Using Bacteria to Quantify Arsenic Contamination in Potable Water

Daily measurements of drinking water quality generally rely on advanced chemical methods. This is no trivial matter for arsenic, a toxic heavy metal contaminating potable water in millions of family-based groundwater wells in Asia. Michael Berg[1], Pham Thi Kim Trang[2], Jan Roelof van der Meer[3]

Expensive instrumental methods, such as atomic absorption spectroscopy (AAS) or inductively coupled plasma-mass spectrometry (ICP-MS), are necessary to measure arsenic accurately. Such equipment is mainly absent in low-income regions. Though chemical field test kits can be used as an alternative, they are often unreliable at low arsenic concentrations. Accurate quantification of arsenic even at low concentrations is important to avoid chronic and toxic exposure and to meet the current WHO guideline for arsenic in drinking water (10 µg/L). Trang et al. [1] have recently reported on the successful validation of a completely different analytical method based on light emission from engineered bacterial cells (Fig. 1).

From the laboratory …

How can bacterial cells detect arsenic and emit light? In order to do so, Stocker et al. [2] equipped Escherichia coli bacteria with the ArsR protein, a naturally occurring arsenite sensing protein in the bacterial arsenic detoxification system. By genetic engineering techniques they then created a circuit in which ArsR controls expression of a reporter protein, such as the enzyme luciferase. As soon as the cells encounter arsenite, luciferase is synthesised and the cells start to emit light, which can be easily measured. Within a certain range, the light emission is proportional to the arsenite exposure (Photo 1).

… to the field

A set of simple bioassays was designed on this principle, thereby allowing accurate detection of arsenic in aqueous samples of very different chemical composition within 30 min to 2 h. To validate the bioassay performance in determining arsenic in real groundwaters, we recently applied the light-emitting biosensors to a region in Vietnam where Berg et al. [3] had reported serious arsenic contamination. A total of 194 groundwater samples from the Red River and Mekong River Delta were analysed both by AAS and the arsenic bioassay method. Compared to AAS, the bacterial assays falsely predicted in 8 % of the samples less than 10 µg of arsenic per litre and more in 2.4 % of all cases. Since this is a far better performance compared to that of chemical field test kits, the bioassay method has a great potential for use in drinking water analysis in developing countries (Photo 2).

Jan R. van der Meer

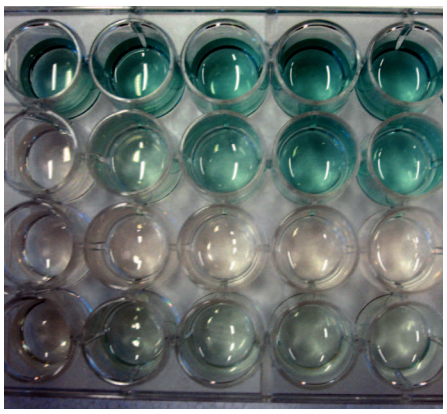


Photo 1: Colourimetric arsenic bioassay. Cells produce beta-galactosidase in response to the presence of arsenite in the medium. Image shows different cell lines (in rows) with varying response kinetics. Arsenite concentrations (left to right): 0, 0.1, 0.2, 0.5, 1.0 and 2.0 µM. Incubation time: 3 h at 35 °C.

Jan R. van der Meer

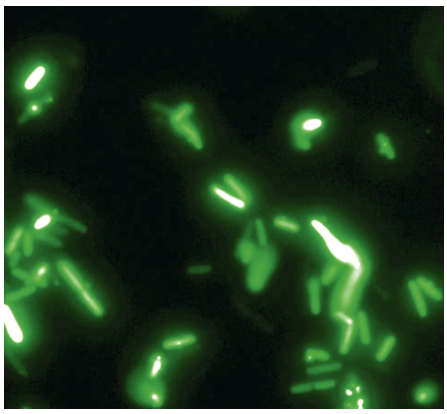
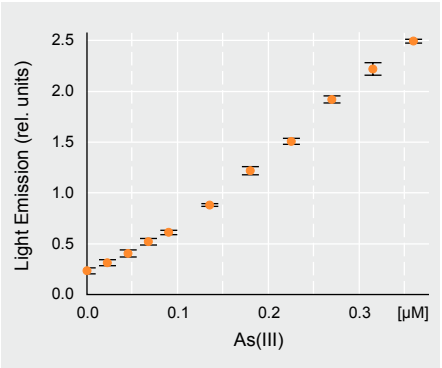


Photo 2: Escherichia coli bacteria producing the green fluorescent protein (GFP) in response to the presence of arsenite in the medium. The GFP signal can be quantified by epifluorescence microscopy, but more easily in steady state fluorimetry. Incubation time: 2.5 h at 30 °C with 0.5 µM As(III).

Figure 1: Calibration curve with the bioluminescent arsenic biosensor. Incubation time: 1.5 h at 30 °C. Measurement: Luminometer plate reader.



[1] Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland.
[2] Centre for Environmental Technology and Sustainable Development (CETASD), Hanoi University of Science, Vietnam.
[3] University of Lausanne, Department of Fundamental Microbiology, Bâtiment de Biologie, 1015 Lausanne, Switzerland.

[1] Trang, P.T.K., Berg, M., Viet P.H., Mui N.V., van der Meer, J.R. (2005): Environ. Sci. Technol., 39, 7625–7630.
[2] Stocker, J., Balluch, D., Gsell, M., Harms, H., Feliciano, J.S., Daunert, S., Malik, K.A., van der Meer, J.R. (2003): Environ. Sci. Technol., 37, 4743–4750.
[3] Berg, M., Tran, H.C., Nguyen, T.C., Pham, H.V., Schertenleib, R., Giger, W. (2001): Environ. Sci. Technol., 35, 2621–2626.