Bacterial bioassay for rapid and accurate analysis of arsenic in highly variable groundwater samples

Trang P.T.K., Berg M., Viet P.H., Van Mui N., Van Der Meer J.R.

Hanoi University of Science, Biology Faculty, CETASD, 334 Nguyen Trai, Hanoi, Viet Nam; Swiss Federal Institute of Aquatic Science and Technology (Eawag), Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland; University of Lausanne, Department of Fundamental Microbiology, B?timent de Biologie, CH-1015 Lausanne, Switzerland

Abstract: In this study, we report the first ever large-scale environmental validation of a microbial reporter-based test to measure arsenic concentrations in natural water resources. A bioluminescence-producing arsenic-inducible bacterium based on Escherichia coli was used as the reporter organism. Specific protocols were developed with the goal to avoid the negative influence of iron in groundwater on arsenic availability to the bioreporter cells. A total of 194 groundwater samples were collected in the Red River and Mekong River Delta regions of Vietnam and were analyzed both by atomic absorption spectroscopy (AAS) and by the arsenic bioreporter protocol. The bacterial cells performed well at and above arsenic concentrations in groundwater of 7 ?g/L, with an almost linearly proportional increase of the bioluminescence signal between 10 and 100 ?g As/L (r^2 = 0.997). Comparisons between AAS and arsenic bioreporter determinations gave an overall average of 8.0% false negative and 2.4% false positive identifications for the bioreporter prediction at the WHO recommended acceptable arsenic concentration of 10 ?g/L, which is far better than the performance of chemical field test kits. Because of the ease of the measurement protocol and the low application cost, the microbiological arsenic test has a great potential in large screening campaigns in Asia and in other areas suffering from arsenic pollution in groundwater resources. ?? 2005 American Chemical Society.

Index Keywords: Absorption spectroscopy; Atomic spectroscopy; Bioassay; Bioluminescence; Cells; Escherichia coli; Groundwater resources; Signal processing; Water pollution; Bacterial bioassays; Bacterial cells; Bioreporter cells; Arsenic; arsenic; ground water; iron; fresh water; luciferase; arsenic; bioassay; groundwater pollution; microorganism; accuracy; analytical error; article; atomic absorption spectrometry; bacterial cell; bioassay; bioluminescence; biotechnology; cost; Escherichia coli; microbiological arsenic test; nonhuman; performance; prediction and forecasting; screening; signal detection; validation process; Viet Nam; water analysis; water contamination; water pollutant; water pollution; water pollution indicator; water sampling; water supply; world health organization; chemistry; comparative study; drug effect; environmental monitoring; metabolism; methodology; statistics; Bacteria (microorganisms); Escherichia coli; Arsenic; Environmental Monitoring; Escherichia coli; Fresh Water; Luciferases; Spectrophotometry, Atomic; Vietnam; Water Pollutants, Chemical

Year: 2005
Source title: Environmental Science and Technology
Volume: 39
Issue: 19

Page : 7625-7630
Cited by: 37
Link: Scorpus Link
Chemicals/CAS: arsenic, 7440-38-2; iron, 14093-02-8, 53858-86-9, 7439-89-6; Arsenic, 7440-38-2; Luciferases, EC 1.13.12.-; Water Pollutants, Chemical
Correspondence Address: Berg, M.; Swiss Federal Institute of Aquatic Science and Technology (Eawag), Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland; email: michael.berg@eawag.ch
ISSN: 0013936X
CODEN: ESTHA
DOI: 10.1021/es050992e
PubMed ID: 16245836
Language of Original Document: English
Abbreviated Source Title: Environmental Science and Technology
Document Type: Article
Source: Scopus
Authors with affiliations:

1. Trang, P.T.K., Hanoi University of Science, Biology Faculty, CETASD, 334 Nguyen Trai, Hanoi, Viet Nam
2. Berg, M., Swiss Federal Institute of Aquatic Science and Technology (Eawag), Ueberlandstrasse 133, CH-8600 D?bendorf, Switzerland
3. Viet, P.H., Hanoi University of Science, Biology Faculty, CETASD, 334 Nguyen Trai, Hanoi, Viet Nam
4. Van Mui, N., Hanoi University of Science, Biology Faculty, CETASD, 334 Nguyen Trai, Hanoi, Viet Nam
5. Van Der Meer, J.R., University of Lausanne, Department of Fundamental Microbiology, B?timent de Biologie, CH-1015 Lausanne, Switzerland

References:

1. Berg, M., Tran, H.C., Nguyen, T.C., Pham, H.V., Schertenleib, R., Giger, W., Arsenic contamination of groundwater and drinking water in Vietnam: A human health threat (2001) Environ. Sci. Technol., 35, pp. 2621-2626
2. Chakraborti, D., Mukherjee, D., Pati, S., Sengupta, M.K., Rahman, M., Chowdhury, U.K., Lodh, D., Basu, G.K., Arsenic groundwater contamination in middle Ganga Plain, Bihar, India: A future danger? (2003) Environ. Health Perspect., 111, pp. 1194-1201
3. Smedly, P.L., Kinniburgh, D.G., A review of the source, behaviour and distribution of arsenic in natural waters (2002) Appl Geochem., 17, pp. 517-568
4. Xia, Y., Liu, J., An overview on chronic arsenism via drinking water in PR China (2004) Toxicology, 198, pp. 25-29
5. Ahmed, K.M., Bhattacharaya, P., Hasan, M.A., Akhter, H.S., Alam, S.M.M., Bhuyian, M.A.H., Imam, M.B., Sracek, O., Arsenic enrichment in groundwater of the alluvial aquifers in Bangladesh: An overview (2004) Appl. Geochem., 19, pp. 181-200
6. Kinniburgh, D.G., Kosmus, W., Arsenic contamination in groundwater: Some analytical considerations (2002) Talanta, 58, pp. 165-180
7. Rahman, M., Mukherjee, D., Sengupta, M.K., Chowdhury, U.K., Lodh, D., Chanda, C.R., Roy, S., Chakraborti, D., Effectiveness and reliability of arsenic field testing kits: Are the million dollar screening projects effective or not? (2002) Environ. Sci. Technol., 36, pp. 5385-5394
8. Erickson, B.E., Field kits fail to provide accurate measure of arsenic in groundwater (2003) Environ. Sci. Technol., pp. 35A-

38A
9. Daunert, S., Barrett, G., Feliciano, J.S., Shetty, R.S., Shrestha, S., Smith-Spencer, W., Genetically engineered whole-cell sensing systems: Coupling biological recognition with reporter genes (2000) Chem. Rev., 100, pp. 2705-2738
10. Van Der Meer, J.R., Tropel, D., Jaspers, M.C.M., Illuminating the detection chain of bacterial bioreporters (2004) Environ. Microbiol., 6, pp. 1005-1020
11. Stocker, J., Balluch, D., Gsell, M., Harms, H., Feliciano, J.S., Daunert, S., Malik, K.A., Van Der Meer, J.R., Development of a set of simple bacterial biosensors for quantitative and rapid field measurements of arsenite and arsenate in potable water (2003) Environ. Sci. Technol., 37, pp. 4743-4750
12. Tauriainen, S.M., Virta, M., Karp, M., Detecting bioavailable toxic metal and metalloids from natural water samples using luminescent sensor bacteria (2000) Water Res., 34, pp. 2661-2666
13. Pet??nen, T., Virta, M., Karp, M., Romantschuk, M., Construction and use of broad host range mercury and arsenite sensor plasmids in the soil bacterium Pseudomonas fluorescens OS8 (2001) Microb. Ecol., 41, pp. 360-368
14. Tauriainen, S., Virta, M., Chang, W., Karp, M., Measurement of firefly luciferase reporter gene activity from cells and lysates using Escherichia coli arsenite and mercury sensors (1999) Anal. Biochem., 272, pp. 191-198
15. Scott, D.L., Ramanathan, S., Shi, W., Rosen, B.P., Daunert, S., Genetically engineered bacteria: Electrochemical sensing systems for antimonite and arsenite (1997) Anal. Chem., 69, pp. 16-20
16. Pet??nen, T., Romantschuk, M., Use of bioluminescent bacterial sensors as an alternative method for measuring heavy metals in soil extracts (2002) Anal. Chim. Acta, 456, pp. 55-61
17. Anawar, H.M., Akai, J., Komari, K., Terao, H., Yoshioka, T., Ishizuka, T., Safiullah, S., Kato, K., Geochemical occurrence of arsenic in groundwater of Bangladesh: Sources and mobilization processes (2003) J. Geochem. Explor., 77, pp. 109-131
18. Duong, H.A., Berg, M., Hoang, M.H., Pham, H.V., Gallard, H., Giger, W., Von Gunten, O., Trihalomethane formation by chlorination of ammonium- and bromide-containing groundwater in water supplies of Hanoi, Vietnam (2003) Water Res., 37, pp. 3242-3252
19. Bednar, A.J., Garbarino, I.R., Ranville, J.F., Willdeman, T.R., Preserving the distribution of inorganic arsenic species in groundwater and acid mine drainage samples (2002) Environ. Sci. Technol., 36, pp. 2213-2218
20. Daus, B., Mattusch, J., Wennrich, R., Weiss, H., Investigation on stability and preservation of arsenic species in iron rich water samples (2002) Talanta, 50, pp. 57-65
21. Gallagher, P.A., Schwegel, C.A., Parks, A., Gamble, B.M., Wymer, L., Creed, J.T., Preservation of As(III) and As(V) in drinking water supply samples from across the United States using EDTA and acetic acid as a means of minimizing iron-arsenic coprecipitation (2004) Environ. Sci. Technol., 30, pp. 2919-2927
22. Meng, X., Korfiatis, G.P., Bang, S., Bang, K.W., Combined effects of anions on arsenic removal by iron hydroxides (2002) Toxicol. Lett., 133, pp. 103-111
23. Luzi, S., Berg, M., Pham, T.K.T., Pham, H.V., Schertenleib, R., (2004) Household Sand Filters for Arsenic Removal, , www.arsenic.eawag.ch/publications, Technical Report, Swiss Federal Institute for Environmental Science and Technology, CH-8600 D?bendorf, Switzerland
24. Boziaris, L.S., Adam, M.R., Effect of chelators and nisin produced in situ on inhibition and inactivation of Gram negatives (1999) Int. J. Food Microbiol., 53, pp. 105-113
25. Harms, H., Rime, J., Leupin, O., Hug, S.J., Van Der Meer, J.R., Influence of the groundwater composition on arsenic detection by bacterial biosensors Microchim. Acta, , in press