin their controlling behavior.

1. Introduction

Naturally occurring carcinogenic arsenic (As) is ubiquitous in the environment and commonly observed in high concentrations in the alluvial aquifers of south-east Asia (Bhattacharya et al., 1997; Nickson et al., 1998; Chatterjee et al., 2003; Charlet and Polya, 2006; Mukherjee et al., 2008; Nath et al., 2011). In south-east Asia, the use of As-enriched groundwater as the primary source of drinking and other household activities has led to an unprecedented human health problem, creating a major concern for the environmental and public health experts (e.g., Smedley and Kinniburgh, 2002). The human health problem is particularly alarming in the rural Bengal Delta Plain (BDP), i.e., in West Bengal (India) and Bangladesh, yet there are no sustainable alternatives of drinking water sources available (Mukherjee et al., 2011).

The role of dissolved organic carbon and/or Fe-oxyhydroxide solids on As mobility in natural groundwater was described in detail (e.g., Charlet and Polya, 2006). For example, dissolved organic carbon (DOC) or natural organic matter (NOM) can compete with As for

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0048-9697/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scitotenv.2013.08.087

Journal of Hazardous Materials 262 (2013) 1167–1175

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Application of natural citric acid sources and their role on arsenic removal from drinking water: A green chemistry approach

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HIGHLIGHTS

- Tomato and lime is reported for the first time to be the promoter of SORAS.
- As/Fe molar ratio is important for effective removal of arsenic from groundwater.
- The arsenic removal competence improved at specific citrate doses.
- Hydroxycinnamates in tomato enhances the generation of photocatalysts.
- Tomato is the most cost-effective and efficient to remove As than lemon and lime.

ARTICLE INFO

Article history:
Available online 13 September 2012

Keywords:
Arsenic
Groundwater
Solar oxidation
Citric acid
Anti-oxidant activity

ABSTRACT

Solar Oxidation and Removal of Arsenic (SORAS) is a low-cost non-hazardous technique for the removal of arsenic (As) from groundwater. In this study, we tested the efficiency of natural citric acid sources extracted from tomato, lemon and lime to promote SORAS for As removal at the household level. The experiment was conducted in the laboratory using both synthetic solutions and natural groundwater samples collected from As-polluted areas in West Bengal. The role of As/Fe molar ratios and citrate doses on As removal efficiency were checked in synthetic samples. The results demonstrate that tomato juice (as citric acid) was more efficient to remove As from both synthetic (percentage of removal: 78–98%) and natural groundwater (90–97%) samples compared to lemon (61–83% and 79–85%, respectively) and lime (39–69% and 63–70%, respectively) juices. The As/Fe molar ratio and the citrate dose showed an 'optimized central tendency' on As removal. Anti-oxidants, e.g. 'hydroxycinnamates', found in tomato, were shown to have a higher capacity to catalyze SORAS photochemical reactions compared to 'flavanones' found in lemon or lime. The application of this method has several advantages, such as eco- and user- friendliness and affordability at the household level compared to other low-cost techniques.

1. Introduction

Groundwater is the main source of drinking water in most part of the Bengal Delta Plain (BDP), the world's largest deltaic alluvium. The easy accessibility of groundwater makes it a vital resource for the rural people living in this region. Currently, groundwater is widely used for agricultural irrigation and crop production [1–4]. Though the aquifer is generally free from bacterial contamination, the large-scale exploitation of groundwater has resulted in severe water quality problems, the most threatening of which is the hydroarsenicosis [5–12].

A number of technologies are currently available for the removal of As from groundwater. For example, iron and alum coagulation [13], lime softening [14], reverse osmosis [15], zero-valent iron and nano-particulate zero-valent iron [16,17], natural/synthetic metal oxides [18,19], iron doped activated carbons [20], granular TiO_2 adsorbent [21], hybrid materials [22] are some of the many proposed removal techniques. Among these, a few treatment technologies are efficient but expensive whereas some are cheaper

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0304-3894/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jhazmat.2012.09.007

Available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/watres

Assessment of arsenic exposure from groundwater and rice in Bengal Delta Region, West Bengal, India

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ARTICLE INFO

Article history:
Received 8 February 2010
Received in revised form
1 April 2010
Accepted 8 April 2010
Available online 16 July 2010

Keywords:
Arsenic exposure
Hydrochemistry
Fe Cycling
Redox chemistry
Rice
Risk assessment

ABSTRACT

Arsenic (As) induced identifiable health outcomes are now spreading across Indian subcontinent with continuous discovery of high As concentrations in groundwater. This study deals with groundwater hydrochemistry vis-à-vis As exposure assessment among rural population in Chakdaha block, West Bengal, India. The water quality survey reveals that 96% of the tubewells exceed WHO guideline value (10 μg/L of As). The groundwaters are generally anoxic (−283 to −22 mV) with circum-neutral pH (6.3 to 7.8). The hydrochemistry is dominated by HCO_3^- (208 to 440 mg/L), Ca^{2+} (79 to 178 mg/L) and Mg^{2+} (17 to 45 mg/L) ions along with high concentrations of As_T (As total, below detection limit to 0.29 mg/L), Fe_T (Fe total, 1.2 to 16 mg/L), and Fe(II) (0.74 to 16 mg/L). The result demonstrates that Fe(II)–Fe(III) cycling is the dominant process for the release of As from aquifer sediments to groundwater (and vice versa), which is mainly controlled by the local biogeochemical conditions. The exposure scenario reveals that the consumption of groundwater and rice are the major pathways of As accumulation in human body, which is explained by the dietary habit of the surveyed population. Finally, regular awareness campaign is essential as part of the management and prevention of health outcomes.

1. Introduction

A growing concern over the incidence of widespread human exposure of arsenic (As) has been seriously noticed during the past three decades globally. The increased exposure of As is generally associated with the incidences of cancer and other public health hazards. The occurrence of As (mostly inorganic forms) in groundwater have been documented in several parts

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0043-1354/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.watres.2010.04.007