Guide to Interpreting Ambient Water and Effluent Variables (ILMB, BC 1998)

The following guide defines each variable, discusses the importance of the variable to the aquatic environment and lists potential anthropogenic sources.

Temperature

Definition: This is a measurement of the intensity (not amount) of heat stored in a volume of water. Surface water temperatures naturally range from 0°C under ice cover to 40°C in hot springs. Natural sources of heat include: solar radiation, transfer from air, condensation of water vapor at the water surface, sediments, precipitation, surface runoff and groundwater. Temperature is the primary influencing factor on water density.

Importance: Temperature affects the solubility of many chemical compounds and can therefore influence the effect of pollutants on aquatic life. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. Vertical stratification patterns that naturally occur in lakes affect the distribution of dissolved and suspended compounds.

Anthropogenic sources: industrial effluents, agriculture, forest harvesting, urban developments, mining.

Turbidity

Definition: This is a measurement of the suspended particulate matter in a water body which interferes with the passage of a beam of light through the water. Materials that contribute to turbidity are silt, clay, organic material, or micro-organisms. Turbidity values are generally reported in Nephelometric Turbidity Units (NTU). Pure distilled water would have non-detectable turbidity (0 NTU). The extinction depth (for lakes), measured with a Secchi disc, is an alternative means of expressing turbidity.

Importance: High levels of turbidity increase the total available surface area of solids in suspension upon which bacteria can grow. High turbidity reduces light penetration; therefore, it impairs photosynthesis of submerged vegetation and algae. In turn, the reduced plant growth may suppress fish productivity. Turbidity interferes with the disinfection of drinking water and is aesthetically unpleasant.

Anthropogenic sources: forest harvesting, road building, agriculture, urban developments, sewage treatment plant effluents, mining, industrial effluents.

pH

Definition: This is the measurement of the hydrogen-ion concentration in the water. A pH below 7 is acidic (the lower the number, the more acidic the water, with a decrease of one full unit representing an increase in acidity of ten times) and a pH above 7 (to a maximum of 14) is basic (the higher the number, the more basic the water). Fresh waters have a pH range from 5.5 in southeast Oklahoma to nearly 9.0 in central Oklahoma,

Importance: Higher pH values tend to facilitate the solubilization of ammonia, heavy metals and salts. The precipitation of carbonate salts (marl) is encouraged when pH levels are high. Low pH levels tend to increase carbon dioxide and carbonic acid concentrations. Lethal effects of pH on aquatic life occur below pH 4.5 and above pH 9.5.

Anthropogenic sources: mining, agriculture, industrial effluents, acidic precipitation (derived from emissions to the atmosphere from cars and industry).

Dissolved Oxygen (DO)

Definition: This is a measure of the amount of oxygen dissolved in water. Typically the concentration of dissolved oxygen in surface water is less than 10 mg/L. The DO concentration is subject to diurnal and seasonal fluctuations that are due, in part, to variations in temperature, photosynthetic activity and river discharge. The maximum solubility of oxygen (fully saturated) ranges from approximately 15 mg/L at 0°C to 8 mg/L at 25°C (at sea level). Natural sources of dissolved oxygen are derived from the atmosphere or through photosynthetic production by aquatic plants. Natural re-aeration of streams can take place in areas of waterfalls and rapids.

Importance: Dissolved oxygen is essential to the respiratory metabolism of most aquatic organisms. It affects the solubility and availability of nutrients, and therefore the productivity of aquatic ecosystems. Low levels of dissolved oxygen facilitate the release of nutrients from the sediments. Oligotrophic (low nutrient) lakes tend to have increased concentrations of dissolved oxygen in the hypolimnion (deeper waters) relative to the epilimnion (defined as orthograde oxygen profiles). Eutrophic (high nutrient) lakes tend to have decreased concentrations of dissolved oxygen in the hypolimnion relative to the epilimnion (defined as clinograde oxygen profiles).

Anthropogenic causes of decreased DO: forest harvesting, pulp mills, agriculture, sewage treatment plant effluent, industrial effluents, impoundments (dams).

Hardness, total

Definition: The hardness of water is generally due to the presence of calcium and magnesium in the water. Other metallic ions may also contribute to hardness. Hardness is reported in terms of calcium carbonate and in units of milligrams per litre (mg/L). Waters with values exceeding 120 mg/L are considered hard, while values below 60 mg/L are considered soft.

Importance: Harder water has the effect of reducing the toxicity of some metals (i.e., copper, lead, zinc, etc.). Soft water may have corrosive effect on metal plumbing, while hard water may result in scale deposits in the pipes. If the water has a hardness of greater than 500 mg/L, then it is normally unacceptable for most domestic purposes and must be treated.

Anthropogenic sources: mining, industrial effluents

Alkalinity

Definition: This is the measurement of the water's ability to neutralize acids. It usually indicates the presence of carbonate, bicarbonates, or hydroxides. Alkalinity results are expressed in terms of an equivalent amount of calcium carbonate. Note that this does not mean that calcium carbonate was found in the sample. Natural waters rarely have levels that exceed 500 mg/L.

Importance: Waters that have high alkalinity values are considered undesirable because of excessive hardness and high concentrations of sodium salts. Waters with low alkalinity have little capacity to buffer acidic inputs and are susceptible to acidification (low pH).

Anthropogenic sources that destroy alkalinity: mining, industrial effluents, acidic precipitation.

Total Dissolved Solids (TDS)

Definition: This is a measure of the amount of dissolved material in the water column. It is reported in mg/L with values in fresh water naturally ranging from 0-1000 mg/L. Dissolved salts such as sodium, chloride, magnesium and sulphate contribute to elevated filterable residue values.

Importance: High concentrations of TDS limit the suitability of water as a drinking and livestock watering source as well as irrigation supply. High TDS waters may interfere with the clarity, color, and taste of manufactured products. High TDS naturally occurs in some parts of western Oklahoma.

Anthropogenic sources: mining, industrial effluent, sewage treatment, agriculture, road salts.

Total Suspended Solids (TSS)

Definition: This is a measure of the particulate matter that is suspended within the water column. Values are reported in mg/L.

Importance: High concentrations of TSS increase turbidity, thereby restricting light penetration (hindering photosynthetic activity). Suspended material can result in damage to fish gills. Settling suspended solids can cause impairment to spawning habitat by smothering fish eggs. Suspended solids also interfere with water treatment processes.

Anthropogenic sources: forest harvesting, road building, industrial effluents, urban developments, placer mining, municipal sewage treatment plants.

Specific Conductivity

Definition: This is the measurement of the ability of water to conduct an electric current - the greater the content of ions in the water, the more current the water can carry. Ions are dissolved metals and other dissolved materials. Conductivity is reported in terms of microsiemens per centimeter (µS/cm). Natural waters are found to vary between 50 and 1500 µS/cm. In Oklahoma, some western rivers have specific conductivity values > 25,000 uS/cm, while many waters in the Ouachita Mountains of southeastern Oklahoma have perennial conductivities of < 25.

Importance: Specific Conductivity may be used to estimate the total ion concentration of the water, and is often used as an alternative measure of dissolved solids. It is often possible to establish a correlation between conductivity and dissolved solids for a specific body of water [dissolved solids = conductivity x 0.55 to 0.9 (the most often used is 0.65)]. Fish diversity typically is inversely proportional to conductivity.

Anthropogenic sources: mining, roads (de-icing salts), industrial & municipal effluents. High conductivity may also be naturally occurring.

Chloride

Definition: Of the halides, chloride appears in the highest concentrations in natural fresh water system, and is reported as mg/L. The average chloride concentration varies widely in Oklahoma with values of < 10 mg/L in southeastern Oklahoma to > 3000 mg/L in the Cimarron and upper Red River watersheds. .

Importance: Chloride is important in terms of metabolic processes, as it influences osmotic salinity balance and ion exchange. Higher chloride concentrations can reduce the toxicity of nitrite to aquatic life. Fish diversity typically is inversely proportional to chloride concentration.

Anthropogenic sources: municipal water supply disinfection, sewage treatment plant effluents, urban developments, industrial effluents, mining.

Sulfate

Definition: Sulfur is commonly found as a component of sedimentary and igneous rocks in the form of metallic sulfides. Sulfides are oxidized upon contact with aerated water, producing sulfate ions in solution. (Lehigh 2010)

Importance: When sulfate is less than 0.5 mg/L, algal growth will not occur. On the other hand, sulfate salts can be major contaminants in natural waters. Excessive levels in water may cause illness. The average sulfate concentration varies widely in Oklahoma with values of < 10 mg/L in southeastern Oklahoma to > 1500 mg/L in the upper Red River watersheds. (Lehigh 2010)

Anthropogenic sources: combustion of fuel, present in soils that are oxidized through natural processes, organic waste treatment, mine drainage, and evaporite sediments, such as anhydrite and gypsum.

Total phosphorus

Definition: This is a measure of both inorganic and organic forms of phosphorus. Phosphorus can be present as dissolved or particulate matter. It is an essential plant nutrient and is often the most limiting nutrient to plant growth in fresh water. It is rarely found in significant concentrations in surface waters, and is generally reported in µg/L or mg/L.

Importance: Since phosphorus is generally the most limiting nutrient, its input to fresh water systems can cause extreme proliferations of algal growth. Inputs of phosphorus are the prime contributing factors to eutrophication in most fresh water systems. A general guideline regarding phosphorus and lake productivity is: <10 µg/L phosphorus yields is considered oligotrophic, 10-25 µg/L P will be found in lakes considered mesotrophic, and >25 µg/L P will be found in lakes considered eutrophic.

Anthropogenic sources: sewage treatment plant effluent, agriculture, urban development (particularly from detergents), industrial effluents.

Orthophosphate (PO_4^{-3})

Definition: This is a measure of the inorganic oxidized form of soluble phosphorus. It is generally reported in µg/L or mg/L.

Importance: This form of phosphorus is the most readily available for uptake during photosynthesis. High concentrations of orthophosphate generally occur in conjunction with algal blooms.

Anthropogenic sources: sewage treatment plant effluent, agriculture, urban developments, industrial effluents.

Nitrite (NO_2^-)

Definition: This is a measure of a form of nitrogen that occurs as an intermediate in the nitrogen cycle. It is an unstable form that is either rapidly oxidized to nitrate (nitrification) or reduced to nitrogen gas (de-nitrification). This form of nitrogen can also be used as a source of nutrients for plants. Nitrite is generally reported in either µg/L or mg/L. It is normally present in only minute quantities in surface waters (<0.001 mg/L).

Importance: Since nitrite is also a source of nutrients for plants its presence encourages plant proliferation. Nitrite is toxic to aquatic life at relatively low concentrations.

Anthropogenic sources: sewage treatment plant effluents, agriculture, urban developments, recreation, industrial effluents, mining (blasting residuals).

Nitrate (NO_3^-)

Definition: This is the measurement of the most oxidized and stable form of nitrogen in a water body. Nitrate is the principle form of combined nitrogen found in natural waters. It results from the complete oxidation of nitrogen compounds, and is generally reported in µg/L or mg/L. Without anthropogenic inputs, most surface waters have less than 0.3 mg/L of nitrate.

Importance: Nitrate is the primary form of nitrogen used by plants as a nutrient to stimulate growth. Excessive amounts of nitrogen may result in phytoplankton or macrophyte proliferations. At high levels it is toxic to infants.

Anthropogenic sources: sewage treatment plant effluents, agriculture, urban developments, recreation, industrial effluents, mining (blasting residuals).

Total Ammonia (NH_3 & NH_4^+)

Definition: This is a measure of the most reduced inorganic form of nitrogen in water and includes dissolved ammonia (NH_3) and the ammonium ion (NH_4^+). Nitrogen is an essential plant nutrient and although ammonia is only a small component of the nitrogen cycle, it contributes to the trophic status of a body of water. Ammonia is generally reported in either µg/L or mg/L. Natural waters typically have ammonia concentrations less than 0.1 mg/L.

Importance: Excess ammonia contributes to eutrophication of water bodies. This results in prolific algal growths that have deleterious impacts on other aquatic life, drinking water supplies, and recreation. Ammonia at high concentrations is toxic to aquatic life.

Anthropogenic sources: sewage treatment plant effluents, agriculture, urban developments, recreation, industrial effluents, mining (blasting residuals).

Kjeldahl nitrogen

Definition: This is a measure of both the total ammonia and the organic forms of nitrogen.

Importance: Excess ammonia contributes to eutrophication of water bodies. This results in prolific algal growths that have deleterious impacts on other aquatic life, drinking water supplies, and recreation. Ammonia at high concentrations is toxic to aquatic life. Organic nitrogen is not immediately available for biological activity. Therefore, it does not contribute to furthering plant proliferation until decomposition to the inorganic forms of nitrogen occurs. Kjeldahl nitrogen is a necessary value for calculating total nitrogen in a system.

Anthropogenic sources: sewage treatment plant effluents, agriculture, urban developments, paper plants, industrial effluents, recreation, mining (blasting residuals).

Total nitrogen

Definition: This is a measure of all forms of nitrogen (organic and inorganic). Nitrogen is an essential plant element and is often the limiting nutrient in marine waters. Total nitrogen is typically calculated by summing nitrate, nitrite, and Kjeldahl nitrogen.

Importance: The importance of nitrogen in the aquatic environment varies according to the relative amounts of the forms of nitrogen present, be it ammonia, nitrite, nitrate, or organic nitrogen (each of which are discussed in detail above).

Anthropogenic sources: sewage treatment plant effluents, agriculture, urban developments, paper plants, industrial effluents, recreation, mining (blasting residuals).

Chlorophyll A

Definition: Chlorophyll a is a green pigment found in plants. It absorbs sunlight and converts it to sugar during photosynthesis. Chlorophyll a concentrations are an indicator of phytoplankton abundance and biomass.

Importance: They can be an effective measure of trophic status, are potential indicators of maximum photosynthetic rate and are a commonly used measure of water quality. High levels often indicate poor water quality and low levels often suggest good conditions. However, elevated chlorophyll a concentrations are not necessarily a bad thing. It is the long-term persistence of elevated levels that is a problem.

Anthropogenic sources: sewage treatment plant effluents, agriculture, urban developments, storm water run-off, natural occurrences.

Trophic State Index

Definition of Trophic State: Trophic state is the total weight of living biological material (biomass) in a waterbody at a specific location and depth. (Carlson, 1996)

Definition of Trophic State Index: A simple and effective management tool for tracking algae growth in lakes worldwide is to express chlorophyll-A as trophic status. Here the concentration of chlorophyll-A is correlated to the biomass of algae in the sampled water. **Carlson's (1977)** trophic state index (TSI) is one of the most commonly used measurements to compare lake trophic status, which is based on algal biomass. Carlson's TSI uses chlorophyll-a concentrations to define level of eutrophication on a scale of 1 to 100. The trophic scale is set up so that a ten-unit increase in trophic state represents a doubling of algae biomass. The OWRB's statewide lakes sampling program assigns one of three trophic states to Oklahoma reservoirs on an annual basis. A lake is considered oligotrophic below 40, mesotrophic from 41-50, eutrophic 51-60, and hypereutrophic when greater than or equal to 61. The biological condition of the waterbody indicates the lake's level of nutrient enrichment or eutrophication. Secchi depth and total phosphorus can also be used to calculate TSI.

Importance: Trophic state is understood to be the biological response to forcing factors such as nutrient additions, but the effect of nutrients can be modified by factors such as season, grazing, mixing depth, etc. (Carlson, 1996)

Fecal Coliform

Definition: Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife. The bacteria can be found in the digestive tract of warm-blooded animals and aid in the digestion of food.

Importance: In themselves, fecal coliform bacteria do not pose a danger to people or animals; however, where fecal coliform are present, disease-causing bacteria may also be present. Fecal coliform contamination may indicate that water is polluted with human or animal waste, which can harbor other pathogens that may threaten human health.

Anthropogenic sources: agricultural runoff, animal waste, human waste, leaky sewer lines, on-site septic systems, straight pipes, stormwater runoff from developed land including roads, buildings and residential yards and surface or land application of human and/or animal waste

Enterococcus

Definition: Like fecal coliform bacteria, enterococci are passed through the fecal excrement of humans, livestock and wildlife. The bacteria can be found in the digestive tract of warm-blooded animals and aid in the digestion of food.

Importance: EPA approves the use of enterococci as an indicator of potential pathogenic contamination in recreational bathing waters.

Anthropogenic sources: agricultural runoff, animal waste, human waste, leaky sewer lines, on-site septic systems, straight pipes, stormwater runoff from developed land including roads, buildings and residential yards and surface or land application of human and/or animal waste

E. Coli

Definition: E-Coli are one type of pathogenic fecal coliform bacteria, and the most common facultative, disease-causing bacteria in the feces of warm-blooded animals.

Importance: Most *E. coli* bacteria are harmless and are found in great quantities in the intestines of people and warm-blooded animals. Some strains, however, can cause illness. EPA approves the use of enterococci as an indicator of potential pathogenic contamination in recreational bathing waters.

Anthropogenic sources: agricultural runoff, animal waste, human waste, leaky sewer lines, on-site septic systems, straight pipes, stormwater runoff from developed land including roads, buildings and residential yards and surface or land application of human and/or animal waste

Statistics

n: The number of discrete values in the population or dataset that are used in analyses.

Mean: The mean is a measure of central tendency, or location within the population. For a population or dataset, the mean is the arithmetic average of all values. If data are normally distributed, the mean is equivalent to the median.

Median: The median is a measure of central tendency. The median can also be defined as the 50th percentile. In a population or dataset, the median is the value that has just as many values above it as below it. If there is an even number of values, the median is the average of the two middle values. For normally distributed populations or datasets, the median coincides with the mean and the center of the distribution. For this reason, the median of a sample is often used as an estimator of the center of the distribution. If the distribution has heavier tails than the normal distribution, the median is usually a more precise estimator of the population distribution center than the mean.

Percentiles: In a population or dataset, the pth percentile is a value such that at least a percent of the values take on this value or less and at least (100-P) percent of the values take on this value or more. For example, the 25th (p25) and 75th (p75) percentiles represent the points that 25 and 75 percent of the population are less than. Along with the median, the p25 and p75 values are also known as the 1st, 2nd, and 3rd quartiles, respectively.

Minimum: The minimum is the smallest measured value in the population or dataset.

Maximum: The maximum is the largest measured value in the population or dataset.

Interquartile Range: The difference between the 3d and 1st quartiles are called the interquartile range (IQR). The IQR is used as a measure of population or dataset variability, or dispersion.

Sampling distribution: The probability distribution of the statistic is called the sampling distribution. When a population or dataset is measured, some summary value (called a statistic) is usually computed. For example, the population mean and variance are two statistics, and the value of the statistic changes as the population changes. The normal distribution is a probability distribution which is bell-shaped, symmetrical, and single peaked. In a normally distributed population or dataset, the mean, median and mode coincide and lie at the center of the distribution. The two tails extend indefinitely and never touch the x-axis (asymptotic to the x-axis). In non-normally distributed datasets, the mean shifts to either the right or left tail of the distribution and is not equivalent to the median.

Literature Citied

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