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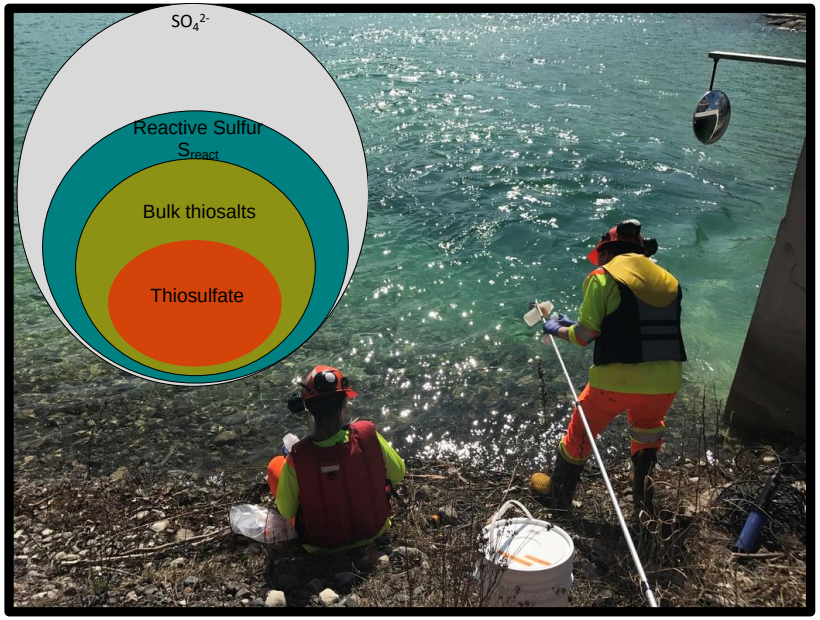
ANNUAL WORKSHOP 2021

MINING, WATER, AND ENVIRONMENT GROUP

Cost-Effective Mass Balance Approach to Monitor Thiosalt Risks for the Mining Industry

~~Reactive Sulfur~~

Kelly Whaley-Martin*, Tara Colenbrander Nelson, Lauren Twible and Lesley Warren (University of Toronto)
Chad Jarolimek, Josh King and Simon Apte (CSIRO)
Stephanie Marshall (ERM)
Sam McGarry (Glencore, Sudbury INO),
Shirley Neault and Landice Yestrau (Hudbay Minerals)
Peter Mercer (Rambler Metals and Mining) and
Helga Sonnenberg (EcoReg Solutions)



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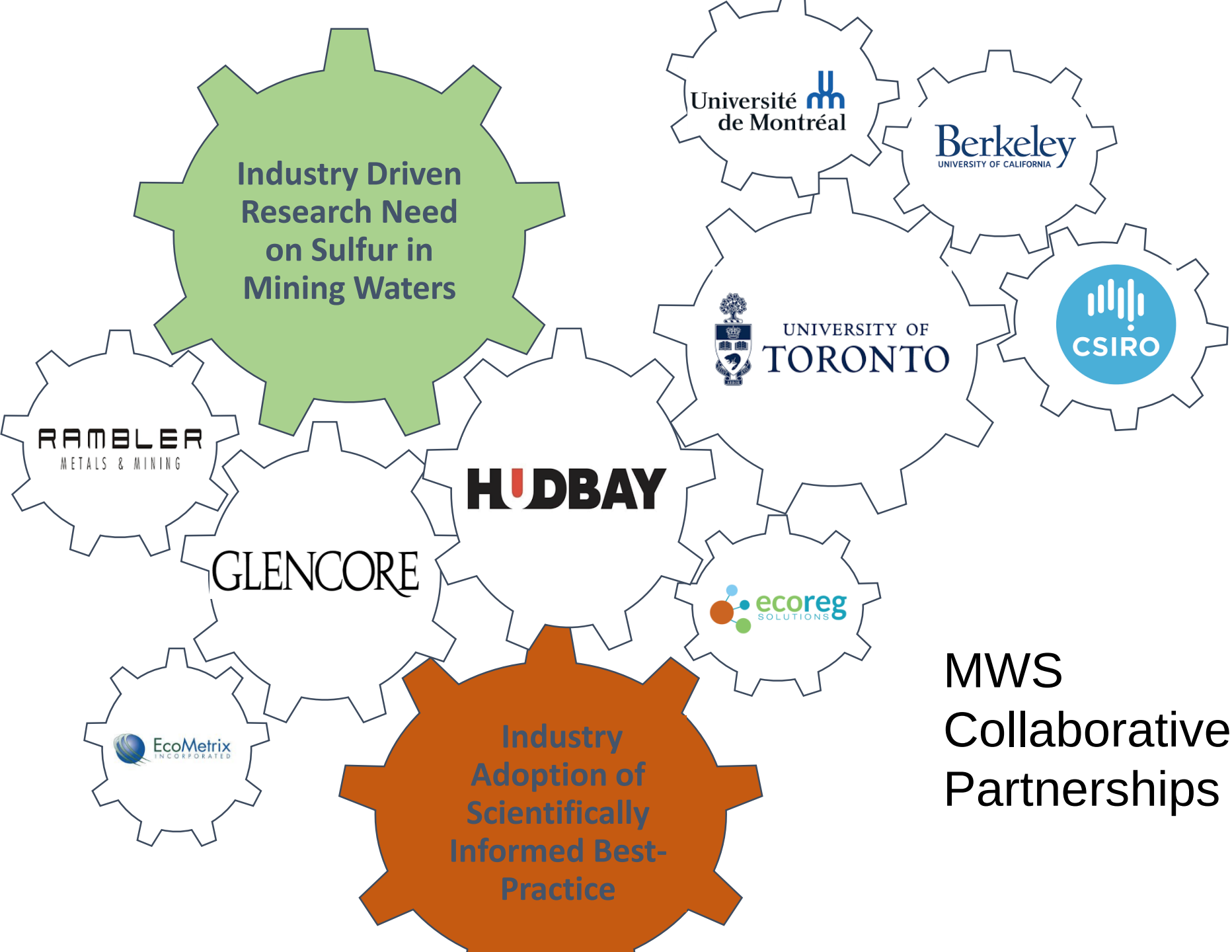


MWS Collaborative Partnerships

The Risk

Dissolved reactive sulfur compounds in mining impacted waters are a global challenge

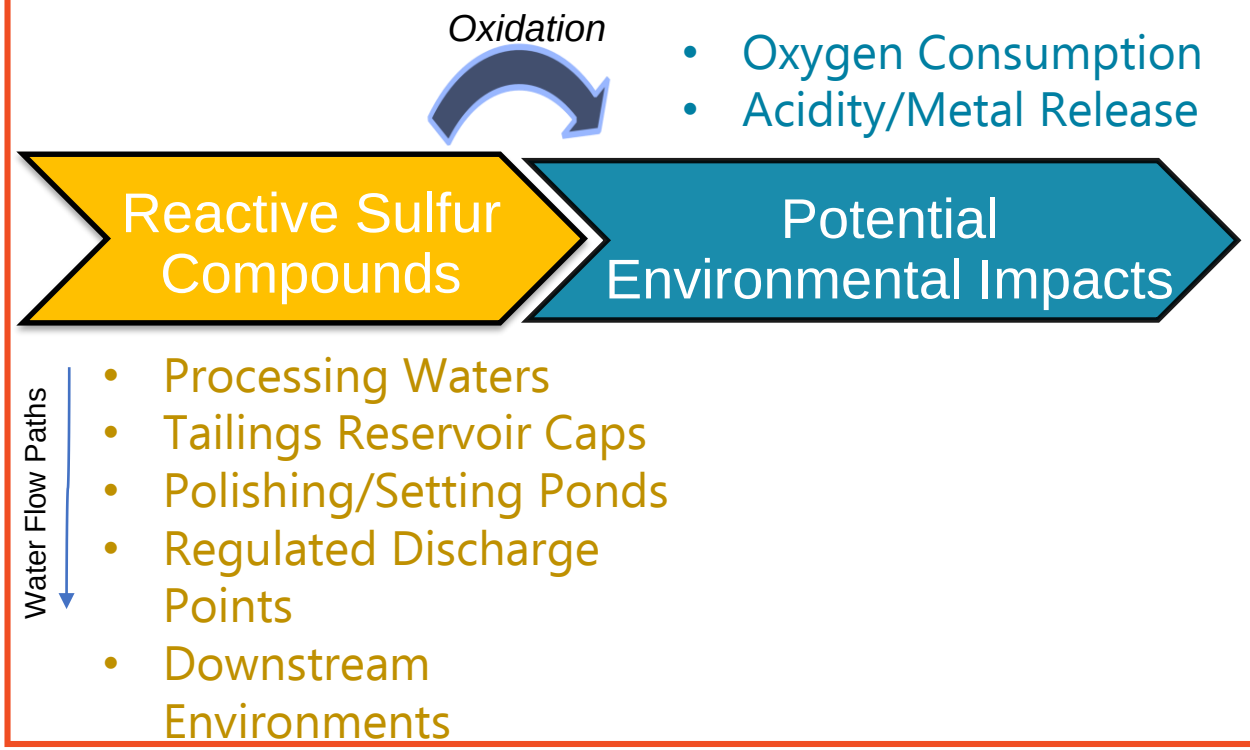
Reactive Sulfur Compounds

Water Flow Paths

- Processing Waters
- Tailings Reservoir Caps
- Polishing/Setting Ponds
- Regulated Discharge Points
- Downstream Environments

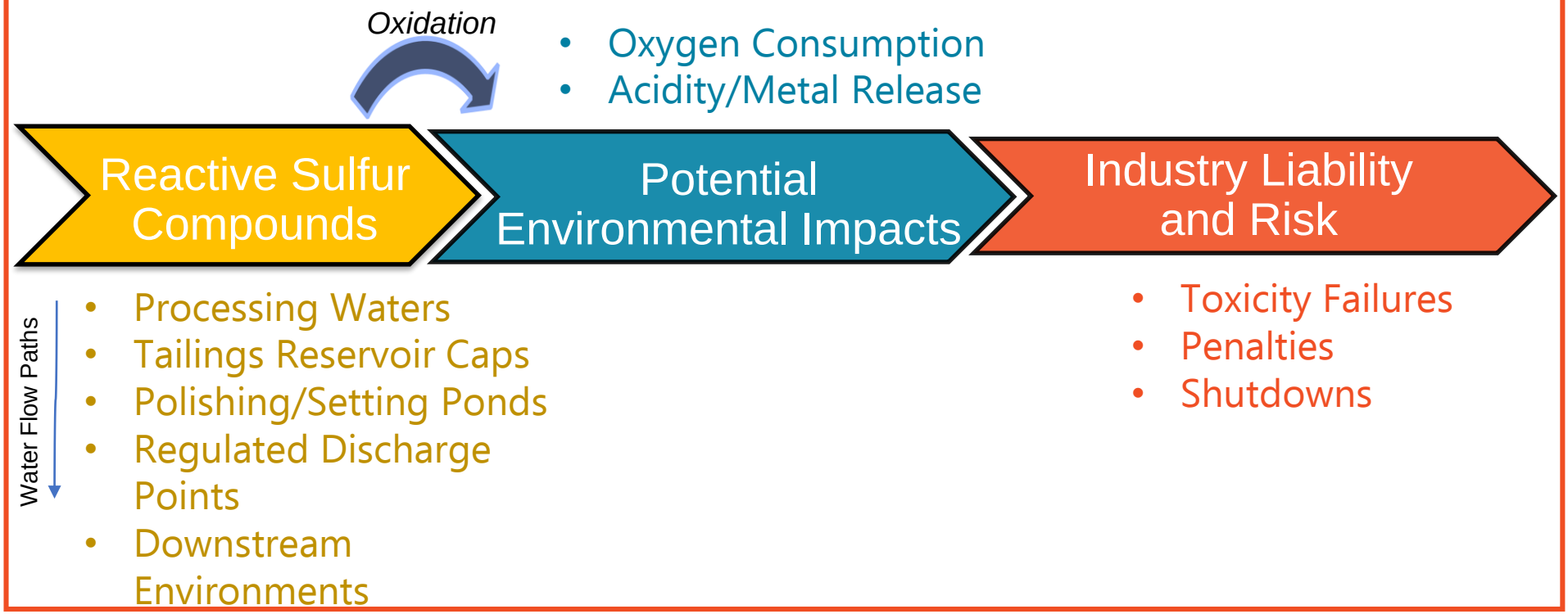
The Risk

Dissolved reactive sulfur compounds in mining impacted waters are a global challenge



The Risk

Dissolved reactive sulfur compounds in mining impacted waters are a global challenge

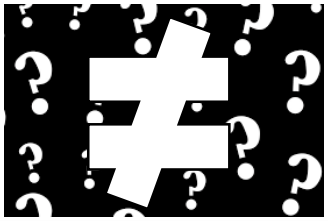


Analytical Definitions and Terminology Matter!

Sulfur oxidative processes are **often intimately connected** with toxicity/**regulatory failures**

MDMER regulations **don't currently regulate SO_4^{2-} or reactive S compounds** in Canadian discharged mine waters…but the term "thiosalts" is an industry-adopted term

Reactive Sulfur Compounds



Thiosalts

Analytical Definitions and Terminology Matter!

Chemical Definition: Reduced sulfur oxyanions formed during milling (grinding, aeration and flotation circuits)

$S_2O_3^{2-}$ $S_3O_6^{2-}$ $S_4O_6^{2-}$ (Thiosalt Consortium/CANMET)

Thiosalts

Analytical Definitions: Serious ambiguity/variation on around how "thiosalts" are measured from mine to mine and/or between commercial laboratories

->leading to "Apples" and "Oranges" data comparisons

Analytical Definitions and Terminology Matter!

Thiosalts

"Bulk Thiosalts"
Acidimetric Titration ($HgCl_2$ Titration)

"Apples"

$S_2O_3^{2-}$

$S_3O_6^{2-}$ $S_4O_6^{2-}$

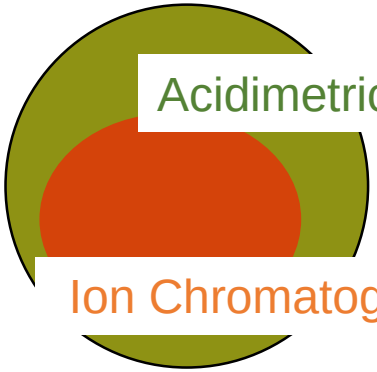
Originally proposed in 1911 (Feld), later modified in 1976 (Noranda Research centre)

"Thiosalts"
Ion Chromatography

"Oranges"

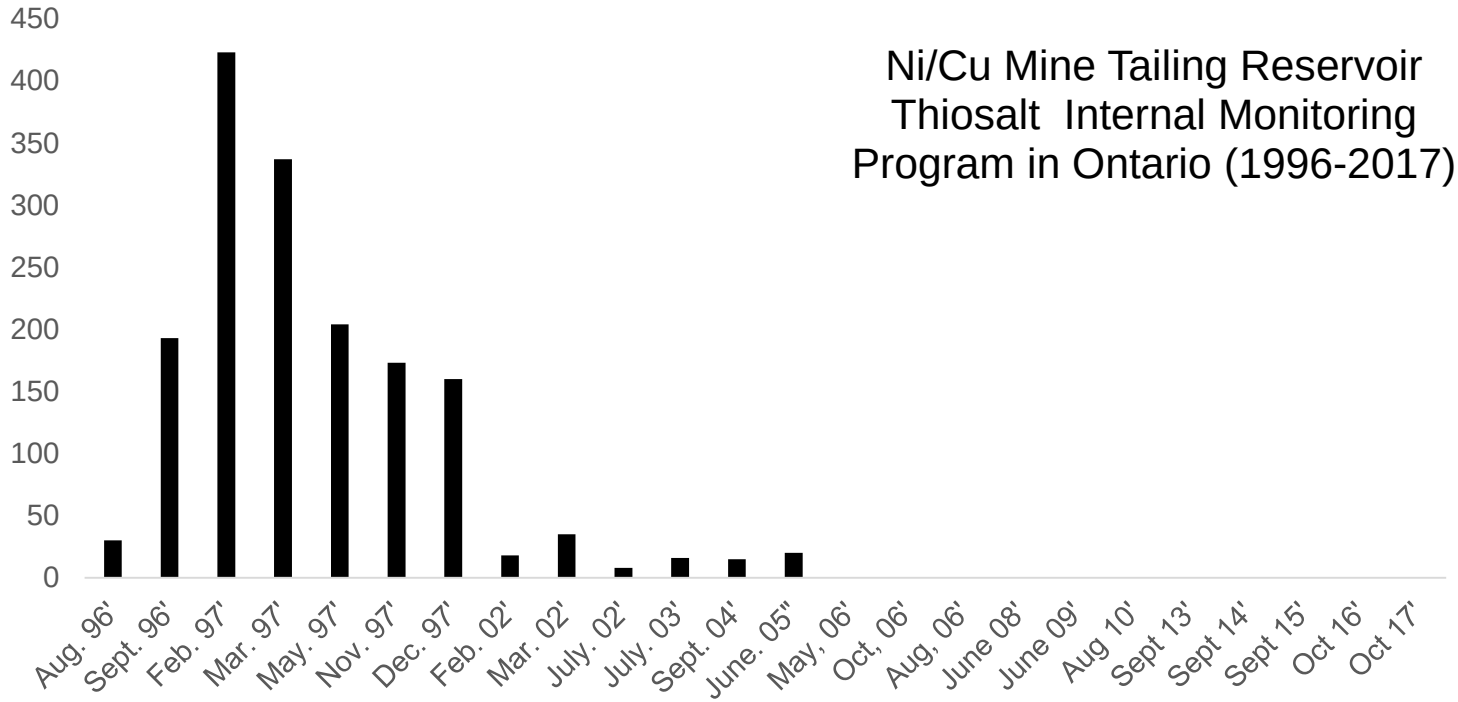
$S_2O_3^{2-}$

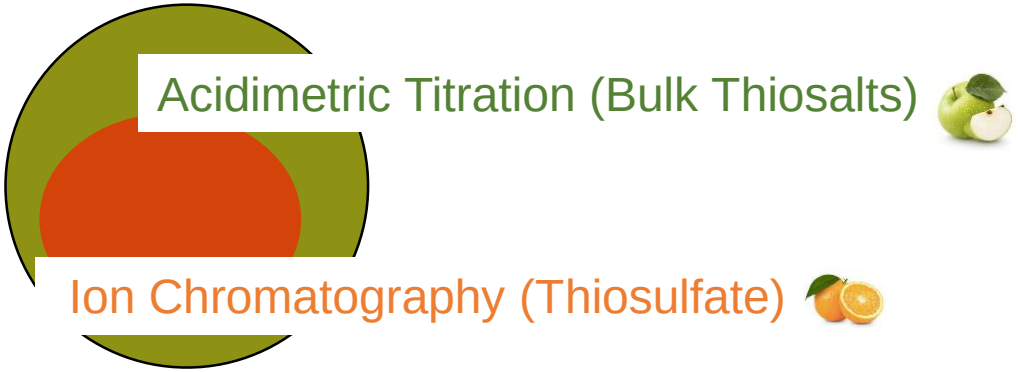
Commercial labs report "thiosalt" numbers but often they are only measure thiosulfate

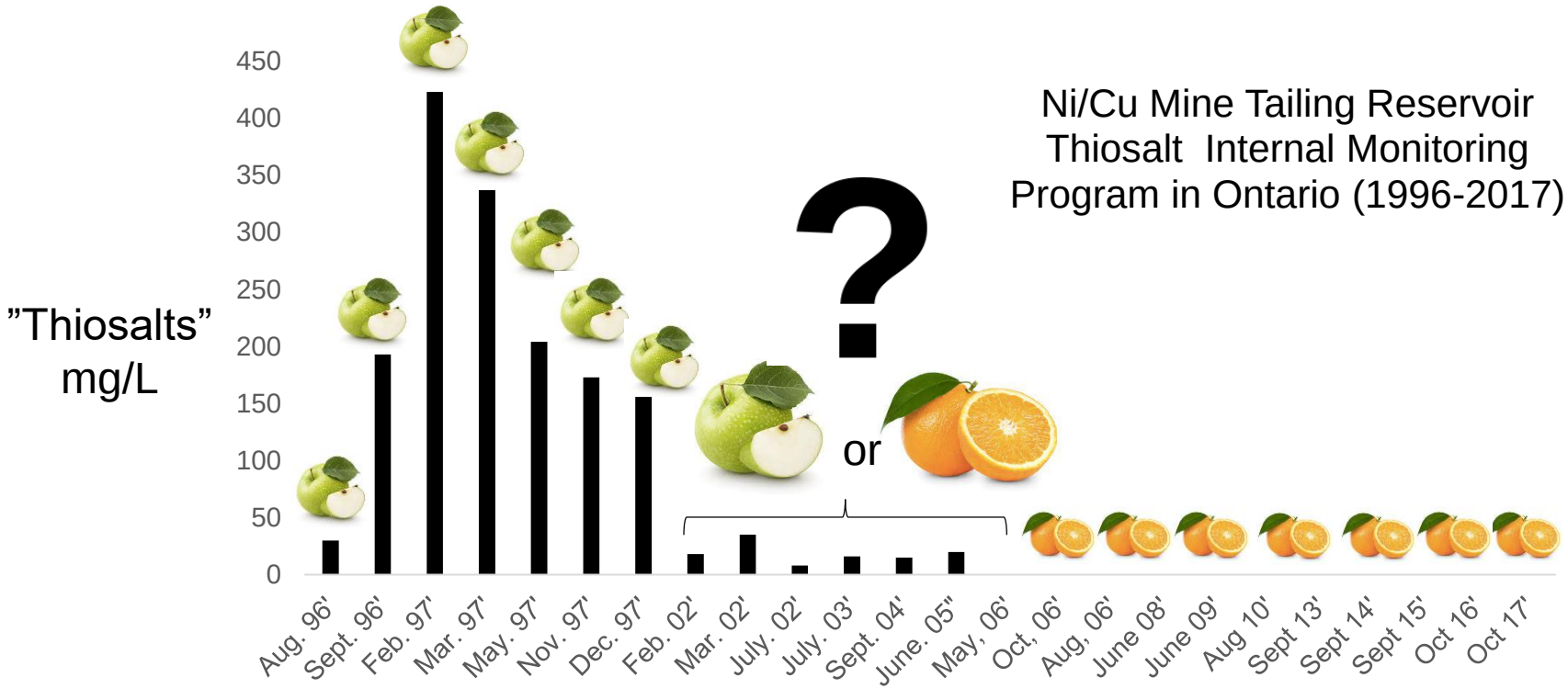


Ni/Cu Mine Tailing Reservoir
Thiosalt Internal Monitoring
Program in Ontario (1996-2017)

”Thiosalts”
mg/L

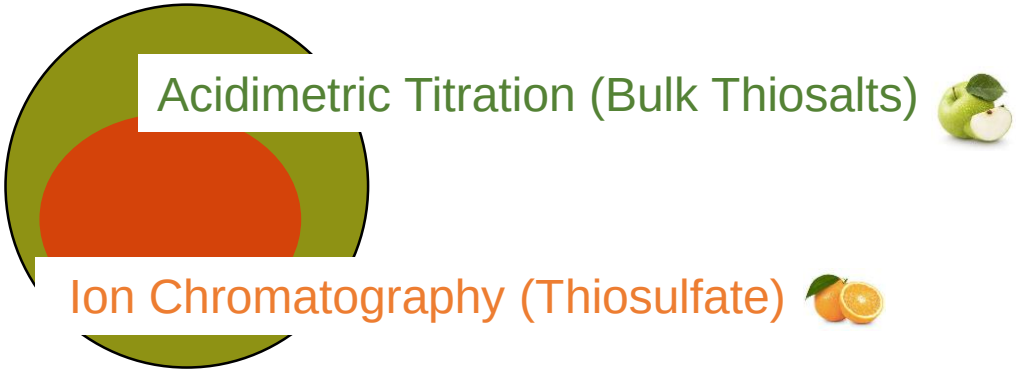


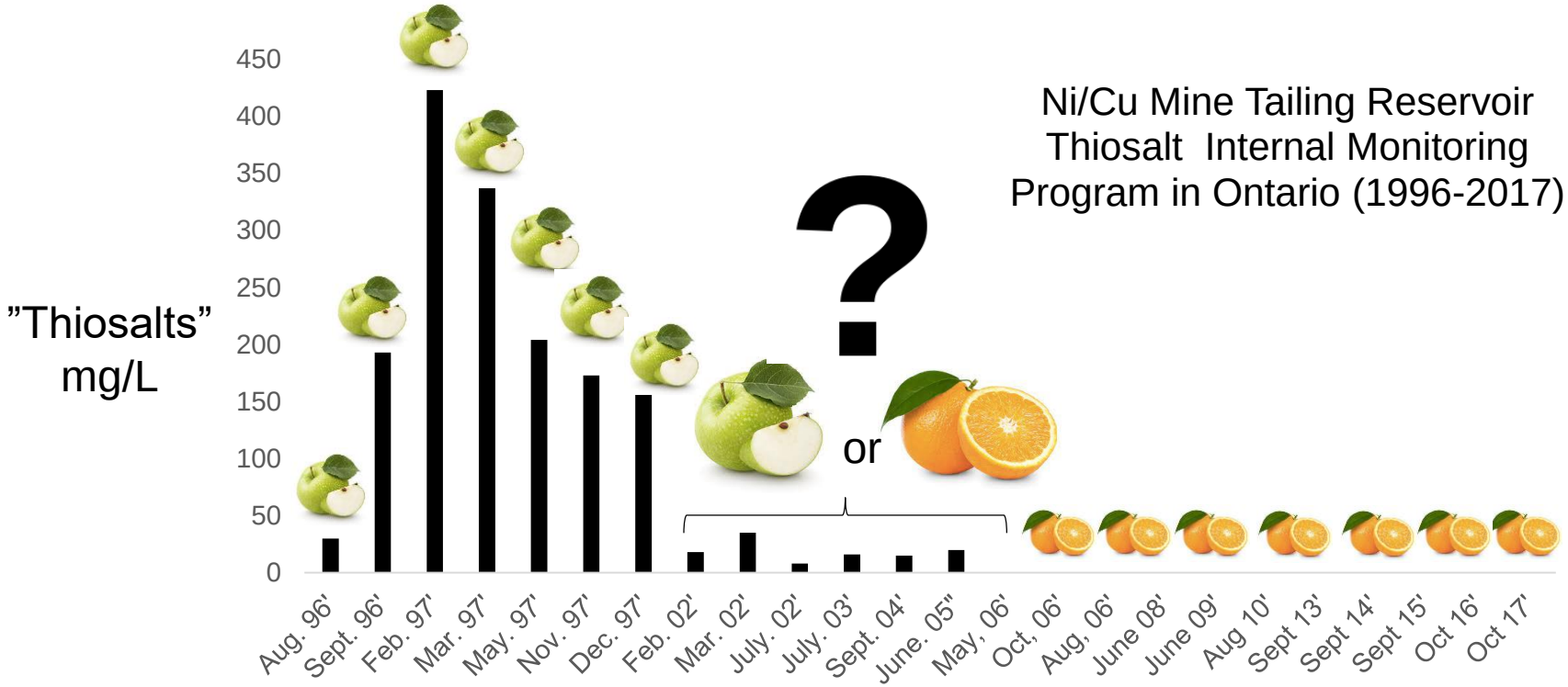




Ni/Cu Mine Tailing Reservoir Thiosalt Internal Monitoring Program in Ontario (1996-2017)

The commercial laboratory was asked…. they stated “*to the best of their knowledge there had been no change in thiosalt methodology over time*”
-Subsequently, when an overview of the analytical method used was asked for, **two SOPs were sent for both Acidimetric Titration and Ion Chromatography**





Ni/Cu Mine Tailing Reservoir Thiosalt Internal Monitoring Program in Ontario (1996-2017)

Ambiguity on analytical definitions, unknown changes to methodologies and lack of information sharing can lead to

→**Incomparable data sets**

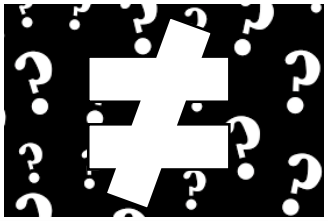
→Misinterpretation of “thiosalt” concentrations over time/space

Analytical Definitions and Terminology Matter!

Sulfur oxidative processes are **often intimately connected** with toxicity/**regulatory failures**

MDMER regulations **don't currently regulate SO_4^{2-} or reactive S compounds** in Canadian discharged mine waters…but the term "thiosalts" is an industry-adopted term

Reactive Sulfur Compounds

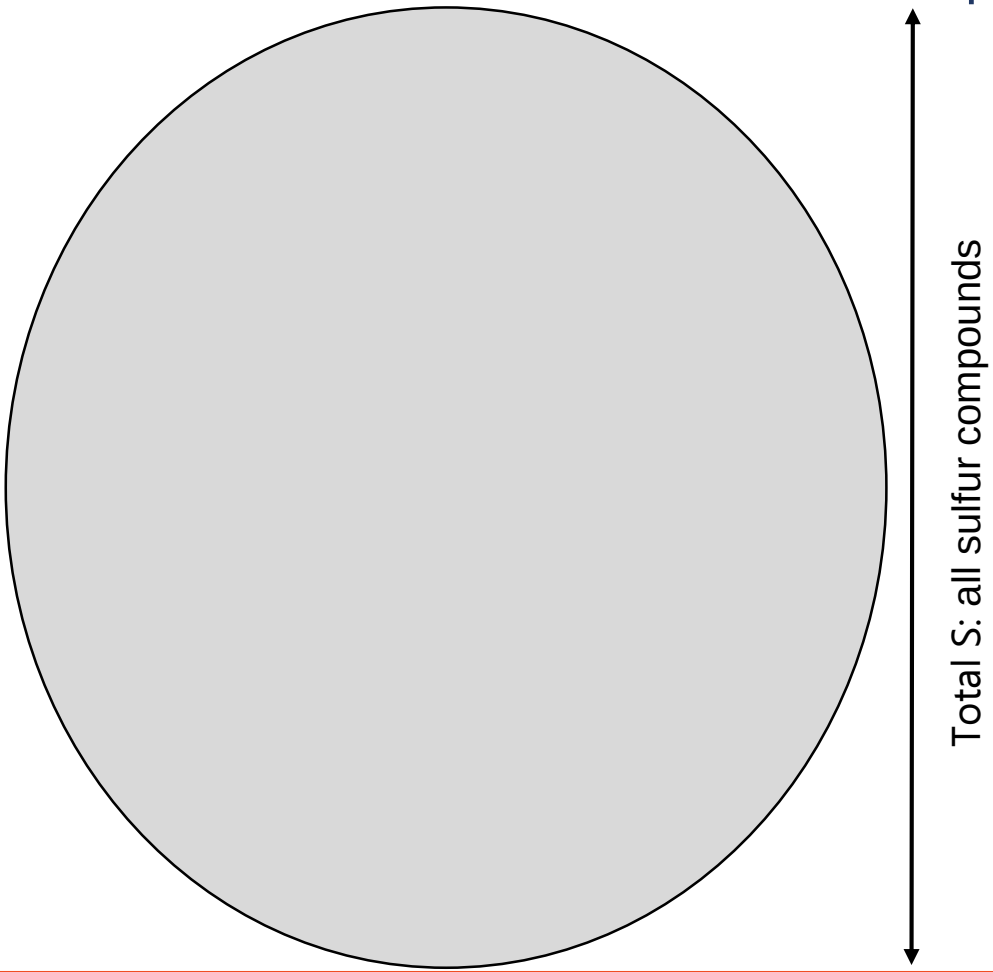


Thiosalts

Analytical Definitions and Terminology Matter!

Reactive Sulfur Compounds

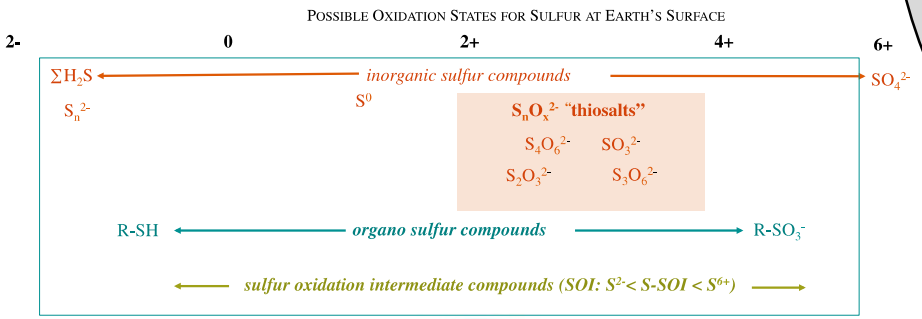
Aqueous sulfur pools can be comprised of many different inorganic and organic sulfur compounds

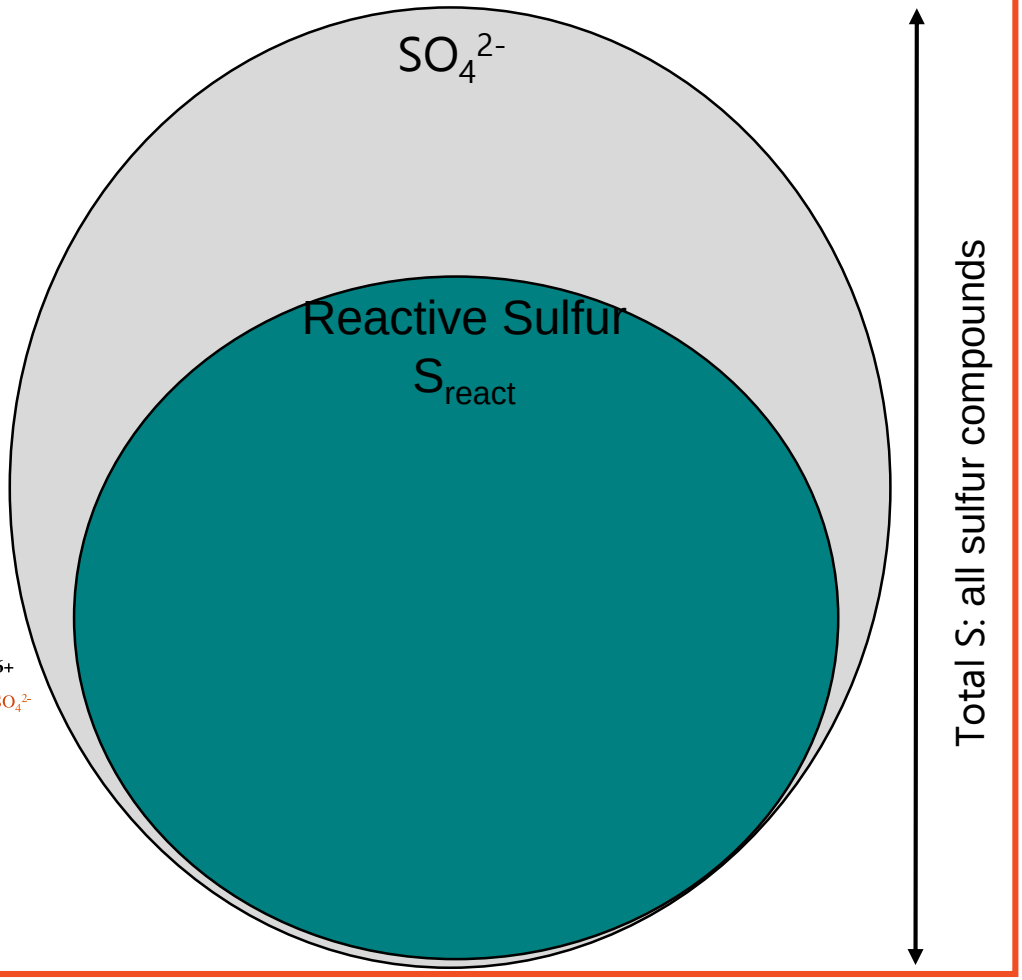


Complex Sulfur Pools are Present in Mining Water

Reactive Sulfur Compounds

Aqueous sulfur pools can be comprised of many different inorganic and organic sulfur compounds



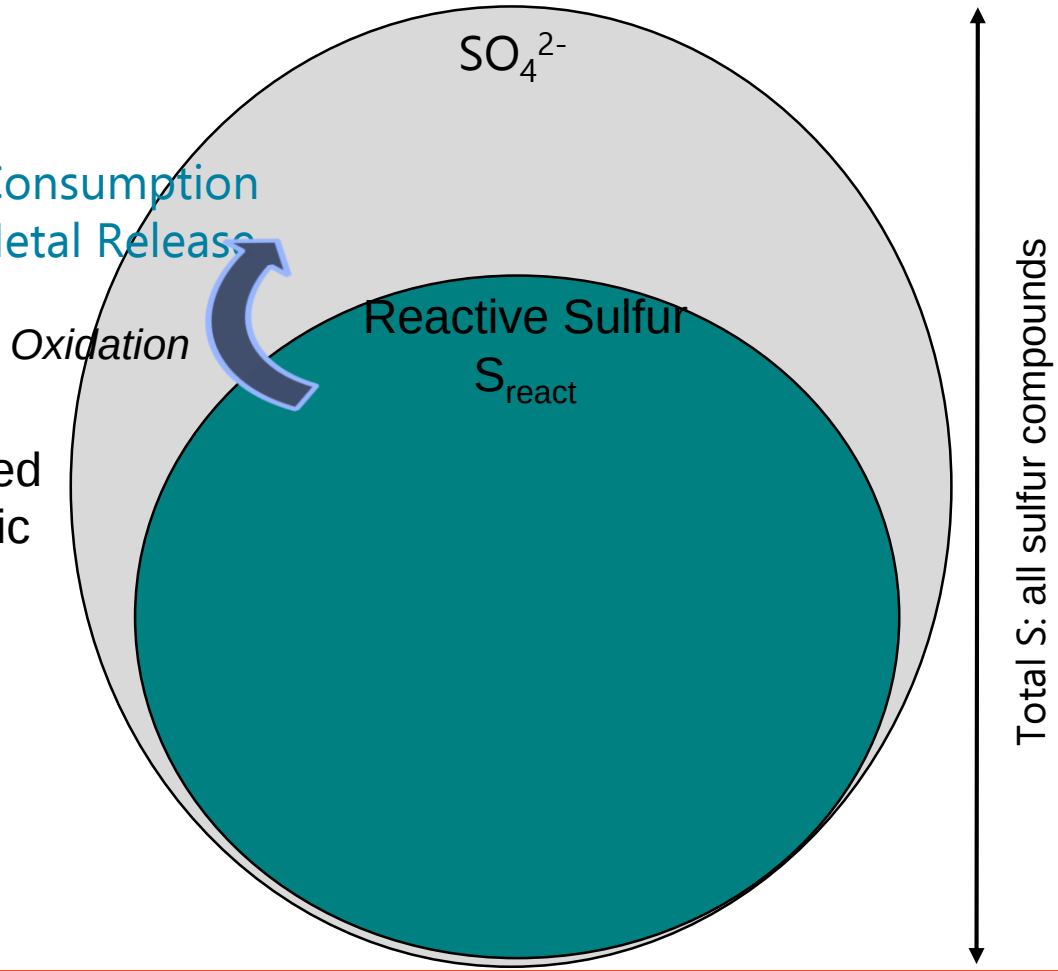


Complex Sulfur Pools are Present in Mining Water

- Oxygen Consumption
- Acidity/Metal Release

Reactive Sulfur Compounds

Aqueous sulfur pools can be comprised of many different inorganic and organic sulfur compounds



Cost-Effective Mass Balance Approach to Monitor Dissolved Sulfur Risks for the Mining Industry

→ Defined a new S method:
→ Reactive Sulfur (S_{react})

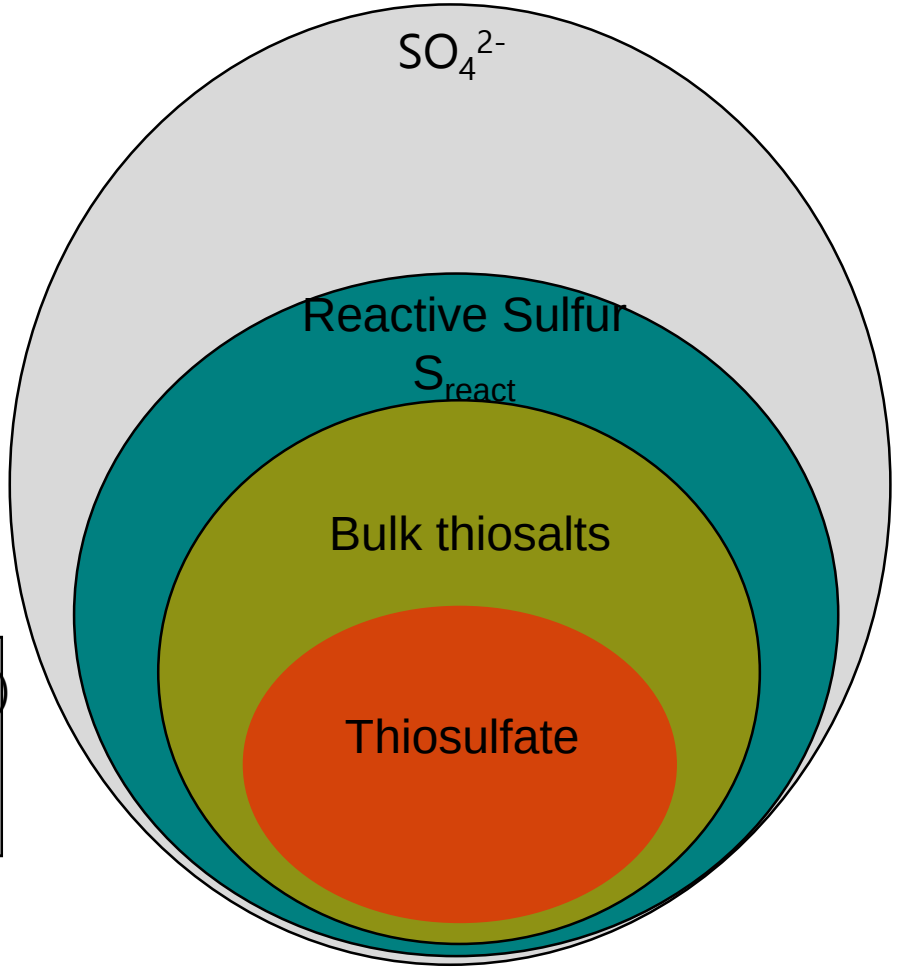
S_{react} = Total S – S-SO_4^{2-}

→ Compare S_{react} to Current Methods

S_{react}
vs.

Bulk Thiosalts (Acidimetric Titration)

Thiosulfate (Ion Chromatography)



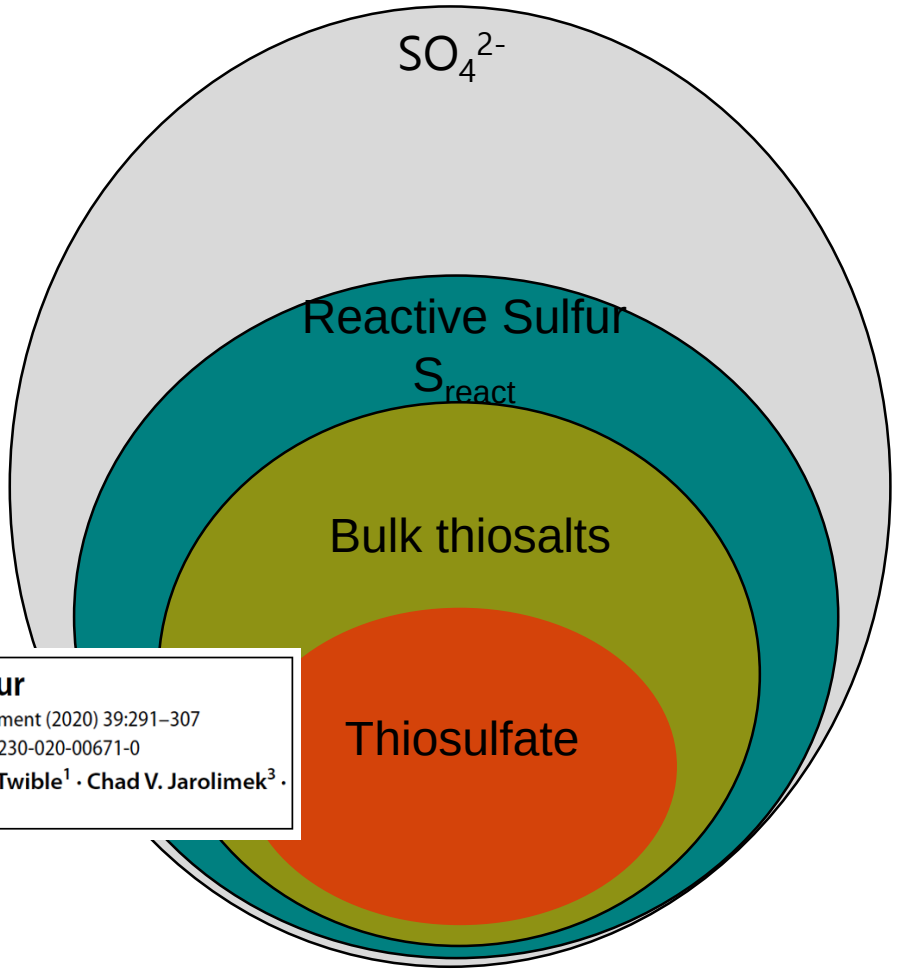
Cost-Effective Mass Balance Approach to Monitor Dissolved Sulfur Risks for the Mining Industry

Mass-Balance Approach

→ defined a new S method: reactive sulfur(S_{react})

Reactive Sulfur S_{react}
(total S – sulfate)

- → More conservative of risk
- → Economical
- → Calculable with current monitoring data
- → Directly comparable across mines



A Mass-Balance Tool for Monitoring Potential Dissolved Sulfur Oxidation Risks in Mining Impacted Waters

Mine Water and the Environment (2020) 39:291–307
https://doi.org/10.1007/s10230-020-00671-0

Kelly Whaley-Martin[1] · Stephanie Marshall[2] · Tara E. Colenbrander Nelson[1] · Lauren Twible[1] · Chad V. Jarolimek[3] · Josh J. King[3] · Simon C. Apte[3] · Lesley A. Warren[1]

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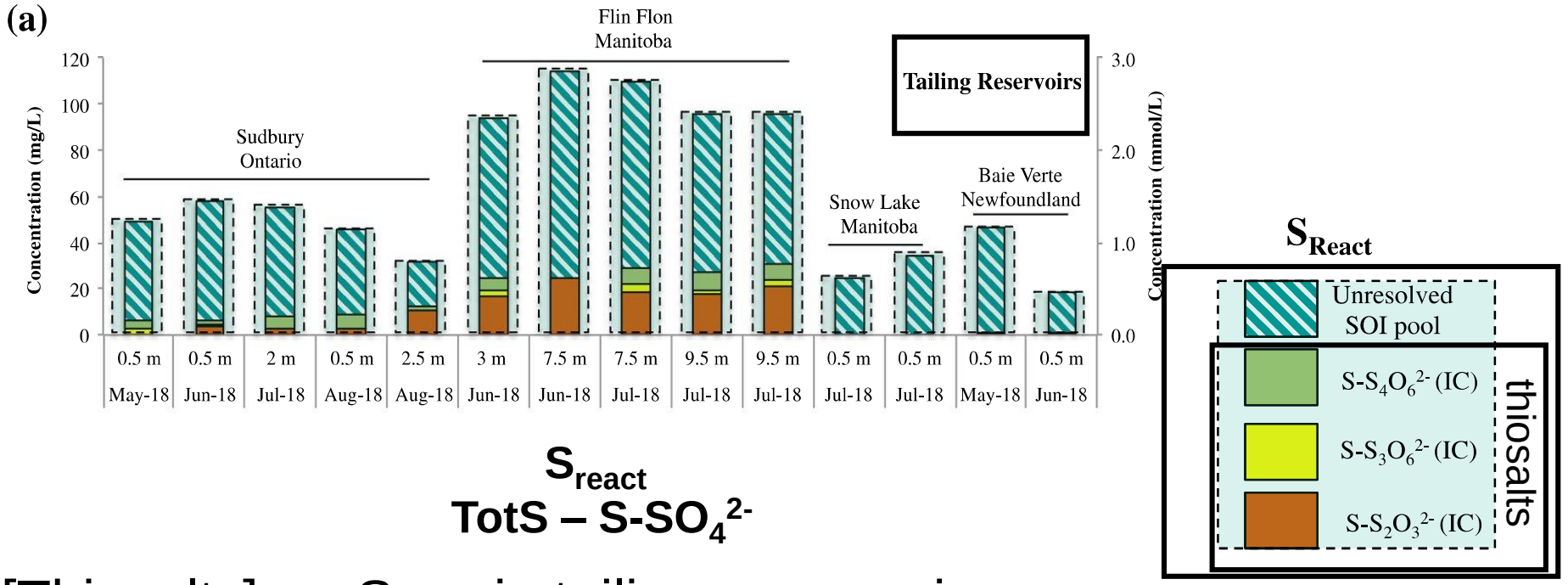
S_{react} speciation across 4 mines
(i.e. How much of S_{react} = sulfur oxyanions?)

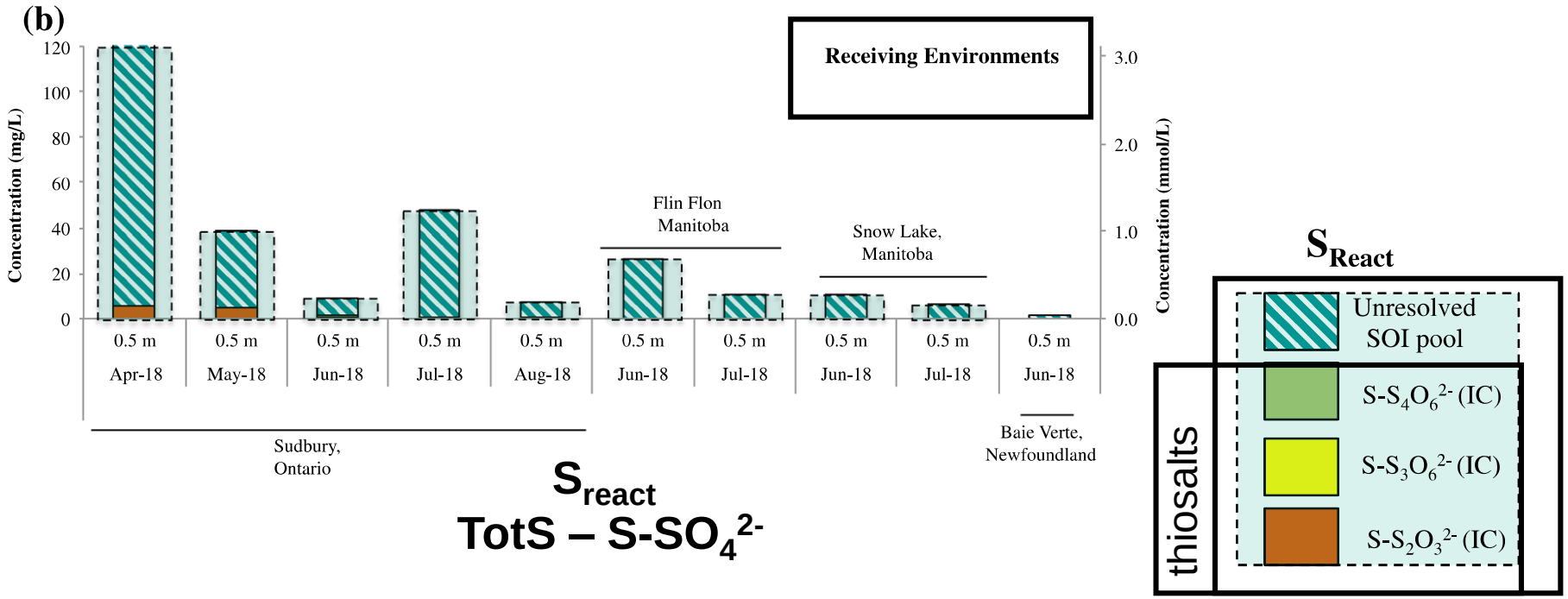


S_{react}
TotS – $S\text{-}SO_4^{2-}$

[Thiosalts] << S_{react} in tailings reservoirs

Thiosulfate ($S_2O_3^{2-}$)
Trithionate ($S_3O_6^{2-}$)
Tetrathionate ($S_4O_6^{2-}$)

Whaley-Martin et al., 2020



Thiosulfate ($S_2O_3^{2-}$)
Trithionate ($S_3O_6^{2-}$)
Tetrathionate ($S_4O_6^{2-}$)

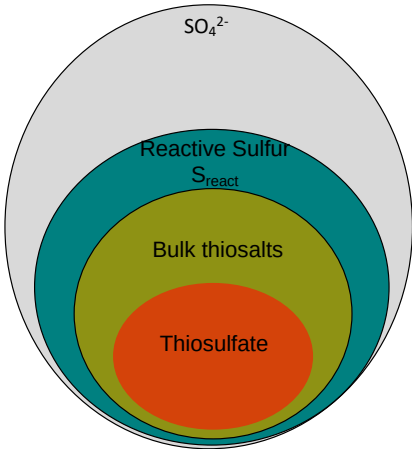
From 2014-2018, ~70 mine water sites →
Thiosulfate was on average only 4% of overall S pools!

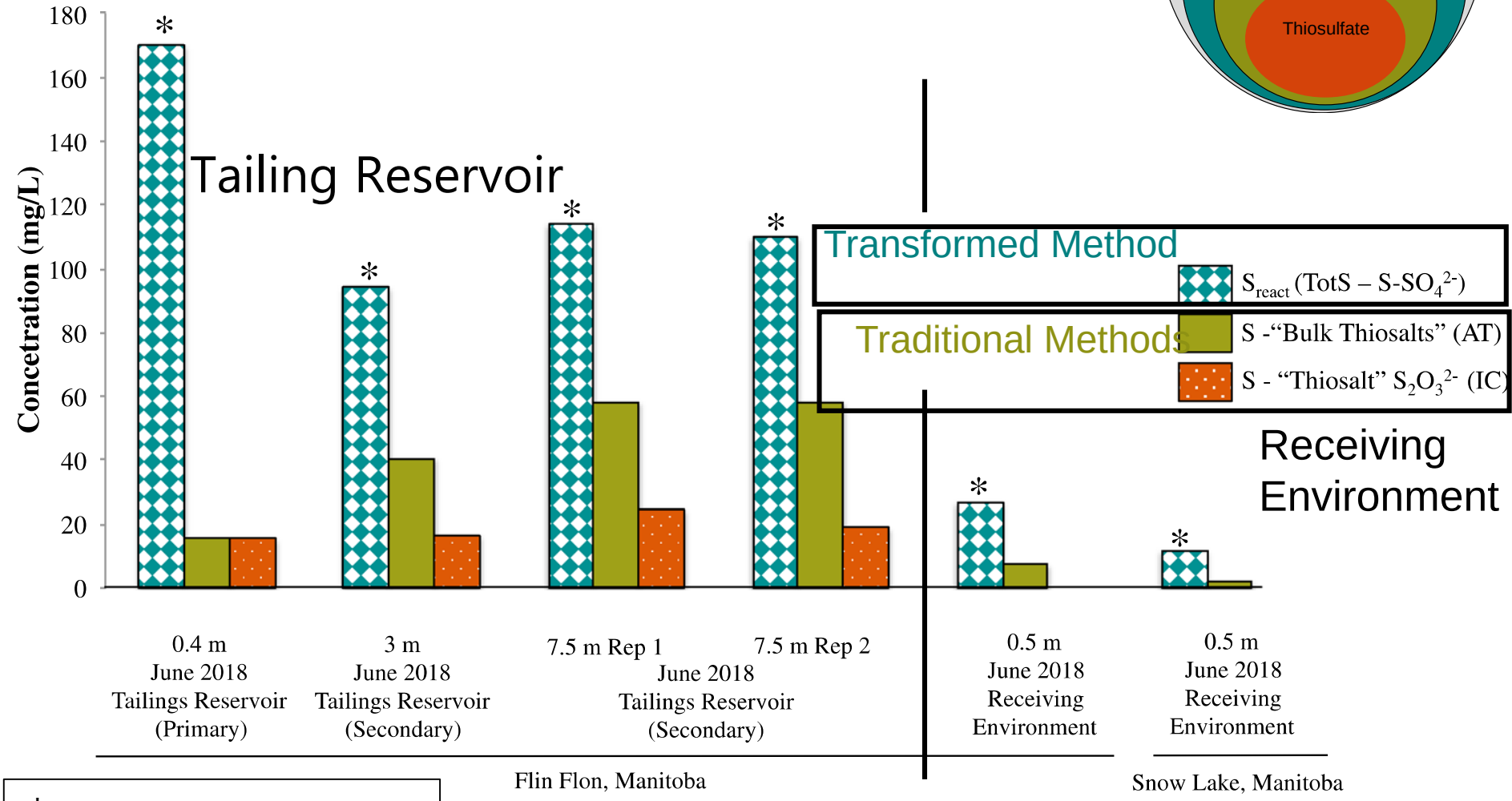
[Thiosalts] << S_{react} in receivers

Undetected S is making it's way through different treatment systems

Whaley-Martin et al., 2020

S_{react} More Conservative of Risk than IC and AT methods





* *Significantly different p< 0.05*

HUDBAY

GLENCORE SUDBURY INO

Whaley-Martin et al., 2020

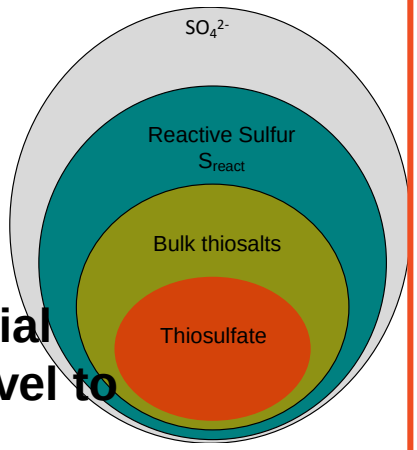

Industry Driven Research Need on Sulfur in Mining Waters
Université de Montréal
Berkeley
UNIVERSITY OF CALIFORNIA
UNIVERSITY OF TORONTO
CSIRO
RAMBLER
METALS & MINING
HUDBAY
GLENCORE
ecoreg
SOLUTIONS
EcoMetrix
INCORPORATED
Industry Adoption of Scientifically Informed Best-Practice
Collaborative Partnerships

Utilizing the Science to Lead Adoption of Best-Practice In the Industry

Electively adopting this methodology to improve their sulfur monitoring capabilities throughout treatment systems

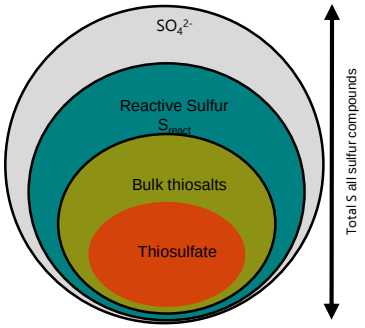
- **Cost Analysis**

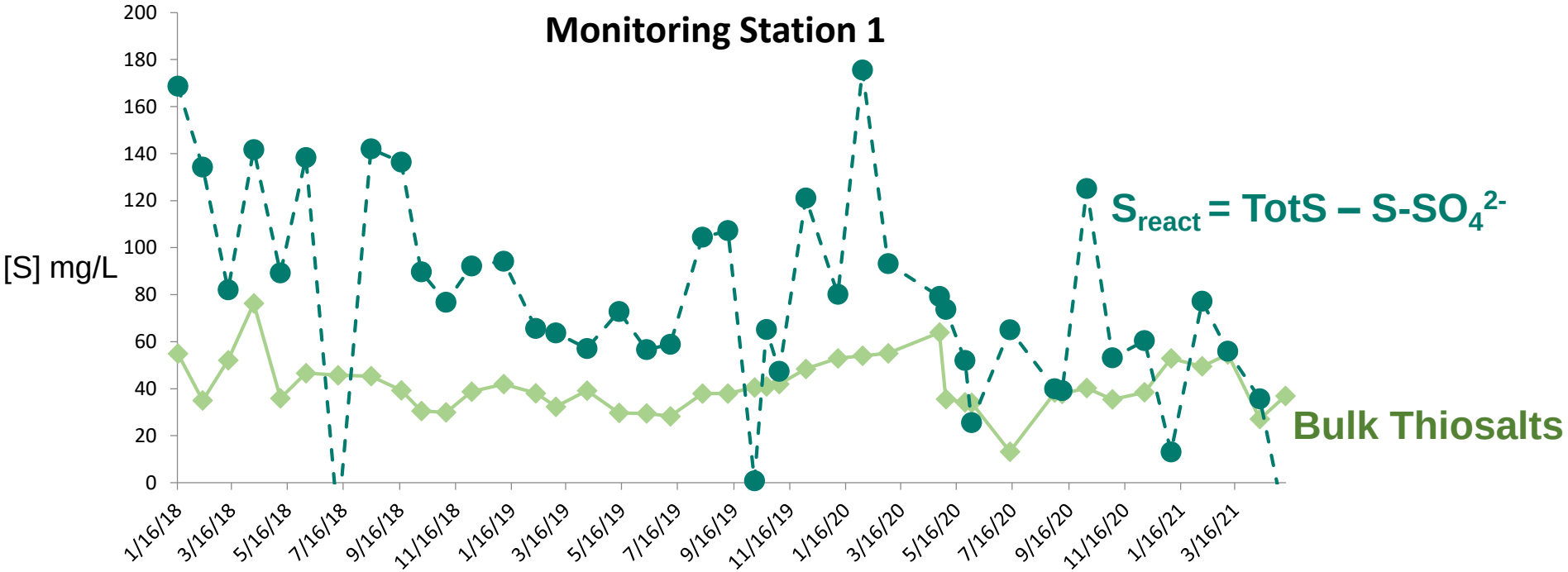
Acidimetric Titration ~$160
vs
Reactive S ~$13



- Hudbay (Flin Flon) currently **has attained provincial approval to use this approach at the regulatory level to replace the traditional acidimetric titration**

Comparing methods over time
S_{react} vs. Bulk Thiosalts (Acidimetric Titration)





Results provided by Shirley Neault and Landice Yestrau (Hudbay minerals)

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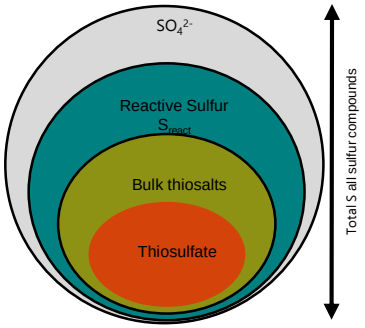

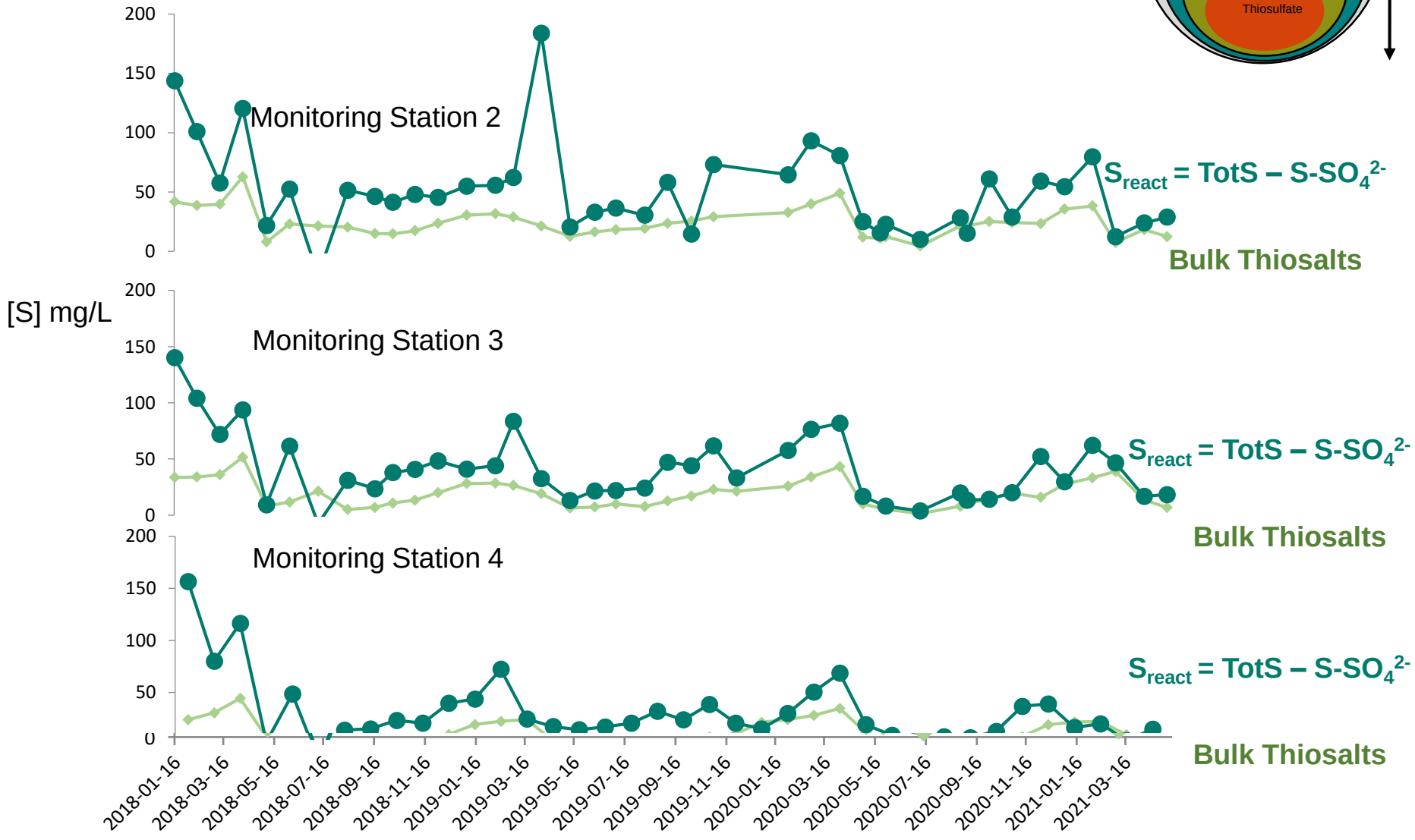

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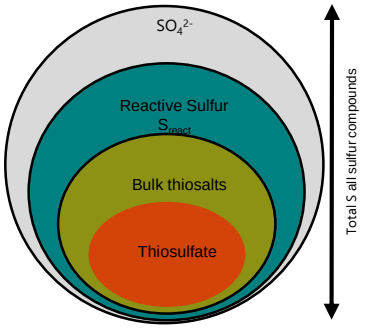
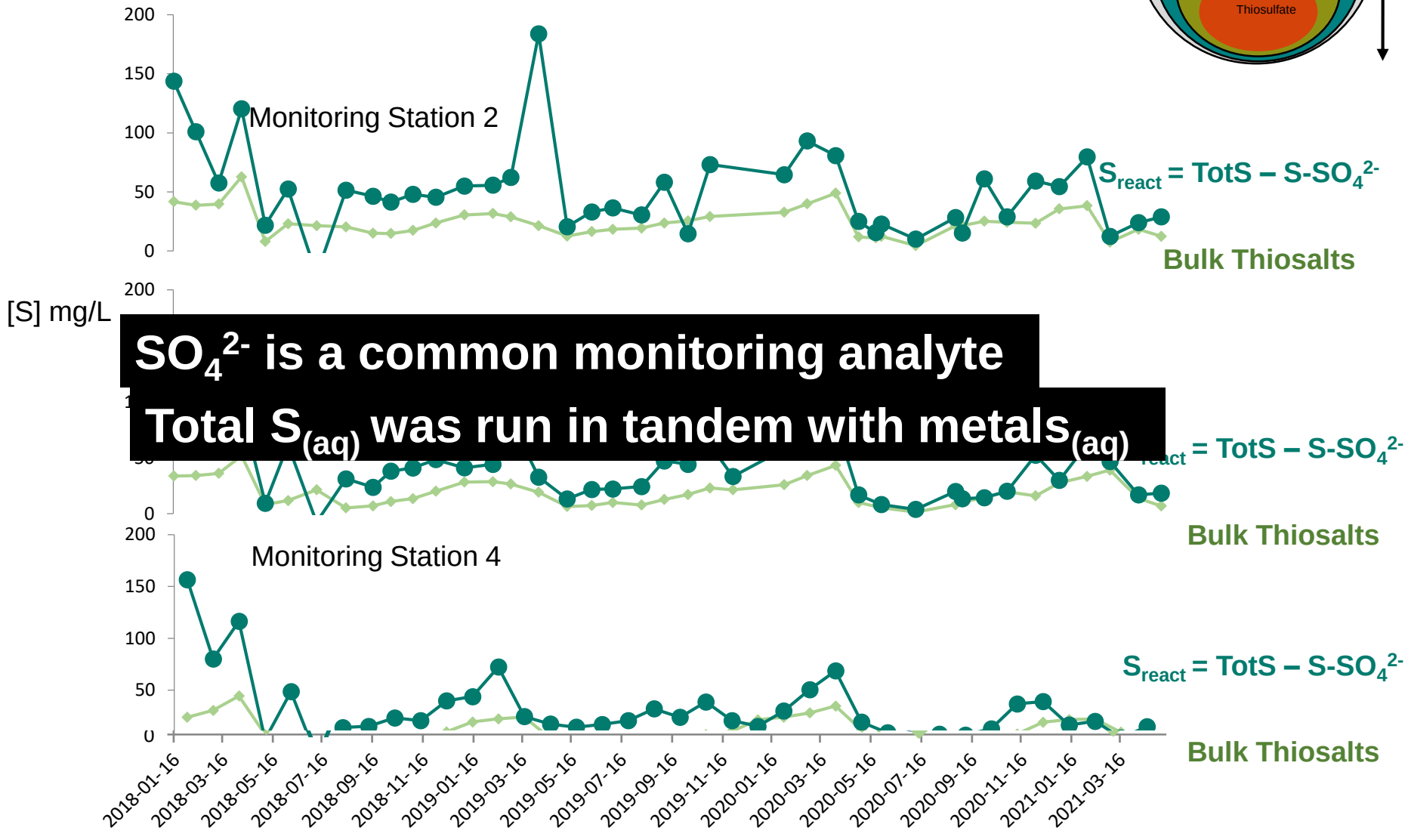


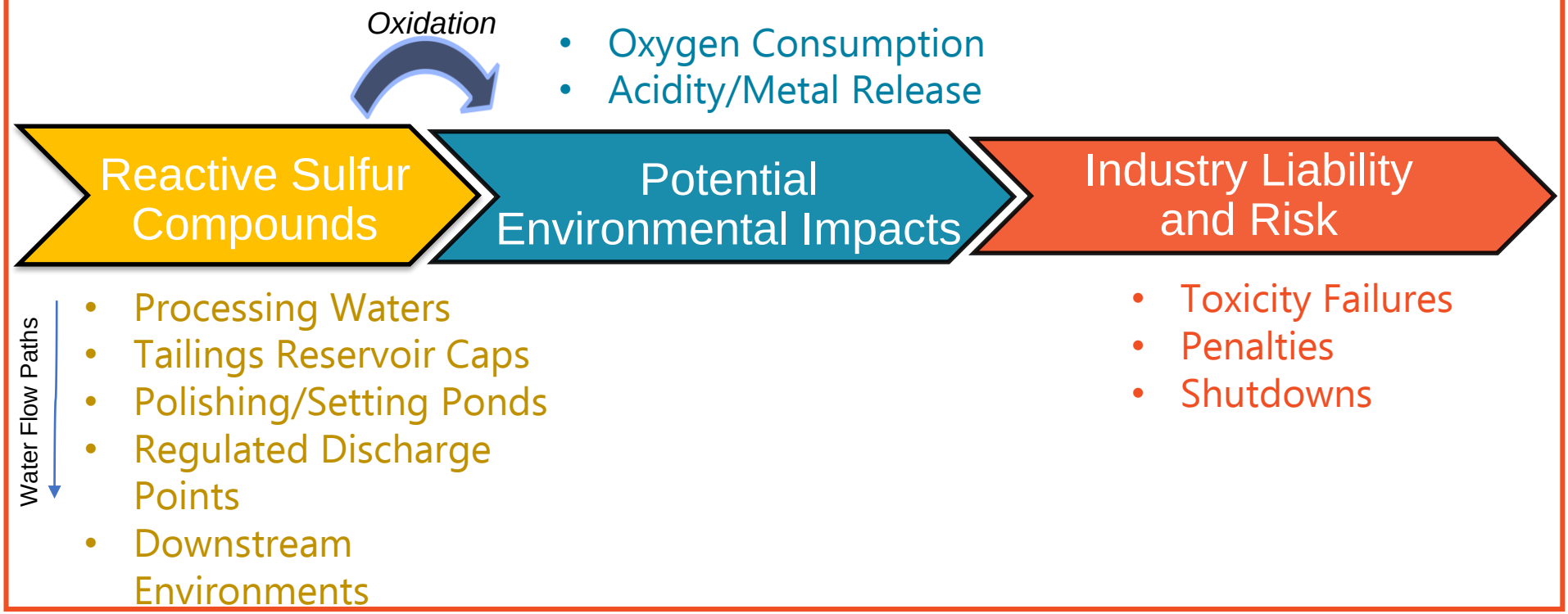


SO_4^{2-} is a common monitoring analyte

Total $S_{(aq)}$ was run in tandem with metals$_{(aq)}$

The Risk

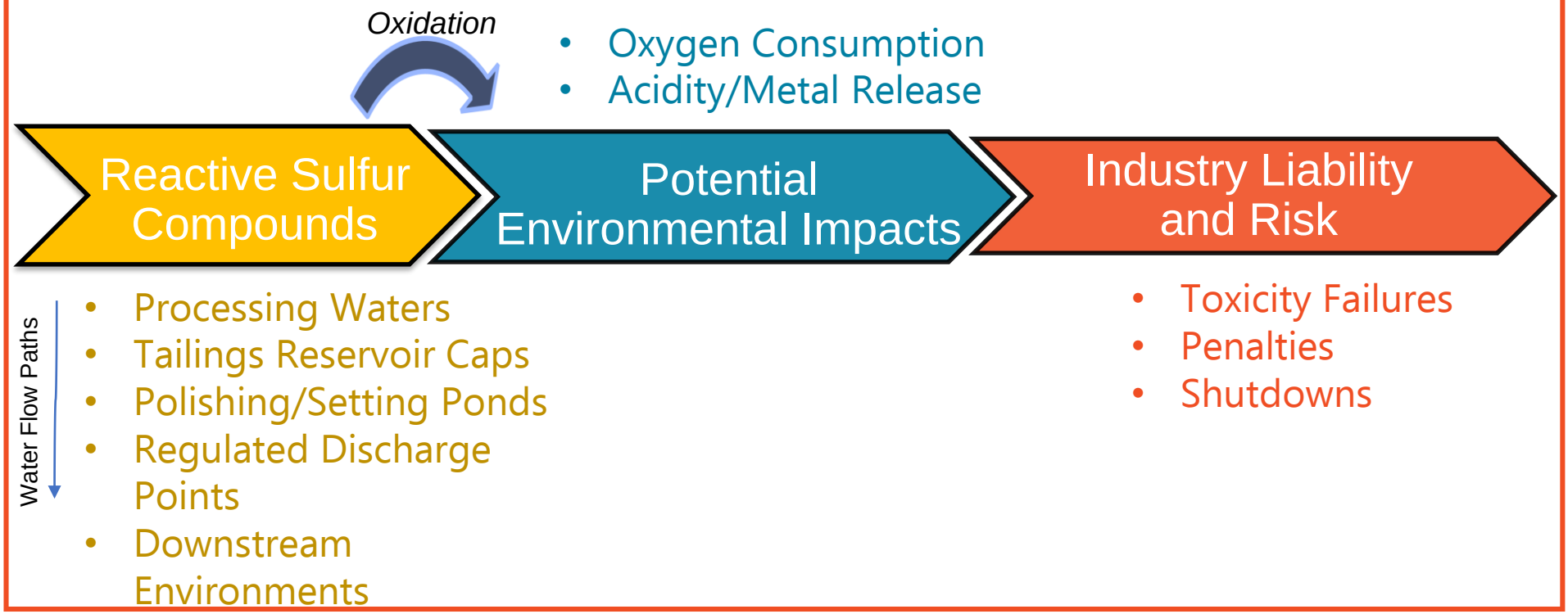
Dissolved reactive sulfur compounds in mining impacted waters are a global challenge



The Risk

You can't manage what you can't detect……

Dissolved reactive sulfur compounds in mining impacted waters are a global challenge



Call to Action

Dissolved reactive sulfur compounds in mining impacted waters are a global challenge

Reactive Sulfur Compounds

Current language around ”thiosalts” is problematic: ambiguity around its definition analytically

<u>Mass-Balance Approach</u>

-**Cost-effective** : reduced cost/more time points/replicates

-Part of many monitoring programs (also allows for historical delineation)

-**More conservative of risk**: able to capture any inorganic or organic sulfur compounds that are “in play” for downstream microbial or abiotic oxidation

-**Easy to calculate**

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Questions/Insights?

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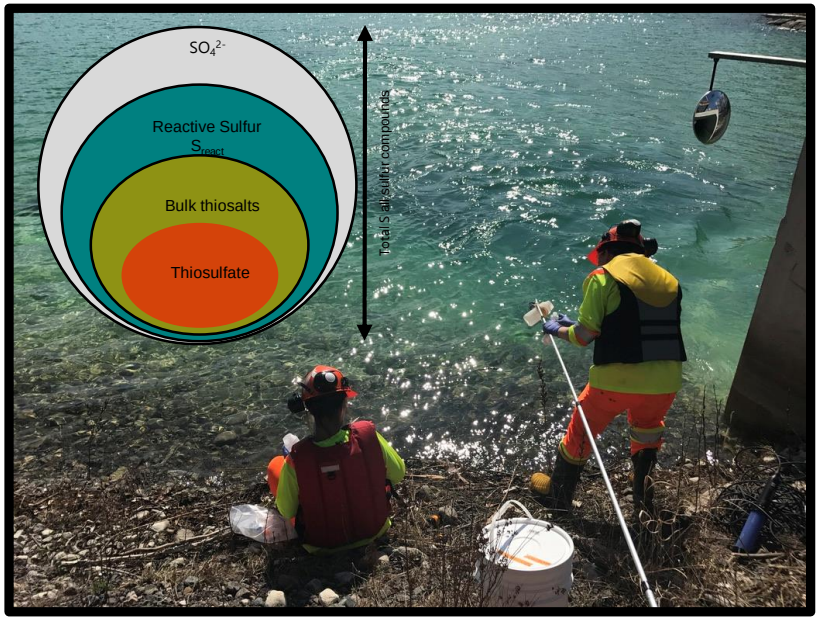

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UNIVERSITY OF TORONTO
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Dr. Simon Apte,
Analytical Chemist, CSIRO

Contact Information
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Biography

Dr. Simon Apte's research focuses on the analysis of trace metals and the links between trace metal speciation and bioavailability in waters. Much of his current work is directed to understanding the impacts of mining on aquatic environments, the impact of hydraulic fracturing in the unconventional gas industry and the fate of nanomaterials in the environment.

Prior to joining CSIRO, Dr. Apte was a Research Scientist in the Environmental Chemistry Group, Water Research Centre in the United Kingdom (UK) from 1985 to 1990.He was Lecturer in Environmental and Analytical Chemistry, Department of Applied Sciences, University of Technology, Papua New Guinea from 1989 to 1990.