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

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Based on my expertise and experience, I have reviewed the findings, assumptions, or conclusions I agreed I could review with confidence. My analysis of the statements that I have considered, which are indicated in italicized text, are summarized below.

Ion exchange, RCF, and RO should be designated BAT for the treatment of hexavalent chromium.

As indicated in the documentation provided to me, the designation of Best Available Technology (BAT) can be made when available evidence indicates that a technology is "effective under full-scale field application" conditions. In addition, the documentation indicates that, "To comply with HSC 116365 requirements to consider costs of compliance using best available technology, treatment technologies identified as BAT must also have cost data available."

The State Water Resources Control Board's Division of Drinking Water staff (i.e., DDW staff) provide a summary of the results of research and testing of three technologies that they have concluded meet the BAT designation described above. My review of the scientific basis and validity of these assumptions for the three methods in the paragraphs listed below.

Ion Exchange

The information cited in the DDW staff summary documents the application of ion exchange treatment at Coachella Valley (Chowdhury et al. 2016). As part of the study, an ion exchange system in a full scale groundwater treatment systems was isolated from the rest of the system and operated for 16 weeks to obtain data on the breakthrough of Cr[VI] from the resin. During the initial stage of the testing, the strong base anion exchange resin was capable of achieving Cr[VI] concentrations as low as 1 μg/L. In my opinion, this trial demonstrated that the technology was a feasible means of removing hexavalent chromium from water under full-scale field applications.

Results of bench- and pilot-scale studies included in the DDW staff summary also provide information needed to understand the effects of changing influent quality and operating conditions on chromium removal. Although these studies were not conducted under full-scale field conditions, they provide additional confidence in the performance of the technology that would be useful to treatment system designers and operators.

The references cited by the DDW staff also contain information that can be used to estimate treatment costs with reasonable confidence. The supporting documents include information

that considered the costs of building and operating ion exchange treatment systems as well as the costs of typical approaches for disposing of spend ion exchange resins and regenerant solutions.

Reduction, Coagulation and Filtration (RCF)

Documents cited in the DDW staff summary include results from bench- and pilot-scale studies indicating that the technology is capable of achieving low levels of Cr[VI] in treated water. One study described a 100 gallon-per-minute (i.e., 0.14 million gallon per day) pilot-scale system that achieved Cr[VI] levels in treated water below 1 μg/L for almost two years (Hazen and Swayer 2013). Other studies described in the documents demonstrated improved performance for systems when chlorine was used to oxidize excess ferrous iron in the first step of the process. Improved performance also was observed when microfiltration was used instead of media filtration to remove the Cr-containing iron particles produced when ferrous iron is oxidized. Despite the ability of the technology to consistently achieve low Cr[VI] concentrations, no full-scale field applications were documented in the supporting materials. In my opinion, the data provided in the references provides us with confidence that this approach is capable of achieving low levels of Cr[VI] under full-scale field conditions. However, I am not sure that a 100 gallon-per-minute pilot scale system can be considered as meeting the requirement for evidence of efficacy under full-scale field conditions. I believe that the determination of whether this has bearing on the designation of RCF as a BAT is a matter of policy and not a scientific issue. Therefore, I will leave it policy experts to make this determination.

The references cited in the DDW staff summary include data that can be used to estimate treatment costs with reasonable confidence. The equipment needed to dose ferrous sulfate into a contact basin as well as the equipment needed to separate the Cr-containing solids from water are relatively common in water treatment systems. Information provided in the references also can be used to assess the impacts of site-specific conditions (e.g., variations in water chemistry) on the performance of the treatment system. Thus, reasonably accurate estimates of treatment costs along with uncertainty associated with the estimates, could be made by application of this information.

Reverse Osmosis (RO)

Documents cites by DDW staff indicate that RO can produce treated water with concentrations in the range being considered for a drinking water MCL in California (i.e., 1-10 μg/L). However, data from demonstration- or full-scale systems were not provided in the staff report. The report referred to the Chino Desalter system, which is a full-scale RO treatment system that is used to remove salts from groundwater. Although I was not able to locate records on the website listed in the DDW staff report, a database published by the Environmental Working Group (https://www.ewg.org/tapwater/system.php?pws=CA3310083) indicates an average Cr[VI] concentrations in the RO-treated water of 2.71 μg/L. I was unable to find any data on concentrations of Cr[VI] in the water at the Chino desalter prior to treatment, but other data form the region suggest that initial concentrations of Cr[VI] were likely well above 10 μg/L.

Available data on the ability of reverse osmosis systems to remove at least 95% of the chromate under the conditions encountered in brackish water treatment systems (e.g., Yoon et al. 2009; https://doi.org/10.1016/j.chemosphere.2009.07.028). Although additional data on Cr[VI] removal at the Chino Desalter would strengthen the analysis, it seems reasonable to conclude that RO treatment is capable of producing water with low concentrations of Cr[VI] under full-scale filed conditions.

Reverse osmosis treatment of brackish groundwater is a reasonably mature technology, with several hundred full-scale treatment plants operating in the United States (Mickley, 2018; https://www.usbr.gov/research/dwpr/reportpdfs/report207.pdf). Therefore, it should be possible to estimate treatment costs with reasonable certainty.

Additional information is needed to designate Stannous Chloride a BAT for the treatment of hexavalent chromium.

DDW staff concluded that stannous chloride treatment is a promising technology but does not yet meet the requirements needed for classification as a BAT. Their report states, "For stannous chloride to be considered a BAT, additional information on the capability of the technology to meet the proposed MCL will be necessary, including information on reoxidation in the distribution system and the ability to meet a potential MCL without exceeding the stannous chloride maximum use level (MUL). Additionally, information on cost and its effectiveness during full scale application is needed."

The main reference in the staff report (Henrie et al. 2019) describes full-scale field testing of stannous chloride to reduce Cr[VI] at a facility in the Coachella Valley. The treated water was sent to a drinking water distribution system and water samples were analyzed for chromium to assess deposition of Cr[III] and Sn[IV] on pipe surfaces. The distribution system studied was served by four wells which each had a design capacity of at least 1500 gallons per minute (Corona Environmental Consultants 2018; http://www.cvwd.org/DocumentCenter/View/4203/CVWD-Improvement-District-8-Full-Scale-Stannous-Chloride-Demonstration-Results).

The DDW staff justified their decision not to consider stannous chloride treatment as a BAT because they were concerned that the technology: (a) could not achieve Cr[VI] concentrations in the low end of the range being considered for future regulations and (b) cost data were not available.

The first issue, relative to performance considered two possible shortcomings of the treatment technology (1) a dose of Sn[II] in excess of the recommended maximum (i.e., MUL) would be required under many of the conditions expected in Cr[VI]-contaminated groundwater; and (2) Cr[III] produced during the reduction process might be re-oxidized to Cr[VI] in the presence of chlorine. Based on the information included in Henrie et al. (2019) these are reasonable concerns that would need to be evaluated in a case-by-case basis by treatment system designers. However, I am not convinced that this is a basis for denying the BAT classification the SnCl2 treatment. After all, any of the three technologies that were determined to be BAT could fail under the wrong set of conditions (e.g., high initial Cr[VI] concentrations, elevated

concentrations of interfering compounds). With the caveat that it may not be able to treat elevated concentrations of Cr[VI] and that it might not be able to achieve low concentrations of Cr[VI], I believe that this technology meets the full-scale filed application criterion.

The second issue, that data were not provided that could be used to estimate the costs of employing stannous chloride treatment are true. However, the reference documents imply that the cost of treating Cr[VI] with these technologies will be substantially less expensive than the other approaches described above. Based on the full-scale demonstration as well as the equipment suppliers and consultants familiar with the technology, it seems likely that cost information could be produced by the Coachella Valley Water District and their consultant.

Considering the guidance provided to me, it appears as if stannous chloride treatment has not satisfied the criteria established for classification as a BAT. The potential limitations to the technology described by DDW staff in their report are valid, but there still may be conditions under which the treatment technology is viable (e.g., water sources for which the initial Cr[VI] concentrations are not much higher than the MCL). Therefore, it seems appropriate to consider application of the technology under conditions in which treatment costs and performance data are available.