Supporting the Science: Investigating Stream Gases

Introduction to Water Bodies

What types of water bodies can you find in your area? Are there ponds, streams, estuaries, lakes, or even the ocean nearby? Water is vital in various processes within the critical zone, including providing habitats, cycling nutrients, exchanging gases with the atmosphere, and transporting weathered rocks and dissolved substances. Scientists gather data on these indicators to assess the health of aquatic ecosystems and examine how these water bodies interact with their environment. This information is crucial for addressing environmental issues stemming from land use changes, urbanization, water quality concerns, and climate change.

The Importance of Studying Gases

Gases can provide significant insights into the conditions of aquatic environments. Different gases help determine which biological processes are occurring in the water and how external factors influence those processes. In this reading, we will explore what the concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the ratio of nitrogen gas to argon gas (N_2:Ar) reveal about stream conditions.

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is prevalent in our environment. Without considering water vapor, CO_2 ranks as the fourth most common gas in Earth's lower atmosphere. It plays a crucial role in the greenhouse effect and serves as a key indicator of biological activity in stream ecosystems. Rising CO_2 levels are primarily responsible for the accelerated climate change we observe today.

The cycling of carbon through CO_2 production and consumption occurs continuously across Earth’s spheres. Photosynthetic organisms, such as submerged, floating, or emergent algae and plants, absorb CO2 during photosynthesis. CO_2 is released during cellular respiration in living organisms (both plants and animals), through the weathering of carbonate rocks, and during aerobic decomposition. Additionally, CO_2 is generated from burning fossil fuels, which humans utilize for electricity and transportation.

In streams, CO_2 levels can indicate the amount of metabolic activity (O2 intake and CO_2 output) occurring. Agricultural runoff can affect CO_2 concentrations by introducing organic matter into the ecosystem, which can lead to algal blooms. These blooms can subsequently heighten CO_2 levels through increased cellular respiration and decomposition. Furthermore, CO_2 reacts with water to form carbonic acid, which can alter the pH of stream ecosystems, making CO_2 measurement essential for assessing water acidity.

Methane (CH_4)

Methane is less abundant in Earth's atmosphere but significantly impacts carbon cycling and the greenhouse effect. Microorganisms in environments with low or no oxygen, such as wetlands and streambeds, decompose organic materials through a process called anaerobic decomposition, producing methane gas (CH_4) as a byproduct. Human activities can also influence CH_4 levels in streams. Leaks in natural gas infrastructure, like that used for residential heating, can increase CH_4 concentrations in stream ecosystems. Additionally, agricultural runoff can introduce more organic matter, leading to higher CH_4 production through increased anaerobic decomposition. High CH_4 concentrations in streams typically indicate elevated rates of anaerobic decomposition, but can also be an indicator of gas leaks or fertilizer runoff.

Nitrous Oxide (N_2O)

Similar to CO_2 and CH_4, nitrous oxide (N_2O) is a greenhouse gas and is the most potent of the three. N_2O is produced during various stages of the nitrogen cycle by microorganisms in soils and stream sediments during nitrification and denitrification. When fertilizers run off into streams, they increase the nitrogen available for these processes in stream beds and wetlands. Elevated N_2O concentrations often signal that human activities, particularly fertilizer use in landscaping, are disrupting natural nitrogen cycling in stream ecosystems.

The N_2:Ar Ratio

Nitrogen (N_2) is the most abundant gas in our atmosphere (comprising 78%), followed by oxygen (21%) and argon (~1%). The remaining atmospheric gases, including water vapor, CO_2, CH_4, N_2O, and other trace gases, constitute less than 1%. Both N_2 and argon (Ar) are inert gases, and the concentration of Ar in the atmosphere remains relatively stable compared to the fluctuations of other gases. In the nitrogen cycle, N_2 is the final product of the denitrification process. Researchers can measure the N_2:Ar ratio to assess the rate of N_2 production via denitrification in an ecosystem. A higher N_2:Ar ratio indicates increased denitrification rates and, consequently, higher microbial activity.

Conclusion

The gases discussed in this reading are vital indicators of the biological processes occurring in streams and their surrounding ecosystems. They also help identify the impact of human activities, such as urbanization and agriculture, on these natural processes. Furthermore, as greenhouse gases—particularly potent ones like CH_4 and N_2O—studying these gases enables researchers to understand the role of dissolved gases in urban ecosystems within the broader context of global climate change.