7 Arsenic

Arsenic (As) is one of the most common chemicals of concern at contaminated sites. Arsenic is ranked #1 on the 2017 Agency for Toxic Substances and Disease Registry (ATSDR) substance priority list (ATSDR 2017). There has been great interest in incorporating arsenic bioavailability estimates in human health risk assessments. A large amount of research and development of methods has produced tools and procedures to predict bioavailability of arsenic in soil and solid wastes. Often the risk driver for arsenic is soil ingestion. This section describes:

- the natural occurrence and contaminant sources of arsenic in soil
- important fate and transport processed that affect bioavailability
- toxicology and exposure
- methods used to measure bioavailability and bioaccessibility
- considerations for site-specific bioavailability assessments
- an overview of case studies that have been performed to estimate arsenic bioavailability
- application of bioavailability to evaluate in situ remediation using soil amendments

Arsenic is a naturally occurring metalloid found in organic and inorganic compounds that occur in oxide, hydrous oxide, sulfide, phosphate, and other minerals. Arsenic has four states of oxidation (V, III, 0, or -III) that control its solubility and **bioavailability** to organisms. In the environment, however, the inorganic forms of arsenate (AsO_4^{-3}) as As(V) and arsenite (AsO_3^{-3}) as As(III) dominate (Cullen and Reimer 1989). Arsenic occurs in different geochemical forms in **soil** systems. Soil arsenic can be found in different mineral forms (oxide, sulfide, arsenate), sorbed to clay minerals, in oxides and organic matter, and in the redox states As(III) and As(V). These forms of soil arsenic vary in solubility and are likely to vary in bioavailability following ingestion.

Arsenic is a natural constituent of all soils. Soil arsenic content often increases with iron, aluminum, manganese oxides, and organic matter content. Soil parent materials high in arsenic include shales and other sulfide-bearing deposits such as those containing arsenopyrite and associated arsenic minerals (Kabata-Pendias and Pendias 2001). In 2007, the U.S. Geological Survey initiated a low-density (1 site per 1,600 square kilometers, 4,857 sites) geochemical and mineralogical survey of soils of the continental United States as part of the North American Soil Geochemical Landscapes Project (Smith et al. 2013).

The mean arsenic content of topsoil (0–5 cm) from this study ranged from <0.6 to 830 mg/kg, with a median 5.2 mg/kg and a median absolute deviation of 3.3 mg/kg. A useful source of information on soil background level of arsenic and other elements (reported at the level of county for the United States) is included in the USGS county soils data (Figure 7-1). Studies have been done at the state level also. For example, Ohio has one of the highest mean arsenic values occurring naturally in soil in the nation (Venteris et al. 2014).

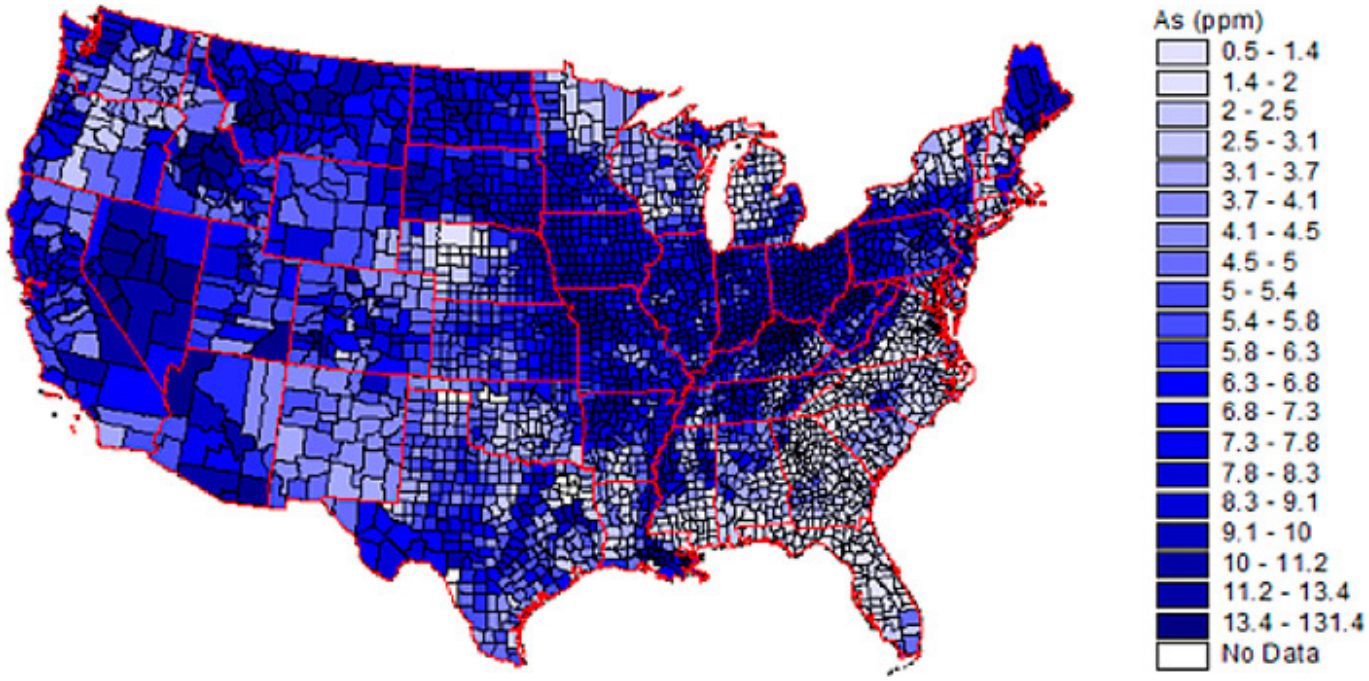

Figure 7-1. Arsenic concentrations in soils.

Source: USGS (2008)

Arsenic occurs in mineral deposits of many elements including copper, silver, gold, zinc, mercury, uranium, tin, lead, molybdenum, tungsten, nickel, and cobalt (Craw and Bowell 2014). Mining operations for any of these minerals can results in soil contamination with arsenic. The most common mineral forms of arsenic associated with mining are arsenopyrite, marcasite, enargite, orpiment, realgar, and tennantite (Craw and Bowell 2014). These minerals weather to form many secondary arsenic minerals in soil. The occurrence and forms of arsenic contamination in soil from mining activities has been recently studied (Bowell and Craw 2014).