

## ***Interactive comment on “Effects of ozonation and temperature on biodegradation of natural organic matter in biological granular activated carbon filters” by L. T. J. van der Aa et al.***

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### General comments

This manuscript evaluates factors affecting biodegradation processes in activated carbon filters, a subject relevant for the DWES. It confirms previous findings that pre-ozonation improves removal of organic matter in activated carbon filters and shows that oxygen consumption can not be used as direct indicator to describe biodegradation in these filters. The manuscript is showing the discrepancy between the removal of organic carbon and oxygen consumption and CO<sub>2</sub> production. Scientific approach and methods applied are valid; the description of experiments and calculations is complete

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and methods and assumptions are well outlined. The results are presented and discussed in a clear manner and support conclusions. The authors give credit to related work and indicate their own new contribution. The title is clear the abstract provide a concise summary. The overall presentation is well structured and clear in fluent and precise language. Mathematical formulae, symbols, abbreviations, and units are defined and used correctly.

### Specific comments

Abstract: Page 1. row 20. Please indicate by how much percent was the theoretical ratio between oxygen consumption and DOC removal exceeded. Page 1 . row 24. Bioregeneration of large NOM molecules was considered not to occur, due to sequestration. Please indicate whether this assumption is still valid and what other mechanism may explain the excess of oxygen consumption at high temperatures.

Introduction: Page 2. row 2. Activate carbon is used worldwide, mainly for same reasons. Suggestion is to remove “In the Netherlands...” Page 2. row 3. please replace ...”and the removal of substances”... by ...”and organic compounds”

Page 2. row 15. I suggest starting a new paragraph that describes benefits of biodegradation with the sentence “When a part of ... “.

Page 2. row 26 -30... Please consider shortening the text to: “A part of NOM can be used by heterotrophic bacteria for growth and maintenance as a source of carbon and energy. In this process bacteria consume oxygen and produce carbon dioxide and water.

Page 2. rows 30-32. “The oxygen consumption per amount of biodegraded NOM is constant (Urfer and Huck, 2001)...”. Urfer and Huck, 2001 measured biological activity as oxygen consumption after the addition of defined substrate to a sample. Oxygen consumption for this particulate substrate is constant. However, the amount of oxygen used for metabolism of various organic compounds varies with the compound.

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Therefore this sentence may be misleading. Please consider removing or changing. Also the purpose of next sentence is not clear. Please consider reformulating ex.: Aerobic biodegradation can be assessed by measuring oxygen consumption and CO<sub>2</sub> formation.

Page 2 row 32 - page 3 row 1-2. Please consider deleting text: "Each bacterial species. . .while others are hardly biodegraded" It does not add much to the information that is stated in the following sentence: "NOM in natural waters. . .".

Page 3 row 2-7. Please consider changing the sentences "NOM in natural waters. . . . . (... Yavich et al., 2004)." to: NOM in natural water sources that are used for drinking water production is usually not easily biodegradable. Pre-oxidation of this water during the treatment process increases biodegradability of NOM, resulting in increased concentrations of . . . . . (...Yavich et al. 2004)"

Page 3 rows 9-15. Please consider starting a new paragraph with the sentence: "Biodegradation increases. . .". This paragraph is about biodegradation in activated carbon filters and previous about biodegradation in general. Please change sentence: "Biodegradation increases. . . ." into "Biodegradation in (B)GAC increases . . . ."

Before explaining the objectives of the research please indicate why we still need more research on biodegradation in GAC. What was the purpose of quantifying effects of ozonation and temperature on the biodegradation?

Methods and Materials:

Page 3 row 30. Please indicate residence time in reservoir.

Results and discussion:

Page 5 rows 15-20. Please indicate if the applied method for CO<sub>2</sub> calculation is sufficiently sensitive to detect reduction of 0.17 g C m<sup>-3</sup> of DOC.

Page 6 rows 26-30. You indicate that due to ozonation AOC concentration in the in-

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fluent is increased and that none of the filters receiving ozonated water were able to reduce AOC concentration to the level before ozonation. Table 3 suggests that the GAC filter receiving non ozonated water is producing AOC, while other 3 filters are removing the AOC. As GAC filtration is not employed for bio-stability, but for other purposes, please clarify what was the effect of GAC and (B)GAC on bio-stability.

Page 8 row 2. Please add "of" before ". . .DOC, AOC and . . ."

Page 8 rows 1-9. Note that oxygen may also be consumed for microbial oxidation of inorganic compounds (ammonium, nitrite, iron). Figure 5 shows that there is also oxygen consumption and CO<sub>2</sub> production before day 194. This should also be considered in the discussion about oxygen consumption and CO<sub>2</sub> production. Page 8 paragraph 3.2.1 In table 3 average oxygen removal per g DOC is presented for different ozone doses. Please consider presenting the difference in oxygen consumption in the filters receiving water after different ozone doses at different temperatures by plotting dO<sub>2</sub> gC<sup>-1</sup> with temperature for 4 different ozone doses in a new figure. Figure 5 indicates highest oxygen consumption at maximum temperature in the filter receiving non-ozonated water. Please address this observation too. Nature of substrate may have effect on the oxygen uptake. Page 9. Paragraph 3.2.3 Please define the change rate in the biomass activity. This is not clear. Depending on the generation time, biomass in GAC filters is completely replaced each In the summer GAC filters are backwashed more often than in the winter what indicates that in the summer more material is accumulated in a filter than in the winter. This material may partly originate from bacteria. Furthermore, increasing temperature is associated with increasing metabolic activity implying higher turnover. This indicates that biomass is more often replaced per unit of time in the summer than in the winter. However, some researchers found lower bacterial growth efficiency at higher temperatures, thus less biomass production but higher respiration at higher temperatures (G. Daneri, B. Riemann and P.J.IeB. Williams. 1994. Journal of Plankton research 16(2): 105-113). Although the correlation between DOC removal and temperature was not significant, figure 4 suggest that for the high ozone

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dose temperature may have an effect on DOC removal (a). Was this data set tested separately? DOC removed in a GAC filter is used for the biomass production and for the maintenance (respiration). The amount of organic C assimilated by bacteria is the sum of bacterial production (BP) and bacterial respiration (BR). Bacterial growth efficiency (BGE) ( $BGE=BP/(BP+BR)$ ) vary for aquatic bacteria between 0.05 and 0.6 and is determined by the rate of supply of energy, the quality of substrate and the energy demands (P.A. del Giorgio and J.J. Cole. 1998. Bacterial growth efficiency in natural aquatic systems. *Annu. Rev. Ecol. Syst.* 29:503-541). Higher oxygen consumption at higher temperatures may indicate higher respiration rate and lower bacterial growth efficiency resulting in same DOC removal but higher consumption of oxygen. Nature of substrates and availability of nutrients in the summer and in the winter may also contribute to differences in bacterial growth efficiency. Furthermore, bacteria in a starvation/limitation phase can utilize internally stored substrate resulting in increased oxygen consumption.

The average oxygen consumption is similar for all filters (table 3), while average CO<sub>2</sub> production varies much more among filters. Please address this observation.

Page 9. row 28. Please consider adding a sentence after the text: "It is possible that at higher temperatures adsorption decreased...". This means that more NOM become available for the biodegradation and therefore more oxygen is consumed as more NOM is biodegraded. Page 10 row 26. Explain why bio-regeneration of large NOM molecules is not likely to happen. Degradation of the side chains of adsorbed NOM molecules could be another mechanism of extra carbon supply in the summer. Conclusions Page 11, row 4. Please explain how is this calculated? AOC production depends also in DOC concentration. It is not clear how is the DOC concentration considered here. Page 11, rows 7-10. Please see the comments for page 6 rows 26-30.

Table 3. Please indicate also minimum and maximum value of the removal (production) absolute and relative (%).

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