Building collaborative approaches for NPDES permit-writers to address bromide

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Steam Electric Power Plant Effluent Limitation Guidelines (ELGs)

Rule finalized on

**September 30, 2015**

Timeline for compliance:

2018-2023
(postponed 2 years for FGD)

“Depending on site-specific conditions and applicable state water quality standards, it may be appropriate for permitting authorities to establish water quality-based effluent-limitations on bromide, especially where steam electric power plants are located **upstream from drinking water intakes**.”

TDD 14-35 and Final Rule p. 67886
Disinfection is critical for public health...

...but it has the unintended consequence of forming toxic DBPs, which have their own health risks
As bromide concentration in source waters increases, bromine-containing DBPs increase.

Increases are observed with very small changes in bromide concentration and in the presence of significant excess chlorine.
Historical surface water bromide concentrations show regional variability.
Bromide enters surface waters from natural and anthropogenic sources.

Where does bromide come from?

- **Background (nonpoint)**
  - Saltwater intrusion
  - Runoff
- **Anthropogenic**
  - Power plant discharges
  - Oil & gas wastewater
  - Coal mine discharges
  - Road treatment

Amy et al. (1994). *Survey of bromide in drinking water and impacts on DBP formation*. AWWA Research Foundation.

There are several potential sources of bromide at coal-fired power plants:

- The coal itself ("natural")
- Added for mercury control
- Added for IRS Section 45 tax credit
- Used as cooling water biocide

EcoLab (2018); Nalco (2010); Mole, B. (2017); Reisch, M.S. (2015); U.S. EPA (2012)
Drinking water intakes may be downstream of multiple power plants and river systems may have additional sources of bromide.

How should a NPDES permit writer think about this challenge?

Slide Courtesy: Dr. Kelly Good
Bromide increases the rate of DBP formation and the bromine incorporation into the formed DBPs

...but bromide alone is not predictive of TTHM.

\[
\text{THM4} = 0.283(\text{DOC} \cdot \text{UV}_{254})^{0.421}(\text{Cl}_2)^{0.145}(\text{Br})^{0.041}(\text{T})^{0.614}(\text{pH})^{1.606}(t)^{0.261}
\]
2015 Steam Power ELG Rule
“Where the DBP problem described above may be present, water quality-based effluent limitations for steam electric power plant discharges may be required under the regulations at 40CFR § 122.44(d)(1), where necessary to meet either numeric criteria (e.g., for bromide, TDS or conductivity) or narrative criteria in state water quality standards. 14:36-37
“All states have narrative water quality criteria that are designed to prevent contamination and other adverse impacts to the states’ surface waters. These are often referred to as “free from” standards. For example, a state narrative water quality criterion for protecting drinking water sources may require discharges to protect people from adverse exposure to chemicals via drinking water. These narrative criteria may be used to develop water quality-based effluent limitations on a site-specific basis for the discharge of pollutants that impact drinking water sources, such as bromide.” 14:36-37
EPA suggests the use of MCLs for DBPs to translate narrative water quality criteria to inform WQ-based limits for bromide in power plant discharges

• “To translate state narrative water quality criteria and inform the development of a water quality-based limitation for bromide, it may be appropriate for permitting authorities to use EPA’s established MCLs for DBPs in drinking water because the presence of bromides in drinking water can result in exceedances of drinking water MCLs as a result of interactions during drinking water treatment and disinfection processes. See 40 CFR § 122.44(d)(1)(vi).”  14:37

• “The maximum level of bromide in source waters at the intake that does not result in an exceedance of the MCL for DBPs is the numeric interpretation of the narrative criterion for protection of human health and may vary depending on the treatment processes employed at the drinking water treatment facility.”  14:37
2019 Steam Power ELG Rule (Proposal)
Key Provisions

• No mandatory requirements for bromide set upon dischargers using standard program

• New optional “voluntary incentives” program sets bromide limits in exchange for more time

• Proposing a series of potential monitoring and minimization alternatives

• Concerns around accounting of costs and benefits
Methods to assess anthropogenic bromide loads from coal-fired power plants and their potential effect on downstream drinking water utilities

• Which power plant permits require review to determine if bromide discharges are of concern for downstream drinking water plants?
• How can bromide concentrations in discharges from select power plants be estimated (in the absence of measured data)?
• Can the concentration contributions of specific discharges (from individual power plants) be quantified at drinking water intakes?
• How can the effect of increased bromide at drinking water intakes be estimated (with respect to TTHM or risk)?
Drinking water intakes downstream of wet FGD discharge(s)

Bromide concentration contributions from wet FGD at drinking water intakes

Geospatial Model Input
- Drinking water intake locations
- Watersheds containing the intakes
- Coal-fired electricity generating units (EGUs) operating wet FGD in watersheds

Geospatial Model Output
- Intakes downstream of wet FGD
- Wet FGD upstream of intakes

Load Model Input
- Wet FGD-associated coal consumption, by plant
- Coal and FGD assumptions following Good and VanBriesen (2016)

Load Model Output
- Bromide load discharged from wet FGD plant

Concentration Model Input
- Streamflow at intake
- Bromide load at intake contributed by wet FGD plant(s)

Concentration Model Output
- Bromide concentration at intake contributed by wet FGD plant(s)

Bromide load contributions from the upstream wet FGD discharges

Coal-fired power plants are found throughout the U.S., many along major rivers.

2015 coal EGUs (operable) by FGD type
- Non-wet FGD, including no FGD
- Wet

Created using data from:
Bromide concentrations reported for FGD wastewater vary widely and are rarely measured in discharges

- Surveys of FGD wastewaters suggest variable bromide concentrations.
- Power plants discharge wastewater under NPDES permits. Flow and constituent concentrations are monitored.
- FGD wastewater is often mixed with other wastewaters prior to monitoring and discharge and makes up a small percentage of the flow at an outfall.
- Bromide is rarely measured in the FGD wastewater or at the NPDES permitted outfall.

In the absence of effluent monitoring data, we can estimate load.

Drinking water intakes downstream of wet FGD discharge(s)

Bromide concentration contributions from wet FGD at drinking water intakes

Bromide loads discharged from power plants can be estimated from information on coal consumption and bromide content.

**PARAMETER**

- **Coal consumption (as-received, million kg/day)**
  - **Rationale**: Varies by plant
  - **Data**: Monthly consumption data by rank in EIA Form 923

- **Br content (ppm dry)**
  - **Rationale**: Natural coal Br varies across and within coal ranks; Also added for Section 45/MATS
  - **Data**: Coal Br content data in COALQUAL (rank, sub-rank, county)

- **Moisture content (%)**
  - **Rationale**: Varies across and within coal ranks; needed to convert as-received coal consumption to dry basis for use with Br ppm dry
  - **Data**: Ranges available in literature (limited); data are also available in COALQUAL

- **Capture in wet FGD (%)**
  - **Rationale**: Not well studied, but most Br expected to be captured in wet FGD slurry
  - **Data**: Key references: Peng et al. (2013) and Meij (1994)


Bromide loads for each upstream power plant can be estimated and summed to determine the bromide load in the river at each drinking water intake.

Based on 2015-2016 coal consumption at each power plant (August) and estimated bromide concentration in the different types of coal used.

Drinking water intakes downstream of wet FGD discharge(s)

Bromide concentration contributions from wet FGD at drinking water intakes

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Geospatial Model Input
- Drinking water intake locations
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Concentration Model Input
- Streamflow at intake
- Bromide load at intake contributed by wet FGD plant(s)

Concentration Model Output
- Bromide concentration at intake contributed by wet FGD plant(s)

Load Model Input
- Wet FGD-associated coal consumption, by plant
- Coal and FGD assumptions following Good and VanBriesen (2016)

Load Model Output
- Bromide load discharged from wet FGD plant

Receiving waters have variable flow that affects bromide concentration contribution from power plant discharged loads.

Low flow conditions will lead to elevated bromide concentrations.

Low flow may occur during times of DBP challenges (3rd quarter).

Data adapted from USGS gaging station 03049500 (Allegheny River at Natrona, PA) for Water Years 1939 through 2014.

The concentration contribution for any power plant to any drinking water intake can be estimated under any river condition of interest.

Modeled Br load

River flow

Predicted Br concentration

Concentration contributions reaching drinking water intakes can be estimated from load and flow analyses.

Shading shows population served by service area (surface water systems only).

Methods to assess anthropogenic bromide loads from coal-fired power plants and their potential effect on downstream drinking water utilities

- Which power plant permits require review to determine if bromide discharges are of concern for downstream drinking water plants?
- How can bromide concentrations in discharges from select power plants be estimated (in the absence of measured data)?
- Can the concentration contributions of specific discharges (from individual power plants) be quantified at drinking water intakes?
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Estimating the concentration contribution from power plants to the drinking water plant allows assessment of potential effects on DBP formation

- Using ICR data, a categorical assessment of effect of increasing bromide can be made.
- ICR data as baseline:
  - LOW (<20µg/L)
  - Moderate (21-65µg/L)
  - High (66-92µg/L)
  - Very High (>92µg/L)
- Effect of movement between bins can be estimated for bromination fraction and TTHM.

Estimating the concentration contribution from power plants to the drinking water plant allows assessment of potential effects on DBP concentrations and associated risk

- Regli et al (2015) used ICR data and the Water Treatment Plant Model to estimate the effect of increasing bromide concentrations on TTHM and associated risk.
- 50 µg/L bromide increase was modeled as having the potential to cause TTHM increase of 1 µg/L at 90% of the plants and 10 µg/L at 5-30% of plants
- Increase of 50 µg/L was associated with potential increase of $10^{-3}$ to $10^{-4}$ excess lifetime bladder cancer risk.

### Table: ΔTHM4 (µg/L) and ΔBr⁻ (µg/L)

<table>
<thead>
<tr>
<th>statistics</th>
<th>ΔTHM4 (µg/L) (plant months)</th>
<th>ΔBr⁻ (µg/L)</th>
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<td>10</td>
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<tr>
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<tr>
<td>maximum</td>
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<td>23.7</td>
</tr>
</tbody>
</table>

\[
\text{OR(THM4)} = e^{\text{THM4} \times 0.00427}
\]

Treatment plant specific models will likely be necessary to link specific bromide concentration changes in source water with changes in individual THM species (and then TTHM).
Treatment plant specific models will likely be necessary to link specific bromide concentration changes in source water with changes in individual THM species (and then TTHM).
Conclusions

• Coal-fired power plants with wet FGD wastewater discharges contribute to bromide concentrations in surface waters.

• Power plant associated bromide loads have been increasing due to increased deployment of wet FGD at power plants and due to addition of bromide for mercury control and for Section 45 tax credits (refined coal).

• Increasing source water bromide increases bromine-incorporation into DBPs, which increases compliance challenges and risk associated with using treated water.

• Spatiotemporal context matters. Dilution may be insufficient to protect downstream drinking water plants as bromide loads increase, especially under low-flow conditions.
Regulatory uncertainties make predictions of future bromide loads difficult
Future Technology Development and Deployment makes prediction of future bromide loads difficult.

NEWS & EVENTS
Eliminating Wastewater: Zero-liquid Discharge Market to $2.7 Billion in 2030

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Eliminating Wastewater: Zero-liquid Discharge Market to $2.7 Billion in 2030

New startups and dominant incumbents GE and Veolia enable a growing market for technologies that can eliminate all liquid waste from power plants and other facilities, Lux Research says.

BOSTON, MA – March 1, 2017 – Zero-liquid discharge (ZLD), an approach to wastewater treatment that prevents any liquid waste from flowing out of a power plant or facility, will grow at a 12% annual rate into a $2.7 billion market in 2030. The market will be boosted by technology innovations, rising water cost, and regulations due to growing concerns over surface water contamination, according to Lux Research.


Source Water Justification Toolkit

- Approaches for SWP
- Common challenges
- Business case
- Leadership and funding approaches