External Scientific Peer Review of the Scientific Basis of Proposed Hexavalent Chromium Maximum Contaminant Level Best Available Technologies

November 11, 2021

Prepared by: Daniel Giammar, Ph.D., P.E.
Washington University in St. Louis

Based on my expertise and experiencea, I am reviewing the findings, assumptions, or conclusions I agreed I could review with confidence:

1. Ion exchange, RCF, and RO should be designated BAT for the treatment ofhexavalent chromium.
2. Additional information is needed to designate stannous chloride a BAT for thetreatment of hexavalent chromium.

Summary: The scientific basis document clearly presents the conclusions. It makes very good use of a considerable body of work that has evaluated different treatment approaches and developed associated cost estimates. In preparing this review, I examined several of the cited references. The Water Research Foundation reports, in particular, were solid documents on which to base the conclusions in the scientific basis document. Appropriate bench-scale, pilot-scale, and demonstration-scale approaches were used, and the research was accompanied by appropriate quality control measures. The conclusions are field-relevant through the use of data from studies that treated actual waters in California. The first conclusion is reasonable given the information available, and my comments below will highlight areas where more information and issues from previous work could have brought into the scientific basis document. The second conclusion makes a clear case that stannous chloride should not be designated a best available technology (BAT) for treatment of hexavalent chromium based on the available information. However, I think that a stronger conclusion could potentially be reached. The conclusion in the document notes that "additional information is needed," but there may be sufficient information already available to determine that stannous chloride should not be designated a BAT.

Comments Regarding Conclusion 1:

1. The conclusion that ion exchange (IX) should be designated a BAT is based on sound research using both weak base anion (WBA) exchange and strong base anion exchange (SBA) exchange processes. It is helpful that IX was evaluated for arange of water compositions, including groundwater in Glendale that has a high total dissolved solids composition that makes it particularly challenging to treat. Cost estimates are provided in the cited references for both WBA and SBA. The cost estimates in Blute et al. (2015a) for WBA are clear and thorough with good documentation of how they were developed. The cost equations for SBA that are provided in Seidel et al. (2013) are reasonable; although they were almost certainly developed based on appropriate sources, the documentation of the specific sources

used to develop the cost equations is not sufficient to check the original source of the cost information.

2. The scientific basis document presents good overall information on the performance of reduction-coagulation-filtration (RCF) for hexavalent chromium treatment using either granular media filtration or membrane filtration as the post-RCF process for removal of chromium-containing suspended solids. The process was evaluated using multiple field-relevant waters with high Cr(VI) concentrations. While the water compositions made their treatment challenging because of the concentrations of Cr(VI) other anions, the waters all had relatively low dissolved organic carbon (DOC) concentrations. DOC can influence the ability of coagulation and flocculation to generate flocs that are most amenable to removal. RCF followed by membrane filtration should still be able to effectively remove Cr(VI) in waters with higher DOC, but granular media filtration performance may be lower for waters with higher DOC. There are geologic reasons why the co-occurrence of Cr(VI) (present in more oxidizing environments) and DOC (more common in organic-rich less-oxidizing environments) may be unlikely, but some discussion of the effects of DOC on the process and the range of DOC encountered in source waters with high Cr(VI) would have been helpful.

3. The cost estimates for RCF are sound and are based on relevant pilot-scale and demonstration-scale evaluations.

4. The most effective and efficient use of RCF occurred when it used controlled doses of free chlorine instead of aeration to complete the oxidation of Fe(II) to generate a low solubility precipitate. The aspect of free chlorine dosing is interesting, especially since it must be carefully controlled to prevent adding more chlorine than is needed to oxidize the Fe(II) since that can reoxidize some of the Cr(III) produced in RCF back to Cr(VI). This is an important issue, and it was somewhat surprising to not see controlled dosing of chlorine included as part of the description of RCF as a BAT. The discussion of the results and the conclusions in Blute et al. (2015a and 2015b) are thorough and clear on the issue of chlorine dosing. The Fe(II) removal can be removed by aeration, but the necessary reaction times for that are sufficientlylonger than those for chlorine that they would influence reactor size and cost.

5. Reverse osmosis (RO) will certainly work for removal of Cr(VI). The scientific basis notes that information from other studies not focused on Cr(VI) removal could be used to get cost estimates. The scientific basis would have been stronger with some specific citations of such references. There are cost equations for RO provided in Seidel et al. (2013), and with clearer identification of the sources used to generate those equations, that reference could provide the necessary support of cost estimates.

6. While the document appropriately concludes that RO should be recommended as a BAT for Cr(VI) removal, it would be valuable to also have some discussion regarding

RO's close cousin nanofiltration (NF). Brandhuber et al. (2004) provided data on Cr(VI) treatment using both RO and NF. One of the NF membranes used was able to achieve 70-90% removal of Cr(VI). This is not as good as for RO (greater than 90% for all conditions studied), but it has the potential to provide effective treatment depending on the composition of the source water and final value of the MCL. If NF is considered effective for Cr(VI) removal, then it could be a useful technology for inland systems requiring hardness removal together with Cr(VI) removal but not needing more extensive removal of total dissolved solids.

7. The data from the Chino Desalter is helpful for providing field-relevant information to support the conclusion that RO is effective in removing Cr(VI). The data are provided without any definitions of the values or description of the system, and it would have been helpful to have had even just a short memo with an overview of the process and organization of the data.

Comments Regarding Conclusion 2:

8. The information available from previous work clearly identifies three issues that are problems for stannous chloride. Given this already established information, there may not be any additional information that could be gained that would ever result in stannous chloride being desigated a BAT for Cr(VI) removal. The first issue is that the stannous chloride process on its own only changes the oxidation state of Cr(VI) to Cr(III) and does not remove it. Given the presence of oxidants in the distribution system, including the required disinfectant residual, any technology that just changes the oxidation state of the chromium but does not remove it from the water isnot going to provide a robust treatment strategy. The second issue is that the dosesrequired for stannous chloride may exceed the maximum use level. The third issue is that the study of Henrie et al. (2019) found that the finished Cr(VI) concentrations were still in the 7-8 μg/L range.