Technical Information Report
Estimation of Bromate Formation in Various Treatment Processes

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Summary

A bromate formation estimation procedure has been developed to estimate the bromate concentration under various treatment alternatives. The model is then applied to estimate the potential bromate concentration under the Ag-Urban Bay-Delta Alternative D1 (dual system with 7,500 cfs isolated cannel capacity). The results indicated that the bromate concentration could vary in a wide range depending on the treatment processes and/or operation parameters such as pH, and different Ozone/TOC ratio in order to achieve different pathogens inactivation target levels.

In general, lower pH and lesser pathogen inactivation requirements will yield lower bromate concentration. For Alternative D1 when pH is lower than 6.8, the effluent bromate can be kept below 5 ppb with 1 log Giardia inactivation. If we use a less stringent bromate criterion, say 10 ppb, and lower the pH to 6.5, then even with 1 log Cryposporidium inactivation the bromate criterion can be met.

The results should lead to a more serious consideration on the cost trade-off among water quality treatment and conveyance facilities in identifying the Bay-Delta solution.

Introduction

The objective of this study is to provide more insight on the formation of disinfection by-products associated with a ***given Bay-Delta alternative***. The CUWA water quality expert panel has recommended 50 ppb bromide and 3 mg/l TOC water quality criteria. The TOC value is constrained by the formation of the TTHM when using enhanced coagulation for TOC removal and free chlorine to inactivate Giardia. The bromide value is constrained by the formation of bromate when using ozone to inactivate Cryptosporidium.

In this study, a bromate formation model has been applied to predict bromate concentration under various treatment alternatives. In the TIR, a brief description of the methodology, and application of the model to the Ag-Urban Alternative D1 are presented in the following sections.

Methodology

The bromate formation model/equation of Ozekin and Amy (Ozekin, 1994) is adapted in our model to evaluate the bromate formation under various ozone dose, bromide, TOC and pH. The equation is:

$$\mathbf{BrO_3 = 1.63x10\text{-}6\ TOC^{-1.26}\ pH^{5.82}\ (O_3\ dose)^{1.57}\ Br^{0.73}\ time^{0.28}}$$

where

BrO_3 = bromate concentration in ppb.
TOC = total organic carbon in mg/l.
O_3 = ozone concentration in mg/l
Br = bromide concentration in ppb.
time = contact time in minutes.

In our approach, temperatura is held constant at 20°C. The contact time is assumed to be 12 minutes in the case study and can be modified easily. These assumptions are consistent with those used in the draft expert panel report (CUWA, 1996).

To apply the above equation to a Bay-Delta alternative and to estimate the long-term bromate performance, the following procedure is developed.

1. Applying the Ag-Urban version of DWRSIM to determine the long term (1922-92) monthly reservoirs, isolated canal and pumps operating schedule for a given alternative.

2. Applying Fischer Delta Model (FDM) to estimate the monthly Bromide and TOC concentration at export pumps (Banks and Tracy) based on the delivery schedule determined by DWRSIM and facility modifications reflecting a given alternative.

3. Blending with Isolated Facility (IF) flow to estimate Bromide and TOC in California Aqueduct and Delta Mendota Canal (DMC).

4. Applying the O'Neill Blending Model (Wang, 1997) to estimate Bromide and TOC at O'Neill Forebay (functioned as an afterbay).

5. Assuming no degradation/change of bromide and TOC between O'Neill and SWP treatment plants. Applying the time series of Br and TOC resulting from step-4 and pluging into the developed bromate model to predict the treatment plant effluent bromate concentration.

Case Study: Ag-Urban Dual System (Alternative D1)

Ag-Urban Alternative D1 is a dual conveyance alternative. Refined Alternative D1 can be developed into the most probable Ag-Urban Bay-Delta alternative. The key assumptions for this alternative at this moment are:

- Capacity of isolated facility = 7,500 cfs
- Minimum pumpage from south Delta water = 3,000 cfs
- Maximum IF Diversion at Hood = 35% of Sacramento River flow during January-March and July-December
- Maximum IF Diversion at Hood = 15% of Sacramento River flow during April-June
- Delta Requirements = enhanced Rio Vista, enhanced E/I ratio, IF diversion excluded from E/I, relaxed X2
- SWP has the first claim of IF diversion (model assumption not policy)

Following the procedure outlined in the previous section, we obtained monthly bromide and TOC concentrations at export pumps and O'Neill Forebay. The developed bromate model was then used to estimated the bromate formation for various treatment options based on the modeled influent bromide and TOC concentrations.

A set of graphs is attached to show the results of the study.

Discussion

1. A bromate model is developed to estimate the bromate formation based on estimated bromide and TOC concentrations and other operation parameters.

2. The case study results (attached graphs) indicated that the bromate concentration could vary in a wide range depending on the treatment processes and/or operation parameters such as pH, and different Ozone/TOC ratio in order to achieve different pathogens inactivation target levels.

3. Lower pH and lesser pathogen inactivation requirements will yield lower bromate concentration. For Alternative D1 when pH is lower than 6.8, the effluent bromate can be kept below 5 ppb with 1 log Giardia inactivation. If we use a less stringent bromate criterion, say 10 ppb, and lower the pH to 6.5, then even with 1 log Cryposporidium inactivation the bromate criterion can be met.

4. The developed model also has the ability to blend SWP water with CRA water with user defined blending ratio. The blending is not necessary to produce better bromate performance.

5. Even though Alternative D1 does not meet the 50 ppb Bromide criterion, it can still meet the 5 ppb bromate criterion under certain treatment configuration.

6. It should be noted that though lower the pH may result lower bromate, the TDS will increase due to the pH adjustment.

7. It would be useful if we can derive the costs associated with those possible treatment options. Coupled with water supply benefit, conveyance facilities and storage cost, we can develop better sense on the trade-off among different Bay-Delta alternatives.

References

1. Ozekin, K., 1994, *Modeling Bromate Formation During Ozonation and Assisting Its Control,* Ph.D. Thesis, University of Colorado.

2. CUWA, December 1996, *Draft Bay Delta Drinking Water Quality Criteria*, Report.

3. Wang, Chuching, 1997, *Salinity Blending Estimate at O'Neil Forebay*, Technical Information Report.