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The Great Lakes basin holds the world's largest supply of surface freshwater and is home to over 35 million people. Climate change is predicted to have major impacts on the natural resources of this system, which will exacerbate existing problems and create new challenges. This series of policy briefs explores several impacts of climate change and emphasizes the need for responsible stewardship of our vital water resources.

Climate Change Impacts on Toxic Substances in the Great Lakes Basin

The history of industrial development in the Great Lakes basin has produced a legacy of toxic contamination. For much of the 20th century, the Great Lakes basin stood at the forefront of North American manufacturing and agriculture, and toxic byproducts of that success, in the form of persistent toxic substances (PTSs), were released into the ecosystem in massive quantities for decades. These PTSs, including polychlorinated biphenyls (PCBs), methyl mercury, and dioxins, resist breakdown and linger in the environment for decades, even centuries, endangering both human health and the environment. Over 43 million cubic yards of PTS-contaminated sediment remain in U.S. "Areas of Concern," or federally designated contamination hotspots, despite major remediation efforts (GLITF 2010, Figure 1). While many PTS sources have been eliminated or reduced in recent decades and overall concentrations are decreasing, removing the remaining PTSs from the soils and waters of the Great Lakes basin remains an enormous environmental challenge.

Figure 1. Great Lakes Areas of Concern. Source: USEPA 2013.

New categories of potentially toxic contaminants are also emerging throughout the Great Lakes basin. Increased concentrations of nanoparticles, surfactants, personal care products, and pharmaceuticals are being discovered in basin waters with little understanding of how they will impact human health and the environment. While methods of detection are being developed and some action is being taken to reduce their presence, these emerging contaminants present a growing concern to the health of Great Lakes residents and wildlife.

Impacts of Climate Change

Climate change will likely confound attempts to remediate toxic substances in the Great Lakes basin. General circulation models predict that in the coming decades climate change may increase air and water temperatures, increase the frequency of extreme weather events, decrease lake levels, and decrease the duration and extent of winter ice cover in the Great Lakes region (Magnuson *et al.* 1997, Lofgren *et al.* 2002). Such changes could affect the exposure and susceptibility of organisms to contaminants, which in turn could have a cascading effect on human health and biological system structure. Baseline conditions for assessing the effects of contaminants on Great Lake ecosystems may continue to shift due to climate change, making management difficult (Schiedek *et al.* 2007). The following are descriptions of several ways climate change may impact toxic substances in the Great Lakes basin.

Increased Toxicity

Increasing air and water temperatures in the Great Lakes basin may modify the chemistry of a number of toxic contaminants, altering their toxicity to organisms (Schiedek *et al.* 2007). The consequences of this may have conflicting impacts on the ecosystem. Warmer temperatures could speed up the degradation of toxic chemicals, decreasing overall levels of particular toxins in the environment. In other cases, higher temperatures may foster the transformation of already toxic substances into more toxic forms or convert benign materials into toxic substances. Warmer temperatures will change the landscape of toxic substances in the basin in ways that are challenging to predict based on current information, making the development of effective future remediation plans difficult.

Increased Uptake by Aquatic Organisms

Increased water temperatures in the Great Lakes basin may also increase the rate of toxic substance uptake by aquatic organisms. Warm water has less capacity to dissolve oxygen than cold water, thus aquatic organisms, especially fish, must ventilate more warm water to meet their oxygen needs (Kennedy & Walsh 1997). Pumping greater volumes of water across their gills brings organisms into more contact with toxic substances, increasing the overall rate of uptake. Even if toxic substance concentrations in water do not increase as water temperatures increase, concentrations within organisms may still continue to rise, increasing the amount of toxic substances in food webs.

Remobilization

Increased frequency of extreme weather events in the Great Lakes basin may lead to the release of formerly immobilized toxic substances. Extreme rain events will increase occurrences of flash flooding, erosion, and channel scouring, all of which could mobilize toxic substances from soil and sediments that had previously remained undisturbed under less dynamic conditions. Decreased lake levels due to climate change may also necessitate the dredging of channels and harbors throughout the Great Lakes basin. Such operations run the risk of reintroducing and suspending once-dormant toxic substances in water bodies, especially in industrial ports where contaminants are often concentrated in sediments. Overall, climate change may lead to the increased mobilization of toxic substances in the waters of the Great Lakes basin, effectively altering the potential success of existing remediation efforts.

Altered Patterns of Transport

Increasing air and water temperatures are believed to be altering the speed (Desai *et al.* 2009) and direction (Waples & Klump 2002) of Great Lake currents, which in turn may be changing the way toxic substances are transported throughout the system. Such changes could introduce toxic substances to previously unexposed habitats and have detrimental impacts on wildlife and human health in those areas. Precisely predicting future patterns of toxic substance transport and their subsequent effects on Great Lakes habitats is difficult due to the many environmental factors governing lake currents. This poses a major challenge to managers and policymakers hoping to prepare for and prevent the spread of toxic substances throughout the system.

Increased Climate-Sensitivity of Aquatic Organisms

Toxic substances may decrease the capacity of aquatic organisms to adapt to climate change. The ability of organisms to adapt to new temperature regimes will be a strong determining factor in the success of future populations (Schiedek *et al.* 2007). Toxic substances may reduce an organism's ability to tolerate these changes, making entire populations more susceptible to climate change (Stahl *et al.* 2013). While recent warming has already exceeded the ability of some species to adapt, toxic substances may accelerate the rate at which Great Lakes food webs are reshaped by climate change.

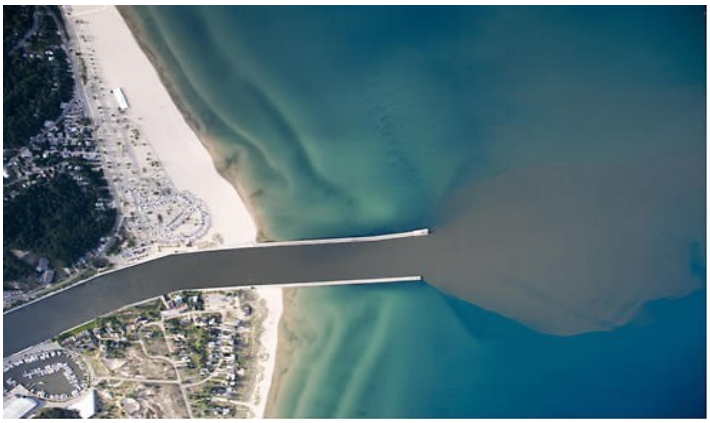

Figure 2. Sediment plume from the Grand River entering Lake Michigan. Schrauben 2010.

Conclusion

In the coming decades, climate change will shift the landscape of toxic substances in the Great Lakes, adding complexity to an existing problem. Climate change will alter the toxicity of toxic substances, increase the uptake of toxic substances by aquatic organisms, and remobilize toxic substances in water bodies. In addition, toxic substances will also decrease the capacity of aquatic organisms to adapt to climate change. Uncertainty about the extent of these effects will pose major challenges to scientists, managers, and policymakers in developing effective remediation solutions. Current understanding of toxic substance dynamics and baselines must evolve to incorporate the uncertainty and variability of climate change.

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