Additional Q&A for **Freshwater Science: Removing Algal Toxins from Drinking Water with Activated Carbon**

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1. I do not have GAC. I use a PAC wood/coal mixture. could we highlight on that a tad? What would be a good dosage PAC for “insurance”?

   Unfortunately, the answer to this question will depend upon the specific configuration of the system, water composition, toxin concentration and PAC properties. However, with the use of a wood/coal PAC the dose should be lower than if a coal-only PAC were used.

2. Have you validated dosing recommendations using Ohio waters experiencing harmful algal blooms? Do recommendations account for NOM and other constituents that might compete for adsorption sites?

   As described in Bajracharya et al. (2019), we tailored the water composition in our experiments to mimic conditions present in a typical Ohio fresh water (e.g., pH and alkalinity). We also evaluated the impact of NOM, including with NOM that was isolated from Grand Lake St Marys, which has chronic blooms. The results demonstrate that NOM competes strongly with microcystins for adsorption sites. This competition is lower for PAC that has a high content of mesopores, like a wood-based PAC.

3. How does contact time and mixing velocity impact adsorption of HAB toxins prior to coagulant addition at rapid mix?

   We have not specifically looked at this particular question, however, contact time is an important factor in removal. Our results presented for microcystin-LR in Bajracharya et al. (2019) demonstrate a strong dependence on contact time. This likely reflects the influence of the time required for toxins to diffuse to accessible sites within the interior pores of PAC once those at the surface are saturated. Thus, there might be a slight dependence on mixing rate during the very initial stage of toxin removal but over more extended times it is this pore diffusion process that will dominate the overall removal.

   The role of coagulant addition is an interesting question that we are currently looking to investigate. We have collected preliminary results with alum and PAC that don’t demonstrate a significant influence of alum addition on microcystin removal by PAC. We caution that these are very preliminary and thus more results are needed to better understand these systems.

4. Also, is adsorption effective after coagulant addition (i.e. during flocculation process)?

   See response to question #3. This is an important question that we are looking to further investigate. Results we have collected to date as well as those in the literature are very limited at this time.
5. When evaluating the role of water composition, was DI water with TOC added or was the TOC matrix from natural sources used? What was the matrix?
As noted in our response to question #2, the water matrix used was formulated to mimic the composition of an Ohio surface water. Details of the composition can be found in Bajracharya et al. (2019).

6. What happens to the toxin when in the pore?
Toxins that diffuse into the interior pores within PAC are removed from solution as they adsorb to the PAC surface. Over time it is possible that these adsorbed toxins could be desorbed from the surface and released back to solution, however, this was not something that we studied.

7. Could you please explain which methods were used to measure removal rates of MC-LR and saxitoxin?
Procedures for all experiments follow those described in Bajracharya et al. (2019), with the exception that the method of toxin detection varies. In some systems, like those described by Bajracharya et al. (2019) we used LC-MS/MS. In others we used UPLC or ELISA. In the case of saxitoxin, ELISA was exclusively used.

8. Based on what is known about taste and odor compounds MIB and geosmin in terms of molecule size and charge, what type of PAC would likely be the most effective?
We have not specifically studied the removal of these compounds, but according to a review article by Srinivasan and Sorial (2011) microporous PAC works well for MIB and geosmin. Based on our results, however, such PAC types would not simultaneously work well for microcystins.

9. Were your carbon filters “saturated” in your experiments such that competition for binding sites when organic matter would be less if more carbon surface area existed? In this way, you could potentially overcome limitations posed by organic matter presence by increasing the surface area of carbon.
The potential for site saturation depends upon the type of experiment. For our isotherm experiments, saturation with microcystin occurred for some systems based on removal following Langmuir-type tendencies. Saxitoxin exhibited linear removal tendencies in all of our isotherm experiments and thus saturation was not achieved. All of our kinetic experiments were conducted under conditions below those identified with saturation conditions in our isotherm experiments.

10. Does increasing contact time of PAC with raw water play an important role in toxin removal?
Contact time is a critical factor in toxin removal, particularly for non-wood PAC. See Bajracharya et al. (2019) for more detail.

11. Can the toxins be removed from the carbon for sustainability of technique like they remove toxins and chemicals in aquaculture?
PAC is a one-time only treatment approach and thus the PAC cannot be regenerated for subsequent use. GAC, however, can be regenerated and this regenerated GAC still exhibits good performance for microcystins (Chen et al., 2021).
12. Are there any recent publications on this work?
We have one published paper using PAC for microcystin-LR removal (Bajracharya et al., 2019) and two looking at the use of GAC for microcystin and cylindrospermopsin removal (Villars et al., 2020) (Chen et al., 2021). We are still working on the manuscript for the use of PAC to remove saxitoxin.

13. To get around the organics issue, would it be recommended to reduce TOC concentrations before adding PAC?
Yes. Removing NOM prior to adding PAC would improve toxin removal.

14. You showed slides showing relative rates of adsorption. What kind of exposure or retention?
These rates were determined from experiments conducted over a period of 72 hours and represent the rate coefficients resulting from the fit of a pseudo-first order kinetic model (Bajracharya et al., 2019).

15. How about GAC? Granulated AC?
We have published results evaluating the use of GAC to remove algal toxins. See Villars et al. (2020) and Chen et al. (2021).

16. How can this research be used to help cities who also use the “ozone” systems as well?
The application of ozone prior to GAC has been shown to be an effective approach removing microcystins (Liu, 2018).

17. Was microcystin and saxitoxin removal kinetics studied in presence of organic matter?
Yes. We evaluated kinetics in the presence and absence of NOM. Results for microcystin-LR are presented by Bajracharya et al. (2019). We are still working on the manuscript for saxitoxin.

18. I don’t think you spoke about PAC dosages in the study. What dosages were evaluated?
For experimental tractability our kinetic experiments with microcystin used a toxin concentration of 50 ppb and a PAC dose of 5 ppm. Those for saxitoxin used a toxin concentration of 1 ppb and a PAC dose of 1 ppm. The isotherm experiments used toxin concentrations that varied from 1 – 50 ppb and PAC doses of 0.1 – 10 ppm.

19. PAC can be effective in removing many types of contaminants. Are you seeing any of those co-benefits in your studies?
We have only been looking at algal toxin removal in our research.

20. What were the NOM concentrations in samples used?
Our NOM concentrations varied from 0 to 10 mg/L, which corresponds to a TOC of approximately 0 to 5 mg-C/L.
21. Drinking water plants routinely use PAC for taste and odor removals. Has anyone looked at toxin removals during those treatment times?

There is extensive literature looking at the removal of taste and odor causing compounds with PAC, however, looking at their removal in conjunction with toxins is not well studied or understood. This is a topic we are interested in pursuing should we be able to find the funding to support it.

22. e.g. soft woods like pine vs. hard woods like oak?

I am not sure what wood types are most commonly used to prepare commercial PAC. Vendors we work with list “wood dust” and “renewable” materials as the source.

23. Can you speak more on the carbon dosages in your studies? What are effective carbon dosages for TOC and algal toxin removal?

Please see response to question #18 with respect to dose for toxin removal. We did not explicitly look at TOC removal for these systems, however.

References Cited


Liu, Y.-L., 2018. The Fate of Cyanotoxins in Drinking Water Sources and Treatment Processes. Ph.D. Dissertation, Department of Civil, Environmental and Geodetic Science. The Ohio State University, Columbus, OH.
