Supporting the Science: Exploring Stream Gases

What kinds of bodies of water exist in your neighborhood? Do you have a pond, a stream, an estuary, or maybe you live on a lake or even the ocean? Water plays a critical role in critical zone processes, including providing habitats, cycling nutrients, exchanging gases with the atmosphere, and carrying weathered rock and dissolved substances from one point to another. Researchers collect data on these indicators to determine the health of aquatic ecosystems and to study the way that these bodies of water interact with the surrounding environment. This information can be used to address environmental challenges caused by changes in land use, urbanization, water quality, and climate change.

Why study gases?

Gases can give key insights into what's going on in the aquatic environment. Different gases can be used to determine which biological functions are occurring in the water, as well as how external influences are impacting those processes. Throughout this reading, we will take a closer look into what the measured concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), as well as the ratio of nitrogen gas to argon gas (N_2:Ar) can tell us about what's going on in a stream.

Carbon Dioxide

Carbon dioxide (CO_2) is everywhere! If you don't include water vapor, CO_2 is the fourth most abundant gas in Earth's lower atmosphere. CO_2 has a strong influence over the Earth's greenhouse effect, and is a key indicator of biological activity in a stream ecosystem. The increased rates of CO_2 production is considered the primary cause of accelerated climate change today.

The cycling of carbon via CO_2 production and consumption is constantly happening between and within Earth's spheres. Photosynthetic organisms take in CO_2 during photosynthesis. In a stream ecosystem, this could include algae or plants that are submerged, floating, or emergent. CO_2 is released as a product of cellular respiration in living organisms (plants and animals), through the weathering of carbonate rocks, and during aerobic decomposition. CO_2 is also produced during the burning of fossil fuels, which humans do to power their electrical plants and vehicles.

CO_2 in streams can be used as a biologic indicator to determine the amount of metabolic activity (O_2 in, CO_2 out) occurring in a stream. Runoff from agriculture can also lead to changes in CO_2 concentrations in streams as they introduce elevated levels of organic matter into a stream ecosystem which can fuel blooms of photosynthetic algae that can increase the CO_2 levels in a stream through increased cellular respiration and decomposition. CO_2 reacts with water to produce carbonic acid, which can alter the pH of a stream ecosystem, so measuring the concentrations of CO_2 in a body of water can be used to determine the acidity of the water.

Methane

Methane is not as abundant in Earth's atmosphere, but still plays a critical role in carbon cycling and has a strong influence on Earth's greenhouse effect and climate. Microorganisms in low- or no-oxygen environments like wetlands and streambeds break down organic materials in a process called anaerobic decomposition, the products of anaerobic decomposition include methane gas (CH_4). Humans can influence the concentration of CH_4 in streams, too. Leaking natural gas infrastructure–like the gas used to heat homes–can add to the CH_4 found in stream ecosystems. Runoff from agricultural

practices can introduce more organic matter into streams, which can lead to increased rates of CH_4 production through additional anaerobic decomposition. Increases in CH_4 concentrations is typically an indicator of increased rates of anaerobic decomposition, but it can also be an indicator of gas leaks or fertilizer runoff.

Nitrous Oxide

Like CO_2 and CH_4, nitrous oxide (N_2O) is also a greenhouse gas–it's the potent of the three! N_2O is found in different intermediary steps of the nitrogen cycle. Microbes in soils and stream sediments produce N_2O during the nitrification and denitrification processes. Fertilizer runoff into streams increases the nitrogen available for nitrification and denitrification in stream beds and wetlands. Increased concentrations of N_2O in streams is usually an indicator that there is some anthropogenic source of nitrogen (most commonly from fertilizers used in landscaping practices) disrupting natural nitrogen processes in the stream ecosystem.

Ratio of Nitrogen to Argon (N_2:Ar)

Nitrogen (N_2) is the most abundant gas in our atmosphere (at 78%) followed by oxygen (21%) and Argon (~1%). The rest of the atmosphere (<1%) is made up of water vapor, CO_2, CH_4, N_2O, and other trace gases. Both N_2 and Ar are inert gases, and the concentration of Ar in any sample of atmosphere is relatively constant, compared with the localized fluctuations of other atmospheric gases. Within the nitrogen cycle, N_2 is the final product of the denitrification process. In order to determine how much N_2 is being produced via denitrification within an ecosystem, researchers can measure the ratio of N_2 to Ar. An increased N_2:Ar ratio indicates increasing rates of denitrification, which indicates increased rates of microbial activity.

Why is it important to study these gases?

The gases that we focused on in this reading are important indicators in the biologic processes that naturally occur in streams and surrounding ecosystems. They can also be used to determine if human activities (like urbanization and agriculture) are influencing those natural processes. Additionally, these gases are all greenhouse gases, CH_4 and N_2O being relatively more potent than CO_2, and so studying these gases allows researchers to evaluate the importance of dissolved gases from an urban ecosystem in the greater global climate picture.