Building collaborative approaches for NPDES permit-writers to address bromide

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February 5, 2020

Steam Electric Power Plant Effluent Limitation Guidelines (ELGs)

Clean Water Act

Rule finalized on ***September 30, 2015***

Timeline for compliance:
2018-2023
(postponed 2 years for FGD)

News Releases from Headquarters › Water (OW) **2017**

EPA Finalizes Rule to Postpone Steam Electric Power Plant Effluent Guidelines Rule

09/13/2017

Bromide is not included directly

News Releases from Headquarters › Water (OW) **2015**

EPA Announces National Limits to Reduce Toxic Pollutants Discharged into Waterways by Steam Electric Power Plants

09/30/2015

"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

Slide Courtesy: Dr. Kelly Good

U.S. Environmental Protection Agency. (2015) Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category; Final Rule; Vol. 80, pp 67838–67903.
U.S. Environmental Protection Agency. *Postponement of Certain Compliance Dates for Effluent Limitations Guidelines and Standards for the Steam Electric Generating Point Source Category; Final Rule*; 2017; Vol. 82
U.S. Environmental Protection Agency. *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*; EPA-821-R-15-007; Washington, D.C., 2015.

Disinfection is critical for public health…

organic matter (NOM, TOC, DOC)

inorganic matter (Br, I, N)

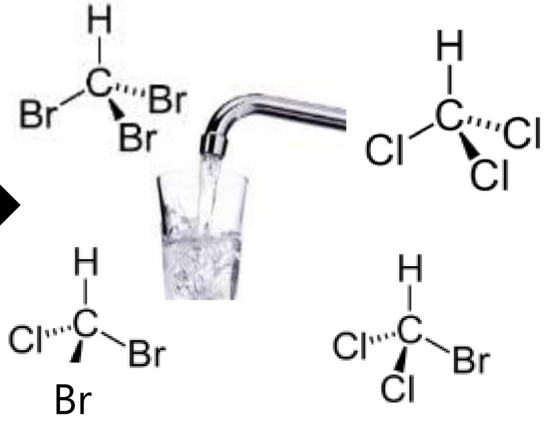
chlorine

chlorine dioxide

chloramines

ozone

>600 DBPs identified



precursors + chemical disinfectant = disinfection byproducts (DBPs)

…but it has the unintended consequence of forming toxic DBPs, which have their own health risks

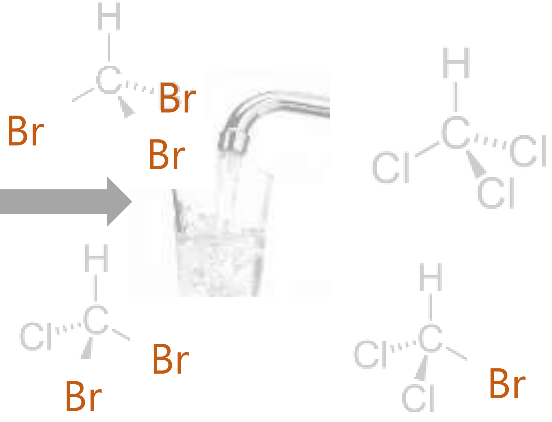
As **bromide** concentration in source waters increases, bromine-containing DBPs increase.

organic matter (NOM, TOC, DOC)

inorganic matter (Br, I, N)

source water

drinking water treatment

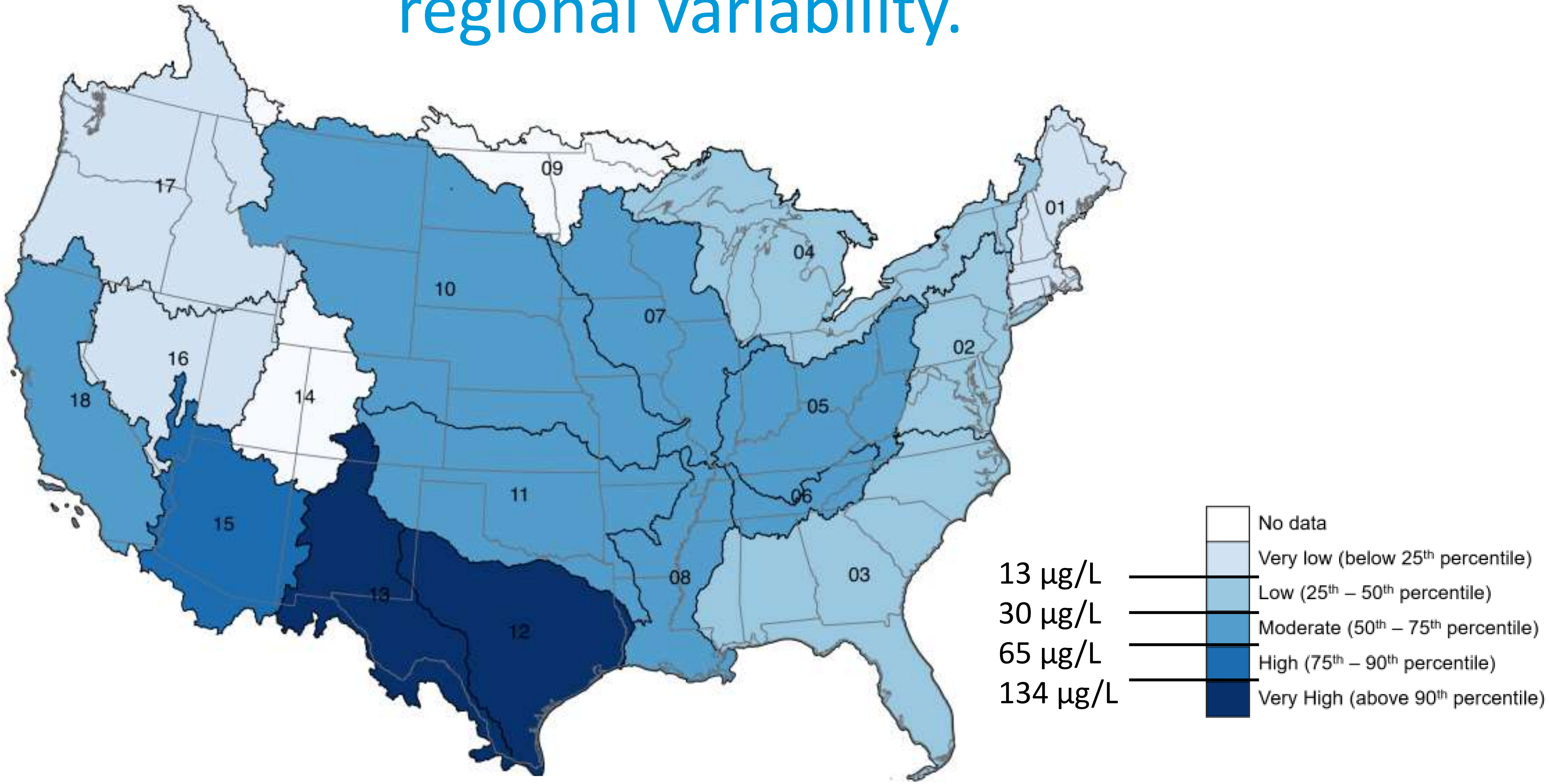


clean drinking water

\+ chemical disinfectant = disinfection byproducts (DBPs)

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.



Created using just source waters listed as surface water from:
USEPA (2000). ICR Auxiliary 1 Database Version 5.0 Query Tool Version 2.0, U.S. Environmental Protection Agency.
Data collected monthly at water utilities July 1997-December 1998. Data below the detection limit (20µg/L) were imputed using regression on order statistics in R. Plotted is the median value for all drinking water utilities reporting in the ICR in each HUC2.

Kolb, C. (2018) Drinking Water Quality and Risk Challenges from Increasing Source Water Bromide: Effects of Climate and Energy Changes, Ph.D. Dissertation, Carnegie Mellon University, Pittsburgh, PA

Where does bromide come from?

- **Bromide sources**
  - **Background (nonpoint)**
    - **Saltwater intrusion**

    - **Runoff**

  - **Anthropogenic**
    - **Power plant discharges**

    - **Oil & gas wastewater**

    - **Coal mine discharges**

    - **Road treatment**

Bromide enters surface waters from natural and anthropogenic sources

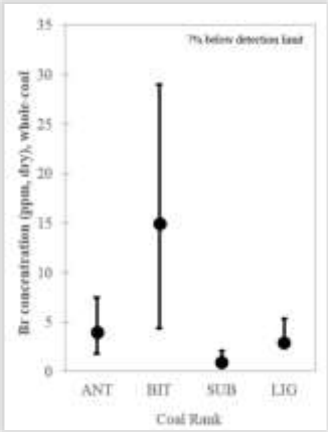
Amy et al. (1994). *Survey of bromide in drinking water and impacts on DBP formation.* AWWA Research Foundation.
Winid (2015). "Bromine and water quality – Selected aspects and future perspectives." Applied Geochemistry 63, p. 413-435.

Slide Courtesy: Dr. Kelly Good

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

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



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY — mercury & air toxics standards

Volume 93 Issue 11 | pp. 17-19
Issue Date: March 16, 2015

Bromine Comes To The Rescue For Mercury Power Plant Emissions

Element now at the top of the list for emission control technologies

By Marc S. Reisch

MerControl® 7895

IRS

With help of coal tax credits, Mylan had a negative 294-percent tax rate in 2016

The company invests in five coal processing companies to get highly valuable tax credits.

MATERIAL SAFETY DATA SHEET

PRODUCT

TOWERBROM® 991

EMERGENCY TELEPHONE NUMBER(S)

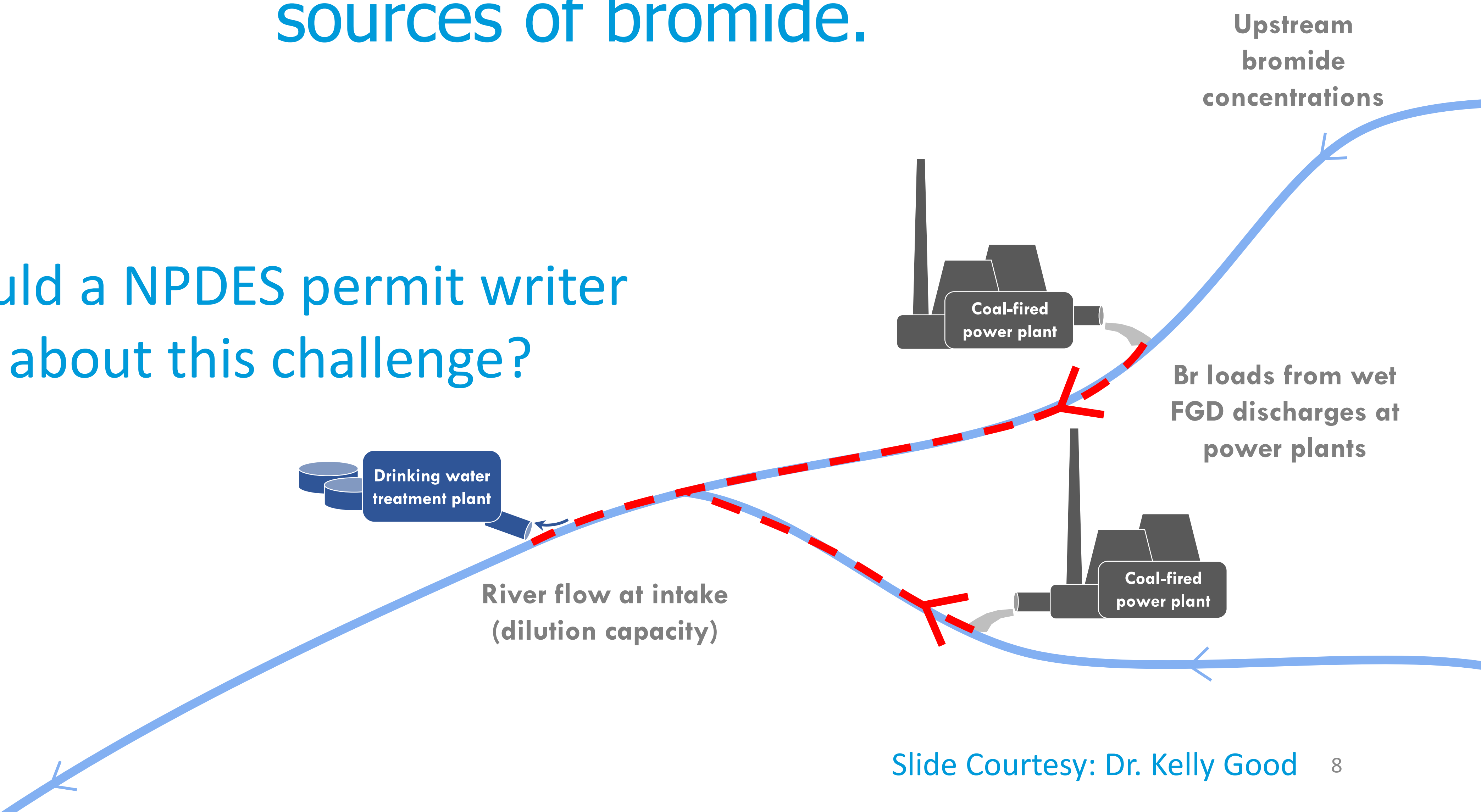
(800) 424-9300 (24 Hours) CHEMTREC

Slide Courtesy: Dr. Kelly Good

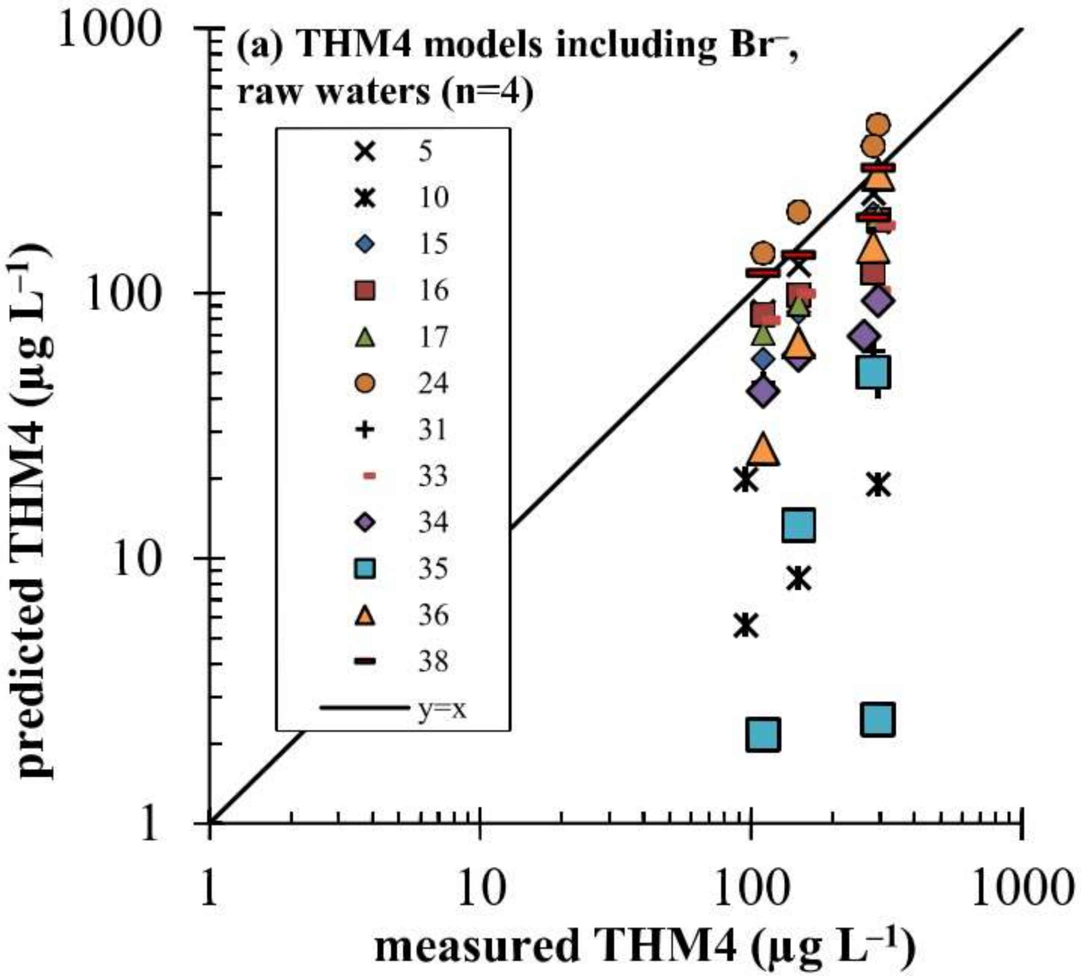
EcoLab (2018); Nalco (2010); Mole, B. (2017); Reisch, M.S. (2015); U.S. EPA (2012)

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

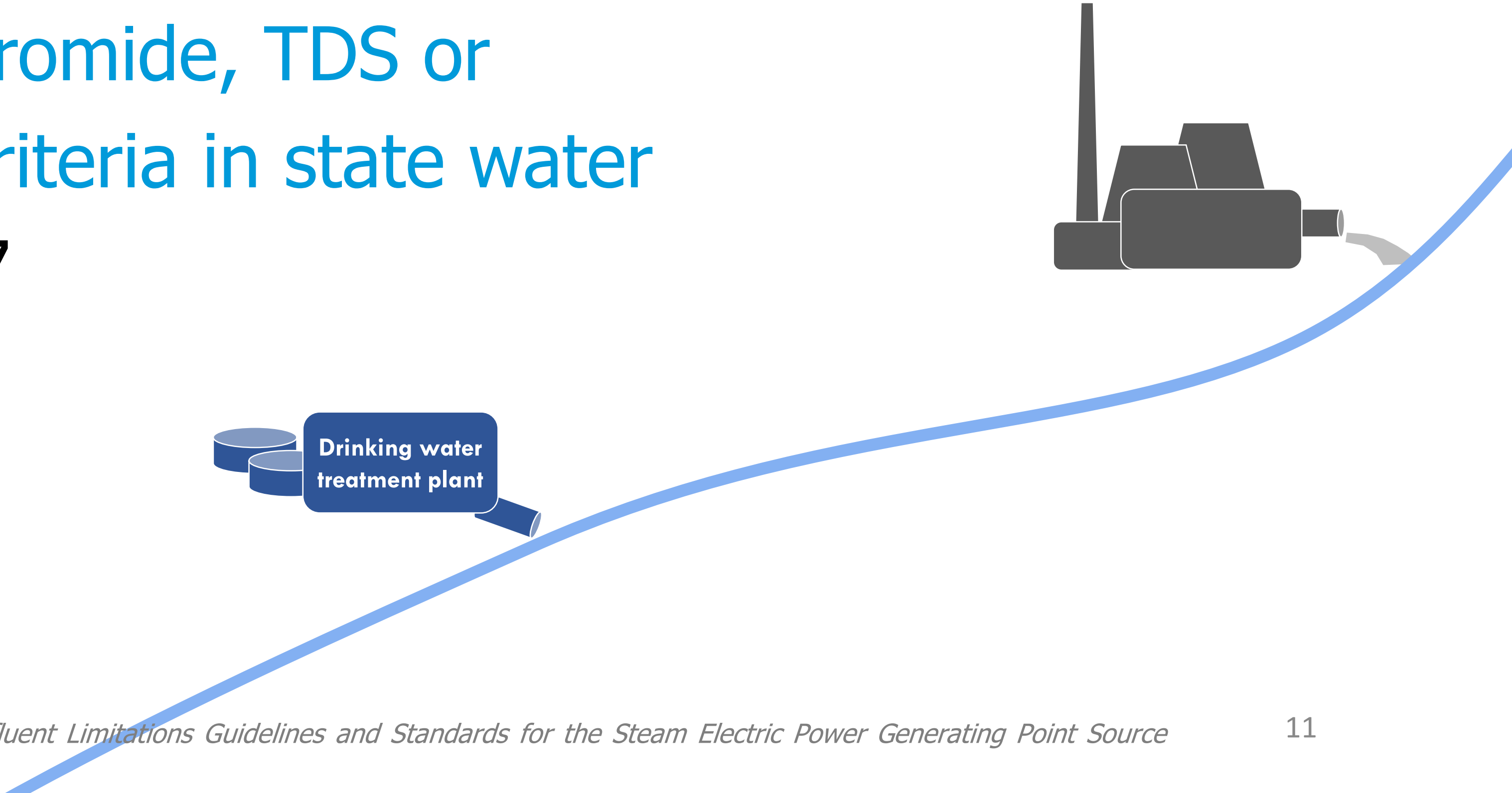
…but bromide alone is not predictive of TTHM.

$$THM4 = 0.283(DOC \cdot UV_{254})^{0.421}(Cl_2)^{0.145}(Br)^{0.041}(T)^{0.614}(pH)^{1.606}(t)^{0.261}$$

Ged et al (2015). Predictive capability of chlorination disinfection byproducts models. Journal of Environmental Management, 149, 253–262.

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



U.S. Environmental Protection Agency. *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*; EPA-821-R-15-007; Washington, D.C., 2015.

"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

U.S. Environmental Protection Agency. *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*; EPA-821-R-15-007; Washington, D.C., 2015.

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

U.S. Environmental Protection Agency. *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*; EPA-821-R-15-007; Washington, D.C., 2015.

2019 Steam Power ELG Rule (Proposal)

Key Provisions

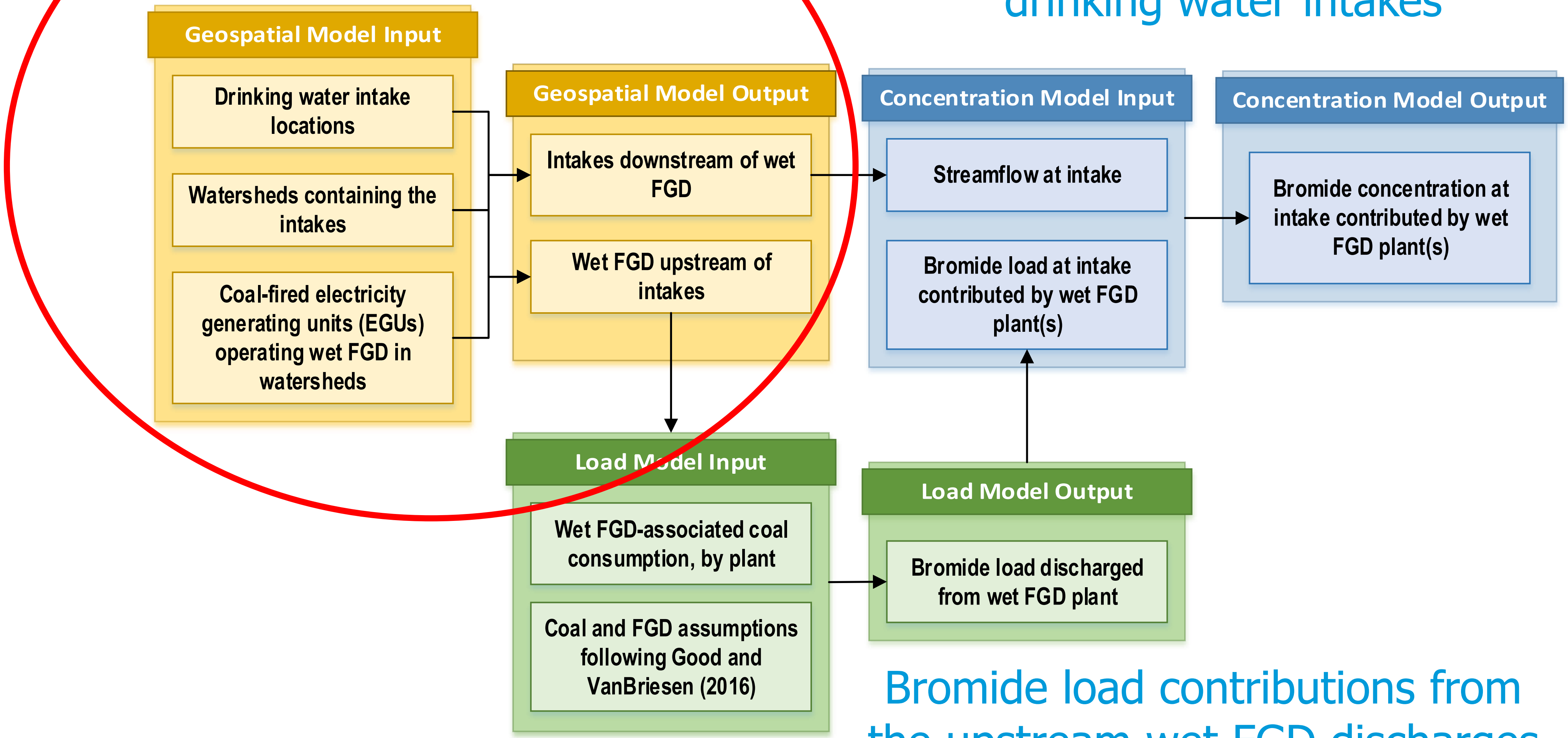
- No mandatory requirements for bromide set upon dischargers using standard program
- New optional “voluntary incentives” program sets bromide limits in exchange for more time
- Proposing a series of potential monitoring and minimization alternatives
- Concerns around accounting of costs and benefits

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)

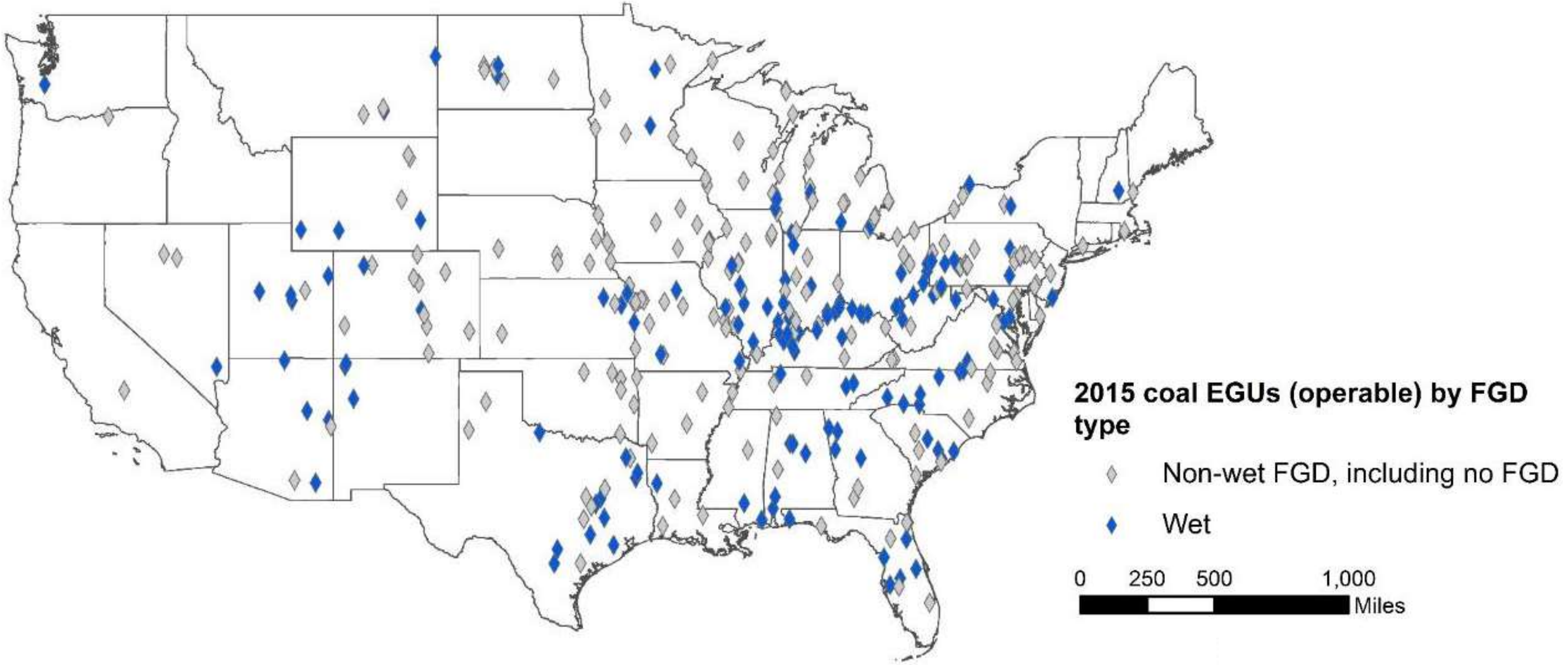
Bromide concentration contributions from wet FGD at drinking water intakes



Bromide load contributions from the upstream wet FGD discharges

Good, K.D. & VanBriesen, J.M. (2017) "Power plant bromide discharges and downstream drinking water systems in Pennsylvania," *Environmental Science & Technology*. 51:20, 11829–11838.

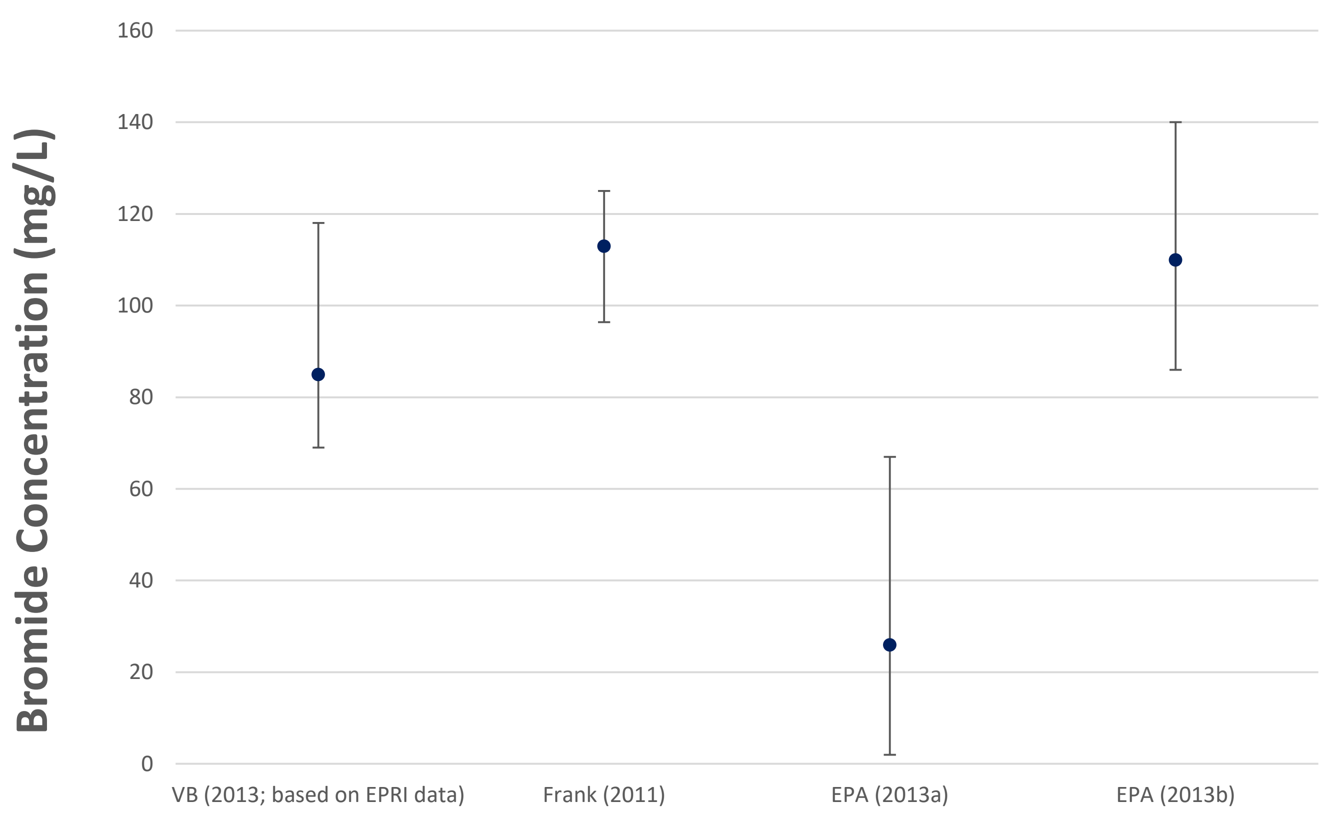
Coal-fired power plants are found throughout the U.S., many along major rivers



Created using data from:
U.S. Energy Information Administration. (2015). Form 860. Available at https://www.eia.gov/electricity/data/eia860/ [Accessed January 14, 2017].

Slide Courtesy: Dr. Kelly Good

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.

VanBriesen (2013) Potential Drinking Water Effects of Bromide Discharges from Coal-Fired Electric Power Plants, submitted comment to ELGs. See EPRI (2000, 2004, 2007) cites within.

Frank, S.M. (2011) Calcium bromide chemical additive sample results. Calcium bromide performance trial February 7 to 12, 2011 NPDES Permit No PA005011 Conemaugh Generating Station. Canonsburg PA Letter Report submitted to PA DEP Southwest Region, Pittsburgh PA.

EPA (2013a). Industry Provided Sampling Data from Duke Energy's Allen Steam Station [DCN SE01809]. Plant Allen FGD Purge Analytical Data from 3/3/09 to 5/23/11. Water Docket EPA-HQ-OW-2009-0819-1227. Washington, DC.

EPA (2013b). Industry Provided Sampling Data from Duke Energy's Belews Creek Steam Station [DCN SE01808]. Belews Creek Biochem Effluent Analytical Data from 12/3/08 to 12/7/09 from EPRI Study. Water Docket EPA-HQ-OW-2009-0819-1226. Washington, DC.

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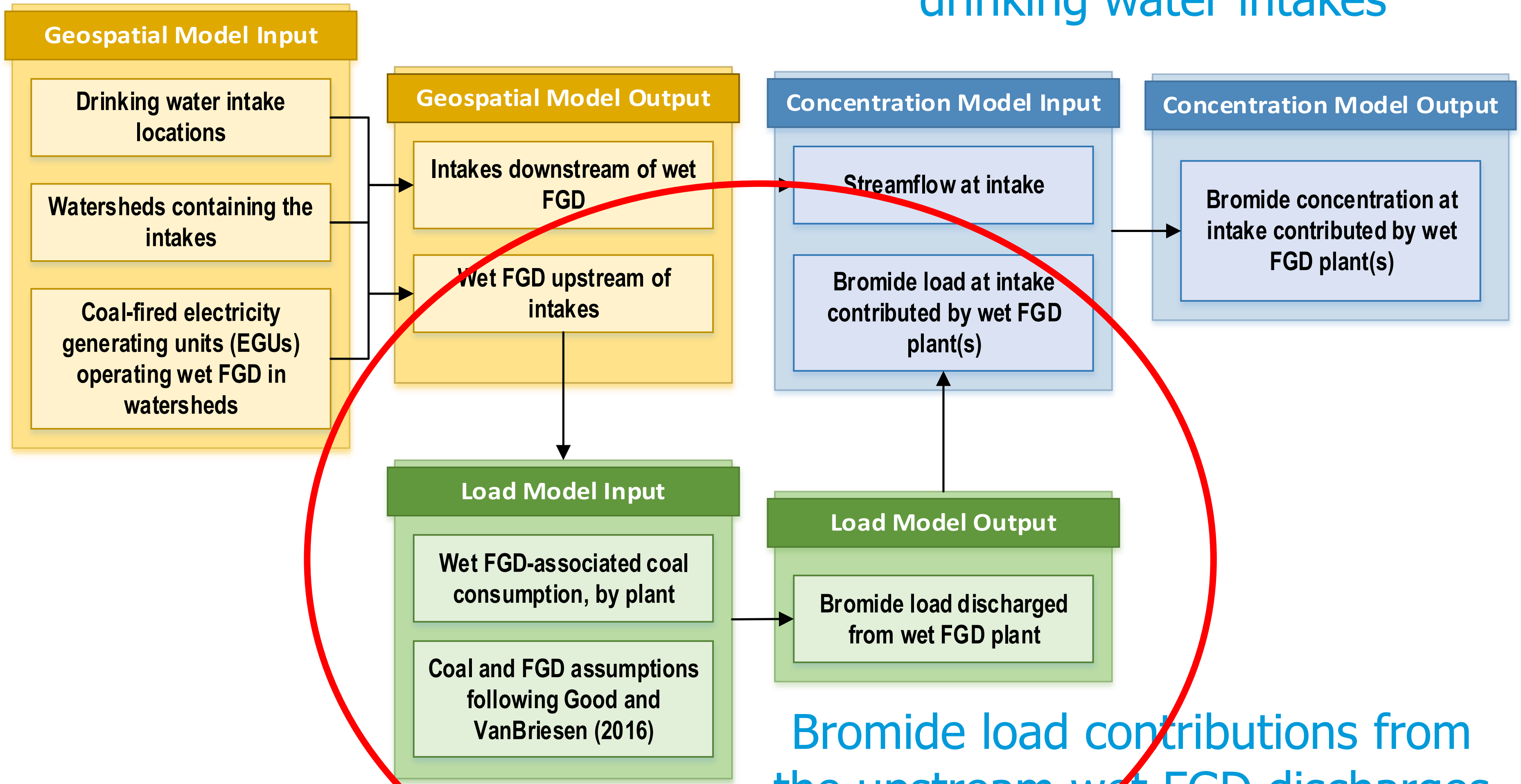
Bromide concentration contributions from wet FGD at drinking water intakes



Bromide load contributions from the upstream wet FGD discharges

Good, K.D. & VanBriesen, J.M. (2017) "Power plant bromide discharges and downstream drinking water systems in Pennsylvania," *Environmental Science & Technology*. 51:20, 11829–11838.

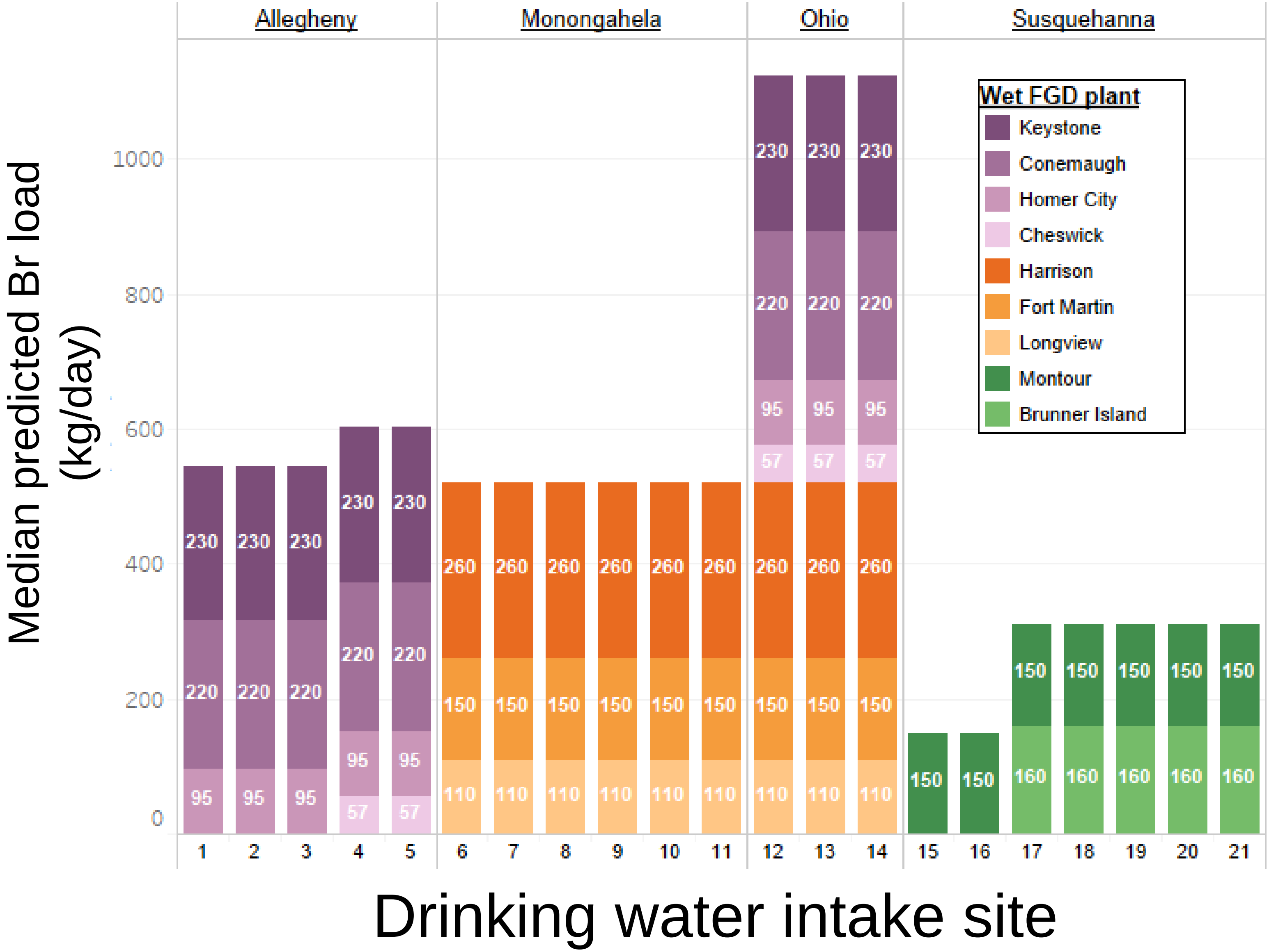
Bromide loads discharged from power plants can be estimated from information on coal consumption and bromide content

PARAMETER	Coal consumption (as-received, million kg/day)	Br content (ppm dry)	Moisture content (%)	Capture in wet FGD (%)
RATIONALE	Varies by plant	Natural coal Br varies across and within coal ranks; Also *added* for Section 45/MATS	Varies across and within coal ranks; needed to convert as-received coal consumption to dry basis for use with Br ppm dry	Not well studied, but most Br expected to be captured in wet FGD slurry
DATA	Monthly consumption data by rank in EIA Form 923	Coal Br content data in COALQUAL (rank, sub-rank, county)	Ranges available in literature (limited); data are also available in COALQUAL	Key references: Peng et al. (2013) and Meij (1994) Modeled as triangular (77%, 84%, 100%) by Good & VanBriesen

Meij (1994) Trace element behavior in coal-fired power plants. Fuel Process. Technol. 39 (1-3), 199–217.
Peng et al (2013). Distribution of bromine and iodine in thermal power plant. J. Coal Sci. Eng. 2013, 19 (3), 387–391.

Good, K.D. & VanBriesen, J.M. (2016). "Current and potential future bromide loads from coal-fired power plants in the Allegheny River Basin and their effects on downstream concentrations," *Environmental Science & Technology*, 50(17): 9078-9088.

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.

Good, K. and J. VanBriesen (2017). "Power plant bromide discharges and downstream drinking water systems in Pennsylvania." Environmental Science and Technology **51**(20): 11829-11838.

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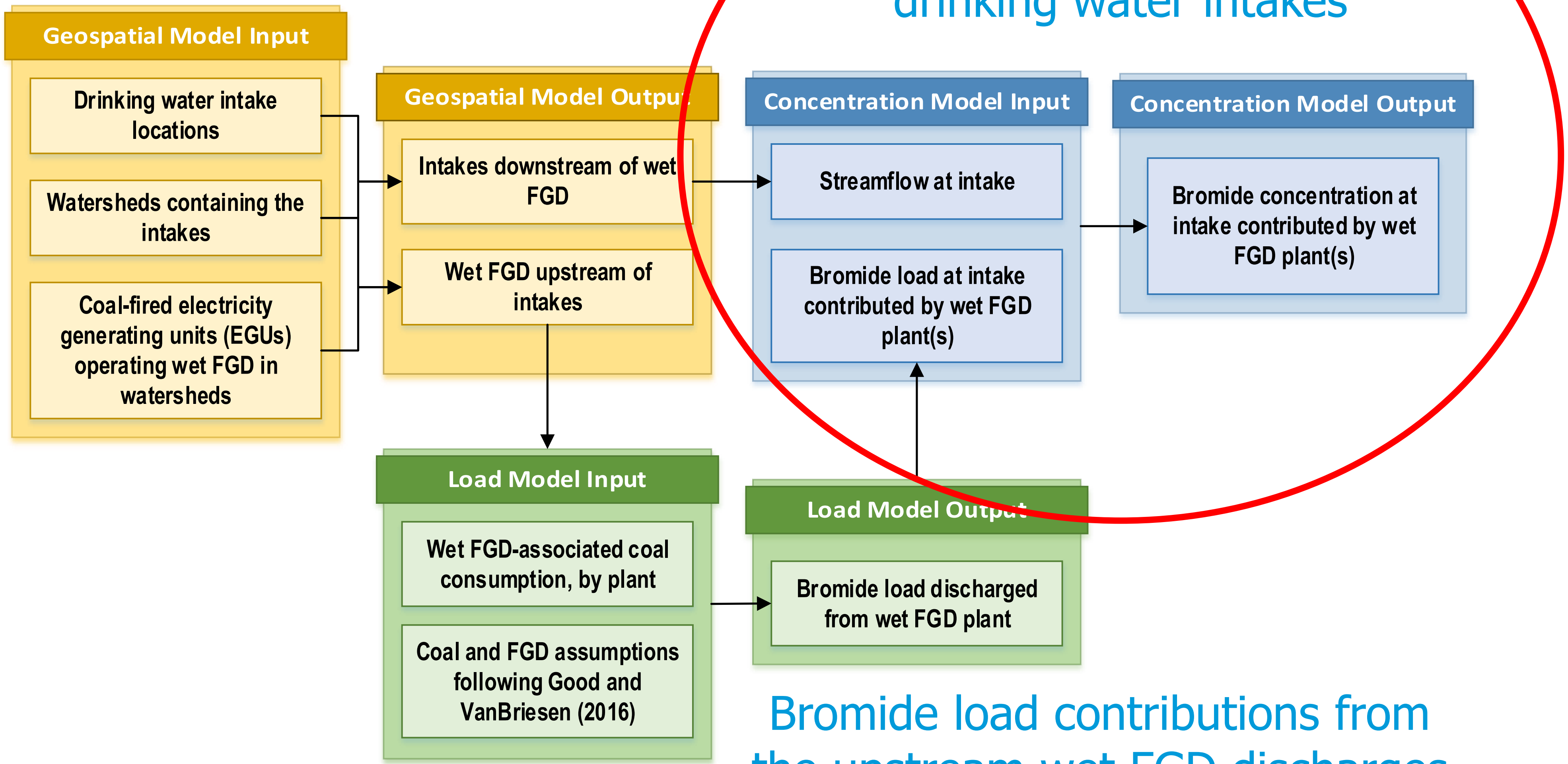
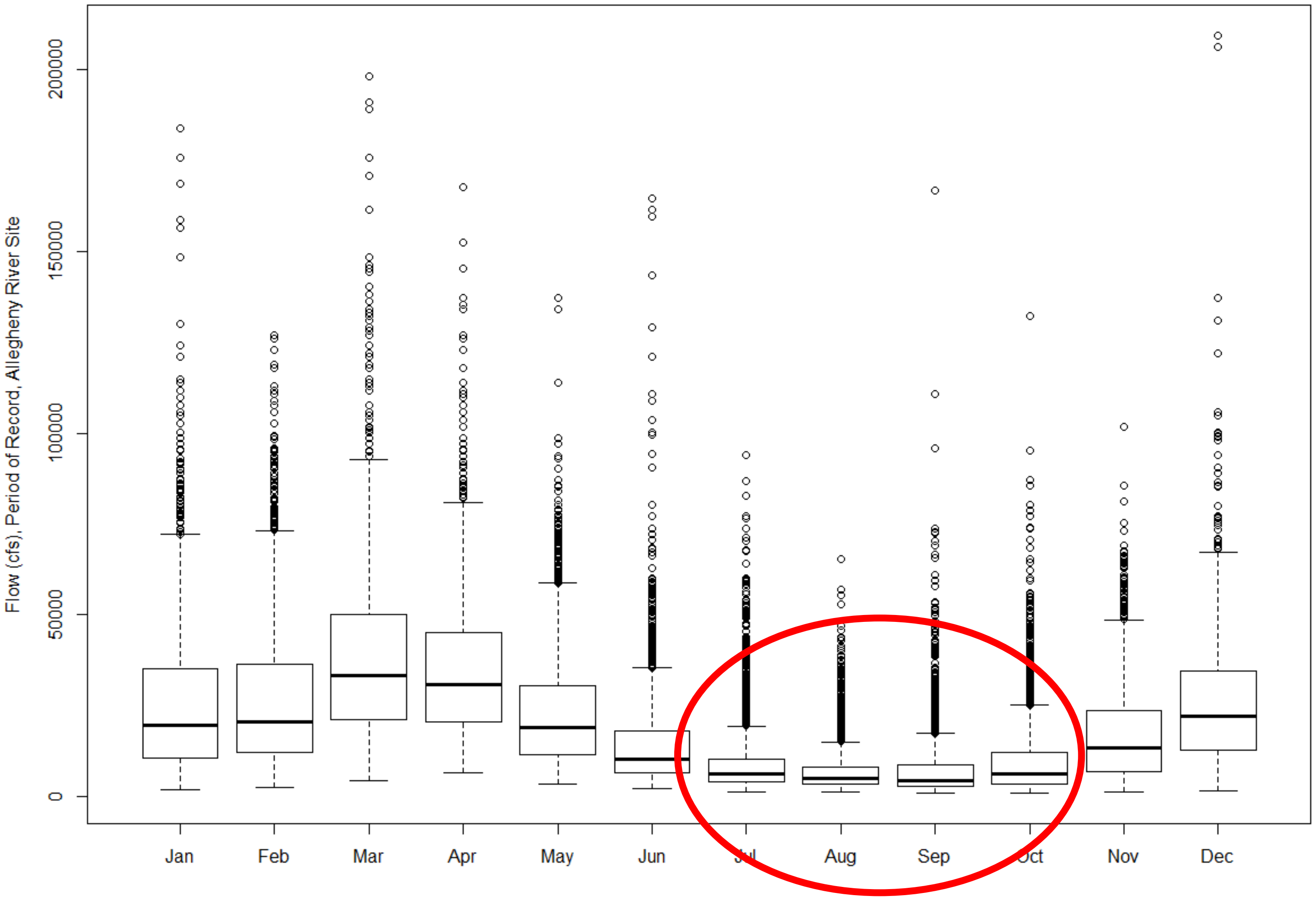


Bromide load contributions from the upstream wet FGD discharges

Good, K. and J. VanBriesen (2017). "Power plant bromide discharges and downstream drinking water systems in Pennsylvania." Environmental Science and Technology **51**(20): 11829-11838.

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



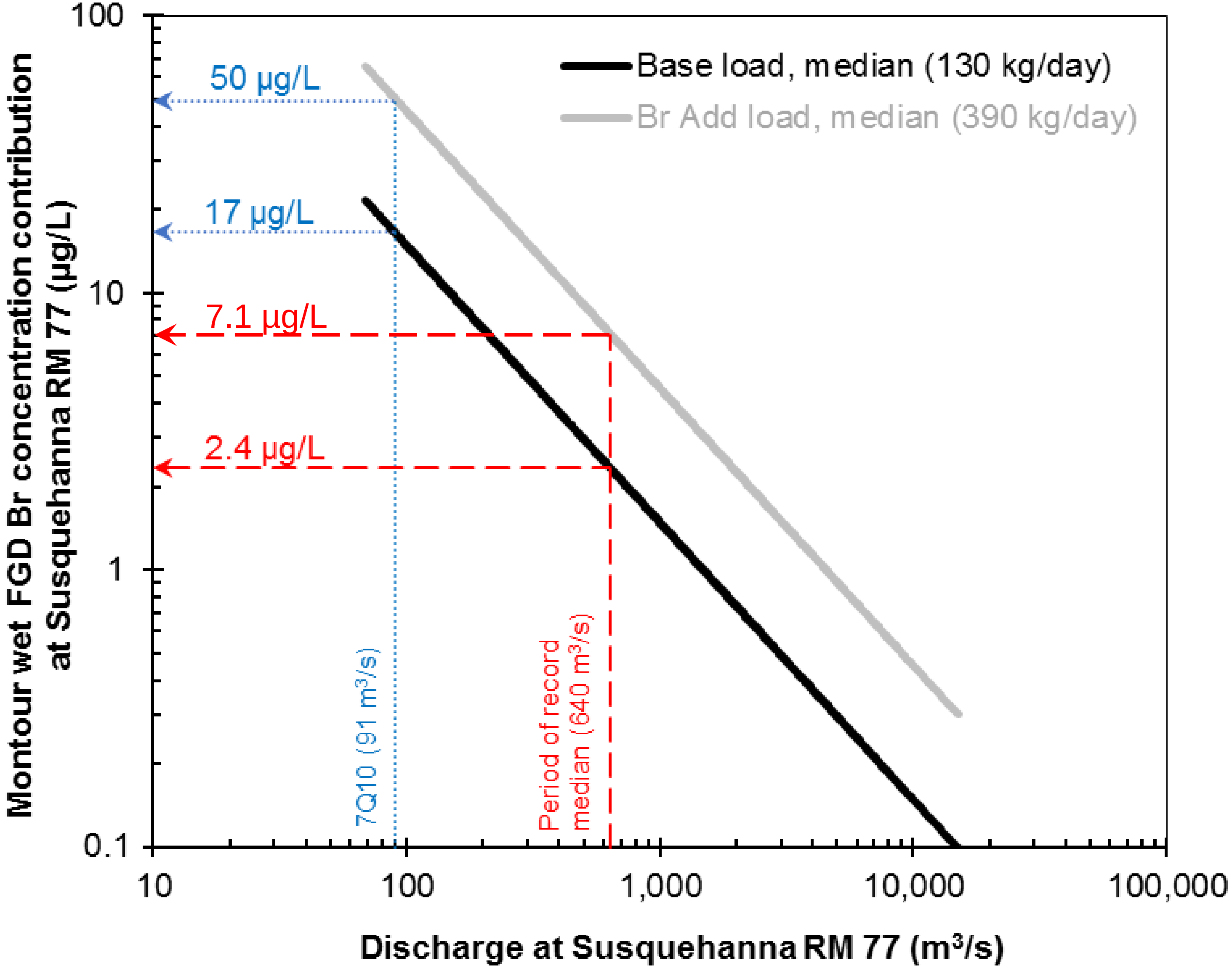
Low flow conditions will lead to elevated bromide concentrations.

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.

Good, K.D. & VanBriesen, J.M. (2016). "Current and potential future bromide loads from coal-fired power plants in the Allegheny River Basin and their effects on downstream concentrations," *Environmental Science & Technology*, 50(17): 9078-9088.

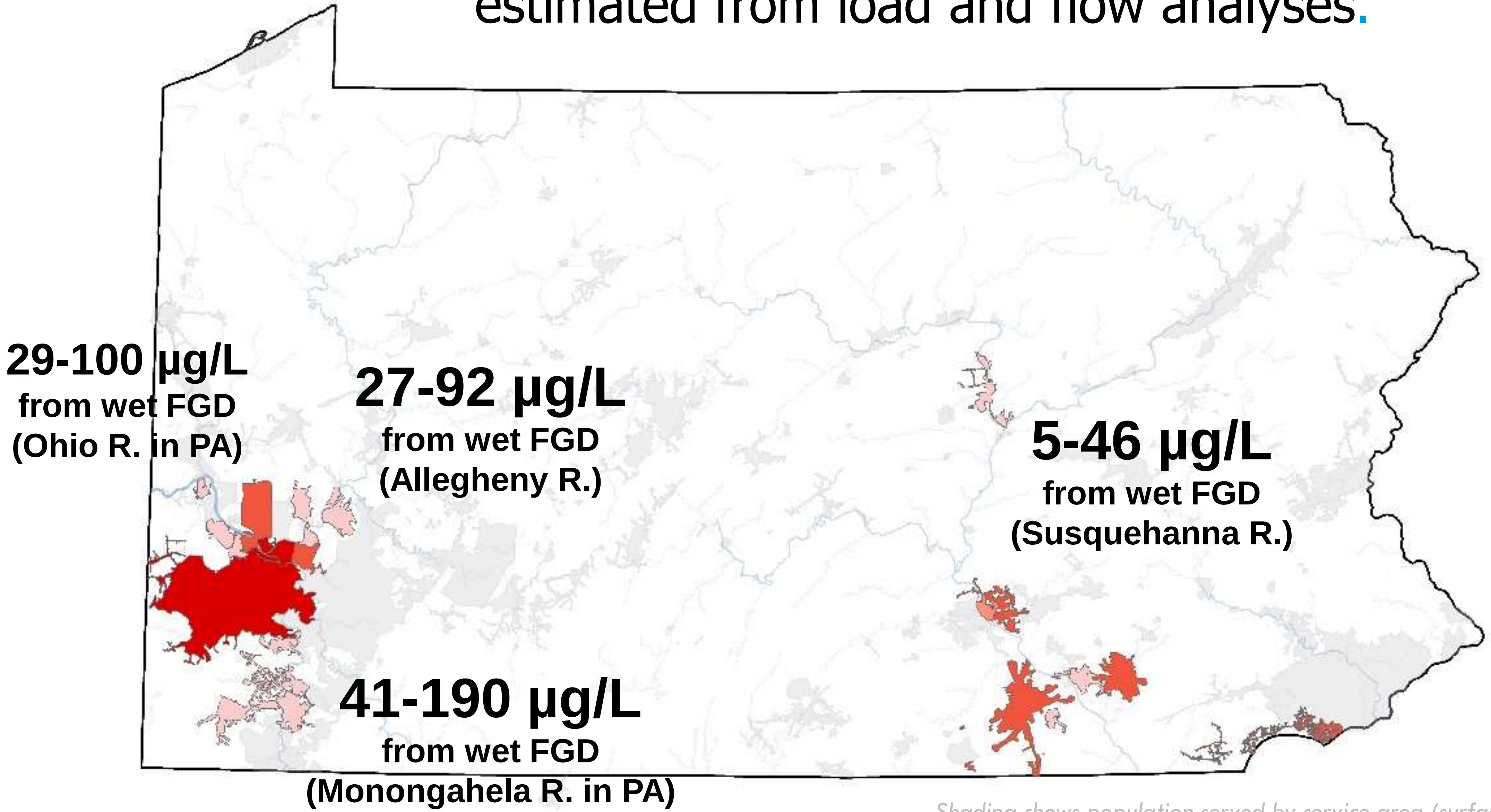
The concentration contribution for any power plant to any drinking water intake can be estimated under any river condition of interest.



$$\frac{\text{Modeled Br load}}{\text{River flow}} = \text{Predicted Br concentration}$$

Good, K. and J. VanBriesen (2017). "Power plant bromide discharges and downstream drinking water systems in Pennsylvania." Environmental Science and Technology **51**(20): 11829-11838.

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).

Good, K. and J. VanBriesen (2017). "Power plant bromide discharges and downstream drinking water systems in Pennsylvania." Environmental Science and Technology **51**(20): 11829-11838.

American Water Works Association

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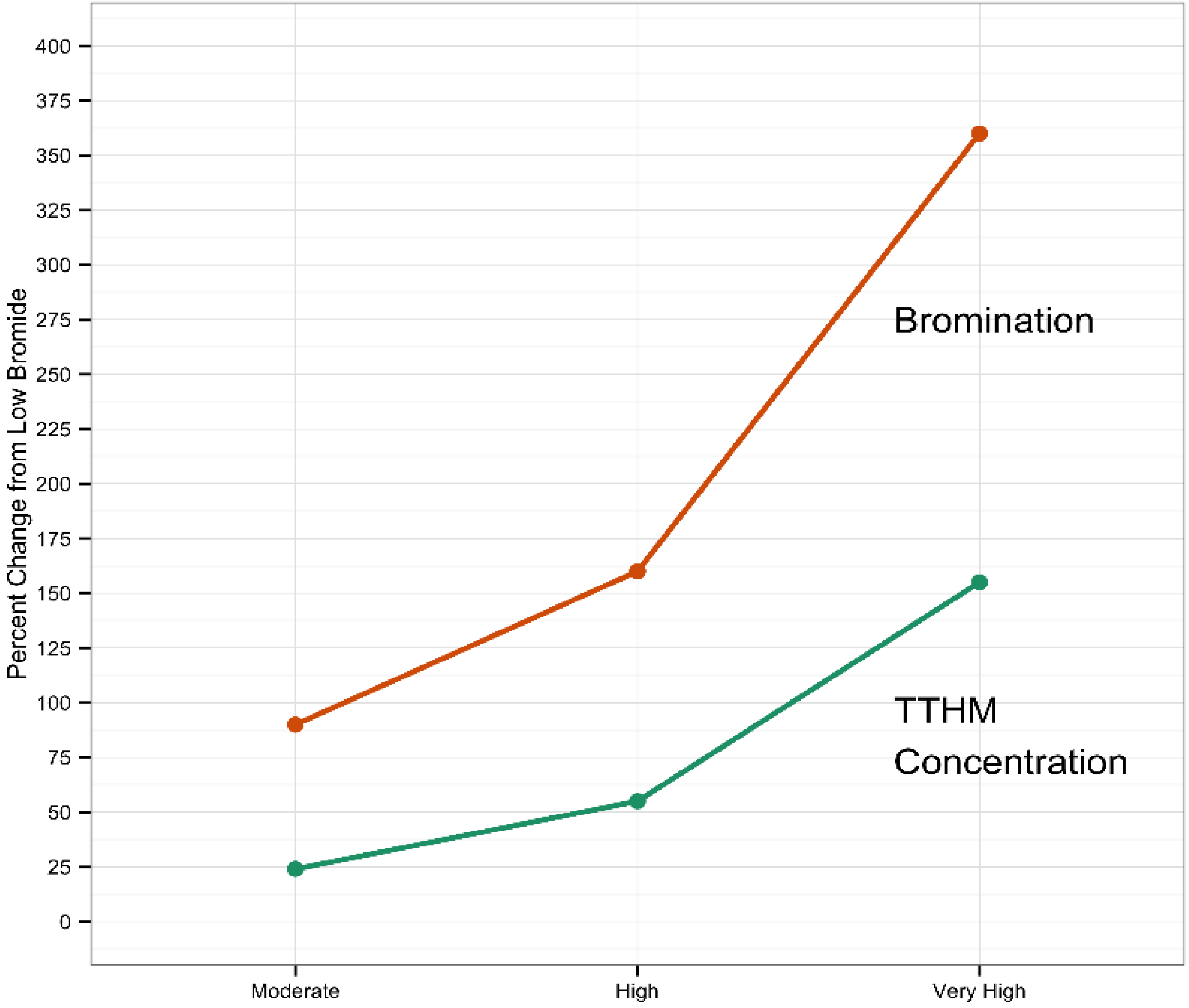
Estimating the concentration contribution from power plants to the drinking water plant allows assessment of potential effects on DBP formation



- 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.

Kolb et al (2017). "Disinfection by-product regulatory compliance surrogates and bromide-associated risk." Journal of Environmental Sciences **58**: 191-207.

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

		ΔBr^- ($\mu g/L$)				
	statistics	10	30	50	75	100
ΔTHM4 ($\mu g/L$) (plant months)	mean	1.3	3.2	4.6	6.0	7.1
	minimum	0.0	0.0	0.0	0.0	0.0
	lower 95% percentile	0.1	0.3	0.5	0.6	0.8
	median	1.1	2.6	3.7	4.9	5.8
	upper 95% percentile	3.4	8.3	11.6	14.8	17.5
	maximum	10.1	23.7	33.2	42.1	49.3

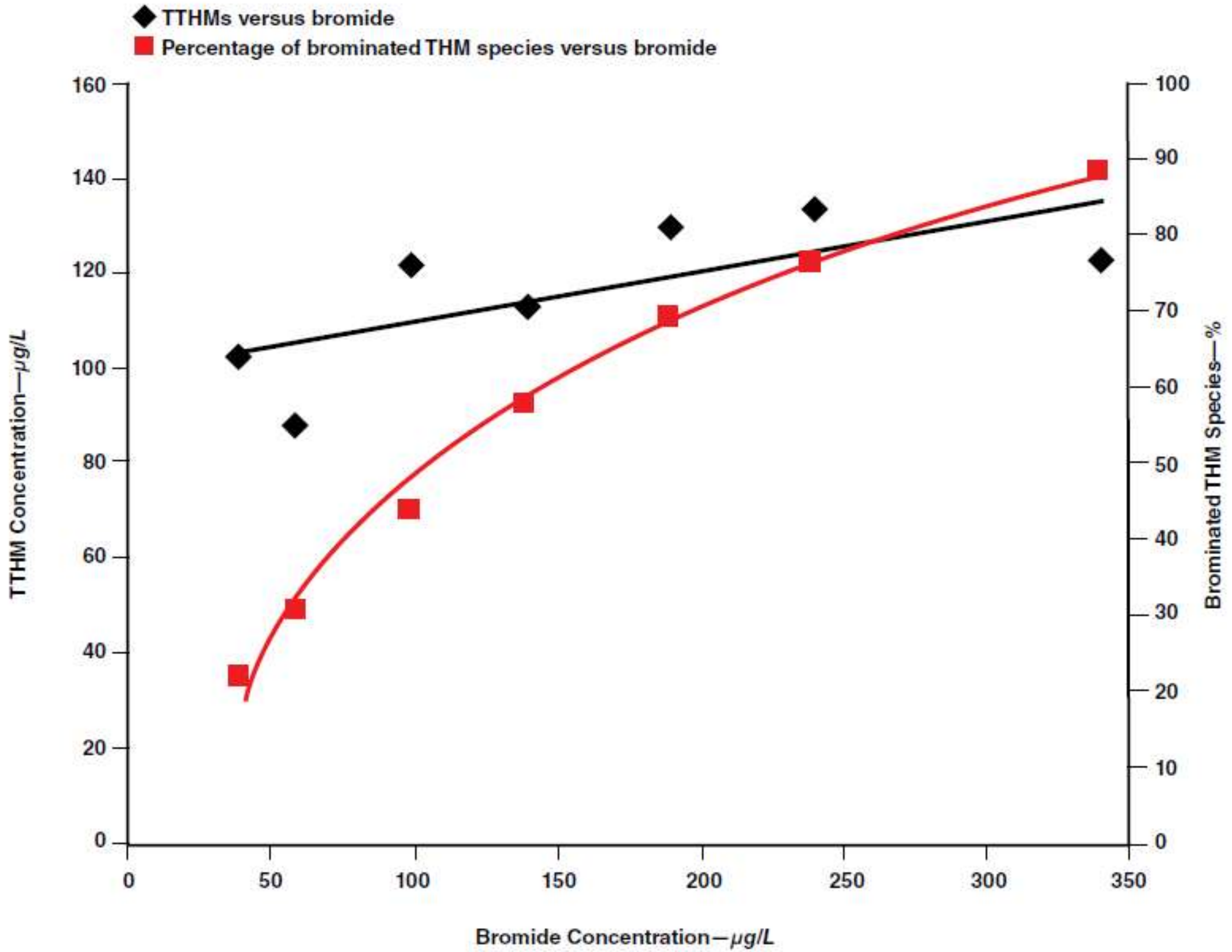
$$OR(THM4) = e^{THM4 \times 0.00427}$$

- 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.

Regli et al (2015) Estimating potential increased bladder cancer risk due to increased bromide concentrations in sources of disinfected drinking waters, ES&T, 49, 13094-13102.

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).

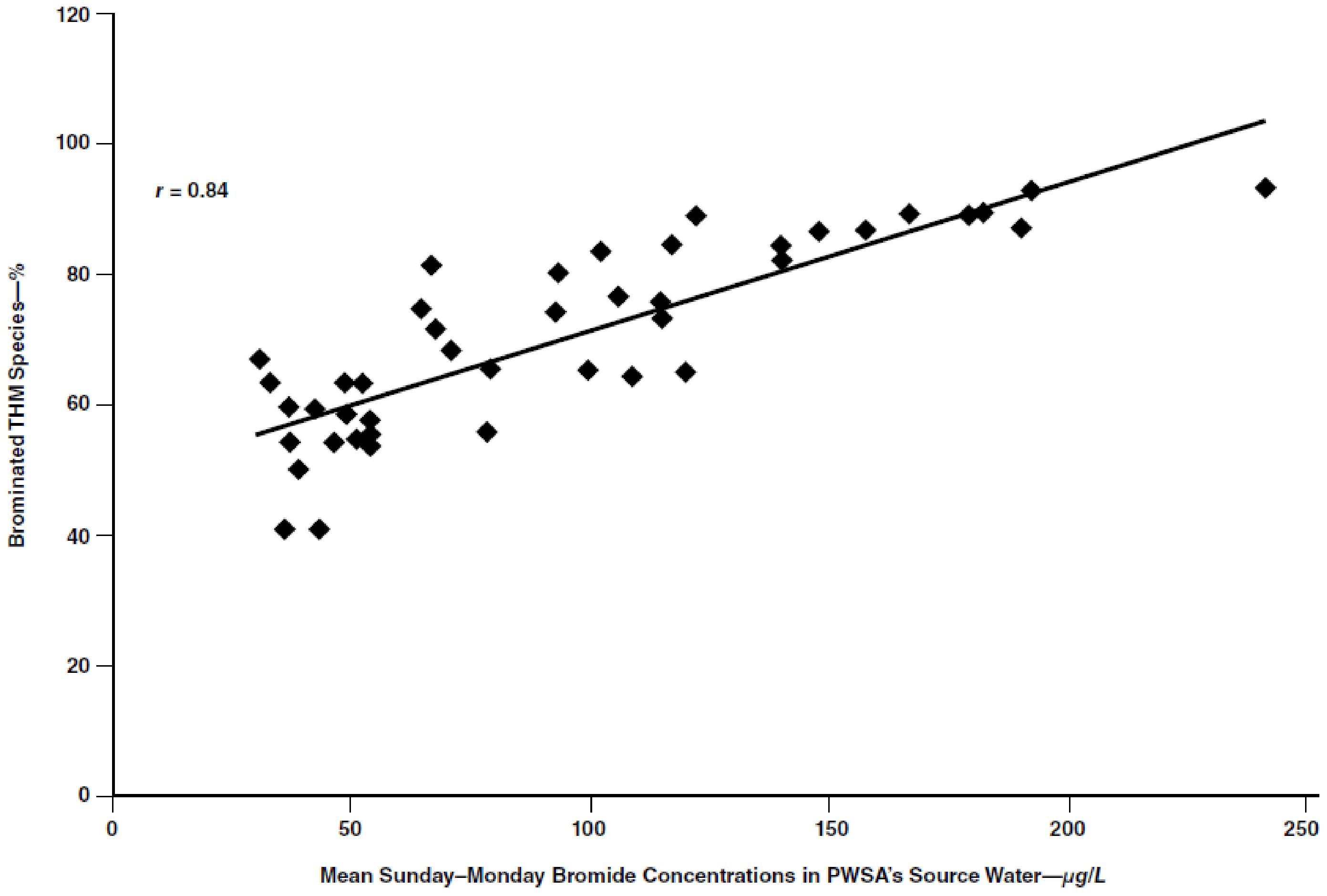
FIGURE 2 TTHM formation potential study—effect of experimental addition of bromide



States et al (2013) Marcellus Shale drilling and brominated THMs in Pittsburgh, PA, drinking water, Journal American Water Works Association, 105:8: E432-E448.

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).

FIGURE 1 Correlation between the percentage of brominated THMs in PWSA's finished water and bromide concentrations in the Allegheny River



PWSA—Pittsburgh Water and Sewer Authority, THMs—trihalomethanes

States et al (2013) Marcellus Shale drilling and brominated THMs in Pittsburgh, PA, drinking water, Journal American Water Works Association, 105:8: E432-E448.

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

DECEMBER 12, 2017

2017

eia

Refined coal has made up nearly one-fifth of coal-fired power generation so far in 2017

News Releases from Headquarters > Water (OW)

2017

EPA Finalizes Rule to Postpone Steam Electric Power Plant Effluent Guidelines Rule

09/13/2017

EPA Advances Proposed Changes to Mercury Rule

2018

10/04/2018 | Sonal Patel

The Environmental Protection Agency (EPA) confirmed it has submitted proposed changes to the Mercury and Air Toxics Standards (MATS) to the White House for review, despite urging by the industry to let the rule stand.

News / News Releases

2018

02.07.18

HOEVEN INTRODUCES LEGISLATION TO EXTEND REFINED COAL TAX CREDIT

Senator's Bill, which Heitkamp Cosponsored, Would Support Reduced Emissions, Affordable & Reliable Electricity Generation

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

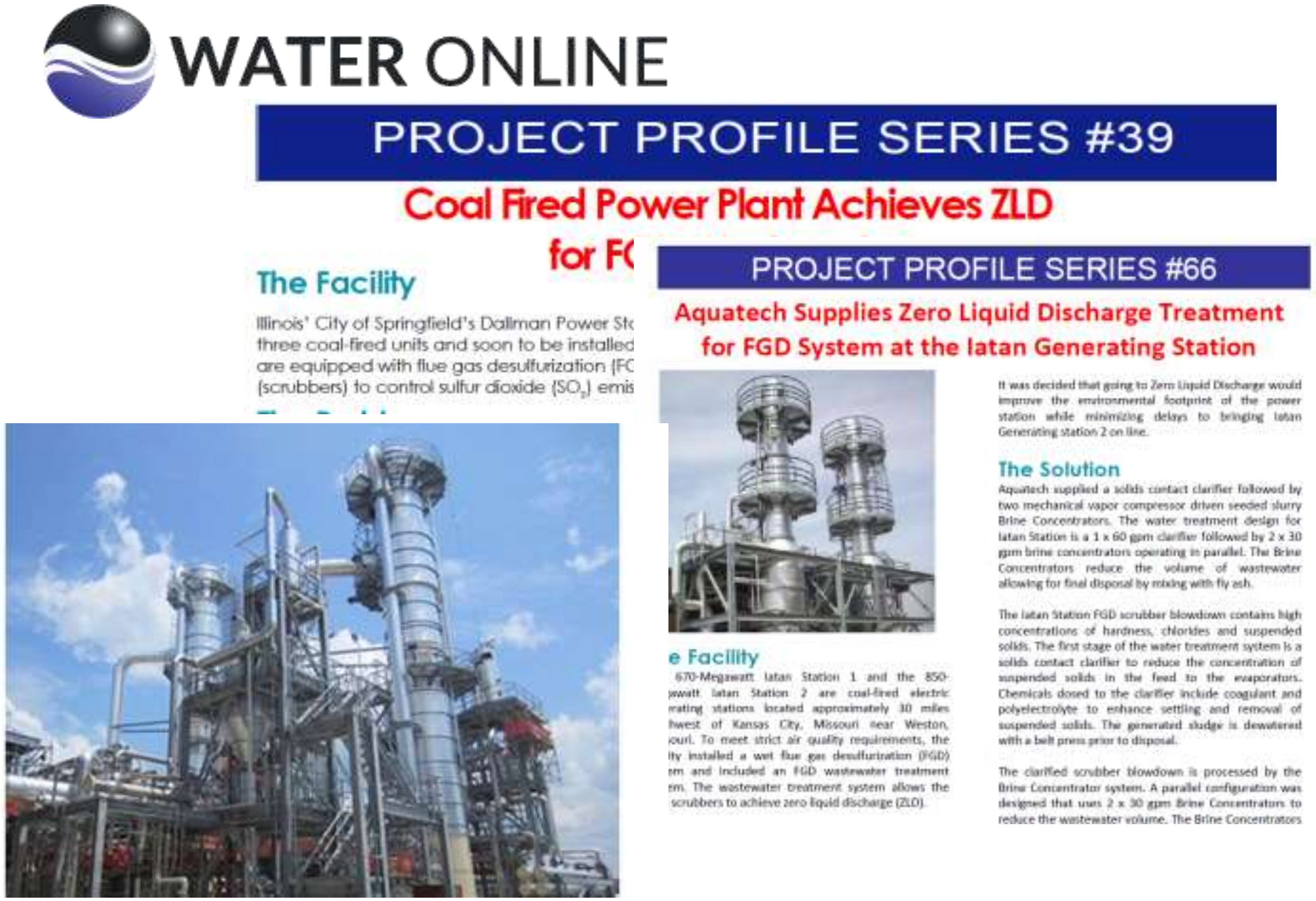
Contact

Emily Fisher
Press@luxresearchinc.com

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

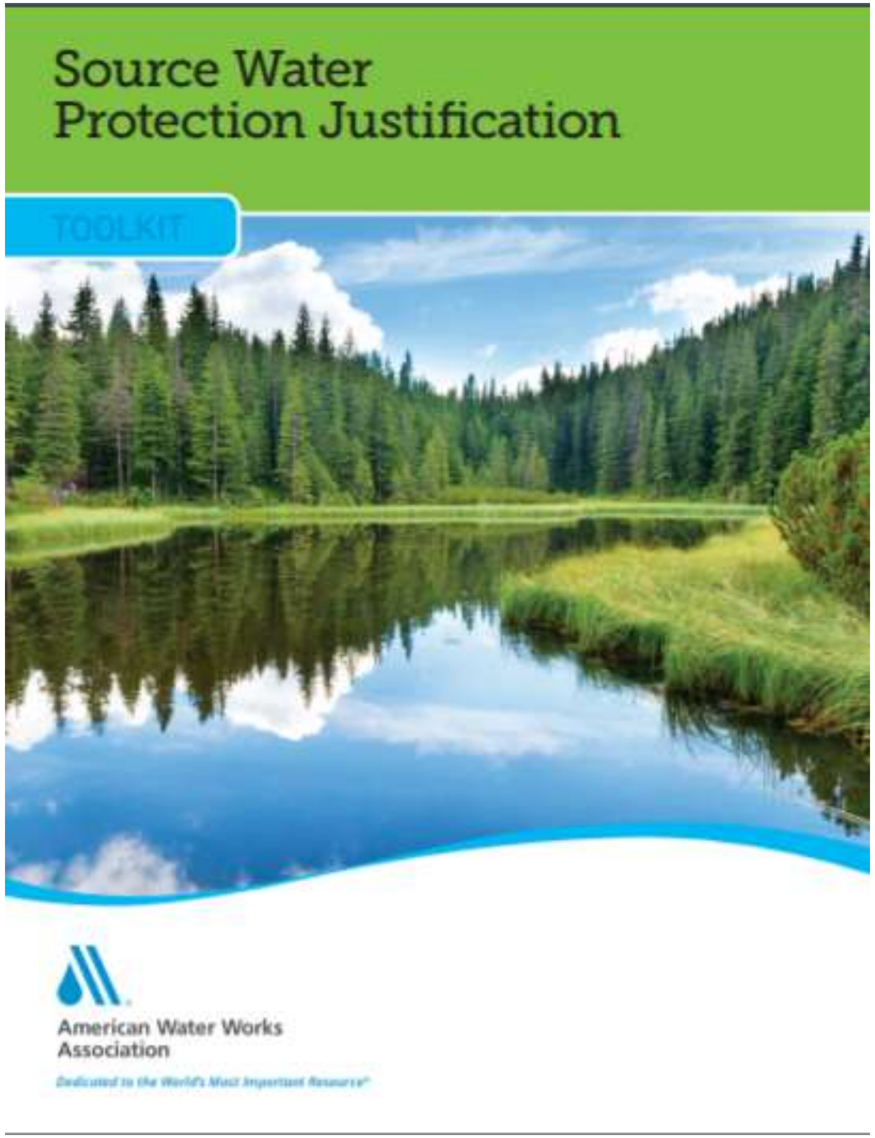
New startups and dominant incumbents GE and Veolia enable a growing market for technologies that can eliminate all liquid waste from power plants and other facilities, Lux Research says

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 factors, 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.



U.S. Environmental Protection Agency. *Technical Development Document for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*; EPA-821-R-15-007; Washington, D.C., 2015b.
U.S. Environmental Protection Agency. Current and Future Industry Profile. DCN SE00444. EPA-HQ-OW-2009-0819 2015.
Case Study: Coal Fired Power Plant and ZLD for FGD Wastewater. Aquatech International Corporation. https://www.wateronline.com/doc/coal-fired-power-plant-and-zld-for-fgd-wastew-0002 Accessed 5/27/2018.
Case Study: Aquatech supplied zero liquid discharge treatment for FGD system at the Iatan Generating Station. Aquatech International Corporation. https://www.wateronline.com/download/Retrieve?FileId=d9b6e56e-db89-46cc-9b4c-4d691178376c&url=aquatech-supplies-zero-liquid-discharge-0001&id=d4fd153e-cb01-438f-82f3-694ca0a78006 Accessed 5/27/2018

Source Water Justification Toolkit



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