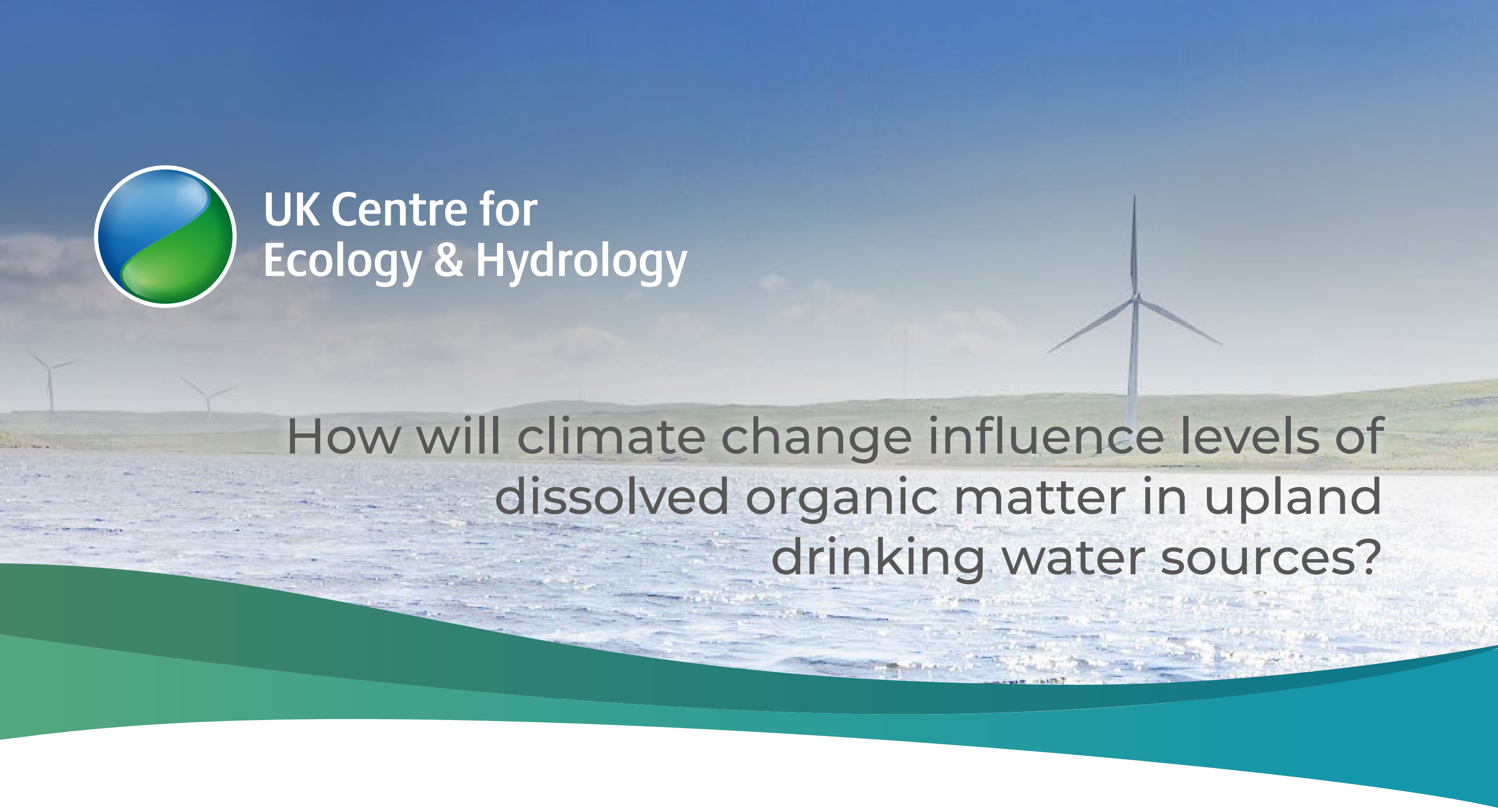


UK Centre for Ecology & Hydrology

How will climate change influence levels of dissolved organic matter in upland drinking water sources?

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

The FREEDOM-BCCR project has focussed on developing a clearer understanding of how climate change will influence future concentrations and treatability of dissolved organic matter (DOM) in upland drinking water source waters, and the options available to the water industry to mitigate potentially deleterious changes. It developed through iterative exchanges between catchment managers and engineers representing several UK water companies dependent on upland water sources, and environmental scientists. This briefing note summarises the potential impact of climate change on DOM levels in the upland drinking water supply, and the project's statistical modelling work that underpinned the exploration of adaptation and mitigation options available to the industry.

Drivers of recent increases in DOM and the potential threat of climate change

Concentrations of DOM in upland waters have been rising over recent decades. This is leading to an escalation in the cost of water treatment as a consequence of the increased use of coagulants and, in some cases, the need for investment in new treatment facilities. The increase in DOM is mainly attributable to a regional scale chemical recovery of upland soils from the effects of acid rain that impacted the UK's uplands from the onset of the industrial revolution until very recently. As acid pollutant loads have declined, soil organic matter has become more soluble, resulting in more being lost to streams and lakes in the form of DOM.

Pollutant deposition is now approaching levels last encountered in pre-industrial days, so it is likely that soil organic matter solubility is starting to stabilise. However, DOM concentrations in upland waters have also been shown to be sensitive to fluctuations in soil temperature and amounts of rainfall, and there are concerns that future changes in the UK climate, due to global warming (see Box 1 below), could result in even higher concentrations in some catchments than are currently being experienced.

How does climate influence DOM levels in upland drinking water sources?

The microbial activity that breaks down soil organic matter to generate DOM is a temperature dependent process, while the rate at which DOM is transported is partially dependent on precipitation and soil moisture. High levels of rainfall and runoff can result in a dilution of DOM. However, in less peaty catchments, DOM lost from the upper soil can be re-adsorbed by underlying mineral soils. In this case, higher flows can lead to higher concentrations in runoff when water flow paths are diverted away from the mineral soil. Consequently, DOM concentrations in upland surface waters often tend to peak toward then end of summer during periods of heavy rainfall.

Some soil-derived DOM that reaches reservoirs is broken down (or photo-oxidised) by sunlight, while some becomes incorporated in particulate matter and is deposited in lake sediments. During drier periods, therefore, when the throughput of water through reservoirs is slower (i.e. longer water residence times), a greater natural removal of soil-derived DOM occurs before the water reaches the WTW. Conversely, if the reservoir is also receiving a sufficient supply of nutrients (such as phosphorus and nitrogen) from agricultural or other sources, higher temperatures can stimulate algal growth within reservoirs. Both growing and decaying algae releases a different form of DOM that is more transparent and less susceptible to coagulation, and hence more difficult to treat using conventional treatment processes.

In the FREEDOM BBCR project, statistical models were developed to describe relationships between variations in climate and DOM concentrations across a range of upland drinking

The UK Met Office published the latest generation of national climate projections for the United Kingdom in 2019. Under a high future CO_2 emission scenario (RCP 8.5; where the acronym RCP stands for Representative Concentration Pathway - considered the 'business as usual' projection), air temperature changes averaged across the UK relative by 2070 are projected to increase by between 0.7°C to 4.2°C in winter, and 0.9°C to 5.4°C, in summer, relative to a 1981-2000 baseline. Projected changes in precipitation range from -1% to +35% in winter, and -47% to +2% in summer.

Under the FREEDOM-BCCR project, an ensemble of modelled future climate predictions (all based on the RCP 8.5 scenario), were generated at a regional level and then downscaled to individual drinking water catchments, allowing the development of future site-specific DOM predictions.

BOX 1 UK CLIMATE CHANGE PROJECTIONS AND THEIR APPLICATION UNDER FREEDOM-BCCR water sources. These demonstrated that dominant soil types and reservoir residence times were both important in determining the relative sensitivity of DOM variation to fluctuations in temperature and precipitation.

Concentrations of DOM in waters draining catchments characterised by peaty soils and short water residence times were found to be particularly sensitive to fluctuations in temperature, so that markedly higher concentrations were observed following warmer summers. In these catchments, the dominant influence of precipitation was to dilute DOM, although short-lived heavy rainfall events in late summer could also lead to DOM surges. Concentration of DOM in catchments with less or no peat coverage were less sensitive to fluctuations in temperature but more likely exacerbated by periods of extreme rainfall.

Relationships between variation in climate variables and DOM "quality", as determined by UV light absorbance per unit organic carbon (or SUVA), were also explored. This provided little evidence that changes in climate would be likely to have a significant impact on the treatability of DOM in what were mostly peaty, low nutrient raw water sources. However, work conducted elsewhere has highlighted the sensitivity of disinfection by-product formation during the chlorination process to water temperatures. This suggests that pre-treatment DOM concentration thresholds might have to be reduced to compensate for the potentially higher chemical reactivity of DOM in warmer water.

FREEDOM BCCR outputs have also shown that the average seasonal pattern of variation in DOM concentration for a water source can be used to predict the sensitivity of a specific site to the effects of changes in temperature and precipitation. This finding formed the basis for the development of a single predictive model that could be applied to a wide range of catchment types.

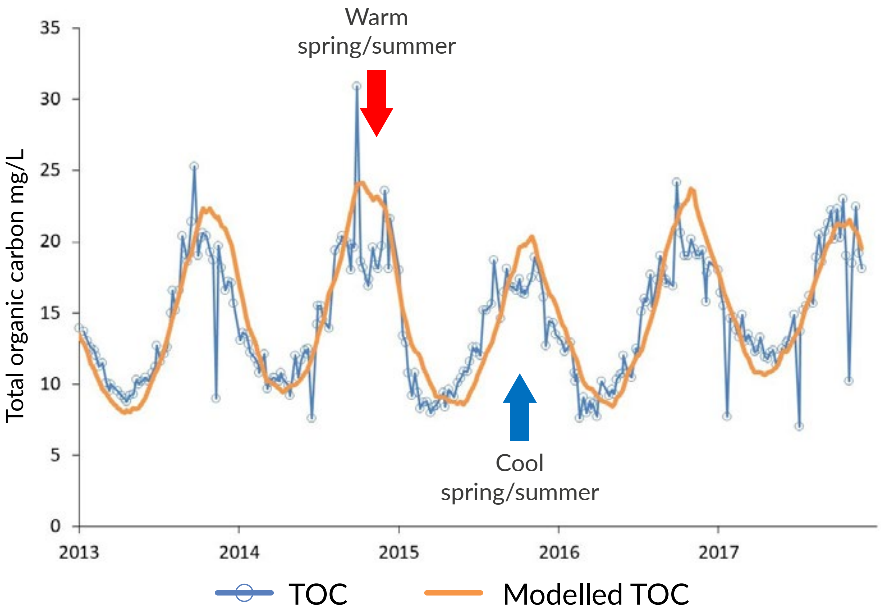
Modelling future DOM change in upland drinking water supplies

Future temperature and precipitation predictions for multiple future climate change projections under the RCP 8.5 scenario (see Box 1, p2) were obtained from a Regional Climate Model at a 12 km^2 resolution. The different projections, representing slightly different rates of warming and changes in precipitation patterns, were chosen to provide a range of plausible future climate change outcomes. All projections indicated a steady ramping in air temperatures up to 2080, and less consistent and more seasonally variable changes in precipitation. These were then downscaled to the 1 km^2 in the centre of each water source catchment, and used to feed site-specific DOM predictions on the basis of the statistical modelling described above (see Figure 1, p4).

Implications for increasing the resilience of the water supply to future climate change

Future warming, and any trend toward drier summers, is likely to result in significantly higher DOM concentrations in water draining peat-dominated catchments particularly. Catchments with more freely draining organic soils appear less sensitive to thermal effects. Concentrations in these systems could be exacerbated if rainfall events become more frequent and intense. In both cases these effects could be magnified in catchments still recovering effects of acid rain where organic matter solubility is still increasing. While expected future changes in DOM are likely to be relatively modest compared to the large changes experienced over the last 30 years, current levels of DOM in some catchments are approaching the upper end of the receiving WTWs treatment envelope. There is a need, therefore, to recognise that future DOM changes will vary in magnitude between catchments, and that some WTWs are currently better equipped than others to cope with increases.

(a)



(b)

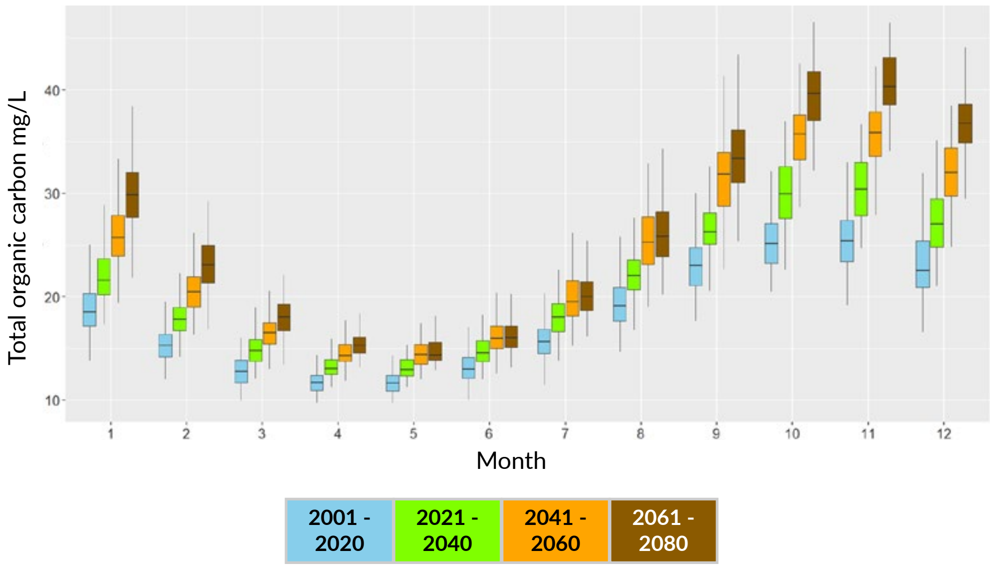


FIGURE 1 EXAMPLE OF THE STATISTICAL MODELLING OUTCOMES UNDER FREEDOM-BCCR

a. The catchment of this reservoir is dominated by deep peat soils and has a relatively short residence time. Total Organic Carbon (TOC) concentrations showed strong seasonality, with TOC peaking in early autumn each year. Modelling demonstrated a strong dependency of TOC in the reservoir source water on temperature during the previous 2 months, while periods of higher rainfall were associated with lower TOC concentrations. While variation between years in peak concentrations was most clearly linked with variation in summer temperature, the relatively high winter-spring concentrations in 2017 were related to a period of unusually low winter rainfall.

b. 1 km^2 downscaled future temperature, precipitation and soil moisture predictions were fed into the site-specific model to predict future ranges of DOM for each month of the year for five 20 year periods between 2001-2080 (represented by the coloured boxes). The model predicted that by 2070 TOC concentrations in October in this particularly temperature-sensitive catchment could be approximately 30% higher than currently experienced, largely due to the projected increase in temperature.

Take-home message: Concentrations of dissolved organic matter in upland drinking water supplies have been rising over recent decades, largely as a consequence of soil organic matter becoming more soluble as soils recover from effects of acid rain. However, concentrations reaching WTWs may be further exacerbated by anticipated changes in climate. Water draining small peaty catchments will be most vulnerable to warming, while DOM concentrations in catchments with a greater coverage of organo-mineral soils will be most sensitive to fluctuations in precipitation. In order for the water industry to increase the resilience of their assets, there is a need to determine where current treatment capacity is most vulnerable to these effects, and to consider the range of potential adaptation and mitigation options across the catchment to WTW continuum, as explored through the course of the FREEDOM-BCCR project.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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

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