TOXIC CHEMICALS: DETAILED CONCEPTUAL MODEL NARRATIVE

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This conceptual model examines surface water and sediment contamination by non-metal toxic chemicals *that originate from human activities*. Although natural biotic and abiotic processes may contribute toxic substances to the environment, these substances are not considered here; metals are discussed in a separate module.

Model Format

The toxic chemicals conceptual model diagram depicts sources and land use alterations that directly and indirectly contribute toxic chemicals to surface waters near the top of the figure, leading down the diagram to steps in the causal pathway, proximate stressors (i.e., increased toxic chemicals), other stressors influencing contaminant concentrations, modes of action, and eventually biological responses at the bottom. This narrative generally follows the diagram from top to bottom, left to right. For more information on interpreting CADDIS conceptual model diagrams, see the Conceptual Model Library homepage.

Linking Sources to Proximate Stressors

Most human activities result in some release of chemicals into the environment; these releases may introduce toxic chemicals to aquatic systems adsorbed to soil particles, in surface runoff, in subsurface waters, by deposition on water surfaces, or by direct discharge into surface waters. Several potential activities leading to chemical contamination are shown across the top of the diagram, linked to an array of specific sources. Both point and non-point sources may contribute toxic chemicals. Non-point sources include waste incineration, fossil fuel combustion, fertilizer and pesticide applications, road salting and animal wastes. These activities spread chemicals across the landscape or emit them into the air with later deposition on land and water surfaces. Surface and subsurface transport processes move these chemicals to surface waters. Septic systems, landfills, and industrial and mining wastes pollute surface waters through more localized runoff and leaching processes. Finally, point source discharges (e.g., end of a pipe discharges) include industrial effluents, wastewater treatment plant effluents, stormwater overflows, and other sources that can deliver chemicals directly into surface waters. Point sources are normally, but not always, discharged under permit. This array of potential sources suggests that any single body of water can be contaminated by many sources, and thus exposed to a mixture of chemicals – some of which may be causing observed effects.

Historical sources are sources that are no longer active. Past deposition of contaminants onto soil, leachates from poorly designed landfills, buried toxic wastes from commercial or military operations, former spills, illegally disposed wastes, or past contamination released from any of the other potential sources may continue to leach toxic chemicals into surface waters through surface or subsurface transport. Many of these sites have been obscured by time, natural vegetative growth, and lost or destroyed records, so their discovery may only occur because of observed biotic effects.

A number of important processes can modify the delivery and toxicity of chemicals released to the environment, although they are not actually sources of chemicals themselves. Channel alteration can lead to channel incision and erosion that may deliver contaminated sediments to streams, creating episodic events. Loss of natural land cover along riparian zones and across the watershed, as well as hardening of land surfaces, enhance delivery of chemicals to water bodies through surface and subsurface transport processes. Delivery of chemicals to surface waters also is influenced by precipitation patterns, a contributing environmental condition (hexagon). Precipitation events may wash toxic chemicals into surface waters; decreased precipitation, as well as water removal for human use, can decrease dilution and increase concentrations of existing chemicals. Dissolved organic carbon also may influence bioavailability and uptake of contaminants.

The toxicity of chemicals can be enhanced or diminished by other stressors, including increased ionic strength and suspended sediments, decreased dissolved oxygen, or changes in temperature. Changes in these additional stressors can alter the impact of chemical toxicity, and may also interact with transport and exposure modifying factors noted above.

Linking Proximate Stressors to Biological Impairment

The proximate stressor in this model is “toxic chemicals” in surface waters (center blue box). Both episodic and sustained exposures to toxic chemicals can lead to the array of effects shown. High concentrations of a toxic chemical delivered in episodic runoff events, effluents released during treatment failures, spills, or other such events may lead to acute toxicity and death of some or all biota. Continuous point sources, atmospheric deposition, contaminated groundwater or other sustained sources may cause impairment through chronic toxic effects of low level concentrations (see hexagons, center). It is likely that different chemicals will be delivered to a water body through multiple transport mechanisms. Clues as to the nature of the chemical and how exposure is occurring may be found in processes (hexagons) that lead to alteration of biotic communities. Emigration from, or avoidance of immigration to, areas within a water body may suggest localized concentrations. Abrupt mortality may suggest acute toxicity;

acute exposures often also cause injuries and increase susceptibility to other stressors. Episodic exposures may cause gill injuries that increase susceptibility to pathogens. Sustained exposures may lead to injuries and deformities, increased parasitism and disease, and a general increase in sensitivity to other stressors. Lowered reproductive success may suggest sustained exposure. Further evidence may be found in evaluating the presence or absence of sensitive taxa or life stages, and changes in population age structure. In some cases loss of one species will influence community structure (e.g., because a critical food source is lost).

Toxic effects depend on numerous factors, including characteristics of the chemical; species, age and condition of the biota; characteristics of the surface water; exposure pathway; amount and mode of delivery; and environmental concentrations of the chemicals. Chemical toxicity can lead to biologically impaired plant, invertebrate and/or fish assemblages. When chemical toxicity is suspected, further investigation is needed to determine which chemical or mixture of chemicals may be the cause of impairment.