MAGGIE XENOPOULOS straps on a pair of hip-waders, grabs a 1-litre plastic bottle from her truck and wades into Ontario's Nottawasaga river. "See this brown colour?" she says, scooping up water the colour of weak tea. "That's dissolved organic carbon. It blocks UV rays. It's a bit like SPF for aquatic life." That's not all it's good for; this murk is also a basic food source in rivers and lakes. Unfortunately, it is possible to have too much of a good thing.

Dissolved organic carbon, or DOC, naturally leaches into waterways from surrounding soil as dead plants decompose. But in recent years, the process has gone into overdrive. Xenopoulos, an aquatic ecologist at Trent University in Ontario, has been sampling rivers throughout the province for the past 12 years and has documented a steady rise. So too have scientists in other parts of North America and Europe. The consequences could be far reaching. As well as damaging aquatic ecosystems, it is likely to increase the cost of water treatment, and could even contribute to global warming.

The irony is that this so-called "browning" is in large part the result of an environmental success story: the reduction of acid rain.

Acid rain began increasing in the mid-1800s as the Industrial Revolution took off, powered by fossil fuels. Burning these hydrocarbons, especially coal, produces sulphur dioxide and nitrogen oxides, which react with water in the atmosphere to produce acids. By the 1970s, it was apparent that this was damaging trees and aquatic ecosystems, and governments started enacting legislation to clean up smokestacks. Acid rain began to decrease. But there was an unforeseen consequence. In many temperate

Rivers and lakes started to become browner when we cracked the problem of acid rain

VINCENT J MUSI/NATIONAL GEOGRAPHIC CREATIVE

TODD KOROL/AURORA PHOTOS

Vicious circle: global warming makes rivers dirtier and this in turn increases warming

and subarctic areas, deposits of sulphur had changed the chemistry of soils, making them "stickier", says Chris Evans, a biogeochemist at the UK's Natural Environment Research Council. This meant most DOC stayed put, and didn't run off into surrounding rivers and lakes. But as soil sulphur concentrations dropped, DOC became unstuck.

In the mid 1990s, Evans and two colleagues were among the first to notice rising DOC levels. A decade ago, their research revealed that concentrations in 22 rivers in the UK had increased by an average of 91 per cent over the preceding 15 years. Two years later, Evans collaborated with a larger group to reveal that rising DOC wasn't restricted to the UK. Their results, published in *Nature* in 2007, showed that 522 remote lakes and streams in North America and northern Europe had seen nearly a doubling of DOC concentrations between the 1990s and 2004. They also firmly tied the trend to decreased sulphur deposition, which had halved during the same period.

You might think that browning would abate once the excess DOC had been flushed out of the soil, but that hasn't been the case. Instead, climate change is thought to have continued the effect. Increased growth in vegetation due to greater availability of carbon dioxide, longer growing seasons and heavier rains could all be behind excess DOC flushing into rivers and lakes. "Anything that causes DOC production to go up will have a greater effect as soil stickiness is gone," says Evans, who likens it to widening the drain in a bathtub.

Global browning

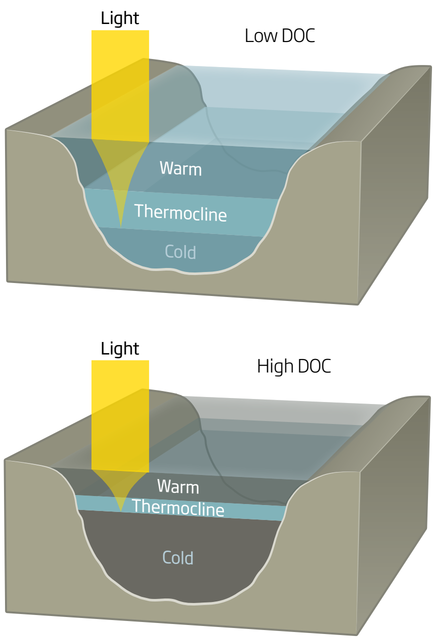
The link between browning and climate change is yet to be confirmed, but one thing is clear: more browning is bad news. One survey of 168 lakes in Norway found that while initial increases in DOC were linked to increases in brown trout numbers, continued rises caused the population to steadily drop. The initial benefits were probably due to DOC's ability to block UV rays and the fact that when it drains into watercourses it often brings phosphorus and nitrogen too, key nutrients that fuel the growth of organisms at the bottom of the food chain. However, DOC levels reach a tipping point when the water turns a deep brown, says Anders Finstad at the Norwegian University of Science and Technology in Trondheim, who led the study. This prevents sunlight from reaching bottom-dwelling algae and, if the water is dark enough, free-floating plankton. No sunlight means no photosynthesis, and no food at the base of the food web.

The opacity of the water causes another problem: it narrows the warm, oxygenated top layer of a lake – prime fish habitat (see diagram, below). "It's sort of a double whammy," says Stuart Jones at Notre Dame University in Indiana. "Lack of light means [photosynthesising] phytoplankton can't grow, so they make less food and they also can't make oxygen, so there is less suitable habitat for fish."

No one yet knows what the threshold for this switch from positive to negative effects is, although scientists expect it will be different for each ecosystem. Finstad, for example, found that shallow lakes switch at higher DOC loads than deeper lakes, probably because light doesn't have to travel so far to reach the bottom.

Deep trouble

Lakes and rivers are becoming browner as more dissolved organic carbon (DOC) enters them. This stops warming sunlight penetrating as deeply, shrinking the upper layer where aquatic life flourishes



And aquatic life isn't the only thing to suffer as a consequence of browning. With less light penetrating the water, phytoplankton die and non-photosynthesising aquatic bacteria start to dominate. These gorge on a banquet of DOC, producing carbon dioxide as waste, which enters the atmosphere where it can contribute to global warming. In other words, climate change seems to be increasing browning and browning, in turn, increases climate change.

That's not all. Rising DOC levels will raise the cost of making water safe to drink. Chlorine – a common disinfectant – reacts with DOC, leaving toxic by-products. To prevent this happening, iron and aluminium sulphate are added to the water, forcing DOC to clump together and drop to the bottom. Surface water can then be safely treated with chlorine. More will be needed if browning intensifies, and that will be expensive.

So what can we do, given that increasing acid rain isn't an option? Some scientists suggest that we should restrict development in sensitive watersheds as digging tends to hasten the release of DOC. Others say we need to reduce fishing quotas in freshwater fisheries to avoid crashes in populations. All agree we need to pay closer attention to browning. "If this continues, we're going to have dramatically different lakes and rivers," says Xenopoulos as she sloshes her way up the bank of the Nottawasaga. "This is going to be a big story." ■

Sharon Oosthoek is based in Toronto, Canada