

focus on Laboratory Products

The Multipurpose Poison

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Throughout the course of history, people have found uses for the various properties of arsenic and its compounds. Red and yellow arsenic sulphides (As_2S_3 and As_4S_4) were used in antiquity as makeup and for hair removal. Artists used arsenic compounds as pigments – as for instance in Van Gogh's 'Self Portrait dedicated to Paul Gauguin' (1888, see Figure 1). So-called Paris Green (copper(II) acetoarsenite) gives the background of this painting its characteristic colour. And, to name just one medical application: the first effective drug to be used against syphilis was the arsenic compound arsphenamine (1910). The best-known use of the element with the atomic number 33, however, is as a poison. People in various regions of the world struggle even today with arsenic as a contamination in drinking water.



Figure 1. Vincent van Gogh used highly toxic copper(II) acetoarsenite as a green background colour in his paintings. The illustration is a self-portrait of the artist which he dedicated to Paul Gauguin.

Arsenic looks back on an unparalleled career as a poison in literature and film. In the play 'Intrigue and Love', Schiller's protagonist Ferdinand von Walter and his lover die of arsenic poisoning. The unhappily married Madame Bovary takes her life in the same way in the eponymous novel by Flaubert. In the classic 1940s film 'Arsenic and Old Lace', two 'charitable' ladies give arsenic to old gentlemen to free them from their dreary lives. Arsenic's career as a poison of choice was brought to a close by the Marsh test, which made it possible to detect arsenic poisoning posthumously beginning in 1836.

A Danger in Real Life

The fact is, arsenic costs many lives even today, though in the absence of premeditation. Industry and agriculture can contribute to elevated arsenic concentrations in ground water. Special geological conditions, however, are primarily responsible for the presence of elevated quantities of arsenic-containing minerals in some regions of the world (e.g., *realgar*; see Figure 2). Geologically young alluvial soils, that is, flood plains and large river deltas, are particularly affected.

This arsenic leaches into the ground water in the form of arsenite (AsO_3^{3-}) and arsenate (AsO_4^{3-}) from sediment particles. Dissolved in the ground water, it presents a hazard to local populations.



Figure 2. Arsenic is not usually to be found in its pure form in nature. One of the compounds frequently encountered is *realgar* (As_4S_4), here seen on a substrate of *stibnite* and *granite*.

Bangladesh: Out of the Frying Pan and Into the Fire

Table 1. Arsenic limit values in various countries

Bangladesh is a crisis region. In the 1970s, deep wells were built to reduce the spread of diseases such as cholera and hepatitis which were caused by contaminated surface water. The ground water is indeed microbiologically pure, however, it contains high concentrations of arsenic due to the composition of the soil. The World Health Organization (WHO) recommends that the arsenic content in drinking water should not exceed $10 \mu\text{g/L}$. In many countries, such as the USA and the countries of the EU, this limit value is prescribed by statute. Table 1 provides an overview of some of the limit values.

An estimated 45 million people in Bangladesh are exposed to higher arsenic concentrations – some 20 million are even exposed to concentrations exceeding the local limit value of $50 \mu\text{g/L}$ [1]. Figure 3 shows the distribution of arsenic concentrations in the ground water in Bangladesh.

Country	Limit value
Argentina	$50 \mu\text{g/L}$
Australia	$7 \mu\text{g/L}$
Bangladesh	$50 \mu\text{g/L}$
Chile	$50 \mu\text{g/L}$
China	$50 \mu\text{g/L}$
Ecuador	$50 \mu\text{g/L}$
EU	$10 \mu\text{g/L}$
Ghana	$50 \mu\text{g/L}$
India	$50 \mu\text{g/L}$
Japan	$10 \mu\text{g/L}$
Canada	$10 \mu\text{g/L}$
Laos	$10 \mu\text{g/L}$
Mexico	$25 \mu\text{g/L}$
Namibia	$10 \mu\text{g/L}$
Nepal	$50 \mu\text{g/L}$
Switzerland	$50 \mu\text{g/L}$
Syria	$10 \mu\text{g/L}$
Taiwan	$10 \mu\text{g/L}$
USA	$10 \mu\text{g/L}$
USA: New Jersey	$5 \mu\text{g/L}$
Vietnam	$50 \mu\text{g/L}$

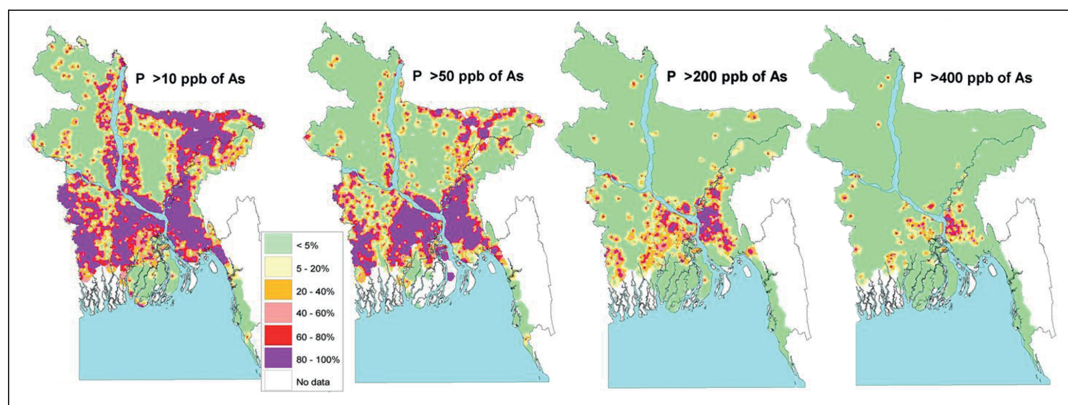


Figure 3. These four maps of Bangladesh indicate the likelihood (P), that the arsenic concentration in ground water exceeds a particular value (10 ppb, 50 ppb, 200 ppb, and 400 ppb; 1 ppb corresponds to $1 \mu\text{g/L}$). As a result, large parts of the population are faced with concentrations that exceed the WHO limit value of $10 \mu\text{g/L}$, sometimes by multiples of that amount. Source: <http://www.geog.cam.ac.uk/research/projects/arsenic/maps.html> (December 2, 2013)



Figure 4. The scTRACE Gold, consisting of an electrode shaft and sensor

Arsenic – a Widespread Problem

According to a recent publication, large areas of China are also affected by the problem. Based on geological data, topography, and soil composition, the statistical model predicts that nearly 20 million people live in areas where there is a risk of elevated arsenic concentrations [2]. According to the WHO, high levels of arsenic in ground water are also present in Argentina, Chile, India, Mexico, and the USA.

Reliable and Rapid Arsenic Determination

Compliance with the limit value is monitored by spectroscopic methods. This often involves very elaborate equipment. Voltammetry using the scTRACE Gold offers a simple, low-cost alternative to the spectroscopic determination of arsenic (Figure 4). The limit of detection is significantly lower than the valid limit value of $10 \mu\text{g/L}$ – the electrode has a recovery rate of 95% for a concentration of $5 \mu\text{g/L}$. Figure 5 shows such a determination. The sensor enables simple and reliable monitoring of the arsenic content of drinking water. The analysis time per sample is approximately 10 minutes.

The handling of the scTRACE Gold is simplicity itself. All three electrodes needed for the measurement are combined in one sensor. To put the scTRACE Gold into operation, it is simply mounted on the electrode shaft and immersed in the sample; then the determination can be started. The innovative gold microwire working electrode eliminates the need for the laborious preparation and conditioning of the electrode. That saves time. It also makes using the sensor easier, because there is no longer the need to assess whether or not the electrode is ready for use. Furthermore, the screen-printed reference and auxiliary electrodes are completely maintenance-free.

As with any electrode, the performance of the scTRACE Gold deteriorates as more and more determinations are performed. However, thanks to the practical plug-in design consisting of shaft and sensor, only the inexpensive sensor needs to be replaced, thus making the procedure a snap. This ensures reliable results at all times.

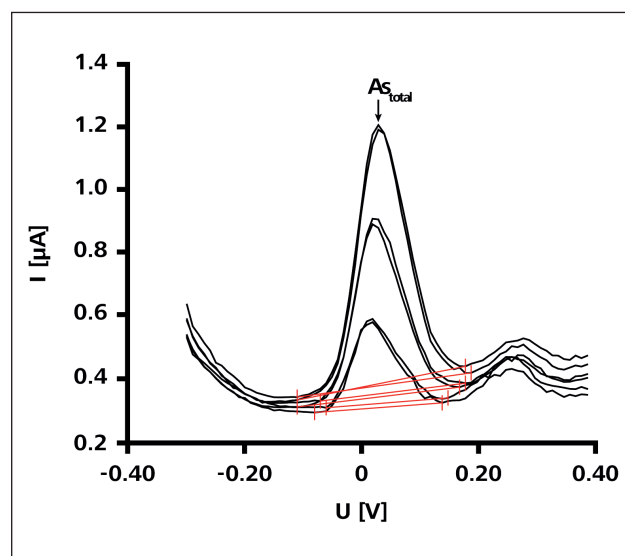


Figure 5. An arsenic determination with the scTRACE Gold in mineral water with two standard additions is shown. Two replicate measurements were performed of the sample and of each standard addition. An arsenic concentration of $4.9 \mu\text{g/L}$ was found.

An additional advantage of voltammetric determination with the scTRACE Gold is its ability to differentiate between the more toxic As(III) and the less toxic As(V) simply through the choice of measuring parameters. The scTRACE Gold can be used with any Metrohm voltammetry measuring stand.

More information about the scTRACE Gold and its handling can be found in the brochure (document number: 8.109.5018) and in Application Bulletin AB-416.

References

- [1] Flanagan, S.V. et al. (2012) Bull. World Health Org. 90, 839–846
- [2] Rodríguez-Lado, L. et al. (2013) Science 341(6148), 866–868



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