

CHAPTER 3 – WATER QUALITY STRESSORS

Human activities can negatively impact surface water quality, even when the activity is far removed from the waterbody. The many types of pollution generated by human activities may seem insignificant when viewed separately, but when taken as a whole, can be very stressful to aquatic ecosystems. Water quality stressors are identified when impacts have been noted to biological (benthic and fish) communities and/or water quality standards have been violated. Stressors apply to one or more use support categories (i.e., aquatic life, recreation, shellfish harvesting, fish consumption, water supply) and may be identified for impaired as well as supporting waters. This chapter provides an overview of how stressors are identified in a watershed, defines commonly identified stressors and reviews the water quality standards that can be listed as potential water quality stressors.

3.1 IDENTIFICATION OF STRESSORS

Identifying stressors is challenging because direct measurements of the stressor may be difficult or prohibitively expensive. DWQ staff use field observations from sample sites, special studies and data collected from ambient monitoring stations to identify potential water quality stressors. Information from other natural resource agencies and concerned citizens are also used. It is important to identify stressors and potential sources of those stressors so that water quality programs can target resources to address water quality problems.

Cumulative Effects

While any one activity may not have a dramatic effect on water quality, the cumulative effect of land use activities in a watershed can have a severe and long-lasting impact.

Most stressors to the biological community are complex groupings of many different stressors that individually may not degrade water quality or aquatic habitat but together can severely impact aquatic life. Sources of stressors (Chapter 4) are most often associated with land use in a watershed as well as the quality and quantity of any treated wastewater that may be entering a stream. During naturally severe conditions, such as droughts or floods, any individual stressor or group of stressors may have more severe impacts to aquatic life than during normal climatic conditions.

3.2 HABITAT DEGRADATION (AQUATIC LIFE)

Good instream habitat is necessary for aquatic life to survive and reproduce. A notable reduction in habitat diversity or a negative change in habitat often leads to significant changes to an aquatic ecosystem. The term habitat degradation includes sedimentation, streambank erosion, channelization, lack of riparian vegetation, loss of pools and/or riffles, loss of organic (woody and leaf) habitat and streambed scour. The stressors to benthic and fish communities can be caused by many different land use activities and less often by discharges of treated wastewater. Many of the stressors discussed below are either directly caused by, or are a symptom of, altered watershed hydrology. The altered hydrology increases both sources of stressors and delivery of the stressors to the receiving waters.

Streams that typically show signs of habitat degradation are in watersheds that have a large amount of land-disturbing activities (i.e., construction, mining, timber harvest, agricultural land use). Habitat degradation is also evident in watersheds that have large impervious surface areas. A watershed in which the stream has been channelized, or most of the riparian vegetation has been removed, will also exhibit habitat degradation, and streams that receive a discharge quantity that is much greater than the natural flow in the stream may also show signs of degradation.

Quantifying the amount of habitat degradation is very difficult in most cases because extensive technical and monetary resources are needed. DWQ and other agencies (i.e., SWCD, NRCS, town and county governments) are starting to address this issue; however, local efforts are needed to prevent further instream degradation. Local efforts are also needed to restore streams that have been impaired by activities that cause habitat degradation. As point source dischargers become less common sources of water quality impairment, nonpoint sources that pollute water and cause habitat degradation must be addressed if we are to improve water quality.

Examples of Best Management Practices (BMPs)

Agriculture

- No till or conservation tillage practices
- Strip cropping and contour farming
- Leaving natural buffer areas around small streams and rivers

Construction

- Using phased grading/seeding plans
- Limiting time of exposure
- Planting temporary ground cover
- Using sediment basins and traps

Forestry

- Controlling runoff from logging roads
- Replanting vegetation on disturbed areas
- Leaving natural buffer areas around small streams and rivers

3.2.1 SEDIMENTATION

Sedimentation is a natural process that is important to the maintenance of diverse aquatic habitats. It is the process by which soil particles washed off of the landscape and streambanks are deposited in the stream channel. Streams naturally tend toward a state of equilibrium between erosion and deposition of sediments. As streams meander through their floodplains, the outside of the stream cuts into the streambanks eroding it away, while the inside of the stream deposits sediments to create sand bars further downstream. The natural process of erosion and deposition can be disrupted by human activities such as dams, dredging, agriculture, urban development or logging. Construction projects or logging in the upper reaches of a watershed may worsen erosion or sediment deposition on property further downstream. If streams are straightened or moved without taking into consideration water's natural energy, erosion and sediment deposition rates can increase. This can result in the loss of valuable agricultural land, damage to roads or structures, destruction of productive wetlands and the addition of sediments and nutrients to waterways that can degrade surface water quality and biodiversity.

Overloading of sediment in the form of sand, silt and clay particles fills pools and covers or embeds riffles that are vital to benthic and fish communities. Suspended sediment can decrease primary productivity (i.e., photosynthesis) by shading sunlight from aquatic plants, thereby affecting the overall productivity of a stream system. Suspended sediment also has several effects on various fish species including avoidance and redistribution, reduced feeding efficiency which leads to reduced growth by some species, respiratory impairment, reduced tolerance to

diseases and toxicants and increased physiological stress (Roell, 1999). Sediment filling rivers and streams decreases their storage volume and increases the frequency of floods (NCDLR, 1998). Suspended sediment also increases the cost of treating municipal drinking water.

Streambank erosion and land-disturbing activities are sources of sedimentation. Streambank erosion is often caused by high stormwater flows immediately following rainfall events or snowmelts. Watersheds with large amounts of impervious surface transport water to streams more rapidly and at higher volumes than in watersheds with more vegetative cover. In many urban areas, stormwater is delivered directly to the stream by a stormwater sewer system. This high volume and concentrated flow of water after rain events undercuts streambanks often causing streambanks to collapse. This leads to large amounts of sediment being deposited into the stream. Many urban streams are adversely impacted by sediment overloading from the watershed as well as from the streambanks. Minimizing impervious surface area and reducing the amount of stormwater outlets releasing stormwater directly to the stream can often prevent substantial amounts of erosion.

Land-disturbing activities such as the construction of roads and buildings, crop production, livestock grazing and timber harvesting can accelerate erosion rates by causing more soil than usual to be detached and moved by water. In most land-disturbing activities, sedimentation can be controlled through the use of appropriate best management practices (BMPs). BMPs that minimize the amount of acreage and length of time that the soil is exposed during land-disturbing activities can greatly reduce the amount of soil erosion. More information on land-disturbing activities and BMPs can be found in Chapter 8.

Livestock grazing with unlimited access to the stream channel and banks can also cause severe streambank erosion resulting in sedimentation and degraded water quality. Although they often make up a small percentage of grazing areas by surface area, riparian zones (vegetated stream corridors) are particularly attractive to cattle that prefer the cooler environment and lush vegetation found beside rivers and streams. This concentration of livestock can result in increased sedimentation of streams due to "hoof shear", trampling of bank vegetation and entrenchment by the destabilized stream. Despite livestock's preference for frequent water access, farm veterinarians have reported that cows are healthier when stream access is limited (EPA, 1999). More information on livestock exclusion and other agricultural practices can be found in Chapter 6.

3.2.2 LOSS OF RIPARIAN VEGETATION

Removing trees, shrubs and other vegetation to plant grass or place rock (also known as riprap) along a streambank often degrades water quality. Removing riparian vegetation eliminates habitat for aquatic organisms, which are a food source for many fish species. Rocks lining a streambank absorb the sun's heat, which then raises the water's temperature. Many fish require cooler water temperatures as well as the higher levels of dissolved oxygen that cool water provides. Trees, shrubs and other native vegetation cool the water by shading it. Straightening a stream, clearing streambank vegetation and lining the streambanks with grass or rock severely impact the habitat that aquatic insects and fish need to survive. The loss of riparian vegetation is

most commonly associated with land-disturbing activities including urban development, forestry, agriculture and pasture grazing.

Establishing, conserving and managing streamside vegetation (riparian buffer) is one of the most economical and efficient BMPs. Forested buffers, in particular, provide a variety of benefits including filtering runoff and taking up nutrients, moderating water temperature, preventing erosion and loss of land, providing flood control, moderating streamflow and providing food and habitat for both aquatic and terrestrial wildlife (NCDENR-DWQ, 2004). DWQ developed a brochure explaining the benefits of riparian vegetation along the stream corridor. A free copy of the brochure *Buffers for Clean Water* can be found on the DWQ Web site (www.ncwaterquality.org/Wateryouknow.htm).

3.2.3 LOSS OF INSTREAM ORGANIC MICROHABITATS

Organic microhabitat (i.e., leafpacks, sticks and large wood) and edge habitat (i.e., root banks and undercut banks) play very important roles in a stream ecosystem. Organic matter in the form of leaves, sticks and other materials serve as the base of the food web for small streams. Additionally, these microhabitats serve as special niches for different species of aquatic insects, providing food and/or habitat. For example, many stoneflies are found almost exclusively in leafpacks and on small sticks. Some beetle species prefer edge habitat, such as undercut banks. If these microhabitat types are not present, there is no place for these specialized macroinvertebrates to live and feed. The absence of these microhabitats in some streams is directly related to the absence of riparian vegetation. Organic microhabitats are critical to headwater streams, the health of which is linked to the health of the entire downstream watershed.

3.2.4 CHANNELIZATION

Channelization refers to the physical alteration of naturally occurring streams and rivers. Typical modifications are described in the text box. Channelization can control floods, reduce erosion, increase usable land area, improve transportation and drain an area more efficiently; however, downstream streambanks are unstable and the damage caused by flooding often increases substantially (McGarvey, 1996).

Direct or immediate biological effects of channelization include injury and mortality of aquatic insects, fish, shellfish/mussels and other wildlife populations as well as habitat loss. Indirect biological effects include changes in the aquatic insect, fish and wildlife community structures, favoring species that are more tolerant of or better adapted to the altered environment (McGarvey, 1996).

Restoration or recovery of channelized streams may occur through processes, both natural and artificially induced. In general, streams that have not been excessively stressed by the

Typical Channel Modifications

- ❑ Removal of any obstructions, natural or artificial, that inhibit a stream's capacity to convey water (clearing and snagging).
- ❑ Widening, deepening or straightening of the channel to maximize conveyance of water.
- ❑ Lining the bed or banks with rock or other resistant materials.

channelization process can be expected to return to their original forms. However, streams that have been extensively altered may establish a new, artificial equilibrium (especially when the channelized streambed has been hardened). In such cases, the stream may enter a vicious cycle of erosion and continuous entrenchment. Once the benefits of a channelized stream are outweighed by the costs, both in money and environmental integrity, channel restoration efforts are likely to be taken (McGarvey, 1996).

Channelization of streams within the continental United States is extensive and promises to become even more so as urban development continues. Overall estimates of lost or altered riparian habitats within the United States are as high as 70 percent. Unfortunately, the dynamic nature of stream ecosystems makes it difficult (if not impossible) to quantitatively predict the effects of channelization (McGarvey, 1996).

3.2.5 IMPOUNDMENTS

The consensus among river ecologists is that impoundments, or dams, are the single greatest cause of the decline of river ecosystems (World Commission on Dams, 2000). By design, dams alter the natural flow regime, and with it virtually every aspect of a river ecosystem, including water quality, sediment transport and deposition, fish migration and reproduction, riparian and floodplain habitat and all of organisms that rely on those habitats (Raphals, 2001). Dams also require ongoing maintenance. For example, reservoirs in sediment-laden streams lose storage capacity as silt accumulates in the reservoir.

The location of dams can lead to the loss of habitat resulting from the inundation of wetlands, riparian areas and farmlands upstream of the impounded waterway. Dams trap sediment and other pollutants and change the water quality. Water quality changes include: reduced sediment transport, decreased dissolved oxygen, altered temperature regimes and increased levels of some pollutants, such as hydrogen sulfide, nutrients and manganese.

Once streams are impounded, water demand dictates the artificial regulation and control of streamflow. The new flow rates and volume often do not reproduce natural conditions. Water released from impoundments often has lower levels of dissolved oxygen, high turbidity and/or different temperatures that can impact downstream aquatic organisms. Not only can reservoir water temperatures and oxygen content differ significantly from expected seasonal temperatures, but critical minimum flows needed for riparian areas may not be maintained. Decreased flow in coastal areas can also increase saltwater intrusion and impact estuary productivity (EPA, 1999). These effects are the result of both large and small impoundments.

In 2003, the Tennessee Department of Environment and Conservation (TDEC), Division of Water Pollution Control was awarded a grant to perform a probabilistic monitoring study of 75 streams below small impoundments. The study measured effects of the impoundments on aquatic life, nutrients, dissolved oxygen, pH, iron, manganese, habitat, flow and periphyton (aquatic plant) growth. Benthic macroinvertebrate communities were adversely affected in most of the downstream sites that were sampled. Of the 75 sample sites below impoundments, only four passed biological criteria guidelines or were comparable to first order references in the seasons they were sampled. Biologists also saw a shift in the type of dominant organisms. Organisms

shifted from pollution intolerant species to more tolerant taxa indicating a loss of biological diversity and integrity.

Sediment deposition was identified as a significant habitat problem in nearly 80 percent of the downstream sites that were sampled. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many aquatic organisms. Other frequently documented habitat problems included embedded substrate, unstable streambanks, no sinuosity and disconnected, or disrupted, streambank vegetation. The study also concluded that impoundments can significantly alter streamflow, decrease dissolved oxygen levels, change the concentration of metals and nutrients, increase water temperature and increase total suspended solids (TSS) downstream (Arnwine et al., 2006).

3.3 WATER QUALITY SPECIFIC PARAMETER AS STRESSORS

Water quality standards are usually direct measurements of water quality parameters from ambient water quality monitoring stations. The water quality standards are designed to protect designated uses (i.e., aquatic life, recreation, shellfish harvesting, fish consumption, water supply). As with habitat degradation, altered watershed hydrology greatly increases the sources of these stressors as well as delivery of the stressors to the receiving waters. Many of the water quality standards discussed in the following section can be found in *Classification and Water Quality Standards Applicable to Surface Waters and Wetlands in North Carolina* (15A NCAC 02B .0200) (DWQ, August 2004).

3.3.1 BACTERIA – RECREATION

Throughout the nation, water quality standards for bacteria are based on human health for recreation and shellfish harvesting and consumption (15A NCAC 2B .0200). North Carolina evaluates waters for the support of primary recreational activities such as swimming, water-skiing, skin diving and similar uses involving human body contact with water where such activities take place in an organized manner or on a frequent basis. Waters of the state designated for these uses are classified as Class B, SB and SA. North Carolina also evaluates waters used for secondary recreation activities such as wading, boating and other uses not involving human body contact with water where such activities take place on an infrequent, unorganized or incidental basis. These waters are classified as Class C, SC and WS.

DWQ conducts monthly ambient water quality monitoring in many freshwater streams and rivers. The monitoring includes sampling for fecal coliform bacteria. The fecal coliform standard for freshwater is 200 colonies per 100 milliliters (ml) of water based on at least five consecutive samples taken during a 30-day period, not to exceed 400 colonies per 100ml in more than 20 percent of the samples during that the same period (15A NCAC 2B .0219). The 200 colonies per 100ml standard is intended to ensure that waters are safe enough for water contact through primary recreation. Class B waters are impaired in the recreation category if the water quality standard for fecal coliform bacteria is exceeded. Fecal coliform bacteria are identified as the stressor to these waters. Class C and WS waters are not rated if the geometric mean exceeds 400 colonies per 100 ml.

For coastal beaches, sounds and estuaries, the DEH monitors bacteria levels through their Recreational Water Quality Monitoring Program (http://www.deh.enr.state.nc.us/shellfish/Water_Monitoring/RWQweb/home.htm (RECMON). Water quality objectives and criteria have been established for enterococci bacteria. DEH has established Tier I, II and III swimming areas/beaches based on their recreational usage. Swimming advisory signs are posted and press releases issued for Tier I swimming areas or beaches (swimming areas used daily) when a minimum of five samples, equally spaced over 30 days, exceed a geometric mean of 35 enterococci per 100 ml or when a single sample exceeds 500 enterococci per 100 ml. The public is notified only by press release, without an advisory sign, when a single sample exceeds 104 enterococci per 100 ml and is less than 500 enterococci per 100 ml. If a second sample exceeds 104 enterococci per 100 ml, an advisory is posted and the public will be notified by press release. An advisory will also be issued when at least two of three samples from a monitoring site exceed 104 enterococci per 100 ml. For an advisory to be rescinded, the station must have two consecutive samples below 35 enterococci per 100 ml.

In a case where a station under advisory is subject to triplicate sampling, two of the three samples must be under the single-sample maximum of 104 enterococci per 100 ml. If two of the three samples are above the single-sample maximum of 104 enterococci per 100 ml, an advisory will be put into place. The advisory will be rescinded when two of the three re-samples are under the single-sample level, as long as the running geometric mean of 35 enterococci per 100 ml has not been exceeded.

Beaches that violate the single-sample maximum criteria are re-sampled at the time of the public notification and/or sign posting, depending on the level of the exceedence. If the re-sample is satisfactory, the advisory may be lifted as early as 24 hours from the time of the initial advisory notification or posting. If the re-sample is unsatisfactory, but the geometric mean is not exceeded, the sign remains posted. If the re-sampling causes the exceedence of the geometric mean, then the geometric mean criteria apply.

The timeframe for posting swimming advisory signs at Tier I beaches, based on the enterococci geometric mean, runs from the beginning of May through the end of September. Weekly sampling of Tier I beaches is from April to October. During April and October, advisories at all Tier I monitoring sites are based on the single-sample maximum for Tier II beaches/swimming areas (276 enterococci per 100 ml.). More information about fecal coliform and enterococci bacteria can be found in Chapter 10.

3.3.2 BACTERIA – SHELLFISH HARVESTING

The Shellfish Sanitation Section (<http://www.deh.enr.state.nc.us/shellfish/index.html>) of DEH is responsible for monitoring and classifying coastal waters as to their suitability for shellfish harvesting for human consumption and the inspection and certification of shellfish and crustacean processing plants. Classifications of coastal waters for shellfish harvesting are done by means of a Sanitary Survey. The survey includes a shoreline survey, a hydrographic survey and a bacteriological survey of growing waters. The surveys are conducted of all potential shellfish growing areas in coastal North Carolina and recommendations are made to the DMF of which areas should be closed for shellfish harvesting. Based on the results of the survey, waters

are classified into one of five categories: Approved (APP), Conditionally-Approved Open (CAO), Conditionally-Approved Closed (CAC), Prohibited (PRO) and Restricted (RES). DWQ evaluated water quality based on the recommendations provided by DEH. More information on bacteria in shellfish waters can be found in Chapter 10.

3.3.3 CHLOROPHYLL

Chlorophyll *a*, a constituent of most algae, is a widely used indicator of algal biomass. North Carolina has a chlorophyll *a* standard of 40µg/l (micrograms per liter) for lakes, reservoirs and slow moving waters not designated as trout waters and a 15µg/l standard for trout waters. Total dissolved gas levels in excess of 110 percent of saturation are also a violation of standards.

3.3.4 DISSOLVED OXYGEN

Dissolved Oxygen (DO) can be produced by turbulent actions, such as waves, rapids and waterfalls that mix air into the water. High levels are found mostly in cool swift moving waters, and low levels are found in warm slow moving waters. In slow moving waters such as reservoirs or estuaries, depth is also a factor. Wind action and plants can cause these waters to have a higher dissolved oxygen concentration near the surface and decline to as low as zero at the bottom. Waters are impaired for aquatic life when greater than 10 percent of samples collected exceed the state DO standard. A minimum of 10 samples is required. The DO water quality standard for Class C waters is not less than a daily average of 5.0 mg/l (milligrams per liter of water) with a minimum instantaneous value of not less than 4 mg/l. Swamp waters (supplemental Class Sw) may have lower values if the low DO level is caused by natural conditions. Trout waters (supplement Class Tr) should not have less than 6.0 mg/L DO.

3.3.5 pH

pH is a measure of hydrogen ion concentration that is used to express whether a solution is acidic or alkaline (basic). Lower values can have chronic effects on the community structure of macroinvertebrates, fish and phytoplankton. The water quality standard for pH in surface freshwaters is 6.0 to 9.0. Swamp waters (supplement Class Sw) may have a pH as low as 4.3 if it is the result of natural conditions.

3.3.6 TEMPERATURE

All aquatic species require specific temperature ranges in order to be healthy and reproduce. For example, trout prefer temperatures below 20° C (68° F) and cannot survive in the warm reservoirs of the piedmont and coastal plain where temperatures can exceed 30° C (86 degrees F). An aquatic species becomes stressed when water temperatures exceed their preferred temperature range, and stressed fish are more susceptible to injury and disease. Water quality standards state that discharge from permitted facilities should not exceed the natural temperature of the water by more than 2.8° C (5.04° F). Waters should never exceed 29° C (84.2° F) for the mountain and upper piedmont area or 32° C (89.6° F) for the lower piedmont and coastal plain areas. The discharge of heated liquids to trout water temperatures should not increase the natural water temperature by more than 0.5° C (0.9° F), and in no case, exceed 20°C (68° F).

Excursions do not constitute water quality impairment, but they do suggest that precautions should be taken to ensure stream temperature is not elevated by human activities. Human activities most likely to contribute to temperature increases in North Carolina include removal of shade trees along streambanks and construction of private dams and ponds. In both cases, more sunlight reaches the stream causing an increase in water temperature. Impervious surface cover also has the potential to increase water temperature. Rain that falls onto impervious surfaces absorbs heat, and the heated stormwater is transferred to nearby streams.

3.3.7 TURBIDITY

Turbidity can influence water clarity, plant and animal growth and drinking water treatment processes. It is often a measure of suspended solids within the water column and is influenced by existing land uses including agriculture, land-disturbing activities and urban stormwater runoff. The water quality standard for receiving waters are not to exceed 50 Nephelometric Turbidity Units (NTU). If the stream has the supplement classification of trout, the receiving water must not exceed 10 NTU. For lakes and reservoirs not designated trout, the turbidity should not exceed 25 NTU. If turbidity exceeds these levels due to natural background conditions, the existing turbidity level cannot be increased. Waters are impaired for aquatic life when greater than 10 percent of samples collected exceed the state turbidity standard.

3.4 TOXIC SUBSTANCES

Rule 15A NCAC 02B .0202(64) defines a toxic substance as “any substance or combination of substances ... which after discharge and upon exposure, ingestion, inhalation or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, has the potential to cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions or suppression in reproduction or growth) or physical deformities in such organisms or their offspring.” Toxic substances frequently encountered in water quality management include chlorine, ammonia, organics (hydrocarbons and pesticides), heavy metals and pH. Because these substances are toxic to different organisms at different levels, their effects can be immediately evident or may manifest only after long-term exposure or accumulation in living tissue.

3.4.1 pH

pH is a measure of hydrogen ion concentration. pH levels that are too high (alkaline) or too low (acidic) can impact the availability of many chemical constituents in the water column including metals, nutrients and oxygen. Metals, for example, become more soluble when pH decreases. Metals that are bound to soil particles can detach, making them more readily available to aquatic organisms. In their detached form, metals are often more harmful and even toxic to the aquatic community. Increases in pH, however, cause metals to precipitate out of the water column. While low pH may not be toxic to aquatic organisms, the metals and the chronic effects associated with those metals can have chronic effects on the community structure.

Changes in the pH of surface waters occur primarily through point source discharges. Changes can also occur during accidental spills, acid deposition (i.e., rain, snow) and algal blooms.

3.4.2 METALS

Some metals can have a negative impact upon both human and aquatic life. Some organic metals (i.e., methylmercury) can build up (bioaccumulate) in the fatty tissue of fish by uptake through the food chain, making them potentially unsafe for human consumption. For aquatic organisms, metals in surface waters can have chronic, sublethal effect and effect neurological and respiratory systems. A variety of water quality characteristics including dissolved and particulate organic carbon, pH and hardness affect the availability of metals and their subsequent impacts upon aquatic life (Bergman and Dorward-King, 1997). Metals can enter surface waters through industrial and wastewater point source dischargers and atmospheric deposition.

North Carolina has adopted numerical water quality standards (maximum permissible levels) for several metals including arsenic, cadmium, chlorine, chromium, cyanide, mercury, nickel and selenium. Action levels, however, are established for metals that do not bioaccumulate in the environment. These metals include copper, iron and zinc. These metals vary in toxicity because of their chemical form, solubility, stream characteristics and/or associated waste characteristics. Limits are not usually assigned to metals that have action level standards unless (1) monitoring indicates that the parameter may be causing toxicity or (2) federal guidelines exist for a given discharger for an action level substance. For those metals not assigned a given numeric standard or action level, a water quality-based limit may be assigned if data indicates the presence of a substance for which there is a federal criterion.

MERCURY

The presence and accumulation of mercury in North Carolina's aquatic environment are similar to contamination observed throughout the country. Mercury has a complex life in the environment, moving from the atmosphere to soil, to surface water and eventually, to biological organisms. Mercury circulates in the environment as a result of natural and human (anthropogenic) activities. A dominant pathway for mercury in the environment is through the atmosphere. Mercury emitted from industrial and municipal stacks into the ambient air can circulate around the globe. At any point, mercury may then be deposited onto land and water. Once in the water, mercury can accumulate in fish tissue and humans. Mercury is also commonly found in wastewater; however, mercury in wastewater is typically not at levels that could be solely responsible for elevated fish levels

Fish is part of a healthy diet and an excellent source of protein and other essential nutrients; however, nearly all fish and shellfish contain trace levels of mercury. The risks from mercury in fish depend on the amount of fish eaten and the levels of mercury in the fish. In March 2003, the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) issued a joint consumer advisory for mercury in fish and shellfish. The advice is for women who might become pregnant, women who are pregnant, nursing mothers and young children. Aside from being issued jointly by two federal agencies, this advisory is important because it emphasizes positive benefits of eating fish and gives examples of commonly eaten fish that are low in

mercury. In the past, the FDA (www.cfsan.fda.gov/seafood1.html) issued an advisory on consumption of commercially caught fish, while the EPA (www.epa.gov/waterscience/fish/) issued advice on recreationally caught fish.

In North Carolina, the Department of Health and Human Services (NCDHHS) issues fish consumption advisories for those fish species and areas at risk for contaminants. NCDHHS notifies people to either limit consumption or avoid eating certain kinds of fish. While most freshwater fish in North Carolina contain very low levels of mercury and are safe to eat, several species have been found to have higher levels (bowfin, catfish, chain pickerel and largemouth bass). For more information and detailed listing of site-specific advisories, visit the NCDHHS Web site www.schs.state.nc.us/epi/fish/current.html.

3.4.3 CHLORINE

Chlorine is a greenish-yellow gas that dissolves easily in water. Because chlorine is an excellent disinfectant, it is commonly added to drinking water supplies to kill bacteria. Chlorine is also used as a disinfectant in wastewater treatment plants and swimming pools and as a bleaching agent in textile factories and paper mills. It is an important ingredient in many laundry bleaches. Even in very small amounts, free chlorine (chlorine gas dissolved in water) is toxic to fish and aquatic organisms. Chlorine becomes more toxic as pH decreases or when it is combined with other toxic substances such as cyanides, phenols or ammonia. Because chlorine reacts quickly with other substances in water (and forms combined chlorine) or dissipates as a gas into the atmosphere, effects are relatively short-lived compared to most other highly poisonous substances. Free chlorine (Cl₂) can also combine with organic material to form compounds called trihalomethanes (THMs). In high concentrations, some THMs are carcinogenic (cancer causing). Unlike free chlorine, THMs are persistent and can pose a threat to human health for many generations.

North Carolina has adopted a freshwater standard for trout waters of 17 µg/l (micrograms per liter) for total residual chlorine. For all other waters, an action level of 17 µg/l for total residual chlorine is applied to protect against toxicity. A total residual chlorine limit is assigned based on the freshwater action level standard of 17 µg/l or a maximum concentration of 28 µg/l for protection against acute effects in the mixing zone. Federal guidelines for residual chlorine of 8 µg/l for chronic effects and 13 µg/l for acute effects are used in saltwaters. New and expanding discharges are encouraged provide dechlorination or alternate wastewater disinfection treatment to avoid discharging chlorine into surface waters of the state.

3.4.4 AMMONIA

Ammonia (NH₃) is a compound of nitrogen and hydrogen. It is a gas at room temperature and is toxic and corrosive to some materials. It has a characteristic pungent odor and is one of the most common industrial and household chemical cleaners.

Ammonia is an important source of nitrogen for many living systems. Nitrogen is essential for the synthesis of amino acids, which are the building blocks for proteins. In humans and animals, ammonia is created through normal amino acid metabolism. It is toxic in high concentrations;

however, our livers convert ammonia to urea through a series of reactions known as the urea cycle. Urea is much less toxic and is a major component of urine. Many plants rely on ammonia and nitrogenous wastes that are incorporated into the soil through the decaying process. Others, such as nitrogen-fixing legumes, however, rely on symbiotic relationships with certain types of bacteria that can convert atmospheric nitrogen to ammonia (Wikipedia, December 2006).

Because ammonia is rich in nitrogen, it also makes an excellent fertilizer. Ammonium salts are a major source of nitrogen for fertilizers. Nitrogen not used by plants can enter streams, rivers and reservoirs during storm events and increase the potential for eutrophication. Even in very low concentrations, ammonia is toxic to aquatic organisms. When levels reach 0.06 mg/l, fish can suffer gill damage. When levels reach 0.2 mg/l, sensitive fish (like trout) begin to die. As levels near 2.0 mg/l, even ammonia-tolerant fish (like carp) begin to die. Ammonia levels greater than approximately 0.1 mg/l usually indicate polluted waters. The danger ammonia poses for fish is dependent upon water temperature, pH and dissolved oxygen and carbon dioxide concentrations. Ammonia is more toxic to fish and aquatic life when the water column contains very little dissolved oxygen and/or carbon dioxide.

Point source dischargers are the primary sources of ammonia in surface waters. Decaying organic matter and bacterial decomposition of animal waste can also contribute to increased ammonia levels in surface water.

DWQ addresses ammonia toxicity through an interim set of instream criteria of 1.0 mg/l in the summer (April to October) and 1.8 mg/l in the winter (November to March). Current limits are no less than 2.0 mg/l in summer and 4.0 mg/l in winter, unless dissolved oxygen problems or modeling analysis dictate stricter limits. These interim criteria are under review, and the state may adopt a standard in the future.

3.5 OTHER WATER QUALITY STRESSORS

3.5.1 NUTRIENTS

Nutrients refer to phosphorus (P) and nitrogen (N), which are common components of fertilizers, animal and human waste, vegetation, aquaculture and some industrial processes. Nutrients in surface waters come from both point and nonpoint sources including agriculture and urban runoff, wastewater treatment plants, forestry activities and atmospheric deposition. While nutrients are beneficial to aquatic life in small amounts, excessive levels can stimulate algal blooms and plant growth, depleting dissolved oxygen in the water column. More information on nutrients and management strategies to control eutrophication can be found in Chapter 11.

3.5.2 TOTAL SUSPENDED SOLIDS (TSS)

TSS are solids (i.e., sediment, decaying plant and animal material, industrial waste, sewage) that can be filtered out of the water column. High TSS can block light from reaching submerged aquatic vegetation, which slows down the rate of photosynthesis and reduces the amount of dissolved oxygen in the water column. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and die. As plants decompose, bacteria will use up even more oxygen from the water, ultimately leading to fish kills.

High TSS can also increase surface water temperature and decreases water clarity. Surface water temperature increases because the suspended particles absorb heat from sunlight. Because warmer waters hold less dissolved oxygen, dissolved oxygen levels tend to fall even further. The decrease in water clarity caused by TSS can affect the ability of fish to see and catch food. Suspended sediment can also clog fish gills, reduce growth rates, decrease resistance to disease and prevent egg and larval development. When suspended solids settle to the bottom of a waterbody, they can smother fish eggs, as well as suffocate newly hatched insect larvae. Settling sediments can fill in spaces between rocks, reducing habitat availability (Mitchell and Stapp, 1992).

3.5.3 COLOR

Color is generally associated with industrial wastewater, municipal plants that receive industrial wastes from textile manufacturers that dye fabrics and pulp and paper mills. Color can affect the aesthetic quality of a waterbody and interfere with sunlight penetration. Submerged aquatic vegetation needs light for photosynthesis. If color blocks out light, photosynthesis will be reduced, thus reducing the production of oxygen needed for the survival of aquatic life. If light levels get too low, photosynthesis may stop altogether, causing algae to die. In addition, fish may not be able to see in waters polluted with color, making it difficult to find food. Color is usually not a toxicological problem. There is no current data showing that colored effluent poses any threats to human health or that it is the sole source of aquatic life impacts.

According to state regulations, colored effluent is allowed in "only such amounts as will not render the waters injurious to public health, secondary recreation, or to aquatic life and the wildlife or adversely affect the palatability of fish, aesthetic quality or impair the waters for any designated uses" (15A NCAC 02B .0211(3)(a)). The state has considered developing a numeric standard for color, but there are many challenges in doing so. Some of these challenges include knowing what the appropriate analytical approach is, assigning the appropriate numeric standard is and determining if a different standard should be used for different regions in the state to reflect variations in natural (background) water color. The practical application of this regulation must also take into account the various ways in which color is perceived. No narrative definition of color impairment can be specified by a simple set of criteria because color is perceived differently under varying conditions. The advantage of a narrative standard is that it is flexible. The disadvantages are that it is subjective and difficult to enforce.

All dischargers with colored waste are required to conduct toxicity testing on the effluent to assure that the discharge will not adversely impact the aquatic organisms in the receiving stream. DWQ believes that the most effective and equitable means of addressing color is to rely on the narrative aesthetic standard as well as on citizen complaints.

3.6 WHOLE EFFLUENT TOXICITY

Whole effluent toxicity (WET) testing is required on a quarterly basis for major dischargers (>1 MGD) permitted through the National Pollutant Discharge Elimination Program (NPDES). Dischargers that contain complex (industrial) wastewater are also required to conduct WET testing. A WET test shows whether the effluent from a treatment plant is toxic, but it does not identify the specific cause of toxicity. Where a facility has indicated potential toxicity, toxicity reduction plans are reviewed by DWQ to evaluate compliance with permit limits. Other testing, or monitoring, that can be done to detect aquatic toxicity problems include fish tissue analyses, chemical water quality sampling and assessment of fish community and bottom-dwelling organisms such as aquatic insect larvae. More information on WET testing can be found in Chapter 2.

3.6.1 PERMIT LIMITS

Many of the toxic substances reviewed in the chapter are identified and controlled through the (NPDES) permitting process. Facilities are inspected and compliance reports are reviewed by DWQ to ensure that permitted facilities are meeting permit limits and not impacting water quality. Permit limits for specific toxicants are based on the volume of the discharge and the flow conditions of the receiving waters. Methods for determining permit limits are established by the federal Environmental Protection Agency (EPA). The limits consider the maximum predicted effluent concentration and the amount of variation in effluent monitoring data. If the point source (permitted facility) is not meeting its permit limits, it can be identified as a water quality stressor. More information on the NPDES permitting process can be found in Chapter 9.

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