

METALS: SIMPLE CONCEPTUAL MODEL NARRATIVE

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Certain regions of the earth have naturally high concentrations of metals, and land disturbance in these areas can increase erosion and mobilize these metals into surface waters. Human activities redistribute and concentrate metals in areas that are not naturally metals-enriched; when these metals are released into the air, water, and soil, they also can reach surface waters. If these metals are biologically available at toxic concentrations, they can contribute to biological impairment of aquatic communities.

Metals enter surface waters from point and non-point sources resulting from a variety of human land use practices. A point source is a direct input from a discrete source, usually an outfall discharging effluent to surface water. Non-point sources include atmospheric emissions and land uses which contaminate soil with metals through the extraction, refinement and use of fossil fuel and mineral resources. Atmospheric emissions can deposit onto surface waters or land surfaces. Metals on land and in soil can infiltrate into subsurface waters (e.g., groundwater) or wash into streams during storms.

Naturally metals-enriched regions become non-point sources when land cover alterations expose rock and soil to erosion. These pathways also apply to areas with legacy contamination, or historical sources. Legacy contamination can include soil contamination from arsenical pesticide residues and long term industrial or urban land use. Land cover alterations which reduce watershed and riparian vegetation (e.g., due to agriculture, forestry, residential and commercial development) decrease infiltration and increase the volume and velocity of stormwater runoff. Channel alteration and increased flow can incise channels and reduce bank stability, resulting in bank and channel erosion and redistribution of metals-enriched substrates. More detailed information on metals sources and factors conveying metals to surface waters can be found in Marsalek et al. (2006).

Once in water, the bioavailability and toxicity of a metal is determined by its speciation, which is itself largely determined by several environmental parameters (e.g., pH, temperature, redox potential, ionic strength, presence of methylating microbes, and the availability of binding sites). Based on these parameters, free metal ions may precipitate as flocculates, form complexes with ligands (i.e., biotic or abiotic binding sites), become transformed to organometallic compounds (e.g., methylation in mercury), or sorb to solid particles. For more details on metals speciation, see Langmuir et al. (2004).

The metal species of primary toxicological concern are free ions. For many metals, acute toxicity results from binding of free metal ions onto chloride cells of the gill epithelium,

disrupting osmoregulation and leading to mortality (DiToro et al. 2001). Certain metal forms may diffuse into the gill epithelium, but these routes of absorption are considered minor relative to free ion binding. Toxicity associated with dietary bioaccumulation of metals and, for some metals, biomagnification within food webs can occur when there are sustained exposures in habitats with persistent contamination. Acid mine drainage can present a physical cause of impairment when drainage water mixes with the higher pH water of a receiving stream and metal hydroxides precipitate. The flocculate that results coats the stream bed and can smother organisms and their benthic habitat.

The physiological mechanisms of metal toxicity may translate into a broad spectrum of organism-level effects, ranging from altered behavior to outright lethality. Biotic responses are both taxa- and metal-specific, and may include increased occurrence of deformities or increased mucous secretion in fish. Differences in susceptibility to metals toxicity can restructure communities. For more details on the ecological effects of metals, see Kapustka et al. (2004).

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