UK Centre for Ecology & Hydrology

Is there potential to manage dissolved organic matter concentrations within upland reservoirs?

One of four FREEDOM-BCCR project briefing notes considering options to increase resilience in the water industry to climate change impacts on dissolved organic matter

Dissolved Organic Matter (DOM) in upland drinking water sources poses an increasing challenge to the water industry as concentrations have risen substantially in recent decades. Work undertaken during the FREEDOM-BCCR project has highlighted the potential for future climate change to exacerbate concentrations further, with important implications for water treatment. There is an urgent need to consider the most efficient and effective adaptation and mitigation options open to the industry to manage any resulting deterioration of raw water quality.

Climate effects on reservoir DOM

Warming across the UK resulting from global climate change will result in warmer soils and increased rates of microbial decomposition of soil organic matter. Work conducted under the FREEDOM-BCCR project has shown that warming is likely to increase the supply of this organic matter, in the form of DOM into reservoirs, particularly those with peaty catchments.

Soils are not the only source of DOM. Algae also release DOM, particularly in reservoirs with higher levels of nutrients, and their growth is also stimulated by warming (Figure 1, p2). This algal-derived DOM is less easily removed from raw water than soil-derived DOM using conventional coagulants. Increased algal production in warmer surface waters would, therefore, shift the balance of these two fractions towards DOM that is harder to treat (refer to briefing note 4 of this series for further information on DOM treatability). Compounding this, de-oxygenation of bottom waters during thermal stratification in the warmer summer months can promote the release of phosphorus from sediments, further enhancing rates of algal growth.

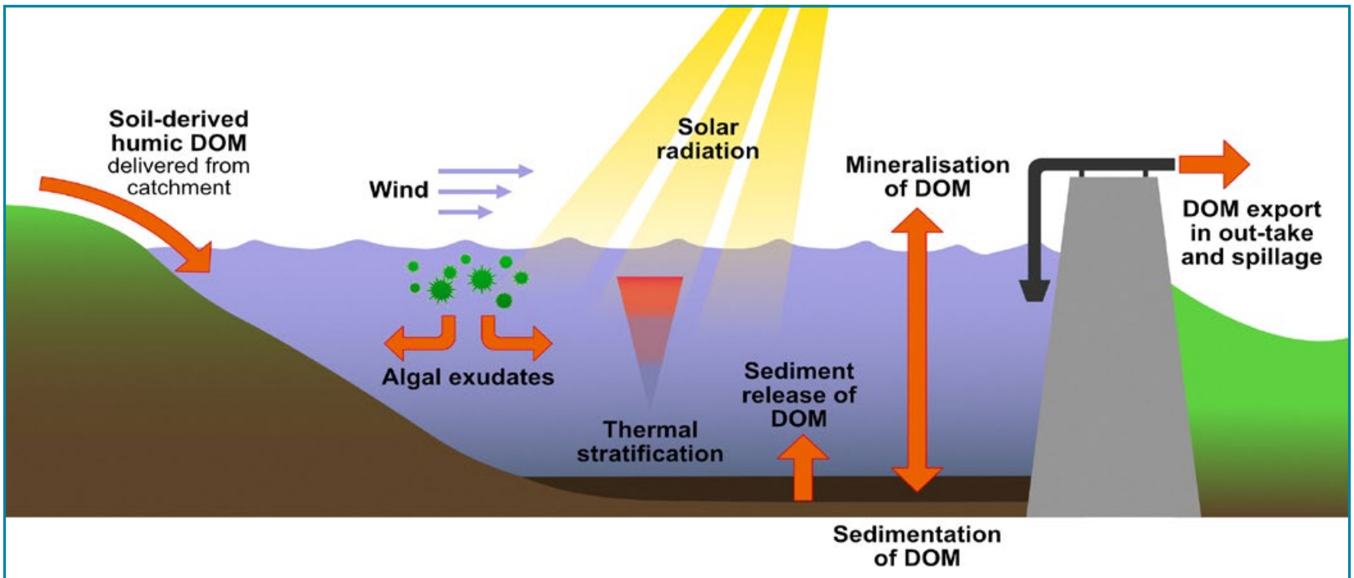

FIGURE 1
Sources and fates of DOM in reservoirs

The combination of warming and greater nutrient concentrations may favour production of cyanobacteria species, leading to taste and odour issues, and/or increase production of filamentous algae which have a tendency to block filters in the water treatment works (WTW).

Insights from FREEDOM-BCCR modelling

Scientific understanding of how changes in climate may be influencing algal production and DOM levels in reservoirs is largely based on modern comparisons between sites, as very few long-term physical, chemical and biological measurements are available for these systems.

Alternatively, process-based models can be used to apply current state-of-the-art understanding of environmental systems to determine the most likely outcome of future environmental change.

The lake model PROTECH, provides insights into how algal communities might respond to future changes in climate, and changes to the availability and balance of nutrients such as phosphorus and nitrogen. Work undertaken for the FREEDOM-BCCR project used a newly parameterised version of the PROTECH model to investigate the implications of future climate change for the timing, amount and quality of DOM produced in reservoirs. Model outputs showed that increases in water temperature will enhance rates of microbial breakdown of DOM, at least partly offsetting increased DOM inputs from the catchment.

However, warming will also increase the strength and persistence of thermal stratification of the water, thereby reducing the amount of mixing and raising the temperature of surface water disproportionately. This, in turn, will promote both algal growth in the surface waters and oxygen depletion in the cooler bottom waters. Going forward, there may be increased need to consider manipulation of reservoir processes in order to minimise the impact of climate change on reservoir DOM.

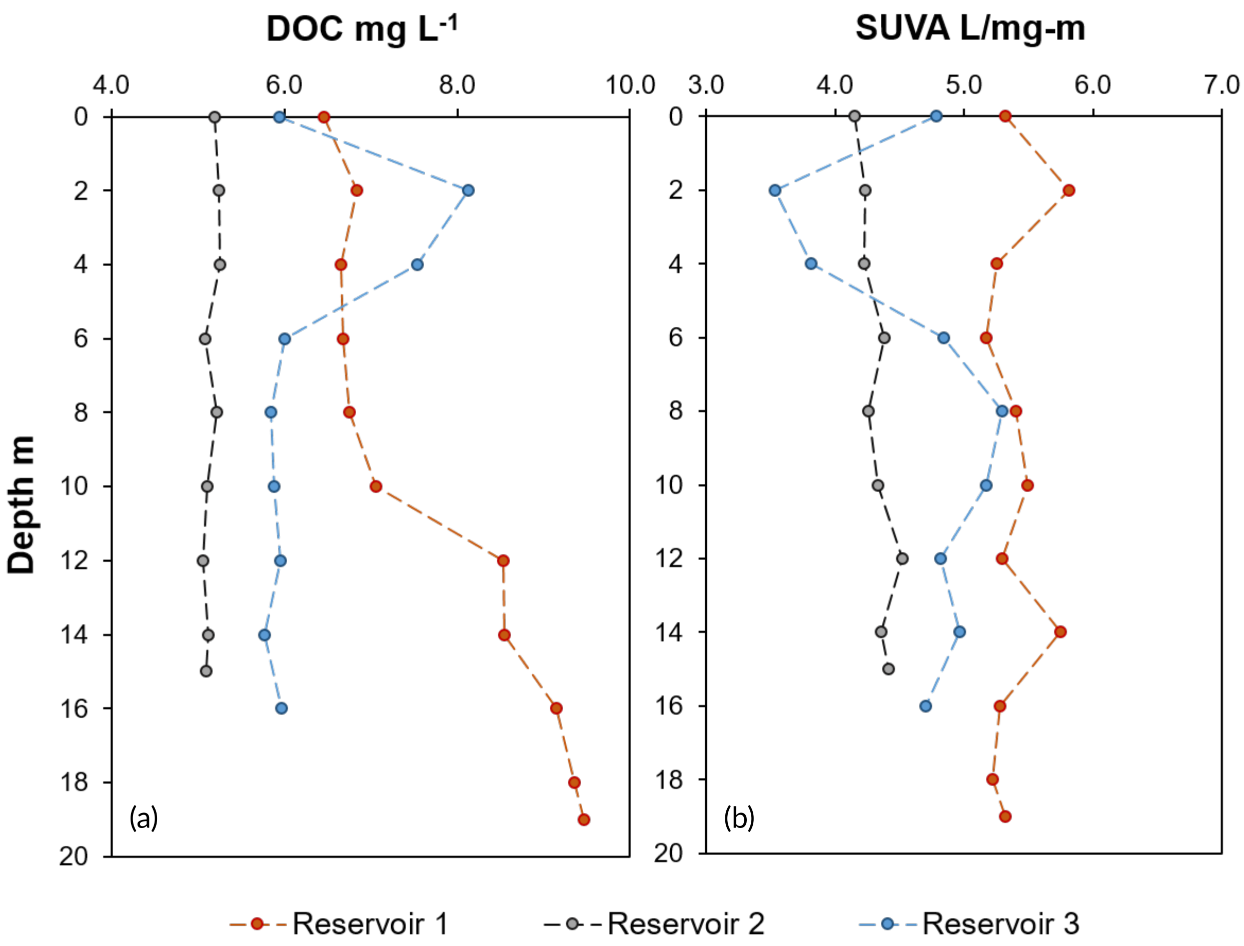

FIGURE 2

a) Dissolved Organic Carbon (DOC) and b) specific UV absorbance (SUVA) changes with reservoir depth. SUVA provides an indication of DOM molecular composition and treatability – water with higher SUVA is easier to remove with coagulant. These profiles were observed at three Scottish Water reservoirs in summer 2018, when:

- **reservoir 1 profiles** suggested DOM was being released from reservoir sediments into the water column;
- **reservoir 2 profiles** were indicative of uniform DOM concentration and composition throughout the water column, and thus a well mixed system with no clear evidence for sediment release;
- **reservoir 3 profiles** implied algal production of less coloured DOM, that is relatively hard to treat, in the near surface water.

The goal for in-reservoir intervention is to minimise within-reservoir production of DOM and/or enhance loss processes, which include sedimentation or oxidisation to carbon dioxide and subsequent loss to the atmosphere. Potential management interventions, some of which are already used to address other water quality issues, include:

i. Change in draw-off depth: has the potential, when reservoirs are thermally stratified, to avoid high DOM concentrations, along with high algal biomass and manganese concentrations, if water quality varies with depth. This could be appropriate in the instance of reservoir 3 in figure 2.
ii. Artificial mixing (aeration): breaks down the stratification of a reservoir and has the potential to reduce algal growth and increase oxygen concentrations in the dense bottom waters. The latter would prevent DOM release from the sediment. However, artificial mixing can also reduce DOM photochemical mineralisation and microbial breakdown due to decreased temperatures within the reservoir.
iii. Sediment capping: involves the application of sediment binders to the reservoir sediment surface, and has the potential to prevent DOM sediment release. It has, however, not been applied in the UK, largely because materials proposed for sediment capping have not yet received regulatory approval for use in reservoirs. There is a need for further testing of potential materials.
iv. Increasing water retention time: can increase DOM loss via sedimentation, microbial breakdown and photochemical mineralisation if a reservoir acts as a sink. Conversely, this can lead to increased algal biomass and thus increased undesirable hydrophilic DOM (refer to briefing note 4 for more information on DOM types).

It should be noted that interventions may not always achieve the desired water quality outcomes, and in some cases may cause unintended negative consequences, such as the encouragement of cyanobacterial blooms. Careful, targeted installation of measures, with consideration of biogeochemical linkages between catchment and the reservoir, is critical to success.

BOX 1 RESERVOIR MANAGEMENT MEASURES FOR DISSOLVED ORGANIC MATTER

Managing reservoirs to improve water quality

The UK water industry have investigated a range of options to manage water quality within reservoirs in order to control issues such as algal blooms, excessive manganese levels, and taste and odour problems, but relatively little attention has been given to the potential to treat DOM-related issues in this way. It is known, however, that various within-lake physical, chemical and biological processes can influence whether a reservoir acts as a sink or a source of DOM (Figure 2, p3), and it is, therefore, worth considering whether there are ways of modifying, or exploiting, these processes in order to reduce DOM concentrations in raw water intakes.

Drinking water supply reservoirs vary considerably in physical characteristics, e.g. depth, volume, wind exposure and residence time, and the quality of water they receive. Understanding how such properties influence the production and removal of DOM is critical in determining the potential for a range of possible in-reservoir mitigation options (Box 1, p4).

Because of the general paucity of temperature, algae and water chemistry data within reservoirs, particularly at multiple points through the water column, there remain considerable uncertainties regarding whole-system responses to changes in climate, and, therefore, the potential for within-reservoir management options to help maintain water quality. A more comprehensive set of observational data drawn from a range of reservoir types would greatly enhance understanding of potential efficacy of these and other within-reservoir water quality management options.

Take-home message: Climate change is expected to influence reservoir water quality, and could lead to higher concentrations of DOM and/or increases in the hard-to-treat algal-derived fraction in some instances. There is potential for management of in-reservoir biogeochemical processes to alleviate the associated pressures, but there remains a need to improve the evidence base surrounding the efficacy of these interventions, so that unintended effects on other water quality parameters can be avoided.

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How to cite

Pickard, A.E., Elliott, J. A., Feuchtmayr, H., Chapman, P.J., Williamson, J., Spears, B.M., Banks, J., Bullen, C., Leith, F., Gaston, L., Moody, C.S., Straiton, S., and Monteith, D.: Is there potential to manage dissolved organic matter concentrations within upland reservoirs? FREEDOM-BCCR briefing note 3 to the water industry. UKRI SPF UK Climate Resilience programme – Project no. NE/S016937/2. 2021.

About the FREEDOM-BCCR project

FREEDOM-BBCR (Forecasting Risks of Environmental Exacerbation of Dissolved Organic Matter in the upland drinking water supply – Building Climate Change Resilience) is led by the UK Centre for Ecology & Hydrology and funded by the Climate Resilience Programme (www.ukclimateresilience.org) - jointly led by UK Research & Innovation (UKRI) and the Met Office under the Strategic Priorities Fund (SPF).

Through the development of a community of scientists and water industry representatives, FREEDOM-BCCR aims to improve understanding of the risks posed by climate change to the quality of water in upland drinking water sources and develop a conceptual framework of mitigation and adaptation options to maximise the future resilience of the supply. The vision of the Climate Resilience Programme is "To enhance the UK's resilience to climate variability and change through frontier interdisciplinary research and innovation on climate risk, adaptation and services, working with stakeholders and end-users to ensure the research is useful and usable."

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Partners

FREEDOM-BCCR is funded through the UK Climate Resilience Programme

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