Pollutants

Introduction

As noted in Chapter 1 of the Statewide Surface Water Management Plan, there are 10 major identified stressors, with associated causes and sources, which result in the delivery of pollutants to surface waters (see below). These pollutants in-turn affect the biological, chemical and physical integrity of Vermont's surface waters, as well as public uses. This Appendix provides brief descriptions of the major pollutants that impact Vermont's surface waters, and identifies the stressors that result in their presence. Links for detailed information about each pollutant are also provided. More detailed descriptions of each Stressor, as well as Vermont's programs to address them, are found in Chapter 2 of this Plan.

Aquatic Invasive Species

Acidification

Channel Erosion

Toxic Substances

Encroachment

Flow Alteration

Thermal Stress

Nutrient Loading (non-erosion)

Land Erosion

Pathogens

Nitrogen and Phosphorus

Stressors resulting in nitrogen and phosphorus pollution to surface waters:




Pollutant description:

Phosphorus and nitrogen are naturally-occuirring nutrients necessary for the maintenance of all life on our planet. The productivity of an aquatic ecosystem, reflected in plant and fish biomass, is closely tied to phosphorus and nitrogen levels. This is because organisms require both phosphorus and nitrogen to synthesize carbohydrates, protein, and other essential “building blocks” for organisms. These nutrients are naturally limited in the aquatic environment and high levels cause aquatic plants, especially algae, to grow in much greater densities than the aquatic ecosystem should naturally support. Phosphorus is the limiting nutrient in freshwater systems, while nitrogen is more typically the limiting nutrient in marine systems. The term “limiting” here means that the nutrients are in sufficiently small supply that they regulate productivity of the food web in waters. A limiting nutrient is akin to baking soda in a cookie recipe – too much, and the cookies blow up while baking.

In excessive amounts, algae can impair recreational uses, aesthetic enjoyment, the taste of drinking water, and the biological community. In some cases, algal blooms – particularly cyanobacteria (or blue-green algae) can produce toxins that harm animals and people. Certain segments of Lake Champlain and a small number of other lakes in Vermont experience excessive algal blooms, including cyanobacteria, as a result of excess phosphorus pollution.

Excess plant growth can reduce the amount of space available to fish for habitat, and alter the fish species community balance. Excessive algal growth can cover lake bottom and vegetative habitat, and can result in reduced spawning success. Under certain conditions, when large amounts of aquatic vegetation dies and decomposes through the winter, extreme conditions of low dissolved oxygen or anoxia may occur which could impact localized fish populations. In this instance, the die off of plant and algae material uses up available oxygen in the water for decomposition, leaving none behind for fishes.

The sources from agricultural runoff include fertilizers, animal manure, milkhouse wastewater and crop residues. Urban sources include fertilizer, pet waste, erosion, atmospheric deposition, sludge, and septic systems. The imperviousness of an urban area also increases the quantity of polluted runoff that would otherwise be absorbed into the ground before reaching a waterway. Because phosphorus adheres to soil particles, erosion from either urban or agricultural activities is another source of phosphorus if the eroded sediments wash into waterways. In addition, the erosion of rivers going through the channel evolution process can release a significant amount of phosphorus.

Phosphorus is relatively insoluble and moves slowly through the environment. Nonpoint source runoff from agricultural and developed landscapes provides the most significant source of phosphorus to waterbodies. Developed land contributes the highest levels of phosphorus compared to other land uses, as indicated by a recent study of land use in the entire Lake Champlain watershed. The study estimated that 53% of phosphorus entering the lake came from urban lands that cover just 8% of the watershed. Agricultural land use is second in line as a source of phosphorus to the lake at 39%. (Troy et al. 2007).

Point sources generally contribute a small percentage of phosphorus to waterbodies. In Lake Champlain, point sources, mainly from waste water treatment plants, are responsible for less than 10% of the phosphorus load (Lake Champlain Basin Program 2008), while in Vermont, wastewater plants account for only three % of the total Vermont load.

Nitrogen in the environment comes from similar land-based sources as phosphorus, but a significant proportion also comes from atmospheric deposition. Direct discharges from treated wastewater and septic systems are also a source. Nitrogen takes several chemical forms such as ammonia or nitrate and nitrite, and it is highly soluble in water. It is easily washed from the soil by rain and carried to surface waters and groundwater. In northern fresh waters nitrogen is generally not a limiting nutrient but in high concentrations it can alter the make up of algal communities and can play a role in the development of blue green algae blooms. There is also a drinking water standard for nitrogen of 10 mg/l to protect against "blue baby syndrome;" a phenomenon where excessive nitrogen causes cyanosis in young children. Fortunately, blue baby syndrome is extremely rare in Vermont.

Links:

Vermont's Restoring Lake Champlain Website and Phosphorus Control Plan

Ecosystem Restoration Program

Lake Champlain Basin Program

Biochemical Oxygen Demand (BOD)/ Chemical Oxygen Demand (COD), as indicator of organic pollution

Stressors resulting in decreased dissolved oxygen in surface waters:

Pollutant description:

Natural organic detritus and organic waste from waste water treatment plants, failing septic systems, and agricultural and urban runoff, acts as a food source for water-borne bacteria. Bacteria decompose these organic materials using dissolved oxygen (DO), thus reducing the available DO for fish and other aquatic organisms.

Biochemical Oxygen Demand (BOD) is a measure of the oxygen used by microorganisms to decompose waste. The more organic waste present, the more bacteria there are decomposing this waste and using oxygen, so the BOD level will be high. The oxygen may diminish to levels that are lethal for fish and aquatic insects. As the river re-aerates due to atmospheric mixing and as algal photosynthesis adds oxygen to the water, the oxygen levels will slowly increase downstream. The drop and rise in DO levels downstream from a source of BOD is called the DO sag curve.

Nitrates and phosphates in a body of water can contribute to high BOD levels, by providing the nutrients for plants and algae to grow quickly. This contributes to organic waste in the water when the plants die, which are then decomposed by bacteria.

BOD is determined by measuring the loss of oxygen from the beginning to end of a 5 day test. The amount of oxygen consumed by these organisms in breaking down the waste is known as the biochemical oxygen demand or BOD.

Chemical Oxygen Demand (COD) measurements can be made in just a few hours instead of the 5 day BOD test to estimate BOD levels. COD does not differentiate between biologically available and inert organic matter, and it is a measure of the total quantity of oxygen required to oxidize all organic material into carbon dioxide and water. COD values are always higher than BOD values. Many wastewater treatment facilities use the faster COD test to estimate BOD levels. The USEPA requires wastewater treatment plants to bring BOD within limits before discharging treated wastewater, thus measuring BOD or COD in treated water is an important part of the monitoring process.

Links:

[USEPA Biochemical Oxygen Demand]

E. coli bacteria, as indicator of pathogens

Stressors resulting in bacterial pollution to surface waters:

Pollutant description:

Waterborne human pathogens are disease-causing organisms which include bacteria, viruses, and protozoa. The pathogens that are of concern in Vermont surface waters are those that come from fecal matter of humans and other warm-blooded animals. These pathogens may cause gastrointestinal problems and pose a more serious health risk to people who have weakened immune systems. Untreated surface waters containing fecal matter may pose a risk to human health when ingested through drinking water or inadvertently through contact recreation.

In surface waters, the most likely source of human fecal matter is sewage from a malfunctioning wastewater treatment plant or septic system. Sources of animal fecal matter are highest in urban and agricultural areas. Wildlife that resides in the water, such as beaver and waterfowl will also contribute pathogens.

It is very costly to measure and identify actual pathogens in waters. Therefore, managers rely on fecal indicator bacteria to suggest the potential presence of fecal matter. Two readily used indicators of fecal matter in freshwater are the enteric bacteria, *Escherichia coli* (*E. coli*), and *Enterococci spp*. These bacteria reside in the intestinal tract of warm-blooded animals and can survive for limited durations after they leave the host. Vermont relies on the *E. coli* indicator. Although most strains of *E. coli* are harmless to humans, epidemiological studies have identified a correlation between concentrations of E. coli in water and an increase in the risk of developing gastrointestinal. Vermont's water quality criterion for *E. coli* bacteria for Class B waters is 77 *E. coli*/100 ml in a single sample. The current criterion, which is based on an erroneous extrapolation of relationships published in EPA epidemiological studies from the early 1980s, yields a scientifically indefensible predicted risk level of less than 4 illnesses per 1000 swimmers. This is the most stringent standard in the United States. The EPA recommended criterion is 126 *E. coli* /100ml expressed as a geometric mean concentration, or 235 *E. coli* in a single sample of representive conditions.

When Vermont beaches are closed based on the occurrence of a single bacteria sample in excess of 77 but below 235, the public inaccurately but understandably concludes that the beach and surrounding waters must be polluted. The science suggests otherwise. Vermont studies show that the current conservative standard of protection is readily exceeded due to natural *E. coli* sources, even in the most pristine forested watersheds. These studies indicate that the Vermont criterion does not reflect the same risk level as the criteria recommended in the above mentioned epidemiological studies. DEC is presently working with the Department of Health and the Water Resources Panel to develop an *E. coli*-based water quality criterion that is reflective of real pollution impacts. In order to assess waters for support of contact recreation using *E. coli* monitoring data, DEC considers at least five reliable and quality assured sample results over a swimming season and gathered across a range of weather/flow conditions to be the minimum practical number of samples necessary.

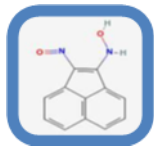
Links:

Citizens Guide to Monitoring Bacteria in Vermont

Department of Health – Swimming Water Quality

Metals

Stressors resulting in metals pollution to surface waters:



Pollutant description – heavy metals:

Heavy metals are a group of metallic elements with atomic weights greater than 40, and a specific gravity of greater than 4.0; they are a natural component of the Earth's crust.

In aquatic systems, the heavy metals of greatest concern are mercury, lead, arsenic, cadmium, selenium, copper, zinc, nickel, chromium, aluminum, antimony and silver. These metals are toxic to organisms above specific threshold concentrations but many of them, such as copper and zinc are also essential for metabolism at lower concentrations. Lead and cadmium are considered non-essential to biota and have no known biological function.

Toxic quantities of heavy metals can be present in industrial, municipal, and urban runoff, and by definition are harmful to humans and aquatic biota. Increased urbanization and industrialization have increased the levels of these trace elements especially in surface waters. Metal contamination in aquatic environments arises from industrial processes such as mining, smelting, finishing and plating of metals, paint and dye manufacturing and from pipes and tanks in domestic systems. Some metals may be discharged from malfunctioning treatment facilities, and others are also deposited atmospherically.

Aquatic organisms may be adversely affected by heavy metals in the environment. The toxicity of metals varies with aquatic species and environmental conditions; water quality (e.g. hardness, pH) greatly affects the chemical form in which the metals are measured. The toxicity is largely a function of the water chemistry and sediment composition in the surface water system. Metals may enter aquatic organisms through three main pathways: they can be absorbed through respiratory gills and diffuse into the blood stream; they can be adsorbed onto body surfaces and diffused into the blood stream; or, they can adhere to food and particulates and be ingested.

The ability of fish and invertebrates to accumulate metals is largely dependent on the physical and chemical characteristics of the metal. Heavy metals are dangerous because they tend to bioaccumulate. Mercury bioaccumulation poses the greatest concern to aquatic biota and humans.

Concentrations of heavy metals in the ambient environment have increased dramatically since the Industrial Revolution, although lead, copper, and even mercury has been in use since Roman times. Many heavy metals cause nervous-system damage, with resulting learning disorders in children. Exposure to metals such as lead and nickel can cause autoimmune reactions. Chromium occurs in a relatively harmless form and a much more dangerous, oxidized hexavalent form. Several studies have shown that chromium (VI) compounds can increase the risk of lung cancer and that ingesting large amounts of chromium (VI) can cause stomach upsets and ulcers, convulsions, kidney and liver damage, and even death, according to the Agency for Toxic Substances and Disease Registry. Many fish are very sensitive to heavy-metal pollution. For example, trout cannot live in waters that contain more than about five parts per billion of copper. Heavy-metal contamination is very widespread for certain compounds, especially lead and mercury.

Most heavy-metal contamination stems from high-temperature combustion sources, such as coal-fired power plants and solid-waste incinerators. Local metal sources may include metal-plating industries and other metal industries. The use of leaded gasoline has led to global lead pollution even in the most pristine environments, from arctic ice fields to alpine glaciers. The metal fluxes from point sources have been strictly regulated, and the introduction of unleaded gasoline has taken a major lead source away. Several sites with severe heavy-metal pollution have become Superfund sites, most of them still under study for decontamination. Site decontamination can be done with large-scale soil removal and metal stripping, or through more gradual methods, like phytoremediation. Nonetheless, even today metals are delivered from the atmosphere to the landscape. In the United States, drinking water is monitored for heavy metals to ensure that their concentration falls below the safe limit or maximum contaminant level (MCL) set by the Environmental Protection Agency. Many urban estuaries like Boston Harbor, San Francisco Bay, and Long Island Sound are severely contaminated with heavy metals. These sedimentary basins will remain polluted for decades, and a small percentage of the sediment-bound metals is released back into the water and occasionally transformed into more dangerous forms.

Pollutant description – iron and manganese in groundwater

Metals that are naturally occurring in soils can have a deleterious effect on surface waters and associated aquatic habitat when they are mobilized in groundwater and released to surface water. Effects most commonly observed are from iron and manganese as precipitates of these two minerals are deposited in streams and lakeshores.

The extent to which iron and manganese dissolve in groundwater depends on the amount of oxygen in the water and, to a lesser extent, upon its degree of acidity. Iron, for example, can occur in two forms: as ferrous iron (Fe^{2+}) and as ferric iron (Fe^{3+}). When levels of dissolved oxygen in groundwater are greater than 1- 2 mg/L, iron occurs as Fe^{3+}, while at lower dissolved oxygen levels, the iron occurs as Fe^{2+}. Although Fe^{2+} is very soluble, Fe^{3+} will not dissolve appreciably.

If the groundwater is oxygen poor, iron (and manganese) will dissolve more readily, particularly if the pH of the water is low. Dissolved oxygen content in groundwater is typically low and the iron dissolves as Fe^{2+}. Under these conditions, the dissolved iron is often accompanied by dissolved manganese. When this water breaks out to surface waters, the dissolved iron reacts with the oxygen in the water, changes to Fe^{3+} (i.e., is oxidized) and forms rust-colored iron minerals. Dissolved manganese may form blackish particulates in the water and cause similar colored stains on rocks.

The resulting water quality impacts represent themselves more as a loss of habitat for aquatic biota as opposed to toxic levels of metals. Precipitates can essentially coat the streambed and significantly impact macroinvertebrate habitat. In addition to the precipitates, iron bacteria can “feed” on the iron and grow into dense slimy mats further inhibiting macroinvertebrates.

Areas with disturbed soils or areas where iron rich soil used as fill is deposited at or below the groundwater table facilitate the exposure of groundwater to these minerals. In Vermont, many instances of water quality impairment exist adjacent to these disturbed areas represented by placement of fill for roads, structures, culverts or landfills.

Pollutant description - mercury

Mercury contamination is ubiquitous in Vermont's still waters. Mercury is a naturally occurring metal used in a wide variety of applications ranging from the production of household bleach to the mining of gold. Like other heavy metals, Mercury can be released into the environment directly to water via waste systems; however, unlike other heavy metals, it is more commonly emitted directly to the atmosphere. Over 90% of mercury contamination in Vermont is from out-of-State emission sources. The combustion of coal for energy production and incineration of municipal and medical wastes produces the majority of mercury deposited onto the watersheds of the northeastern US and eastern Canada. Once on the ground, mercury migrates through watersheds, arriving eventually into surface waters. Some mercury also enters the aquatic environment from direct wastewater discharges. Once in the environment, natural ecological processes will convert a small proportion of the mercury to the extremely toxic and readily bioaccumulated methyl-mercury.

Through the processes of biomagnification, the toxic methyl-form of mercury is passed up food chains, increasing to levels in fishes that pose a significant threat to those organisms at the top of the aquatic food web. Organisms that are at risk of methyl-mercury exposure include top-level carnivorous fish such as walleye, lake trout, and smallmouth bass, as well as fish eating birds such as eagles and loons. Top-level carnivorous fish are often the species most targeted by anglers. For example a larger walleye (>25 inches) caught by anglers in Lake Champlain may be 10 to 15 years old. The long life span allows for many years of accumulation of mercury within the fish’s body. As a result of this, humans who consume large quantities of top-level fish are also at risk.

The Vermont Department of Health has general advisories for women of childbearing age and children younger than six to limit consumption of fish. In addition, the department also identifies specific waterbodies where eating resident fish carries a greater level of risk because of elevated mercury concentrations in fish tissue. In Lake Champlain for example, children and women of childbearing age are advised not to eat any walleye or meals of lake trout 25 inches or greater. The primary health effect of methylmercury is impaired neurological development. Symptoms of methylmercury poisoning may include; impairment of the peripheral vision; disturbances in sensations; lack of coordination of movements; impairment of speech, hearing, walking; and muscle weakness.

Links:

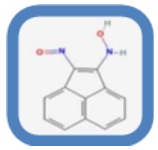
Vermont Department of Environmental Conservation – MERCVT

Hubbard Brook Research Foundation

USEPA

Organic contaminants (PCB's and PBDE's)

Stressors resulting in organic contaminant pollution to surface waters:



Pollutant description – PCBs

In the past, poly-chlorinated biphenyls or PCBs were used for a variety of chemical processes including the production of plastics like PVC piping. PCBs were also a component in the dielectric fluid used in transformers, capacitors and other heat transfer systems. The manufacture of PCBs was stopped in the US in 1977. Any remaining PCB transformers in Burlington were decommissioned by the late 1980s. Presently, stores of PCBs exist in landfills nationwide.

PCBs can escape into the environment either by waste incineration or via landfill leachate. Past manufacturing practices also dumped PCBs into waterways. PCBs do not readily breakdown in the environment and like mercury, PCBs also bioaccumulate, increasing in concentration with each step up the food chain. To date, fish tissue testing has uncovered PCB contamination only in the tissues of large lake trout from Lake Champlain and in smallmouth bass, white suckers and yellow perch in the Connecticut River. PCBs are known by USEPA to be carcinogenic to animals, and are considered likely human carcinogens as well. The Vermont Department of Health recommends that people limit their intake of lake trout based on PCB concentrations. Based on a considerable remediation initiative undertaken by the New York State Department of Environmental Conservation, PCB concentrations in Lake Champlain lake trout are expected to decline in the coming years.

Links:

USEPA

Pollutant description - PBDEs

Poly-brominated diphenyl-ethers (PBDEs) are a flame retardant used in a variety of household products including fabrics, furniture and electronics and are ubiquitously found in the environment and fish tissues. Significant public health concerns exist for PBDEs in other states and Europe, where studies have documented health impacts that are similar in nature to those attributed to PCBs. In Europe and elsewhere, studies have also shown that PBDEs bioaccumulate in fish, and have similar ecotoxicological effects to PCB's. While the scientific literature indicates that these compounds are ubiquitous in the environment, the occurrence of PDBEs has to date been completely uncharacterized in Vermont. An assessment of the presence of PBDEs in specific lakes - perhaps Lake Champlain is a first step in characterizing their ubiquity in Vermont, and is warranted. Certain classes of PBDEs have been banned from use in the European Union, Maine and

Washington State, and a similar ban has been considered by the Vermont General Assembly.

Links:

USEPA

Invasive Species as Pollutants

Stressors resulting in invasive species pollution to surface waters:

Pollutant description –invasive species in Vermont

Invasive species are aquatic and terrestrial organisms introduced into new habitats that produce harmful impacts on natural resources. In nuisance levels, aquatic invasive species can seriously hinder recreational use of a waterbody, out-compete native plants and animals, and otherwise alter the natural environment.

Aquatic invasive plants include Eurasian watermilfoil (*Myriophyllum spicatum* L.), water chestnut (*Trapa natans* L.), European frog-bit (*Hydrocharis morsus-ranae*), European water nymph (*Najas minor*), curly leaf pondweed (*Potamogeton crispus)*, purple loosestrife (*Lythrum salicaria*), and the algae didymo or rock snot, *Didymosphena.* Aquatic invasive animals include zebra and quagga mussels (*Dreissena spp.)*, rusty crayfish (*Orconectes rusticus*), white perch (*Morone americana*), alewife (*Alosa pseudoharengus*) and Tench (*Tinca tinca).* Riparian invasives include common reed (*Phragmites australis*), yellow flag iris (*Iris pseudacorus*), and Japanese knotweed (*Polygonum cuspidatum*). In addition, a number of other problematic exotic species are at the state's doorstep. Aquatic plant species include hydrilla, *Hydrilla verticillata,*). Animals include round nose goby (*Apollonia Neogobius melanostomus)* and tubenose goby (*Proterorhinus semilunaris),* and the spiny waterflea .

The establishment of invasive species can result in a range of impacts. For example, alewives have recently become established in Lake Champlain. It may be years before their impacts are fully understood, however, in other systems alewives are known to impact native fish communities in a variety of ways. Alewives can out-compete other native fish species for food and cause shifts in zooplankton species composition and size structure, which can impact water quality. They are known to feed on the eggs and larvae of native fish species, they undergo massive fluctuations in abundance, and they have recently been identified as the cause of early mortality syndrome in salmon and trout fry.

Pollutant description – Eurasian watermilfoil and water chestnut

The presence of Eurasian watermilfoil often brings a change in the natural lake environment. Over time, it may out-compete or eliminate the more beneficial native aquatic plants, severely reducing natural plant diversity within a lake. Since its growth is typically dense, milfoil weed beds are poor spawning areas for fish and may lead to populations of stunted fish. Although many aquatic plants serve as valuable food sources for wildlife, waterfowl, fish, and insects, Eurasian watermilfoil is rarely used for food. Commonly found in shallow bays and in bands along the shoreline, dense surface mats of milfoil can also make fishing, boating and swimming virtually impossible.

Links:

Watershed Management Division AIS Website

Pollutant description – fish pathogenic diseases

In addition to the recognized invasive species, many fisheries biologists now consider newly introduced fish diseases as invasive species. These diseases are often viral and spread through similarly to other invasive species. For example, Viral Hemorrhagic Septicemia has been found in the Great Lakes and some inland waters of New York State. Viral hemorrhagic Septicemia (VHS) is a deadly fish virus that is considered to be one of the most serious diseases of trout and salmon in freshwater environments in Europe. The new strain of VHS now found in the Great Lakes region of North America has been found to infect over 30 species of freshwater fish. Outbreaks of the VHS virus can result in severe fish mortality events in commercial aquaculture practices as well as in wild populations, and can often have serious socio-economic consequences.

Links:

Department of Fish and Wildlife

Chlorides

Stressors resulting in chloride pollution to surface waters:

Pollutant description - chlorides

Chloride is a naturally occurring mineral used in a variety of materials and foods. Natural chloride deposits are not common in Vermont, and chloride concentrations above background are assumed to be associated with human activities. Chloride sources can include industrial effluents, landfill leachate, municipal wastewater, agricultural waste, and septic system effluents. Increasingly, winter road, parking lot and sidewalk maintenance practices are recognized as contributing large amounts of chloride to the environment each year.

There is little concern about human health as a result of elevated chloride in the aquatic environment though the Vermont Department of Health does consider chloride above 250 mg/L to be a drinking water contaminant that impacts taste. EPA's Ambient Aquatic Life Criteria do address chloride. At concentrations exceeding 250 mg/L, "chronic" effects to aquatic biota (e.g. poor reproduction, poor health) are expected, with "acute" effects (severe illness or death) likely at concentrations exceeding 850 mg/L. Tolerance to elevated chloride varies widely among aquatic biota. Some organisms, including many fish, are not affected by chloride at concentrations exceeding 10,000 mg/L. Concentrations above 250 mg/L in lakes have been observed to impede natural mixing and stratification processes due to the formation of a strong density gradient. In time, poor mixing results affects water quality and oxygen availability within the waterbody.

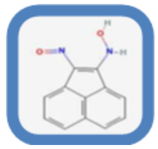
Links:

United States Geological Survey Report on Chloride Contamination

An Assessment of Selected Urban Stream in Chittenden County Vermont

Contaminants of Emerging Concern, including Pharmaceuticals and Personal Care Products

Stressors resulting in organic contaminant pollution to surface waters:



Pollutant description

Contaminants of Emerging Concern can be defined as newly identified manmade compounds that result from human usage (e.g. pharmaceuticals, personal care products, homecare products, nano-technology products). Pharmaceuticals and Personal Care Products as Pollutants (PPCPs) refers, in general, to any product used by individuals for personal health or cosmetic reasons. PPCPs comprise a diverse collection of thousands of chemical substances, including prescription and over-the-counter therapeutic drugs, veterinary drugs, fragrances, lotions, and cosmetics. This topic is becoming increasingly important as studies worldwide highlight the ubiquity of these substances in certain waterbody types.

These compounds enter aquatic environments through a variety of sources, including, but not limited to, wastewater effluent, treated sewage sludge, landfill leachate, industrial effluent, combined sewer overflows, aquaculture, and animal feed lots. Pharmaceuticals and personal care product constituents are being detected in groundwater, streams, rivers, lakes, reservoirs, and drinking water supplies of the Northeast at very low concentrations, and have commonly been detected in combinations of chemicals. Currently there are no US EPA/state ambient water quality criteria, water quality standards, or drinking water standards for most of these individual chemicals.

The effects of PPCPs are different from conventional pollutants. Drugs are purposefully designed to interact with cellular receptors at low concentrations and to elicit specific biological effects. Unintended adverse effects can also occur from interaction with non-target receptors. Environmental toxicology focuses on acute effects of exposure rather than chronic effects. At this time, many unknowns remain regarding the potential for adverse effects on ecological receptors and humans from exposure to PPCPs in the environment. Research on human health effects should recognize the effects on sensitive populations such as children, pregnant women, and those with compromised immune systems.

Effects on aquatic life are a major concern. Exposure risks for aquatic organisms may be much larger than those for humans. Aquatic organisms have: continual exposures, embryonic exposures, multi-generational exposures, exposure to higher concentrations of PPCPs in untreated water and possible low dose effects. The presence of these chemicals in water bodies have been linked to impacts on aquatic species, including changes in fish sex ratios, development of female fish characteristics in male fish, changes in nesting behavior by fish, and adverse effects on invertebrates.

Links:

New England Interstate Water Pollution Control Commission

USEPA

US Geological Survey

Acid Deposition (a.k.a., Acid Rain)

Stressors resulting in acid rain pollution to surface waters:

Pollutant description – acid rain

Acid deposition is caused by the combustion of fossil fuels (coal, oil and gas). The primary pollutants of concern are sulfur and nitrogen oxides. The sulfur and nitrogen come from electrical power plants, industrial sources and automobiles. These pollutants get in the atmosphere and mix with rain, snow and fog to create “acid rain”. Emissions from primarily eight mid-western states account for almost half of Vermont’s sulfur pollution during the summer months, when air pollution is the worst. The pollution is visible as a smoggy frequently brownish layer in the atmosphere that can best be observed at high elevation when atop the Green Mountains.

Acid rain is formed when precipitation absorbs these pollutants from the atmosphere. The acidity of precipitation and waterbodies is measured by the **pH scale.** This scale ranges from 0-14 with 0 being the most acidic and 14 being the most alkaline. Normal rain and snow is slightly acidic and has a pH of 5.6. However, the rain and snow that falls on Vermont is much more acidic than what is attributable to natural causes. In Vermont, the average precipitation is now 4.3 – 4.5 with extremes ranging from 2.8 to 7.4. The pH scale is logarithmic which means that each numerical change in pH is a ten-fold change in acidity. So, rainfall with a pH of 4.6 is 10 times more acidic than normal rainfall of 5.6 and a pH of 3.6 is 100 times more acidic.

Vermont has been monitoring the chemical and biological effects of acid rain on lakes since 1980. We currently have 36 lakes listed as impaired by atmospheric deposition and monitor 12 acid lakes seasonally through the Vermont Long-Term Monitoring Project (VLTM). This project has revealed that many lakes have seen reductions in acid concentration as a result of the implementation of acid rain controls in the 1990 Clean Air Act. These controls have reduced sulfur deposition by greater than 50% and further reductions in both sulfur and nitrogen oxides are anticipated. However, these lakes have also seen reductions in their ability to buffer incoming acidic pollutants with declines in both calcium and magnesium. This means that even though our lakes are receiving less atmospheric pollutants, the loss of buffering has yielded little overall improvement in the lakes pH. As a result, we have seen no improvement in the biological condition of these lakes.

What are the consequences of acid rain to our lakes and sensitive streams?

Headwaters are susceptible to damaging pH decreases during spring runoff and periods of high flow. High elevation waterbodies are often naturally low in calcareous bedrock with limited ability to neutralize incoming acids.

Acid rain will dissolve and leach out aluminum and other metals that naturally occur in Vermont soils. These metals are then swept into lakes and rivers during precipitation events. If the waterbody has a pH lower than 5.6, the incoming aluminum can be toxic to fish and other aquatic life.

As acidification progresses, lake water clarity may improve for one of two reasons. Either, 1) the aquatic plankton that give water a typical green or aqua color are lost; or 2) naturally dark, tannic-colored lakes may, in time, become less stained as the strong mineral acids like sulfuric and nitric acid, replace the naturally occurring organic tannins. It is expected that as the acid levels improve because of the Clean Air Act, the color of acid lakes should be less transparent with the return of plankton and organic acids replacing the mineral acids.

Links:

Watershed Management Division

Sediment

Stressors resulting in sediment pollution to surface waters:

Pollutant description - sediment

Sediment is fine particulate matter originating from soils. The accumulation of sediment on the bottom of a waterbody results in sedimentation, while the suspension of sediment in the water column causes turbidity. Turbidity degrades habitat for aquatic biota, reducing visibility for predators as one example.

Sedimentation smothers necessary rocky or riffle habitat for the invertebrates that provide an important source of food for fish. Some smaller species of fish also rely on the crevice space between rocks as a primary habitat. Sedimentation can cover spawning substrate and suffocate fish eggs by preventing water circulation and oxygenation. Additionally, the accumulation of sediment over spawning gravel may even deter fish from spawning at all. Fish species like walleye, trout and salmon rely on clean gravel for spawning.

One source of sediment is runoff of bare soils from areas such as constructions sites, gravel roads and plowed fields. Runoff from storm events and snowmelt, especially where concentrated in urban areas, can easily pick up soil particles and wash it into waterbodies. Stream channel instability and the lack of vegetated riparian buffers result in stream channel erosion. Vegetative buffers help to stabilize stream banks and retain nonpoint runoff thereby reducing the amount of sediment input. Vegetated riparian buffers also benefit the aquatic biota by keeping water temperatures lower due to increased shading and, like lakes, provide food in the form of terrestrial insects. For the most part, erosion is a result of cumulative human disturbances, including flood plain encroachments, removal of riparian vegetation, channelization, wetland drainage, urbanization and in-stream gravel mining.

Links:

Watershed Management Division – River Management Program

Vermont Clean and Clear Action Plan

Thermal Modification

Stressors resulting in thermal pollution to surface waters:

Pollutant description – temperature

Thermal modifications result in water temperatures that are too high or too low to fully support appropriate aquatic life. Thermal modification affects over 500 river miles in Vermont. High temperatures have a negative impact on coldwater fisheries. Removal of trees and shrubs and the cooling shade they provide along riverbanks results in higher water temperatures. Dams and their resulting impoundments expose large surface areas of water to sunlight causing higher downstream water temperatures.

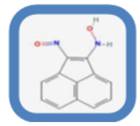
Temperature is a primary regulator of biological activities and an increase in the temperature regime of small streams may have an adverse impact on fish populations by increasing their rate of metabolism while, at the same time, reducing the amount of dissolved oxygen in the water. Elevated water temperatures may reduce the vigor of cold-water fish species and make them more susceptible to disease or parasites. Small headwater streams are most likely to be affected by the clearing of streamside vegetation.

Temperature is one of the most important factors in limiting trout abundance. Temperatures of 77 ºF can be lethal to trout. Directly related to temperature is dissolved oxygen. As temperature increases, dissolved oxygen levels decrease. Because trout require high oxygen levels, they require low temperatures. Once temperatures have reached the low 70s ºF, the amount of dissolved oxygen is low enough to drive trout out of marginal waters and into coldwater refuges, such as deep holes or groundwater seeps. They may stay in these protected enclaves as long as water temperatures remain high. Over prolonged periods of high temperatures, fish kills can occur (VFWD 1993).

Cyanobacteria toxins

Stressors resulting in cyanobacteria toxins in surface waters:



Pollutant description

Cyanobacteria, or so-called “blue-green algae” are a common and natural part of the algae community and are expected to be present in most Vermont waters. Under the right conditions, typically too much phosphorus, cyanobacteria can become very abundant, forming unsightly surface scums and discoloring the water. These nuisance conditions are reported from lakes around the state each year.

In some cases, cyanobacteria also produce toxins that affect humans, pets, livestock and wildlife. Some of these toxins have been documented routinely on Lake Champlain and dog deaths on the lake have been linked to them in the past. Anatoxin and microcystin are two cyanotoxins that are most commonly detected in areas of dense cyanobacteria blooms. Around the world, cyanobacteria toxins have been linked to human illness and, very rarely, death. People can be exposed to these toxins through recreational activities on affected lakes or through drinking water sources. In Vermont, there have been no known instances of human illness due to cyanobacteria toxins.

How does Vermont respond to cyanobacteria?

Excessive cyanobacteria are of concern because they lead to poor water quality and an increased risk of exposure to cyanobacteria toxins. Management practices that control nutrient inputs will also result in smaller populations of cyanobacteria. The Agency of Natural Resources and the Agency of Agriculture, Farm and Markets are focused on nutrient reduction from the landscape. The Agency of Natural Resources (Water Supply Division) and the Agency of Human Services (Department of Health) work with water suppliers, public beaches and towns around the state to monitor and respond to cyanobacteria in drinking water supplies and recreational settings. There are currently no federal or state regulations or guidelines for cyanobacteria toxins.

Links:

Vermont Department of Health

Watershed Management Division

Pesticides

Stressors resulting in pesticide releases to surface waters:

Pollutant description

Pesticides are used in Vermont for a wide variety of pest control activities. The most widespread use of pesticides with the opportunity to widely affect surface waters is the agricultural use of herbicides in the growth of corn to feed dairy cattle. Other major uses of pesticides in Vermont include: golf course vegetation management; utility right of way vegetation control; forestry; aquatic nuisance vegetation control; and, lawncare activities.

Pesticide manufacturers have been gradually replacing older pesticides, such as the corn herbicide Atrazine, with pesticides which are designed to be more target specific and breakdown in the environment more easily. Ideally, pesticides are highly specific to the target pest, and then breakdown very quickly such that adverse side effects are minimized. In practice pesticides, do not kill just the target pest, do not stay solely where they are applied, and do not disappear as soon as they have done their intended job. Thus, the challenges are to minimize unnecessary pesticide use, migration of pesticides away from the point of use, and ultimately toxicity to non-target organisms.

The difficulty with management of pesticide impacts to surface waters, as compared with the other types of toxics and most "pollutants" is that these compounds are intentionally being added to the environment. All pesticide use in the US and Vermont is regulated to some degree, with those compounds applied most heavily, or those viewed as most hazardous being the ones most tightly regulated. Household pesticide use is one area where regulatory mechanisms are less stringent.

With the exception of pesticides used for aquatic nuisance control, the source of all pesticides in the aquatic environment is migration of pesticides away from the point of use and into the waters of Vermont. Many pesticides are at least moderately water soluble and therefore are capable of washing off target with rain water runoff, while other pesticides will bind with soil and other particulates, and be transported off-site when erosion occurs. Use of water soluble pesticides can cause more widespread contamination of Vermont's aquatic environment because they travel with the water, but these compounds tend to dilute relatively rapidly. Non-water soluble pesticides remain associated with sediment particles and can conceivably accumulate to high levels.

Links:

Vermont Agency of Agriculture, Food, and Markets