DHI CASE STORY

BIOACCESSIBILITY OF ARSENIC

Measuring the bioaccessibility of arsenic in soil at former fruit orchards

Since the late 19th century, lead arsenate has been used as one of the 'first generation pesticides'. During site investigations, elevated concentrations of arsenic and other metals have been found in the soil at two former orchards. We conducted a health risk assessment and bioaccessibility testing for arsenic to provide more detailed answers regarding potential pollution-related health risks.

Spraying of pesticides at a fruit orchard in the 1950´s. Historical photograph provided by © Stefan Outzen

ARSENIC IN SOIL

Arsenic is a naturally occurring trace element found in rocks and soil. However, arsenic can also be found as a result of soil pollution (for example, by use of arsenic -containing pesticides). Arsenic is toxic and contact with arsenic-polluted soil (for example, involuntary ingestion of polluted soil) can have negative health impacts.

Thus, understanding the physico-chemical properties of arsenic in soil is important to obtain a better understanding of the major factors influencing the bioaccessibility of arsenic and to thereby evaluate health risks.

SUMMARY

CLIENT

Region Zealand, Denmark and Danish Environment Agency

CHALLENGE

- Lack of knowledge about the bioaccessibility of arsenic (the amount of arsenic that can potentially be transferred from contaminated soil into the human body and cause toxic effects)
- Need to know which soil properties in particular influence the bioaccessibility of arsenic
- Need to accurately measure the bioaccessibility of arsenic. This is required in order to identify unacceptable risks to human health and help reduce efforts and costs for site clean-up

SOLUTION

Bioaccessibility testing for arsenic in soil, combined with relevant supplementary analysis and geochemical modelling

VALUE

- Bioaccessibility testing serves as a tool in health risk assessment
- Potential cost savings ensue, if results show that site clean-up can be avoided or reduced

LOCATION / COUNTRY

Hørsholm, Denmark

INITIAL HEALTH RISK ASSESSMENT

We conducted an initial comparative health risk assessment of soils polluted by excessive amounts of arsenic, lead, cadmium and Polycyclic Aromatic Hydrocarbons (PAH). This assessment showed that arsenic was the soil contaminant which was most critical to human health, and should therefore be dealt with first. To evaluate the extent of pollution-related health risks that may be expected, we conducted bioaccessibility testing.

BIOACCESSIBILITY TESTING AS A TOOL IN HEALTH RISK ASSESSMENT

It is typically assumed that all of a given soil contaminant poses a risk to soil environment and human health. However, the effect of a contaminant depends on how much of it is accessible to be absorbed – in the human body, for instance. Bioaccessibility of soil contaminants depends on the contaminant chemistry, soil properties and the chemical conditions in the human body.

TAILORED TESTING TO PROVIDE ANSWERS

In conjunction with the client, we conducted a test program that would provide information on:

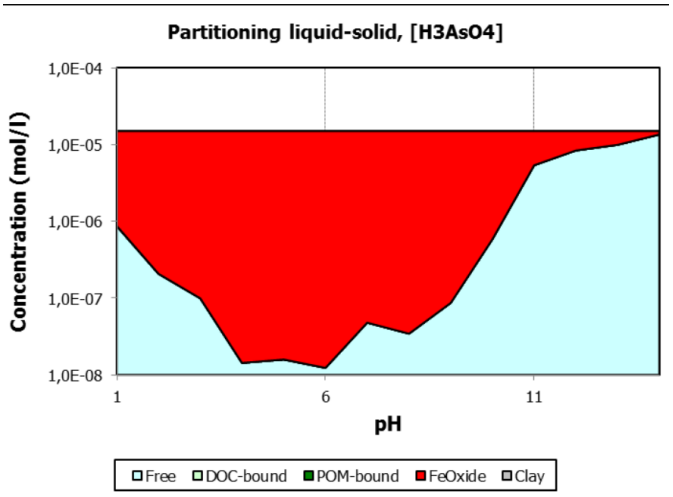
- the bioaccessibility of arsenic in soil from the two fruit orchards
- the major factors influencing the bioaccessibility of arsenic in the soils

We carried out the following tests and analyses:

- Bioaccessibility tests
- Analysis of arsenic, reactive surfaces (for example hydrous ferro-oxides, HFOs) and arsenic speciation
- pH-dependent leaching test

The soil contained more than 20 mg/kgDM of arsenic and arsenate was the dominating species. Results from the bioaccessibility tests indicated that more than half of the arsenic present in the soil is bioaccessible and suggested that the lower the content of HFO-reactive surfaces in the soil, the higher the bioaccessibility of arsenic.

We carried out geochemical modelling based on the results obtained from a pH-dependent test. Our modelling results confirmed that HFO-reactive surfaces greatly influence the sorption of arsenate onto soil.



At neutral pH (around 6 to 7), almost all arsenate is absorbed to iron oxide surfaces. At very high pH-values, arsenate will be dissolved

Our solutions provided useful information to the client. Data underpinned that it is recommended to use bioaccessibility testing in risk assessments. Often, less than 100% of a contaminant present in soil is dissolved when soil is ingested. Thus, the total content of soil pollution may be a poor indicator of the actual risks associated with a contaminant.

BIOACCESSIBILITY TESTS

A number of different *in vitro* bioaccessibility methods are available as an indicator for *in vivo* bioavailability (the fraction of a soil contaminant that reaches the blood stream). The in vitro laboratory test methods offer a good alternative to the *in vivo* methods using experimental animals. However, it is crucial that those methods are validated to provide results that are well correlated to accepted *in vivo* bioavailability methods.

At DHI, we use the *RIVM*-method. This method has been validated and in Denmark, the Danish Environmental Protection Authority (EPA) has accepted its use for determination of the bioaccessibility of lead and cadmium. The test can only be done qualitatively for nickel and PAH.

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