Why is Stream Water Quality Important?

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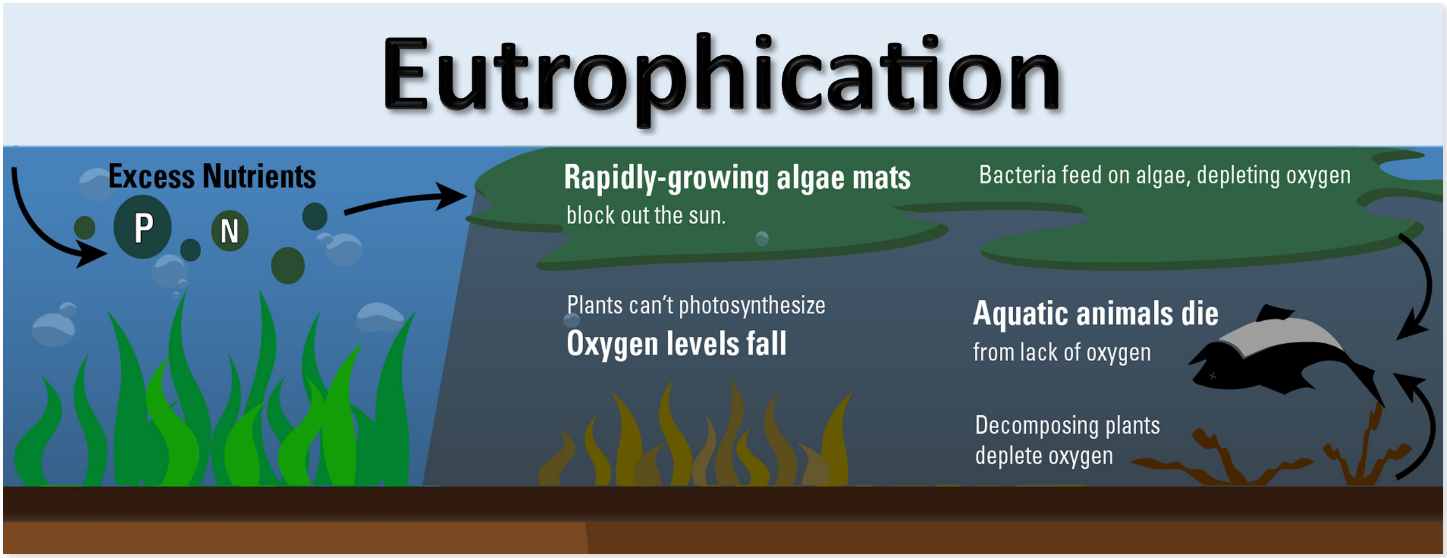
Introduction

Water quality can provide an indication of the overall health of aquatic systems, such as lakes, reservoirs, rivers, and streams. We often assess water quality using the following measurements: water clarity, salinity, nutrient and chemical concentrations, aquatic organism abundance, presence of harmful bacteria, and physical and hydrological conditions (Florida Keys National Marine Sanctuary, 2011). While water quality considers only what is present in the water column, effects of water quality can manifest throughout an entire ecosystem, from tiny organisms that live in the sediments in streams to aquatic plants and fish. Poor water quality can indicate an unhealthy ecosystem, and good water quality can indicate a healthy, thriving ecosystem. Due to its ability to indicate ecosystem health, water quality is an important consideration when studying lakes, streams, and other surface waters. This factsheet will help readers understand the different parameters and importance of water quality in surface water.

Water Quality is Important for Aquatic Organisms

One main aspect of water quality is the resource it provides as a habitat for aquatic organisms. Aquatic organisms are plants or animals that live at least part of their life in water. Good water quality ensures that aquatic organisms will have both physical and chemical water quality needs met. For example, fish are often sensitive to water temperature fluctuations, so fish prefer deep pools and shade from fallen logs or undercut banks to keep cool. Fish also lay eggs under small rock particles in stream beds under small rock particles to prevent their eggs from being pursued by large predators. However, fish eggs can be smothered in a streambed containing large amounts of fine sediment. Fine sediment, such as soil lost from erosion and transported in runoff from a nearby field or unpaved road, fills the gaps in rocks on the stream bottom and limits oxygen availability for the fish eggs. These are examples of physical-hydrologic characteristics that help maintain aquatic health.

Figure 1. Eutrophication is the process by which nutrient enrichment causes harmful algal growth, which can block sunlight and inhibit aquatic plant growth.



Note: Oxygen levels decrease due to microbial activity feeding on algae and decomposing plants, and the lack of aquatic plants producing oxygen. Aquatic organisms die without oxygen. Image adapted from the Virginia and West Virginia Water Science Center (2023).

Chemical water quality information is also essential, as this data can indicate the presence of toxic chemicals, herbicides, and/or pesticides that could inhibit aquatic species growth and development. Changes in salinity levels and nutrient loads in an ecosystem are also important parameters for species habitat. Each of these water quality characteristics affects aquatic habitat, which can have pivotal effects on entire ecosystems.

The Impacts of Nutrients on Water Quality

Nutrient loads can have especially strong impacts on water quality. Nutrients, such as nitrogen (N) and phosphorus (P), facilitate plant growth and are key components of fertilizers, animal waste, and eroded soil. Farmers, residents, and even cities regularly apply fertilizer on their fields, lawns, or flowerbeds. Meanwhile, human and animal waste is generated in increasing amounts and is not always treated before leaching into the ground or spilling into surface waters via runoff. Unfortunately, terrestrial plants rarely take up all nutrients made available from fertilizers or waste, whether applied intentionally or unintentionally. Excess nutrients are washed off the land by runoff and end up in streams, rivers, lakes, and even oceans.

Excess nutrients often cause eutrophication in water bodies. Eutrophication is a process where excess nutrients in the water column cause excess growth of phytoplankton and algae (Havens, 2018; Paul et al., 2017). While this can occur naturally in some systems, the increase in eutrophication across many formerly pristine water bodies is problematic. Extreme algal growth can restrict sunlight penetration through the water column. Restricted light penetration reduces sunlight to submerged vegetation, which can be fatal for photosynthetic organisms that live on the bottom of a water body or plants that are rooted in the stream or lake bottom. Additionally, some species of algae are toxic, meaning they release harmful chemicals into the environment that can be dangerous to animals, plants, and humans (Ohio Sea Grant College Program, 2023). When large masses of phytoplankton die, whether toxic or not, they sink and begin to break down. This increases a process called respiration, carried out by decomposers, which can reduce the amount of oxygen in the water. Without enough photosynthetic organisms to reintroduce oxygen to the water column, hypoxic, or low oxygen, conditions develop, suffocating fish and other heterotrophs (Havens, 2018). The presence of excess nutrients can cause a cascade of ecosystem devastation (Figure 1).

Eutrophic conditions are becoming more problematic across the globe. In the United States, toxic algae blooms in Lake Erie and both algal blooms and hypoxia in the Gulf of Mexico have received national attention. Excessive nutrients are delivered by the Mississippi River to the Gulf of Mexico, creating a hypoxic zone in the Gulf where dissolved oxygen drops to levels where many aquatic organisms cannot survive (U.S. EPA, 2023). Many organisms must migrate out of the hypoxic zone before conditions limit their survival or they perish. Many streams in Arkansas eventually drain into the Gulf of Mexico, rendering Arkansas' role in limiting nutrient exports, and thus limiting nutrient loads delivered to the Gulf of Mexico, essential.

The Importance of Water Quality for Humans

While eutrophication can be devastating for aquatic life, humans also suffer when there is poor surface water quality. Recreation on or near water bodies is popular throughout the United States. Whether people swim, boat, kayak, hike, fish, travel or even live near water, humans can enjoy the serenity of nature. While decreased water quality reduces humans' safe access to nature and recreation, impaired water quality can also cause economic strains for communities dependent on access to surface water. Cities dependent on aquatic trade routes, annual tourism, or even commercial fisheries are all economically affected by decreased water quality. Consequently, poor water quality can limit both commercial and recreational use, which can be devastating for communities and economies dependent on access to and use of aquatic resources.

Although the recreational and economic uses of waterways are important for humans, drinking water is yet another key issue for water quality. Some regions in the Unites States, such as Northwest and Central Arkansas, depend on surface water for municipal drinking water. Water deemed safe for drinking must undergo extensive filtration and purification procedures before being dispensed to a community. However, water that is initially cleaner will have a less intense filtration and purification process. Beaver Lake, a reservoir in Northwest Arkansas, is the source for most of the drinking water for the region (Figure 2). Water is pumped from

Figure 2. Beaver Lake in Northwest Arkansas sources drinking water for the region. Beaver Lake is also a popular place for recreation including fishing, boating, and hiking.

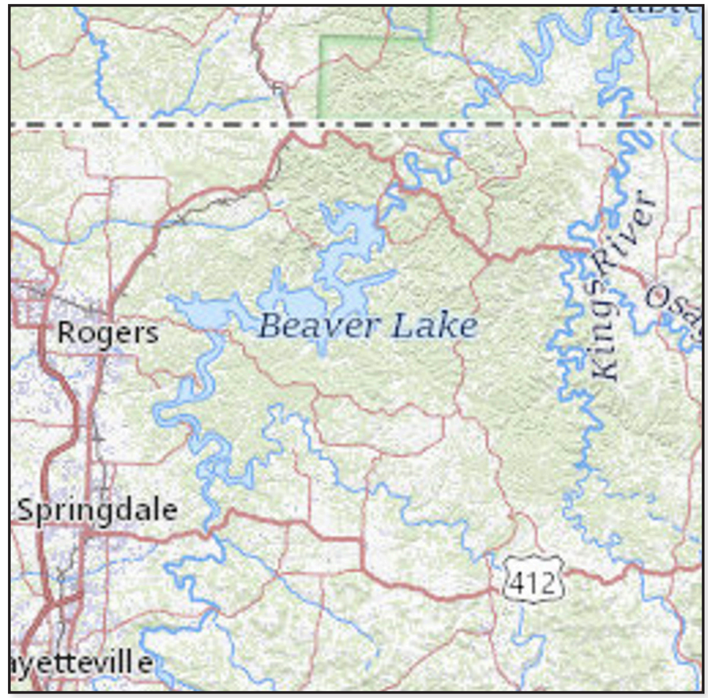


Image from the USGS Science Data Catalog (Hudson, 2022).

the lake, passed through high-tech filtration and purification systems, and then transported to homes throughout Northwest Arkansas. However, if lake water quality decreases substantially, the filtration and purification systems will have to be updated and expanded. This would require extensive time, energy, and funding from tax dollars to further purify the lake water for human consumption. In turn, this will increase costs for end-users.

Measuring Water Quality

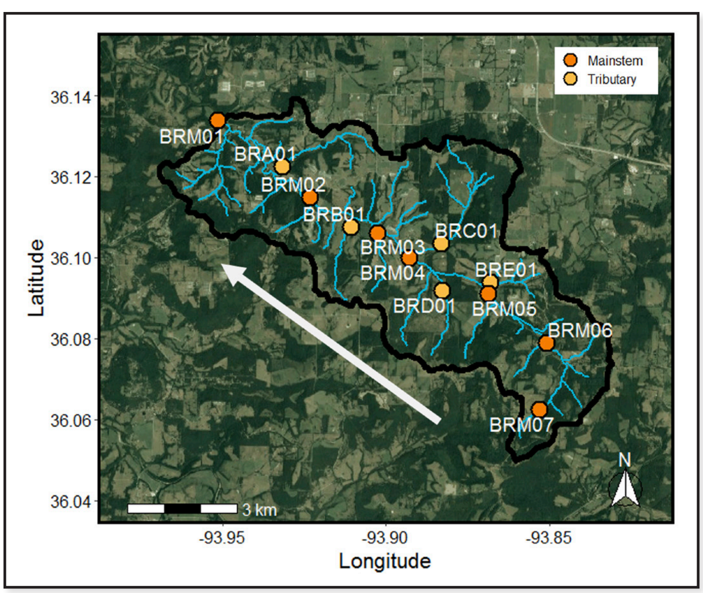
There are different standards for water quality depending on the functional use of the water and can vary by Environmental Protection Agency (EPA)- defined ecoregions (Daniels et al, 2009). Baseline water quality can vary across the nation naturally. For example, a freshwater stream in the Pacific Northwest will have lower temperatures and lower salinity than a tidal estuary in Florida. However, new fluctuations or permanent changes in water temperature, salinity, nutrients, etc. outside of the system's previously normal conditions may be detrimental to overall water quality. Depending on the ecosystem and functional use of the surface water, different measurements of water quality may be more important than others.

Brush Creek Case Study

Researchers at the University of Arkansas are conducting a watershed study of Brush Creek, a key tributary of Beaver Lake in Northwest Arkansas (Daniels et al, 2007). Beaver Lake is both the main drinking water source for Northwest Arkansas, as well as a large recreational area (Figure 2). In Arkansas, waterfront property on Beaver Lake and other lakes is highly sought after, and many people enjoy recreational use of water bodies. Therefore, limiting sediment and nutrient inputs into Beaver Lake is a regional priority. Because pasture and animal agriculture are prevalent in the Beaver Lake watershed, there is a critical need for research on conservation practices that reduce nutrient and sediment loss from agricultural lands, allowing farmers to maintain profitable agricultural operations, while protecting adjacent streams, rivers, and lakes.

Bi-weekly water samples are collected at 12 sites within the Brush Creek watershed. Seven of the sites are on the mainstem of Brush Creek, and five are tributary sites (Figure 3). Samples are collected from the most downstream site, the watershed outlet (BRM01), to the most upstream site (BRM07) to avoid disturbing sediments from upstream prior to sampling a given site. Samples are processed for dissolved nutrients, dissolved oxygen, conductivity, temperature, and turbidity at each site. Total suspended solids (TSS) are measured at the watershed outlet (BRM01), and visual flow status is recorded at each site. These measures give a snapshot of water quality throughout the watershed and demonstrate how nutrients and sediment travel throughout the watershed.

Figure 3. Brush Creek site map. Mainstem sites are noted in orange and names begin with "BRM." Tributary sites are noted in yellow. The black outline represents the watershed area, and the white arrow represents the general flow direction. BRM01 is the watershed outlet.



Nutrients. Dissolved nutrient concentrations indicate nutrient availability for living organisms. Nitrate (NO_3^-), ammonium (NH_4^+), and soluble reactive phosphorus (SRP) are measured in Brush Creek. Nutrients, such as NO_3^-, NH_4^+, and SRP, are necessary for life, but can encourage plant growth when present in excess. Additionally, these nutrients are often present in large concentrations in fertilizers and animal waste. When these nutrients leave the land in runoff and make their way into waterways, they can trigger eutrophication and other ecosystem imbalances.

Physical and Chemical Parameters. In addition to collecting water samples to characterize dissolved nutrient concentrations, dissolved oxygen, conductivity, temperature, and turbidity are also measured in Brush Creek. Dissolved oxygen indicates the amount of oxygen available for organisms within the water column. Low dissolved oxygen, or hypoxic conditions, can suffocate organisms, resulting in species migration or potential die-offs. Conductivity is a measure of ionic exchange, or electrical current in the water column, such that conductivity can be a proxy for salinity, where, as salinity increases, conductivity also increases. Temperature can be a baseline for measuring biological activity. Some species do better in warmer temperatures, while others thrive in cooler temperatures. As climate conditions change, annual water temperature conditions can also change, prompting concerns for native aquatic organisms. Turbidity measures the clarity of water, where the less turbid water is clearer and has less suspended solids than more turbid water. In this way, measuring turbidity in streams can indicate the transport of sediment, suspended algae, and other materials throughout a watershed. Turbidity in lakes and other water bodies also suggests how much filtration would be needed to purify the water for human consumption. Turbidity, temperature, conductivity, and dissolved oxygen are all measures of water quality, and are often collected in surface water research.

Total Suspended Solids. Total suspended solids (TSS) are measured at the outlet of the Brush Creek study area. Measuring TSS at the outlet most accurately quantifies the amount of suspended sediment and other solids that are discharged from Brush Creek into Beaver Lake.

Water Flow. In addition to the above water quality parameters, visual flow status is also recorded when sampling Brush Creek. Brush Creek is an intermittent stream, meaning that portions of the stream do not flow all year. In dry, summer months, Brush Creek is mostly pooled or dry in the middle of the watershed; although some sites are spring-fed and flow even during the driest conditions. Stormflow can cause consistent flow for a few days after a storm event, even in the summer. However, in wet, winter months, most sites are consistently flowing. To document flow status, sites are noted as flowing, pooled, or dry at the time of sampling. "Flowing" represents connected, moving water at the sampling location; "pooled" indicates stagnant water without upstream/downstream connectivity; and "dry" has no surface water present at the time of sampling. When a site is dry, no water quality parameters can be collected from the site on that sampling date.

Dissolved nutrients, dissolved oxygen, conductivity, temperature, turbidity, TSS, and visual flow data are all examples of water quality measurements made in streams and other surface waters to assess water conditions for a particular use. Other water quality parameters, such as microbial communities, microplastics, chlorophyll concentrations, flow velocities, and physical hydrology, may also be measured in surface water depending on the purpose of the study. Studies, such as the ongoing Brush Creek work, are needed to understand water quality dynamics within a watershed. Understanding water quality dynamics can prevent downstream ecosystem degradation, as well as maintain resilient human economies.

Summary

Measures of water quality depend heavily on the purpose of the water quality study and the water resource's intended use. Testing for drinking water quality requires different measurements than stream water quality, where the main concern may be wildlife habitat. Consequently, drinking water often comes from lakes or other surface water, so maintaining good water quality in tributary sources is important. Of course, hundreds of streams may contribute to lakes and, while some are more natural, pristine streams in forested watersheds, some streams have industrial watersheds that may include feed lots or commercial mining operations, and others may be in agricultural watersheds where fertilizers, pesticides, and animal wastes are used to produce food. While agricultural and industrial areas can be major pollutants to surface water, residential areas can also affect water quality. Leaky septic tanks, car wash soap, unpaved roads over stream crossings, and many other chemicals, nutrients, and pollutants may originate from residential areas to affect surface water quality. The Brush Creek study offers an example of water quality measurements currently conducted in an agricultural watershed that empties into a regional drinking water source. Even small changes in water quality can affect wildlife habitat, eutrophication, economies that depend on access to and use of surface water, and communities that draw drinking water from surface water. Maintaining good surface water quality throughout watersheds is crucial to thriving ecosystems and human communities. Preventing water quality degradation is a more efficient way of protecting water quality than remediation to correct degradation.

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