FACTSHEET ON WATER QUALITY PARAMETERS

# Nutrients

Nutrients play a critical role in the biodiversity and healthy functioning of aquatic ecosystems by supporting the growth of aquatic plants and algae that provide food and habitat for fish, shellfish, and smaller organisms. Nitrogen and phosphorus are two of the most important nutrients.

## Why do we measure nutrients?

Excess (or elevated) nutrients is among the most common water pollution problems affecting waterbodies in the U.S. High nutrient concentrations resulting from human activities can diminish ecosystem health. Excess nutrients in a waterbody can lead to excess biological growth (eutrophication) and harmful algal blooms (HABs). In freshwater, HABs are often caused by cyanobacteria (blue-green algae) and may have negative effects on humans and ecosystems (Figure 1).

Certain types of cyanobacteria can produce toxins that are harmful to humans and animals through recreational exposure or through consumption of drinking water. Toxins can also work their way into the aquatic and terrestrial food webs and potentially harm animals and humans. Additionally, algal blooms can lead to hypoxia, or low dissolved oxygen (DO) in the water, either through algal respiration or consumption of oxygen, by decomposers when the algae die off. Persistently low DO can harm sensitive aquatic animals, resulting in chronic stress or even mortality.

*Figure 1. Harmful algal blooms cause thick, green scums that impact water, recreation, businesses and property values. Credit: Photo courtesy of USGS, photographer J. Nelson*

Nutrients affect other water quality parameters, such as:

- **pH** – A basic parameter controlling water chemistry and aquatic health. Daily variation in pH is amplified when nutrients promote increased growth of aquatic primary producers (plants, algae and cyanobacteria).
- **Organic carbon** – The amount of organic matter in the water; it may increase if nutrients promote growth of aquatic plants and algae.
- **Total suspended solids** – The amount of particulate matter in the water; it may increase if nutrients promote algal growth.
- **Turbidity or water clarity**– An indicator of water transparency. Water may be more turbid (cloudy) if algae and aquatic plant growth increase in response to higher nutrient concentrations.
- **Chlorophyll *a*** – An algal and aquatic plant pigment that is useful as an indicator of algal biomass and that may increase in response to higher nutrient concentrations.
- **DO** – The amount of oxygen in the water available for fish and other aquatic organisms. DO may decrease if an algal bloom proceeds to the point where bacterial decay of dead algae consumes oxygen.

There can be a lag time between an increase in nutrients and changes in these parameters. For example, excess nutrients promote increased algal growth, which can then lead to subsequent changes in other parameters.

# What affects nutrients?

Nutrients in surface water come from both point sources (specific discharge points) and nonpoint sources (pollution dispersed over general land area).

| Point sources |
| --- |
| Discharges from wastewater treatment facilities and industrial discharges may be rich in both nitrogen and phosphorus. |

| Nonpoint sources |
| --- |
| **Fertilizers** – Runoff from cropland contributes nitrogen and phosphorus from fertilizers to surface waters (Figure 2).<br><br>**Manure** – Livestock operations produce large amounts of manure, which contains nitrogen and phosphorus. If not managed properly, manure can be carried in stormwater runoff to streams or contaminate streams when animals have direct contact with the waterbody.<br><br>**Urban runoff** – Nitrogen and phosphorus sources in urban areas that can be carried in runoff include lawn fertilizer, pet waste, and wildlife droppings.<br><br>**Atmospheric deposition** – Atmospheric deposition occurs naturally but can be contaminated by human activities. It can be a significant source of nutrients, especially nitrogen, in certain regions (for example, downwind of urban and agricultural areas). |

Nutrient concentrations in rivers can vary considerably from year to year, as shown by EPA's *Report on the Environment for Nitrogen and Phosphorus Loads in Large Rivers in the U.S.* (2019) (Mississippi, Columbia, St. Lawrence, and Susquehanna).

Nutrient concentrations can also fluctuate throughout the year. Several seasonal trends affect nutrient concentrations:

- **Spring** – Snowmelt and rain deliver nutrients from agricultural land into streams and groundwater. Some studies, as summarized by EPA's report *Monitoring and Evaluating Nonpoint Source Watershed Projects* (2016), have shown that in northern areas, the majority of the annual nutrient pollutant load can be delivered within a few weeks. Nutrients in groundwater can mobilize and be discharged into surface waters. Nutrient availability in lakes may increase during spring turnover due to release of nutrients from the sediment at the bottom of the lake.
- **Summer** – Warmer water temperatures and lower flows create preferred conditions for increased algal growth, especially during the summer growing season.
- **Fall** – Nutrient availability in lakes may increase during fall turnover due to release of nutrients from the sediment at the bottom of the lake.
- **Winter** – As plants die and decompose in the late fall and winter, nutrients are released into water.

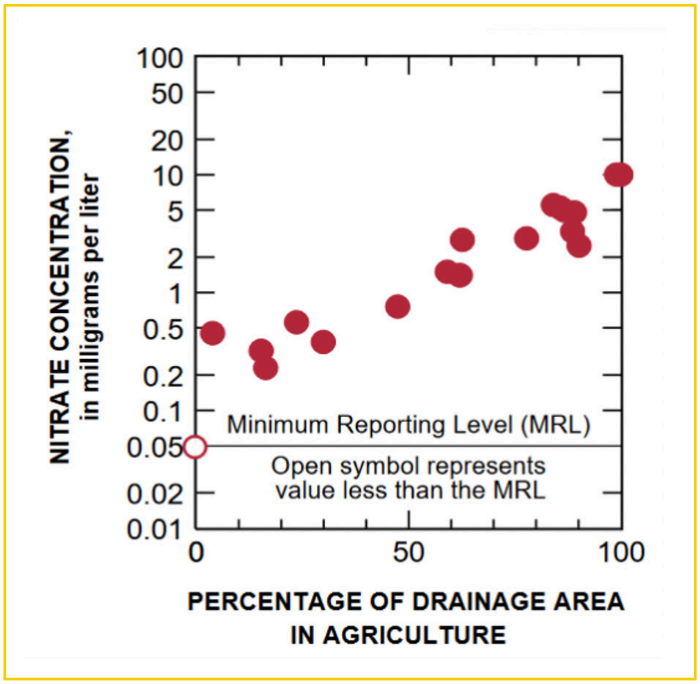


*Figure 2. Graph showing increasing nitrate concentration in streams in proportion to the percentage of drainage area in agriculture in the Willamette Basin. Source: USGS (Nd)*

## What are EPA's recommended criteria for nutrients?

Nutrient concentrations are highly variable in waterbodies across the U.S. To interpret monitoring data, it is helpful to be familiar with typical nutrient concentrations for healthy and disturbed waterbodies in your area. When nutrient concentrations are higher than an aquatic system's natural background concentrations, the water has most likely been affected by urban or agricultural activities, including both point and nonpoint source contributions.

Unlike many water quality pollutants, there is no single national criterion for either phosphorus or nitrogen because the thresholds for impairment vary regionally and by waterbody type (river, lake, estuary, etc.) and characteristics (stream/river size, lake depth, etc.). Instead, EPA has published technical support documents with recommended water quality criteria for fourteen specific areas of the U.S. (ecoregions). Criteria for your ecoregion can be found on EPA's Ecoregional Criteria website (2020a). As an example, Table 1 shows the ecoregional criteria for Aggregate Ecoregion III (Xeric West). EPA is encouraging states and tribes to develop and adopt numeric water quality criteria for total nitrogen and total phosphorus or to develop a process to interpret the narrative criteria for nutrients. For information on state adopted nutrient criteria please visit EPA's website on State Progress Toward Developing Numeric Nutrient Water Quality Criteria for Nitrogen and Phosphorus (2020b).

*Table 1. Ecoregional criteria for Aggregate Ecoregion III (Xeric West).*

| | Rivers and Streams |
|---|---|
| Total Phosphorus (µg/L) | 21.88 |
| Total Nitrogen (mg/L) | 0.38 |
| Chlorophyll *a* (µg/L) | 1.78 |
| Turbidity (NTU) | 2.34 |

*[1] All or parts of the States of: Washington, Oregon, California, Nevada, Idaho, Wyoming, Montana, Utah, Colorado, New Mexico, Arizona, and Texas, and the authorized Tribes within the Ecoregion. Source: USEPA (2014)*

## How do we measure nutrients?

Nutrients are measured by taking water samples in the field and are commonly reported as milligrams per liter (mg/L) or micrograms per liter (µ/L) of water. When deciding where and when to take samples to measure nutrient concentrations, consider:

- Sources of pollution in your watershed and where they may enter streams or lakes to identify areas that may have high concentrations. These may include both point and nonpoint sources. Identify areas that have historically had problems with nutrient pollution.
- Flow characteristics that may affect how quickly nutrient pollution moves through the system.
- Sampling at different depths to identify vertical variability in nutrient concentrations through the water column, especially in the summer months.
- Whether it has been dry or has recently rained or snowed.

Sample throughout the year (if feasible) to capture seasonal variability in nutrient concentrations, sources, and changes in vertical variability (seasonal turnover in lakes may increase nutrient availability).

A monitoring program must establish which forms of nitrogen and phosphorus to analyze. Both nitrogen and phosphorus have natural cycles in which they are converted into different forms (also called "species") by plants and microorganisms. Figure 3 shows an example of a general nitrogen cycle.

Nitrogen and phosphorus exist in both inorganic and organic forms, and those forms can be either dissolved in the water or bound to particulates. Particulates may remain suspended in water, or they can settle to the bottom of a waterbody and potentially release nutrients back into the water.

Table 2 lists typical nitrogen and phosphorus forms for which samples can be analyzed. Total nitrogen and total phosphorus provide an overall indication of the amounts of nutrients in a system. Additional analyses can be done to determine the different forms of nitrogen and phosphorus. If the samples are filtered to remove particulates, then the dissolved fractions can be measured (the particles retained on the filters could also be analyzed).

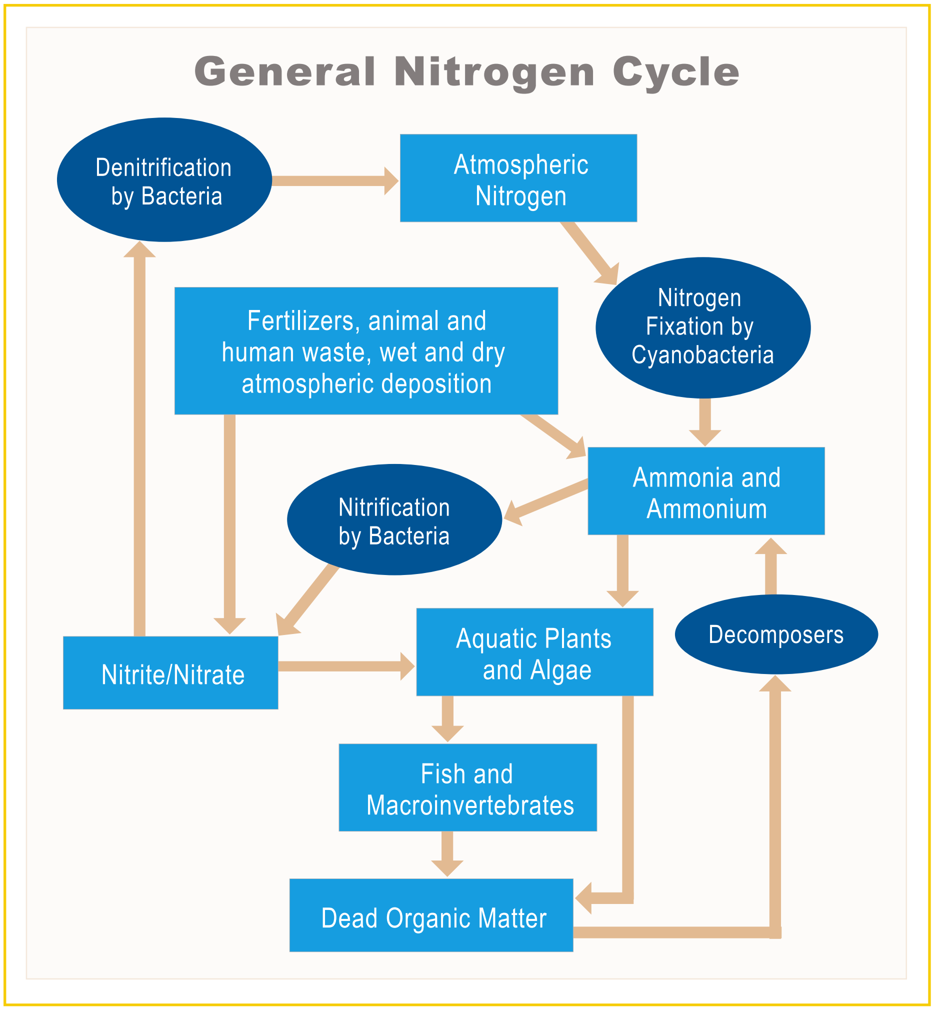


*Figure 3. Example of a general nitrogen cycle.*

Taken together, a suite of analyses can help in tracking sources of inputs and the amounts of the most bioavailable forms of nitrogen and phosphorus.

*Table 2. Typical forms of nitrogen and phosphorus for which samples may be analyzed in the laboratory.*

| Form | Units | Common Names | Description | Why Sample? |
|---|---|---|---|---|
| Total nitrogen, mixed forms | mg/L | TN | Captures all forms of nitrogen. (Commonly TKN + Nitrate + Nitrite) | Important overall parameter to understand nutrient levels in a waterbody. |
| Nitrate + nitrite | mg/L | Nitrite-nitrogen ($NO_2^-$-N), Nitrate-nitrogen ($NO_3^-$-N) | Inorganic forms of nitrogen, bioavailable for aquatic plant and algae growth. Main form in surface waters with high N concentrations. Nitrate is the more common form - nitrite is unstable in natural waters. | Valuable for monitoring the impacts of inputs such as agricultural and urban runoff, wastewater treatment plants, leaking sewage systems, industrial point sources, and other sources. |

*Table 2 continued. Typical forms of nitrogen and phosphorus for which samples may be analyzed in the laboratory.*

| Form | Units | Common Names | Description | Why Sample? |
|---|---|---|---|---|
| Ammonium/ ammonia | µg/L | Ammonia nitrogen, $NH_4^+$-N, $NH_3$ | Inorganic forms of nitrogen, bioavailable for aquatic plant and algae growth. | Valuable to monitor because of ammonia toxicity to aquatic life and for monitoring the impacts of wastewater treatment plants, leaking sewage systems, industrial point sources, agricultural and urban runoff, and other sources. |
| Total Kjeldahl Nitrogen (TKN) | mg/L | Dissolved ammonia plus organic nitrogen | A measure of organic nitrogen plus dissolved ammonia. | Useful to evaluate contributions of organic nitrogen from wastewater treatment plants, manure, and other potential sources. Useful for in-depth evaluations of N bioavailability in surface water. |
| Inorganic nitrogen | mg/L | $NO_2^- + NO_3^- + NH_3 + NH_4^+$ | Nitrogen as nitrite, nitrate, ammonia, and ammonium. | Useful for understanding nitrogen sources and how readily the nitrogen will be taken up by plants. |
| Total phosphorus, mixed forms | µg/L | TP | Captures all forms of phosphorus. | Important overall parameter to understand nutrient levels in a waterbody. |
| Orthophosphate | µg/L | $PO_4^{3-}$ | Inorganic form of phosphorus that is most readily taken up by aquatic plants and algae. Equivalent to Phosphorus as $PO_4^{3}$. | Valuable for monitoring inputs such as fertilizers in agricultural and urban runoff, sewage, and industrial effluents. |

## What are the challenges of using nutrients as a water quality parameter?

Monitoring for nutrients can be challenging because it involves measuring very low concentrations, down to 0.01 mg/L or even lower. Nutrients are also difficult to monitor because of seasonal and episodic trends. In some cases, such as agricultural areas, year-round sampling may be warranted to capture seasonal trends in nonpoint source pollution. However, sampling is generally conducted in the summer because of weather and safety considerations. Another challenge is the lack of specific numeric thresholds for assessing water quality when the criteria are narrative.