

Phase I Regulatory Framework and Aquatic Toxicity Review

Summary Presentation

**International Aluminium Institute (IAI)
Aquatic Fluoride Project**

16 December 2020



Project Aim and Rationale

Project Aim

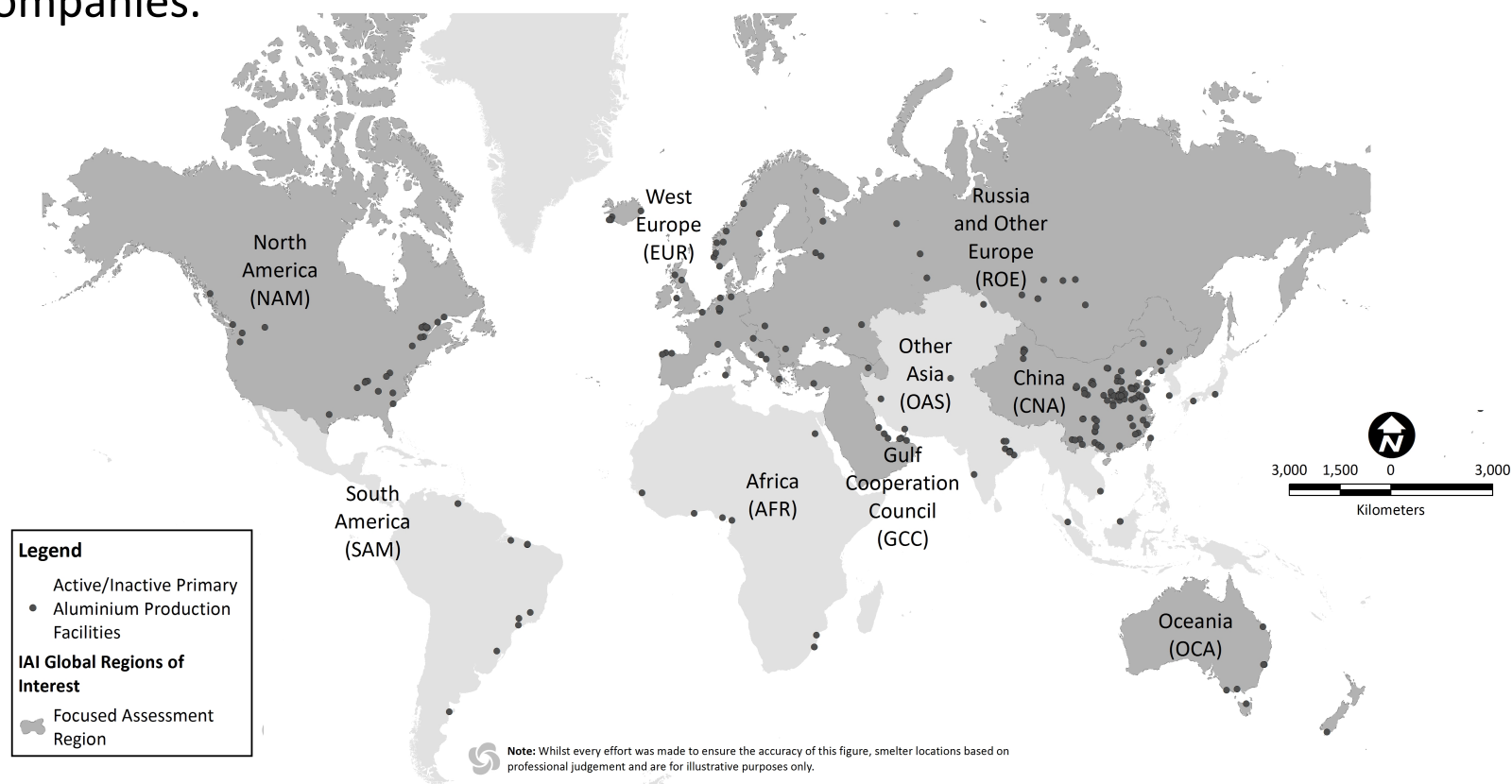
- To provide a scientifically sound basis to inform the development of aquatic fluoride regulation and management around aluminium production facilities.

Rationale

- Fluoride-containing compounds are critical to the production of aluminium.
- Increasing regulatory pressure to reduce fluoride discharges in effluent waters from aluminium smelting facilities.
- Limited treatment approaches are available for fluoride and they are not cost effective.
- Management of fluoride-containing wastes can directly impact the viability of businesses that rely heavily on the use of fluoride.

Study Area

- Investigation focused on select primary aluminium smelting regions representative of IAI member companies.

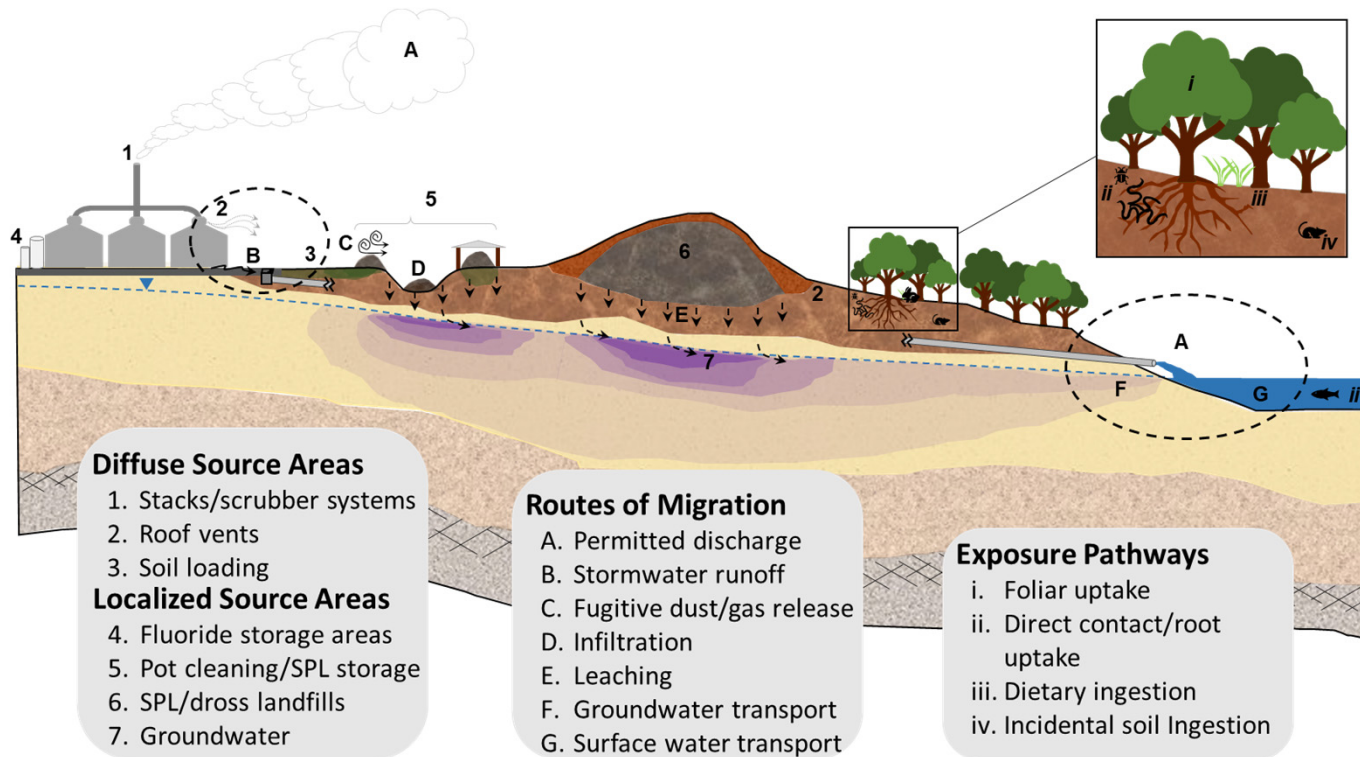


Objectives of Phase I Investigation

- Determine the sources of fluoride to the aquatic environment and assess background surface water concentrations in marine and freshwater environments.
- Conduct a critical review of existing regulatory guidelines for aquatic fluoride throughout the study area.
- Review surface water fluoride toxicity information from primary literature sources and develop preliminary water quality guidelines that consider key factors that are known to ameliorate the toxicity of fluoride.
- Synthesize key information to support stakeholder understanding.

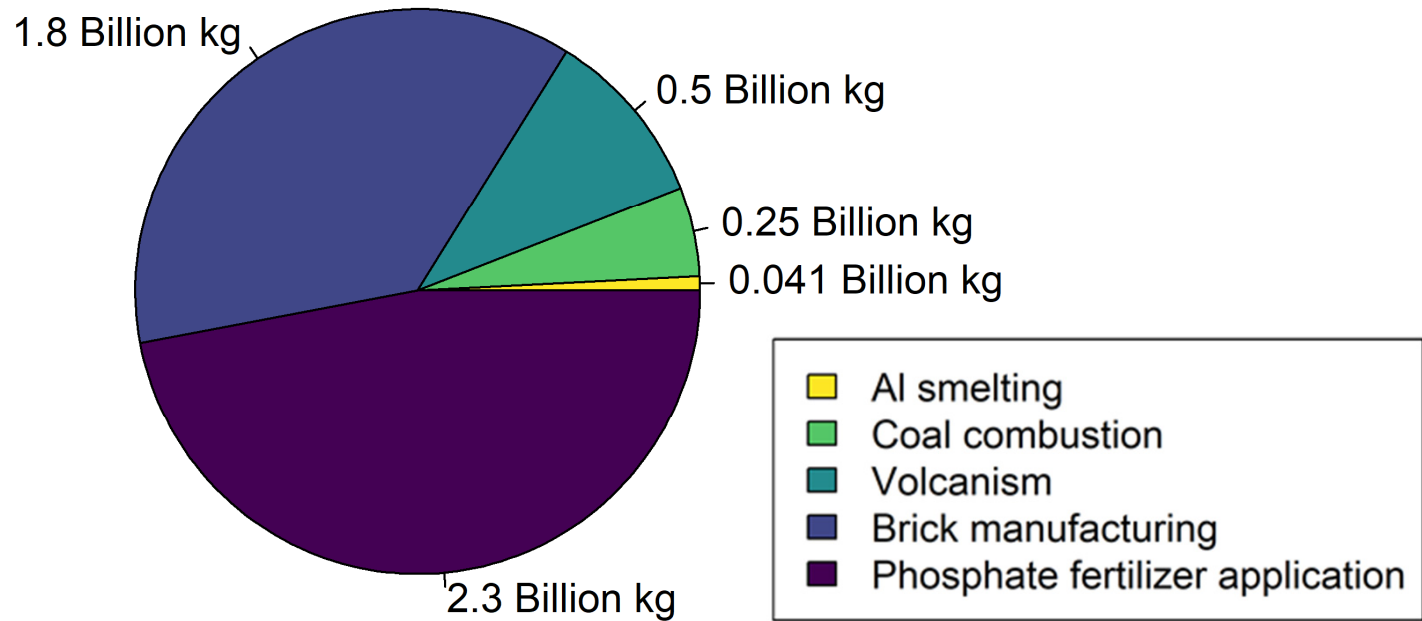
Fluoride Conceptual Site Model

- Fluoride source areas, migration routes, and exposure pathways shown below.
- Diffuse sources from roof vents/soil loading and permitted discharges primary focus.



Background – Sources of Fluoride

- Natural mineral weathering largest source of fluoride to environment.
- Phosphate fertilizer application, brick manufacturing, and coal combustion among largest anthropogenic sources.



Adapted from Fuge (2019) and Pyle and Mather (2009)

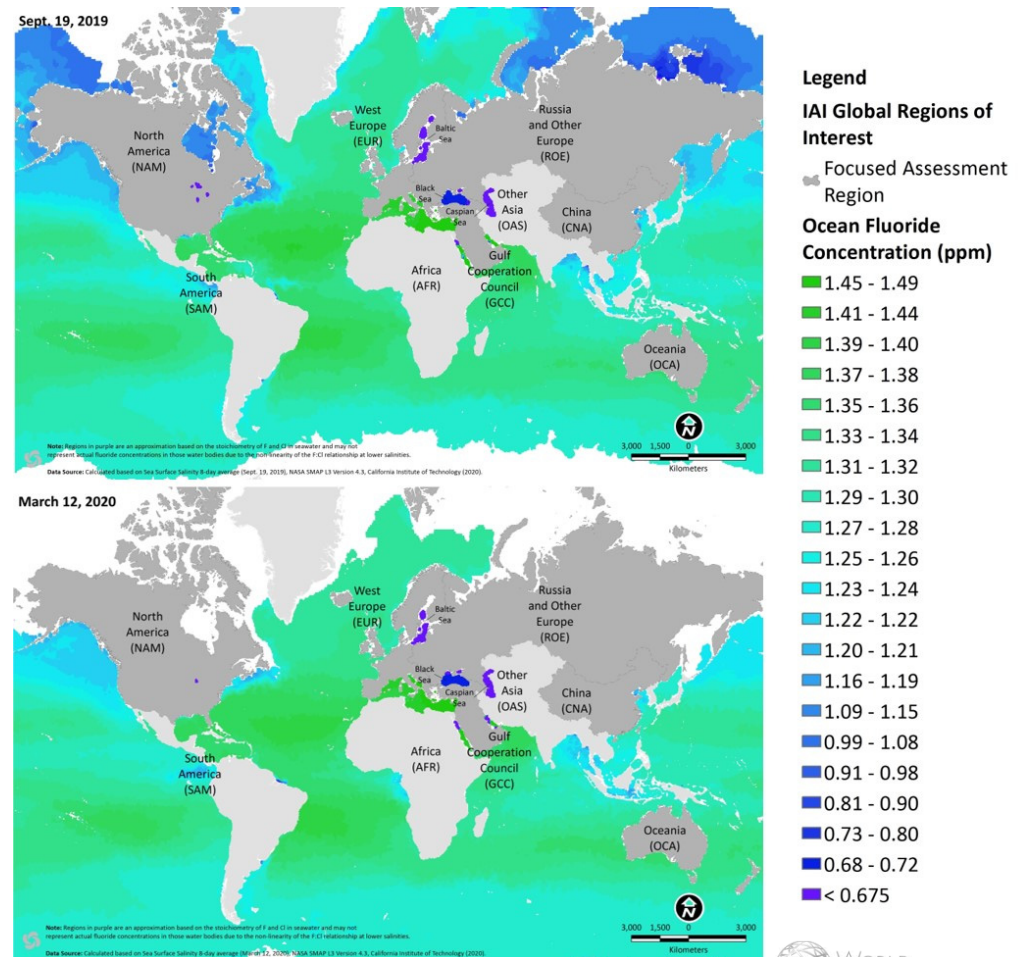
Background – Fluoride in Fresh and Marine Waters

Freshwater

- Freshwater fluoride concentrations typically ranged from 0.1 to 0.3 mg/L.
- Concentrations were highly variable at smaller scales, mainly due to differences in geology.

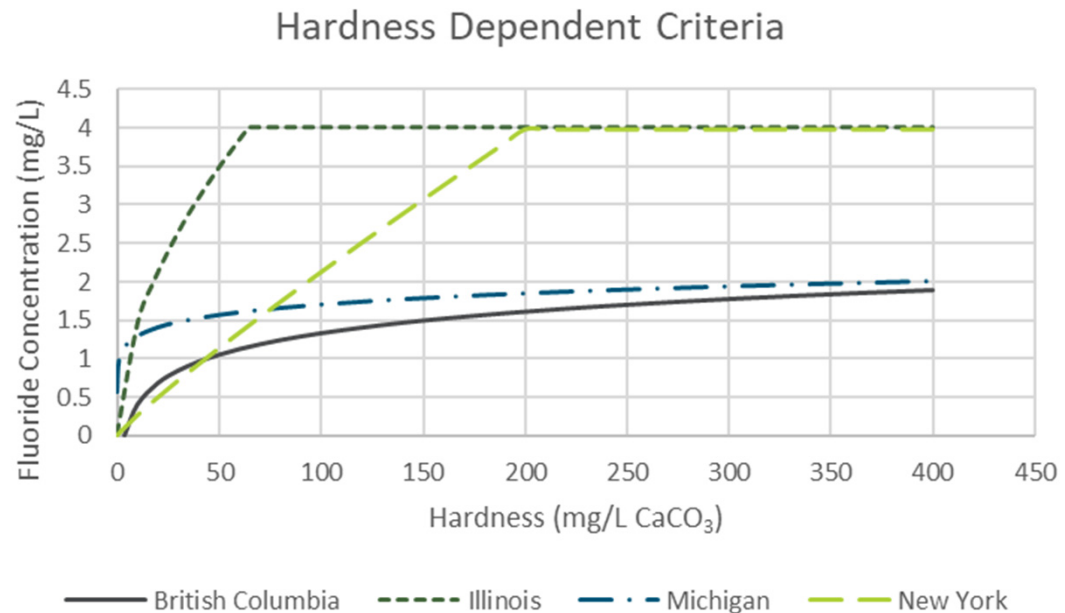
Marine Water

- Marine water fluoride concentrations are greater and are predominately around 1.3 mg/L.
- Concentrations dependent on evaporation rates, which are greater in the mid-latitudes.



Regulatory Review – Fluoride Criteria

- Drinking water guidelines ranged from 1.0 to 4.0 mg/L fluoride (median = 1.5 mg/L).
- Aquatic life criteria ranged from 0.12 to 4.0 mg/L fluoride with no criteria value above the promulgated USEPA drinking water standard of 4.0 mg/L.
- Three states and one province in North America currently use hardness-dependent criteria.
- Chloride is known to ameliorate the toxicity of fluoride; however, no criteria use chloride to predict appropriate fluoride levels.



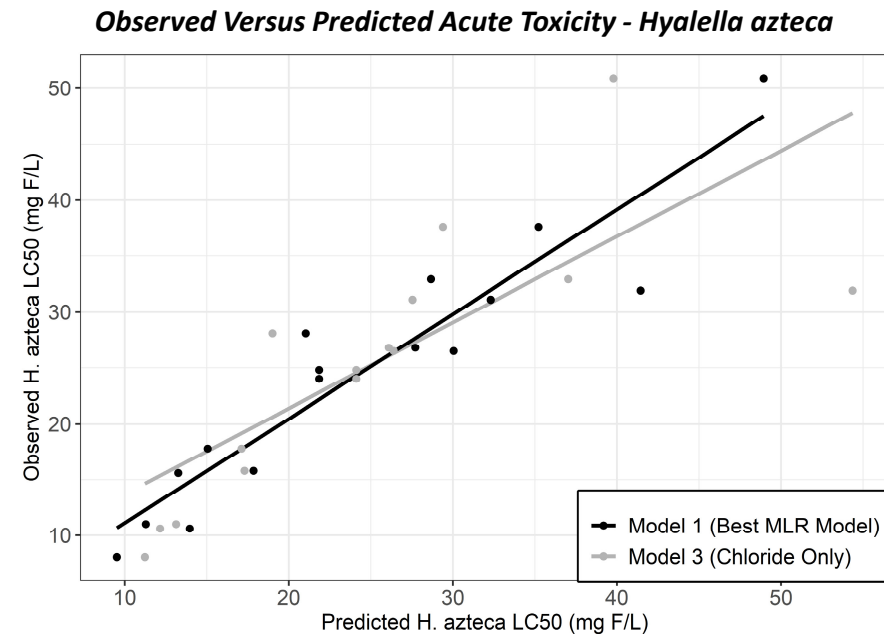
Aquatic Ecotoxicity – Derivation Process Used to Develop Preliminary Guideline Values

Guideline derivation process outlined below; focused slides follow on items 4, 6, and 7

1. Review and assess the suitability of fluoride aquatic toxicity studies.
2. Reduce toxicity dataset to those studies that meet acceptability criteria.
3. Determine whether other physical or chemical conditions affect the toxicity of the compound of interest through univariate or multivariate statistical analysis.
4. *Identify the most suitable model to predict toxicity.*
5. Apply the identified model to normalize aquatic toxicity results to desired normalization parameter.
6. *Assess how regional water quality parameters for areas of aluminium production influence preliminary guideline values.*
7. *Estimate suitable chronic or acute guideline values using the distribution of the normalized toxicity data.*

Aquatic Ecotoxicity – Ameliorating Effects Assessment

- Accounting for the ameliorating effect of water quality parameters improves the ability to predict toxicity of fluoride.
- Multivariate approaches are appropriate for predicting fluoride toxicity in freshwater.
- Site-specific water quality parameters should be incorporated into fluoride regulations.



Source: EHS Support using data from Pearcy et al. (2015)

- Chloride, hardness, and alkalinity best predicted acute $R^2=0.90$.
- Chloride alone not as effective ($R^2=0.80$).

Aquatic Ecotoxicity – Regional Water Quality

- *Low Ion Water Scenario* - Represents aluminium production regions in Pacific Northwest and British Columbia

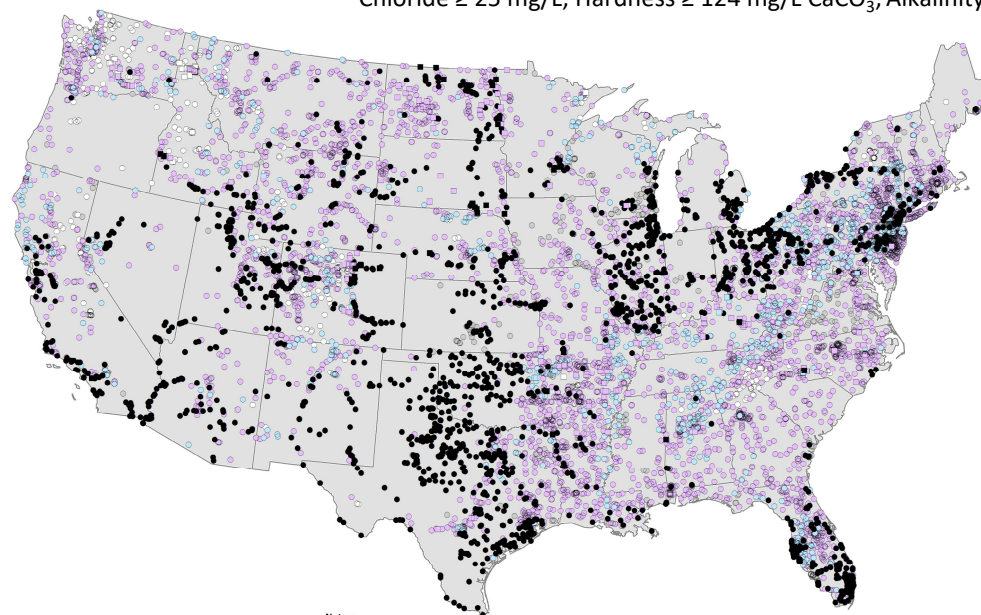
- Chloride ≤ 1.5 mg/L; Hardness ≤ 66 mg/L CaCO_3 ; Alkalinity ≤ 58 mg/L CaCO_3 .

- *High Ion Water Scenario* - Represents aluminium production regions in Great Lakes and St. Lawrence

- Chloride ≥ 25 mg/L; Hardness ≥ 124 mg/L CaCO_3 ; Alkalinity ≥ 92 mg/L CaCO_3 .

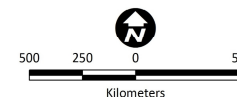
Legend

- Complete Dataset: At or Above High Ion Water Scenario
- Complete Dataset: Between Low and High Ion Water Scenarios
- Complete Dataset: Mixed Results
- Complete Dataset: At or Below Low Ion Water Scenario
- Chloride and Hardness At or Above High Ion Water Scenario
- Chloride and Hardness Between Low and High Ion Water Scenarios
- Chloride and Hardness Mixed Results
- Chloride and Hardness At or Below Low Ion Water Scenario
- Incomplete Dataset
- △ No Data



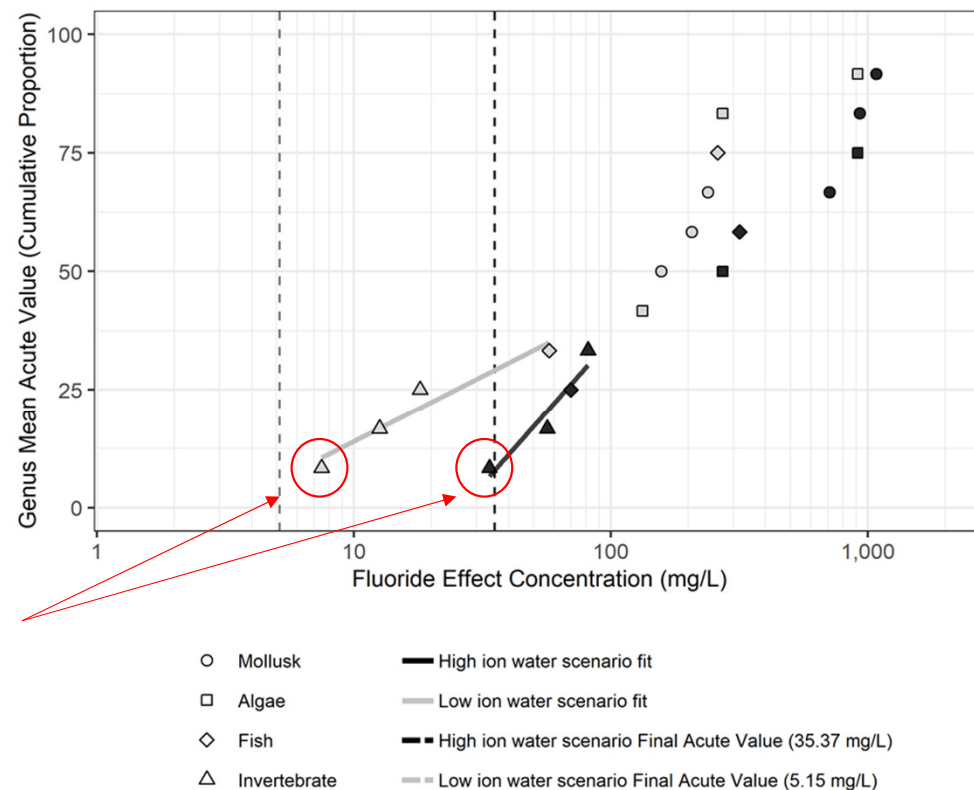
Notes:

-Surface water data sourced from USGS from 1970 to present
 -Comparisons based on median concentration of analyte for available data
 -Low Ion Water Scenario: Cl ≤ 1.5 mg/L; Hardness ≤ 66 mg/L; Alkalinity ≤ 58 mg/L
 -High Ion Water Scenario: Cl ≥ 25 mg/L; Hardness ≥ 124 mg/L; Alkalinity ≥ 92 mg/L
 -Hardness and alkalinity presented on the basis of mg/L CaCO_3
 -Mixed results indicates that conditions of water quality parameters span more than one water ion scenario
 Data Source: United States Geological Survey (USGS), 2020.



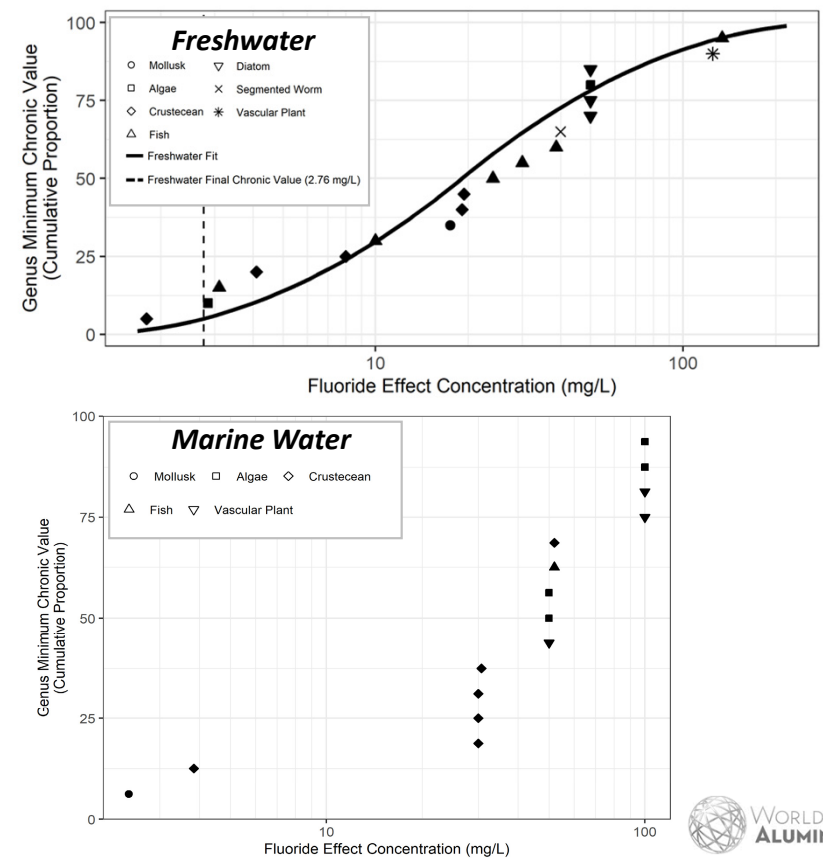
Aquatic Ecotoxicity – Preliminary Guideline Development That Considers Water Quality Parameters

- High ion final acute value (FAV) = 35.4 mg/L;
low ion FAV = 5.2 mg/L.
- Acute-to-chronic ratios (ACR) used to estimate preliminary chronic criteria:
 - **High ion water chronic estimate = 11.8 mg/L**
 - Low ion water chronic estimate = 1.7 mg/L.
- Estimates may be biased low due to effect of overly sensitive taxa (*Hyallela azteca*).



Aquatic Ecotoxicity – Preliminary Guideline Development That Does Not Consider Water Quality Parameters

- Preliminary freshwater and marine chronic criteria were also derived using a species sensitivity distribution (SSD) approach that did not account for water quality conditions:
 - Freshwater final chronic value (FCV) = 2.8 mg/L
 - Marine water not estimated but between 4 and 30 mg/L.
- **Guideline values derived without considering water quality conditions will be more conservative.**



Conclusions

- On a global scale, the aluminium industry represents a small source of fluoride to the environment relative to other natural and industrial sources.
- Existing aquatic fluoride criteria are overly conservative.
- Water quality parameters such as chloride, hardness, and alkalinity have an important role in mediating or ameliorating the toxicity of fluoride to aquatic receptors.
- Accounting for water quality parameters results in nearly **10-fold** differences in preliminary guidelines based on the two freshwater scenarios evaluated.
- The lower bound of derived guidelines were commensurate to existing guidance with the upper bounds resulting in much greater management limits.
- The aquatic ecotoxicity review demonstrates that more scientifically robust approaches to derive criteria needs to be employed for fluoride, and that these advances will result in departure from overly conservative guidance.

Thank you.

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