European Commission

Science for Environment Policy

# Floods due to rising sea levels may mobilise arsenic from contaminated soils

**25 January 2018**
**Issue 501**

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**Source:** LeMonte, J.J., Stuckey, J.W., Sanchez, J.Z., Tappero, R.V., Rinklebe, J. & Sparks, D.L. (2017). Sea level rise induced arsenic release from historically contaminated coastal soils. *Environmental Science & Technology*, 51(11): 5913–5922 DOI: 10.1021/acs.est.6b06152

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**New research has shown that flooding of soils contaminated with arsenic, which may occur as sea levels rise due to climate change, could lead to the mobilisation of this toxic element in the environment.** The study shows that arsenic is more stable in soil flooded with saltwater, compared to river water, as salt stabilises mineral oxides and could inhibit microbial activity. However, microbes that transform arsenic into water-soluble forms may adapt to saline conditions, and the risk of arsenic entering waters due to rising sea levels should receive further attention.

**A mean sea-level rise of 0.8 m is predicted to occur over the next century due to climate change, resulting in flooding of coastal areas and along rivers in these areas.** Floods will lead to chemical and mineralogical changes in coastal soils, but these effects have not yet been widely investigated, according to the researchers. The movement and fate of toxic contaminants in these soils is of particular importance, as they could pose a threat to human and ecosystem health. This study aimed to look at how the toxic element arsenic in coastal soils would be affected by flooding and increased salinity (salt levels).

Elevated levels of arsenic in soils can occur due to both geogenic (it occurs naturally in the earth's crust) and anthropogenic (through pollution from human activity) causes. In Europe, higher than average levels of arsenic are found in soils in south-west England, north-western Portugal and Spain, and the south of France[1]. Arsenic is also found in groundwater, which can endanger health if consumed or used in agriculture, as has occurred in Bangladesh, for example[2]. Some crops, such as rice, absorb arsenic easily, leading to contamination in the food chain. Given the importance of minimising exposure to arsenic, research has been undertaken to better understand how arsenic behaves in the environment, especially in soil, for example in the EU-funded BIOMETA project. However, this is the first study to look at the effects of sea-level rise on arsenic in coastal soils.

Through a series of experiments, the researchers evaluated the effects of flooding with seawater and river water on soil-borne arsenic in a coastal region of Delaware State, USA, where sea levels are predicted to rise by 1 m by 2100. Historically, activities such as leather tanning, chemical production and ore processing have led to widespread arsenic contamination in this area.

The researchers collected soil samples from ten locations on the banks of a tidal basin constructed as part of a remediation project in the city of Wilmington. The samples were combined and analysed for characteristics such as pH, texture and levels of organic matter. Total metal content was determined, and the amount of iron oxide in the soil — which can influence the chemical behaviour of arsenic — was also measured. Initial arsenic concentration in the soil was 13.3 grams (g) per kilogram (kg), mostly in an oxide form known as trivalent arsenite.

The soil, which had been dried and ground, was placed in a microcosm system (a miniature version of an environment) designed to simulate conditions that might occur after sea levels rise. The researchers propose that flooding will cause chemical reactions that alter the composition of arsenic and other chemicals in the soil; this stage was designed to study these processes. To introduce microbes typically found in the site, they added some fresh soil from the same site, plus 10 g of powder made from a reed that grows there, *Phragmites australis*, and some glucose to 'feed' the microbes.

*Continued on next page.*

1. Lado, L.R., Hengl, T. & Reuter, H.I. (2008). Heavy metals in European soils: a geostatistical analysis of the FOREGS Geochemical database. *Geoderma,* 148(2): 189–199

2. WHO (2016). Fact Sheet: Arsenic. Available from: http://www.who.int/mediacentre/factsheets/fs372/en/

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Further treatment, including the addition of nitrogen gas and oxygen, provided ideal conditions for oxidation/reduction processes to occur in the microcosm. Oxidation is where an element is transformed by losing electrons (e.g. combustion), and it increases with higher levels of oxygen. This process might occur in the natural environment, when chemicals are exposed to fresh water or air (e.g. rust). Reducing conditions, with low levels or total absence of oxygen, could occur after flooding when chemicals are exposed to stagnant water.

The behaviour of arsenic at six different levels of oxidising or reducing conditions was observed. The researchers then mixed the soil with two solutions — one was seawater and the other was river water — to mimic the effect of flooding. Levels of other chemicals in the solution were also monitored to see how these correlated with changes in the arsenic.

The study's main finding was that approximately twice the arsenic was released from the soil in the river water treatment, compared to the seawater solution. The researchers suggest this could be due to both biotic and abiotic processes. Sulfates, which are present in higher levels in sea water than in river water, could potentially stabilise arsenic-bearing oxides of soils by forming non-soluble complexes. Besides, sulfates are more likely to undergo chemical reactions with microbes in the water before these react with arsenic-bearing oxides, therefore reducing the potential for arsenic to be released into the water through this process (dissimilatory reduction).

The difference could also be partly explained by the diminution of microbes by salt in the seawater, say the researchers. However, slightly more acidic conditions, which inhibit microbial activity, were found in the seawater compared to the river water, due to the chemical action of salt. The researchers note that a slow transition to more saline (salty) conditions, as with gradual sea-level rise, may allow microbes to adjust and survive, however.

The researchers also noticed that the highest concentrations of arsenic in water were correlated with higher amounts of dissolved organic carbon (organic material), suggesting that more available carbon stimulated microbes to release arsenic from its oxide compound form. The organic material itself can also carry arsenic through water, making it more mobile.

In conclusion, the study asserts that biogeochemical changes in coastal areas following sea-level rise will change the ability of soils to store contaminants. Flooding will cause arsenic to be released into water due to the transformation of mineral oxide compounds within the soil that contain arsenic. However, this study shows that this effect is more pronounced with river water flooding. The researchers say that monitoring in the field, as well as further laboratory research, should be undertaken to increase understanding of the impacts of sea-level rise on the cycling of contaminants in coastal areas.