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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Will UK peatland restoration reduce dissolved organic matter concentrations in upland drinking water supplies?" *by* Jennifer Williamson et al.

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Anonymous Referee #2 Received and published: 3 May 2021 Overall, the paper covers an interesting topic that is within the scope for HESS. It is interesting to acknowledge that DOC has been increasing in the UK and is impacting water treatment. The real substance of the paper is assessing literature about catchment management benefits on DOC export, and whether this can be an effective strategy to reduce DOC in waters. Whilst the paper is relevant and covering and interesting topic, I do not believe it is yet ready for publication. The structure of the paper has problems in my view that detract from the story and I found many sentences and paragraphs lack-

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Discussion paper

ing the necessary level of precision and accuracy to really support the claims. There are also typographical and editorial issues, making it seem it wasn't thoroughly proof-read before submission. The paper is reviewing literature, mainly specific to material UK, but needs to more obviously try to bring together the story and synthesize the results. After reading the conclusions I was not convinced about the scale or nature of the benefits from different management actions, and yet strong statements are made recommending catchment management. I also found the section on in-lake processing to be too generic without a clear focus – the message is that lake processes can mediate (increase or decrease) incoming DOC before it hits the treatment plant, but I find lacks any clear conclusion, other than making a connection with nutrient management. What is the typical difference between input DOC and offtake DOC? Even as a broad range to give some indication would make the review much more powerful. For a review like this I refer to the authors to a document like this one: https://www.sciencedirect.com/science/article/pii/S221501611930353X "Method for conducting systematic literature review and meta-analysis for environmental science research" by Mengist et al. Ideally adding some conceptual models or diagrams bringing together the ideas in the paper would be very beneficial and help add meaning to the literature, which is currently quite mixed in terms of its results, as a way explaining some of the differing reports. For this reason, I think the paper needs some major revision and re-working to give it improved focus and flow, refine some of the text, and to highlight key take home findings that are supported by the data. It could certainly be a strong paper with some further development, and I have provided some more specific comments below to support the recommendation. We thank the reviewer for their time and helpful comments on the manuscript.

2.1: Abstract The two opening sentences could be better re-written to highlight the problem to the water industry. Currently it is asserted to be a problem and implied to be associated with colour, but I suspect the concern is related to treatment by-products. For the sentence "One of the primary evidence gaps is the extent to which catchment management is capable of influencing DOM concentrations at the point of abstraction,

field studies rarely extending beyond sub-catchment or stream scale." . . .needs re-wording – the first part makes sense but the second half is a fragment. Given the lack of evidence is discussed to establish the link between management and response, including something like "research priorities were therefore established" would be logical, rather than ending on the result that evidence is insufficient. Further, the last sentence and second-to-last sentence seem to contradict each other. One says insufficient for wide spread application and then it says the measures have good potential. I think these two sentences could benefit from some rewording to avoid confusion, and make the outcome of the paper more clear. Reword abstract to fit above comments: 80% of the large reservoirs constructed for public water supply in the UK are in upland areas (CIWEM 2011), the majority of which are situated in catchments that contain at least some organic rich soils. Organic matter leaching from these soils imparts a brownish colour to water, primarily due to the presence of dissolved organic matter (DOM). Water companies must ensure DOM concentrations are at negligible concentrations prior to chemical disinfection to prevent the formation of potentially harmful disinfection by-products, and to minimise taste and odour problems. In recent years, water companies have increasingly considered the capacity for catchment interventions to improve raw water quality at source, relieving the need for costly and complex engineering solutions in treatment works, but there is considerable uncertainty around the effectiveness of these measures. The primary evidence gap is the extent to which catchment management is capable of influencing DOM concentrations and treatability at the point of abstraction, as the majority of published field studies have been carried out at plot, sub-catchment or stream reach. Published evidence for the effectiveness of the four main catchment management options utilised on organic soils (ditch blocking, revegetation, reducing forest cover and cessation of managed burning) for reducing DOM concentrations or increasing treatability is generally insufficient to support wider scale application at present. The evidence suggests that the presence of plantation forestry on peat soils is increasing DOM concentrations, though studies assessing the removal of plantation forestry have found that this effect is not rapidly reversed. Although not

widely studied, the available evidence suggests that Sphagnum mosses produce DOM that is more easily removed via conventional treatment processes compared to vascular plants such as heather and grass species. One evidence gap that became apparent during the review process was the extent to which in-reservoir processes may mitigate or exacerbate changes in inflowing DOM when assessed in conjunction with catchment management work. Research priorities to assess these evidence gaps include: experiments to monitor the whole catchment impact of catchment management interventions and to seek to understand the potential interactions between catchment management and within reservoir processes.

2.2: Introduction The opening sentence seeks to make the claim DOC is increasing from 1980- to present, but has a citation that is 1989 and 2001. The rest of the paragraph could be polished in terms of wording. Second sentence repeats the claim of 1980's beginning. Last sentence suggests a more recent reference which is good, but comes after a sentence related to international evidence. Overall, I the paragraph is somewhat awkward, and could more clearly make the argument that a) UK rivers have experienced rising DOC from 1980 to present, and b) similar trends have also been seen elsewhere in the world. The paragraph also doesn't give much quantitative evidence of how much things have changed. It is probably beneficial to include here a figure (or reproduce a figure?) allowing readers to see an example of what this increasing trend looks like.

We suggest including the attached figure showing the annual mean and standard error DOC concentrations from the Upland Waters Monitoring Network sites and rewording the paragraph as follows: Dissolved organic matter (DOM) concentrations in UK surface waters have been rising since the 1980's (e.g. Naden and McDonald, 1989;Watts et al., 2001, Harriman et al., 2001;Robson and Neal, 1996, Freeman et al., 2001;Worrall et al., 2004) and subsequently this has emerged as an international phenomenon affecting surface waters across large areas of Europe and North America (Monteith et al., 2007). The UK Upland Waters Monitoring Network demonstrates that the in-

crease in dissolved organic carbon (DOC) concentrations is sustained, though the rate of increase has reduced in recent years, with DOC concentrations in 2015 being approximately double those seen in the late 1980's (Figure above). At the sub-catchment scale Chapman et al (2010) found that water colour increased by between 22 and 155 percent over a 20 year period between 1986 and 2006.

2.3: Lines 48-60 are describing DOM but no references support the statements. As mentioned in reply to reviewer 1 at comment 1.1.

2.4: Section 1.2 heading issue Line 73 – why is E coli mentioned? Is it related to DOM? If not provide context. Does this need Paragraph 1 would sit better after the DBP/THM paragraph, before the paragraph starting as "Higher concentrations . . ." The reference to the E.coli limit is because elevated DOM in treated water can provide a substrate for bacterial regrowth in the water pipes. Also, the reaction between free chlorine residuals and DOC that produces THMs can reduce the level of chlorine residual to a point where bacterial growth can occur should there be any incursion. As I came at this section from a water industry perspective perhaps this section would be better reframed as these are the potential risks from elevated DOM in water supplies and these are the regulatory measures in place to ensure public safety, which is I think the order the reviewer suggests above, and we will modify the order as suggested.

2.5: Line 91 – Opening line would benefit from a reference The information regarding potential increased treatment processes (lines 91) has resulted from numerous discussions with water industry representatives as part of the NERC funded Freedom project that funded this review. The outcomes of these discussions are currently in the final editing process before publication as a series of briefing notes aimed at the UK water industry so we would suggest referencing Pickard et al 2021 (full reference: Pickard, A.E., Chapman, P.J., Williamson, J., Spears, B.M., Banks, J., Bullen, C., Leith, F., Gaston, L., Moody, C., and Monteith, D.: Rising concentrations of dissolved organic matter in drinking water supplies: can peatland restoration help? FREEDOM-BCCR briefing note I to the water industry. UKRI SPF UK Climate Resilience programme – Project

no. NE/S016937/2. 2021.)

2.6: Section 1.3 is interesting. I think it could be refined to more clearly point out that there are drivers associated with (geo)chemical changes and those associated with hydrological changes; currently they are slightly intertwined. The section could end by summarising the research unknowns that remain. The climate change sentence at the end seems to be less relevant to this section since it is explaining the past and I don't think the single sentence does this issue justice. Maybe this would be better moved to the start of paragraph 2; something along the lines of "As sulphur deposition declines towards pre-industrial levels, hydrological drivers are likely to become the dominant driver of DOM change. Future climate change is predicted to result in increased temperatures and more extreme storm events (Met Office 2019)..." into paragraph 2? Since the early 2000's a number of hypotheses have been advanced to explain regional scale increases in DOM concentrations, some focussing on the impact of land use change, others focussing on the impact of climate change (on DOC production and hydrological processes) and others on the interaction between nutrients within the peat'. These initially focussed on increasing temperatures (e.g. Freeman et al., 2001), drought-rewet cycles (e.g. Watts et al., 2001), and increasing atmospheric carbon dioxide concentrations (Freeman et al., 2004), before negative correlations with indicators of acid deposition, such as sulphate concentration, became increasingly apparent in the USA (Stoddard et al., 2003) and UK (Evans et al., 2005). A regional study of DOC trends (Monteith et al., 2007) demonstrated consistent significant negative relationships between rates of change in acid anion concentrations (sulphate & chloride) and rates of change in DOC, and that the effect was more marked for waters with lower concentrations of calcium and magnesium (i.e. base cations). Hence, sites with soils that were least able to buffer the effects of deposited acidity were the most responsive. The links with changes in atmospheric deposition have since been supported by studies of soil cores (Clark et al., 2011) and field experiments (Evans et al., 2012;Ekström et al., 2015). Hruska et al. (2009) demonstrated that ionic strength (a measure of the electric charge produced by ions in water) is a particularly effective

chemical predictor of change in DOC. A reduction in the deposition of acid anions from the atmosphere reduces both the acidity of soil and the ionic strength of soil water, and together these processes appear to increase the solubility of soil organic matter and hence the increasing concentration of DOM draining from organic rich upland soils. DOM concentration in soil solution and surface waters is also known to respond positively to variation in temperature (e.g. Vance and David, 1991), while shifts from vertical to more lateral routing of flow paths during periods of heavy rain have also been found to increase concentrations in some circumstances (e.g. Austnes et al., 2010), with increases in DOC concentration being primarily driven by the increase in water table at the event scale (Rosset et al., 2019). Shifts in stream DOC character, and hence treatability, are also possible following changes in flow path routing as a result of DOC inputs from different source pools (Hood et al., 2006). Long-term increases in DOC in southern Sweden have been linked to the combination of decreasing sulphate deposition and a multi-decadal increase in precipitation and consequently river flow (Erlandsson et al., 2008). Future climate change, particularly in relation to increasing temperatures and a change in total rainfall and an increase in the intensity of storm events (Met Office, 2019), is therefore likely to influence future DOM trajectories and has the potential to become the dominant driver as atmospheric pollutant deposition declines toward pre-industrial levels.

2.7: Line 140 – I think a sentence that is pivoting like this needs to being with Also, or Further or In addition. Perhaps “However” would be a good start to the sentence, and would show the direction of the sentence more clearly.

2.8: Line 142 – It is asserted here that catchment management activities are not seen at the point of abstraction (presumably you mean at the reservoir outlet?) but it is not obvious from the prior text this is established. Is there a published paper saying this, or just a “hunch”? Section 2 obviously goes into this, but in this case the text is out of order. We would suggest rewriting this to make it clearer we’re referring to absence of published evidence of measured effects at the point of abstraction (which is usually,

but not always, the reservoir outlet), not evidence of absence. This is an area the water industry in the UK is picking up on but we are not aware of any published studies to date that have demonstrated the effectiveness (or lack) of catchment management at reducing DOC concentrations at the point of abstraction.

2.9: Line 147 – ditch blocking mentioned here but not above in the catchment management section, so seems out of context. I find the aims statement buried in sub-section 1.4, quite deep into the manuscript, to be somewhat awkward. The aims statement is weak in that the aim of the paper "bring together information" and "contribute to our understanding" and "go on to examine". These aims lack specificity and are overly general in my view, making it difficult for the reader to clearly understand what the outcomes of the paper will be. Whilst I acknowledge it is a review paper, a good review can still have specific aims. E.g "Is there evidence that . . .". or "The review is used to develop a conceptual model. . .." As suggested for reviewer 1, an opening paragraph to the introduction stating the aims more strongly – the question being is there evidence to support peatland restoration through catchment management being used as a tool to improve water quality at source by water companies in the UK? – would help. I think it may also help the information flow more easily – this is the aim of the review, this is the background as to why DOC in raw water has become an issue, and these are the catchment management tools that have been trialled to help solve the issue. Then the in-lake processing becomes part of an unknown within the context of catchment management – we don't know what may change within the lakes so it may be that in-lake processes "deal with" most of the extra DOC coming in anyway so reducing inflowing DOC doesn't reduce outflowing concentrations to the same extent.

2.10: Line 155 – this paragraph flows well Thanks.

2.11: Line 166 – the line "While these results are persuasive, they do not necessarily imply that effects will be translated through to surface waters and ultimately to the point of abstraction" seems unnecessary at this point, between describing pore water changes and ditch water changes. We will remove this sentence

2.12: Line 175 – I struggled to follow this logic. If a study was from a hydrological point of view then there is a view that DOC decreases? But Wilson says that DOC load went down but not conc? This section could benefit from the authors make a conceptual diagram to synthesise the results. The aim of this was to show that DOC load only decreased because water flux decreased as concentrations stayed the same. As water inputs to the catchment (rainfall) are highly unlikely to have declined by ∼90% since the start and although peat surface can move in response to rainfall inputs they don't have any evidence to suggest it's done so by the volume required, then it is likely that the water is still leaving the catchment but via an unmonitored route such as overland flow so fluxes are higher than they are reporting.

2.13: Line 207 – I don't think the last two sentences of this paragraph are relevant for an international journal. We will remove these sentences.

2.14: Line 331 – This sentence is not really adding anything – It is great people are doing more work, but in this paper it would be just better to present published findings. We will remove this sentence.

2.15: Section 3 – this section reads reasonably well. The key is whether the creation or consumption of DOM is big or small relative to the a) the observed increases mentioned in the introduction, and b) the catchment management activities. I cant tell from reading this. We will include this as one of the uncertainties in our understanding of the interactions between catchment management and inn-lake processes.

2.16: Conclusions – A lot of the conclusions seems more like opinion, and I'm looking for more specific summary here – scientifically what is the evidence, per km2 of land, that DOC will go up or down for a given intervention? Is one intervention more effective? How does land management actions compare to in-lake processes in potential amounts of DOC removal? Finally, is there a role for models to help compute a DOM budget? It seems that modelling is overlooked, but can be useful for assessing this issue and so should be in the review.

We feel that part of the conclusion of this review is that the evidence is not yet there to be able to put a figure on a given intervention changing DOC concentrations by X per km2 of land under differing management. The aim at the start of the project was to be able to do this but we haven't found sufficient evidence in the published literature. There is a role for modelling but feel that this is outside the scope of this review. We can include mention of models in the conclusions section as part of the suite of tools available to assess this issue but it is possible that parameterising such models would have the same issue of data availability. We agree that a good future point to reach would be if a water company (or other interested party) could have the information that they are blocking ditches on X ha of a catchment, revegetating Y ha and restoring Z ha of conifer plantation to bog and use that to predict a reduction in DOC by . . .mg/l but there isn't this level of information available that we can identify at present.

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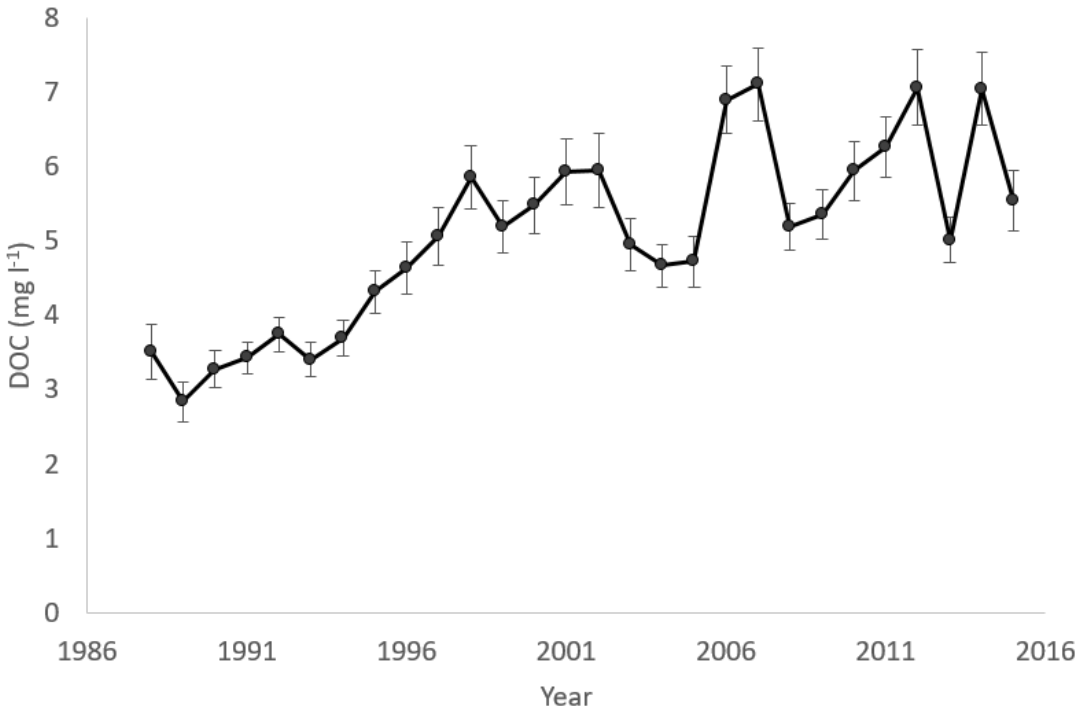

Fig. 1.

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