Investigation and Assessment of Potential for Cr Leaching from Paste Backfilling Operations: A Case Study from Brucejack Gold Mine

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OVERVIEW

1. Cr in the environment and potential mine-related sources of Cr(VI)
2. Water quality predictions for Brucejack Gold Mine
3. Potential mitigation options based on site-specific experimental data sets
4. A summary of the Cr management plan implemented and monitoring results

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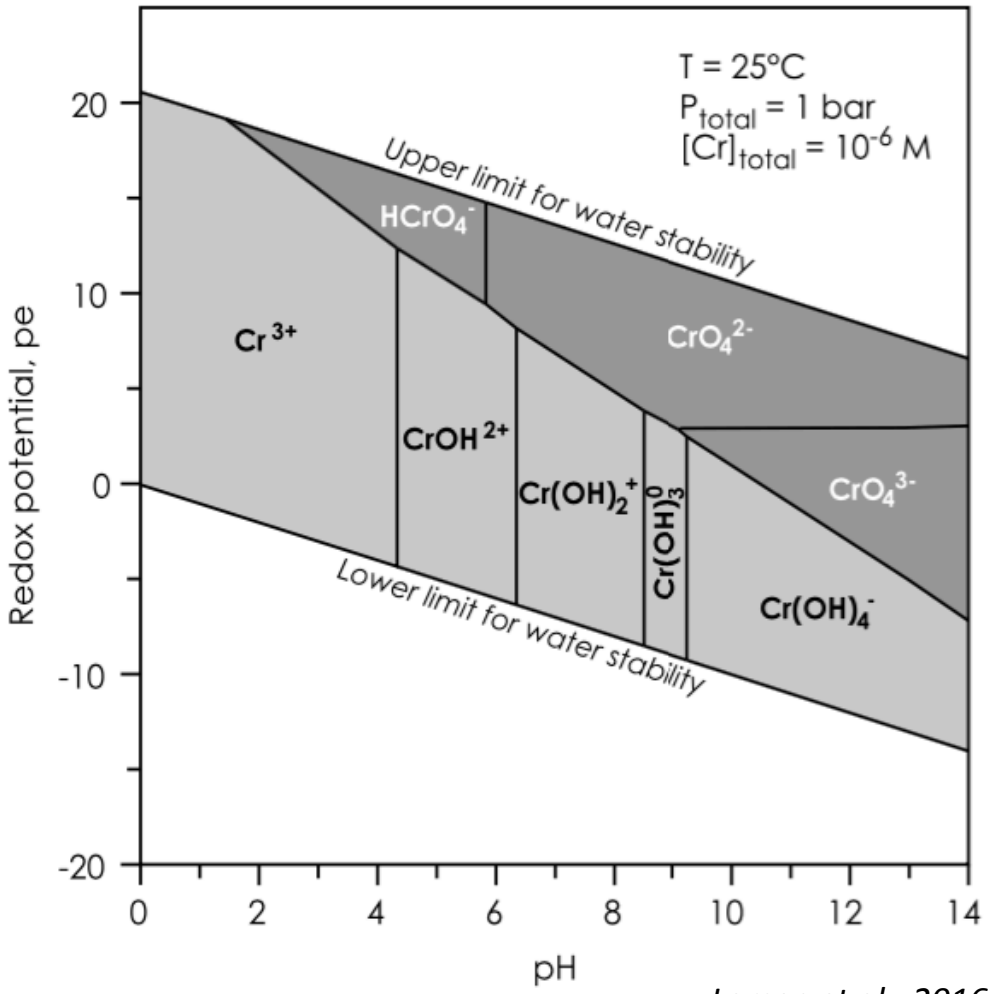
CHROMIUM IN THE ENVIRONMENT

- Natural rocks contain range of Cr concentrations ACA ~100 ppm – dominant form is Cr (III)
- Various aqueous forms of Cr present, with more oxidizing alkaline conditions favouring Cr(VI)
- Cr(VI) is the more hazardous form of Cr due to its higher toxicity, solubility and mobility
- BC FWAL guideline for Cr (VI) is 1 µg/L; for Cr (III) is 9 µg/L

Cement fabrication process: oxidizes Cr (III) to Cr (VI) in the cement kiln



Larsen et al., 2016

Cr speciation diagram - light grey shading shows Cr(III) species and dark grey shows Cr(VI) species

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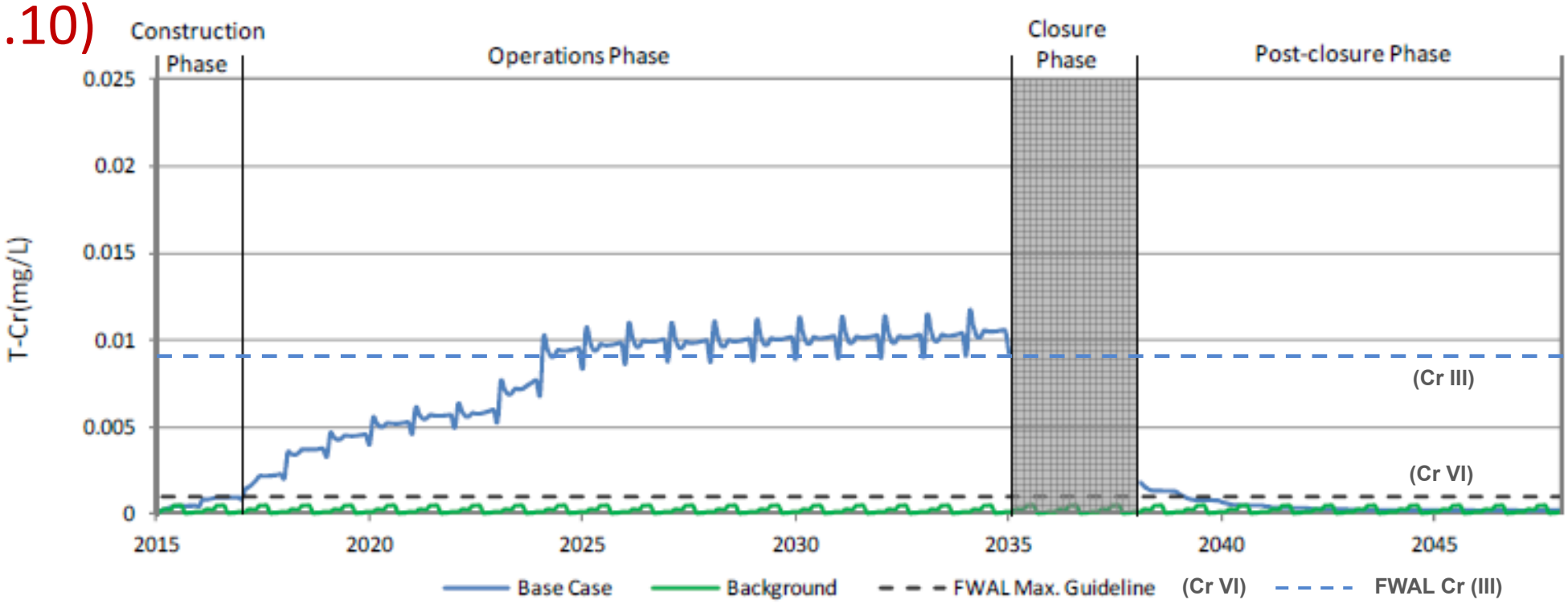
POTENTIAL MINE-RELATED SOURCES OF Cr(VI)

- Cemented paste backfill
- Shotcrete to stabilize underground workings
- Grout to plug drill holes

BRUCEJACK GOLD MINE

- Underground high grade gold and silver mine in northern BC in operation since July 2017
- Up to 50% of tailings generated will be placed UG as paste backfill with 2-11% cement binder
- Lorax developed a site-specific water quality model based on mine schedules, water management plans and baseline geochemical characterization studies

Cr PREDICTIONS AT EFFLUENT COMPLIANCE POINT (BJ 3.10)



- Water quality predictions as presented in the 2015 MA/EMA permits application – dominant source of Cr loadings from cemented paste backfill
- Original humidity cell tests used metallurgical tailings and generic cement
- Cr (III) treated by WTP, Cr (VI) is not – speciation and potential mitigation investigated

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Cr INVESTIGATIONS AT BRUCEJACK GOLD MINE:

- To confirm the preliminary humidity cell test results using vendor-specific cement and tailings from metallurgical tests;
- To determine the speciation of Cr leached from the cemented paste; and
- To evaluate the efficacy of ferrous sulfate addition as a potential mitigation strategy – where Fe(II) is the reducing agent.

$$CrO_4^{2-} + 3Fe^{2+} + 8H_2O \rightarrow Cr(OH)_3 + 3\,Fe(OH)_3 + 4H^+$$

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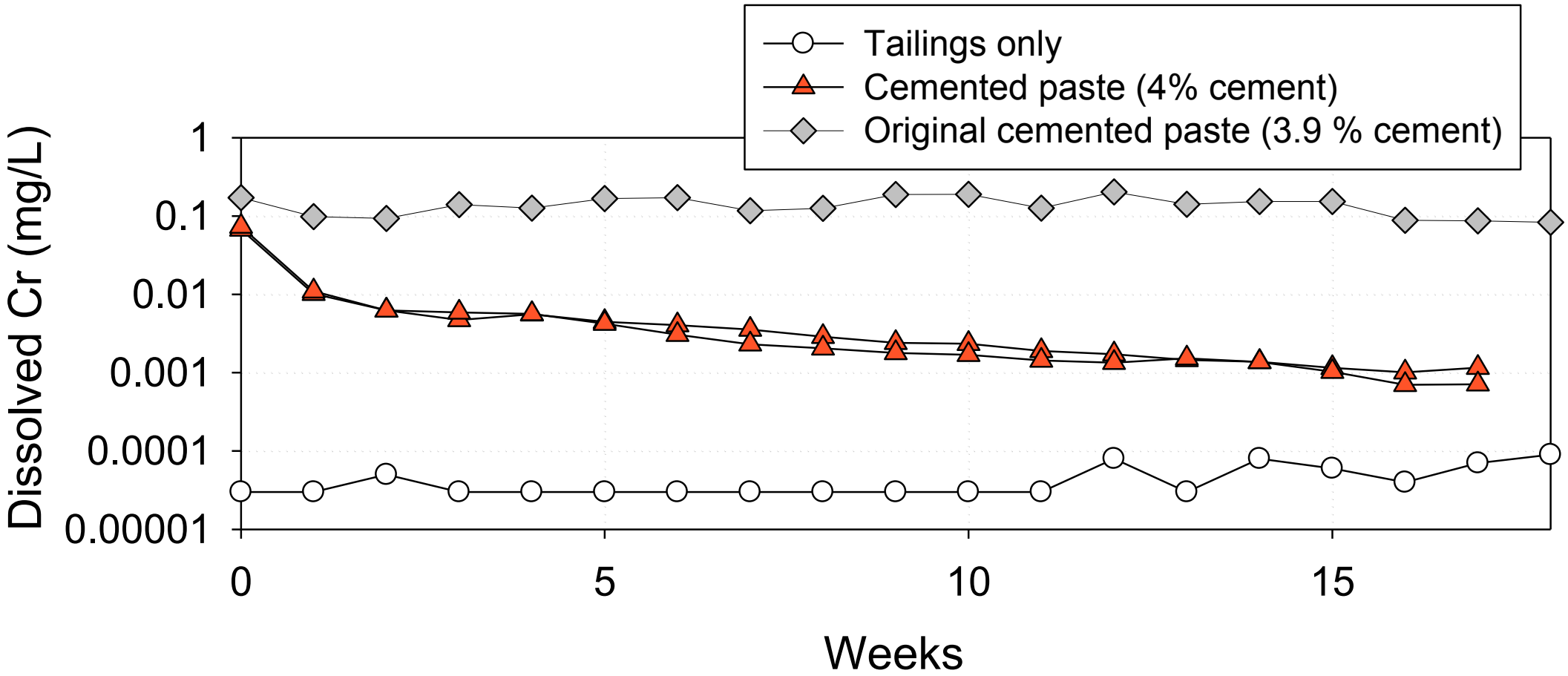
Cr INVESTIGATIONS AT BRUCEJACK GOLD MINE: HUMIDITY CELL RESULTS



- Elevated D-Cr as compared to tailings only
- Less Cr released using representative material as compared to original experiments

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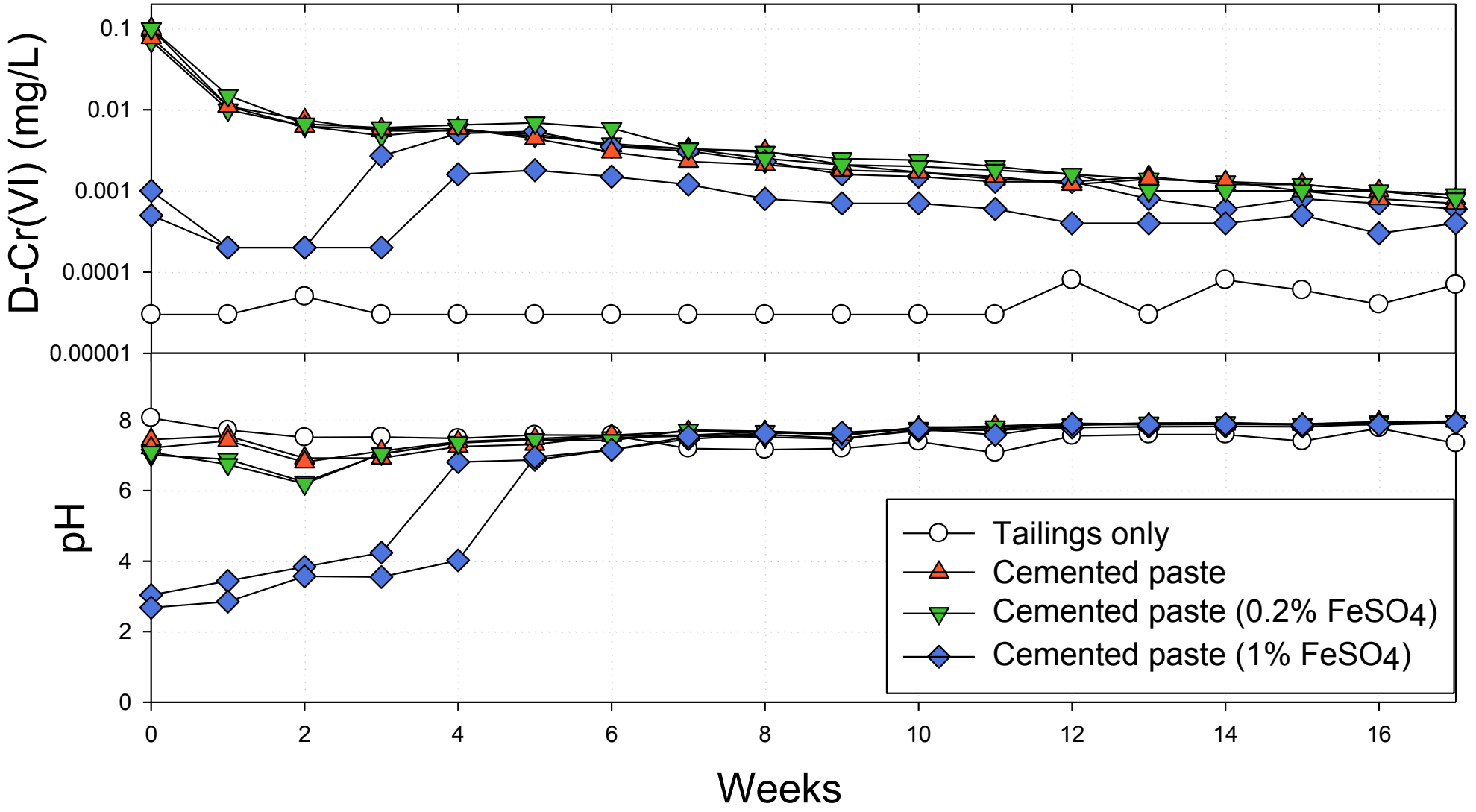
Cr INVESTIGATIONS AT BRUCEJACK GOLD MINE: HUMIDITY CELL RESULTS



BRUCEJACK GOLD MINE Cr MANAGEMENT PLAN

1) Monitoring program for analysis of:

- Cr content in cement binder, tailings and paste backfill
- D-Cr in WTP influent, WTP effluent and BJ 3.10, with speciation analyses carried out if triggers exceeded
- Drainage from backfilled stopes

2) Definition of management triggers and actions

3) Follow-up investigations of mitigation options

- Addition of reducing agents to shotcrete
- Addition of reducing agents to mine water

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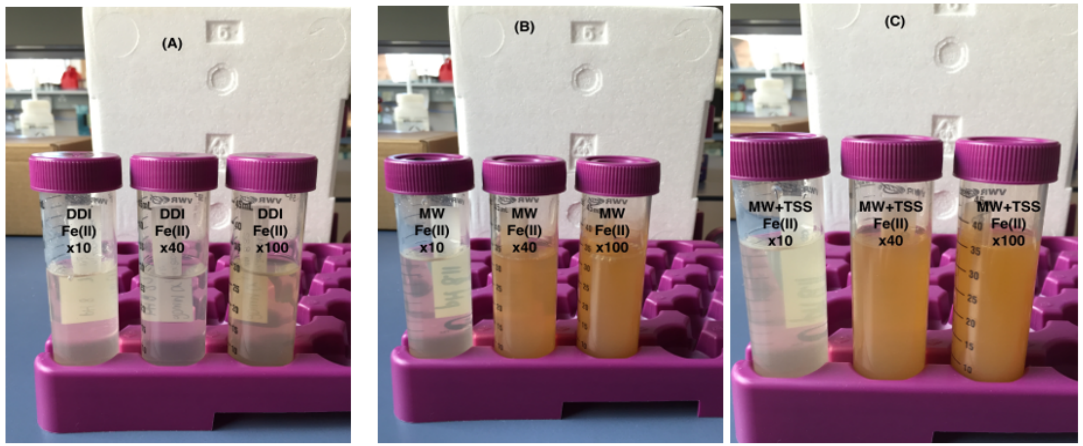
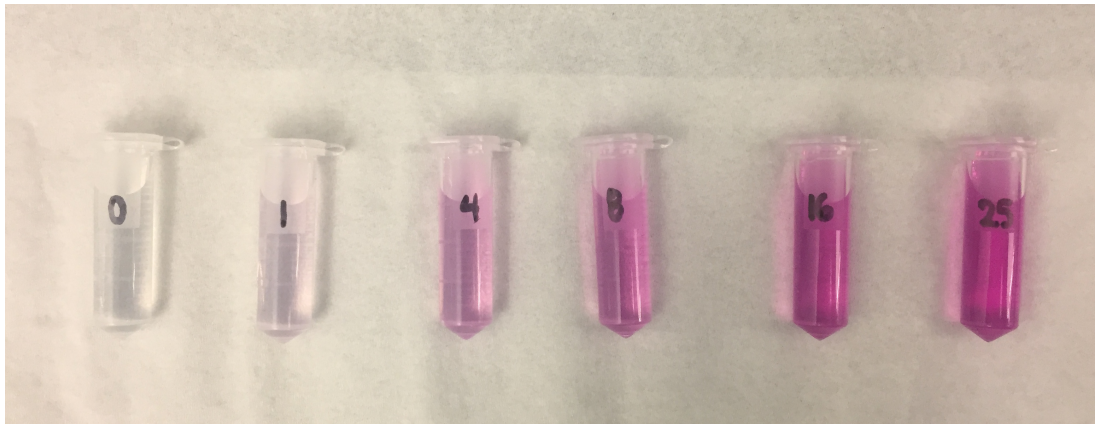
Cr INVESTIGATIONS AT BRUCEJACK GOLD MINE: MINE WATER

- Experimental program developed to assess the efficacy of Cr(VI) reduction through the addition of ferrous sulphate to water
- Carried out experiments at UBC using DI water and mine water over a range of experimental conditions:
  - pH: 4-10
  - Temp: 4 and 20ºC
  - TSS: 0, 1000 and 50,000 mg/L
  - [Cr(VI)]: 500 – 1500 µg/L
  - Fe(II)/Cr(VI): 1 to 200
- Samples analyzed using the diphenylcarbazide spectrophotometric method





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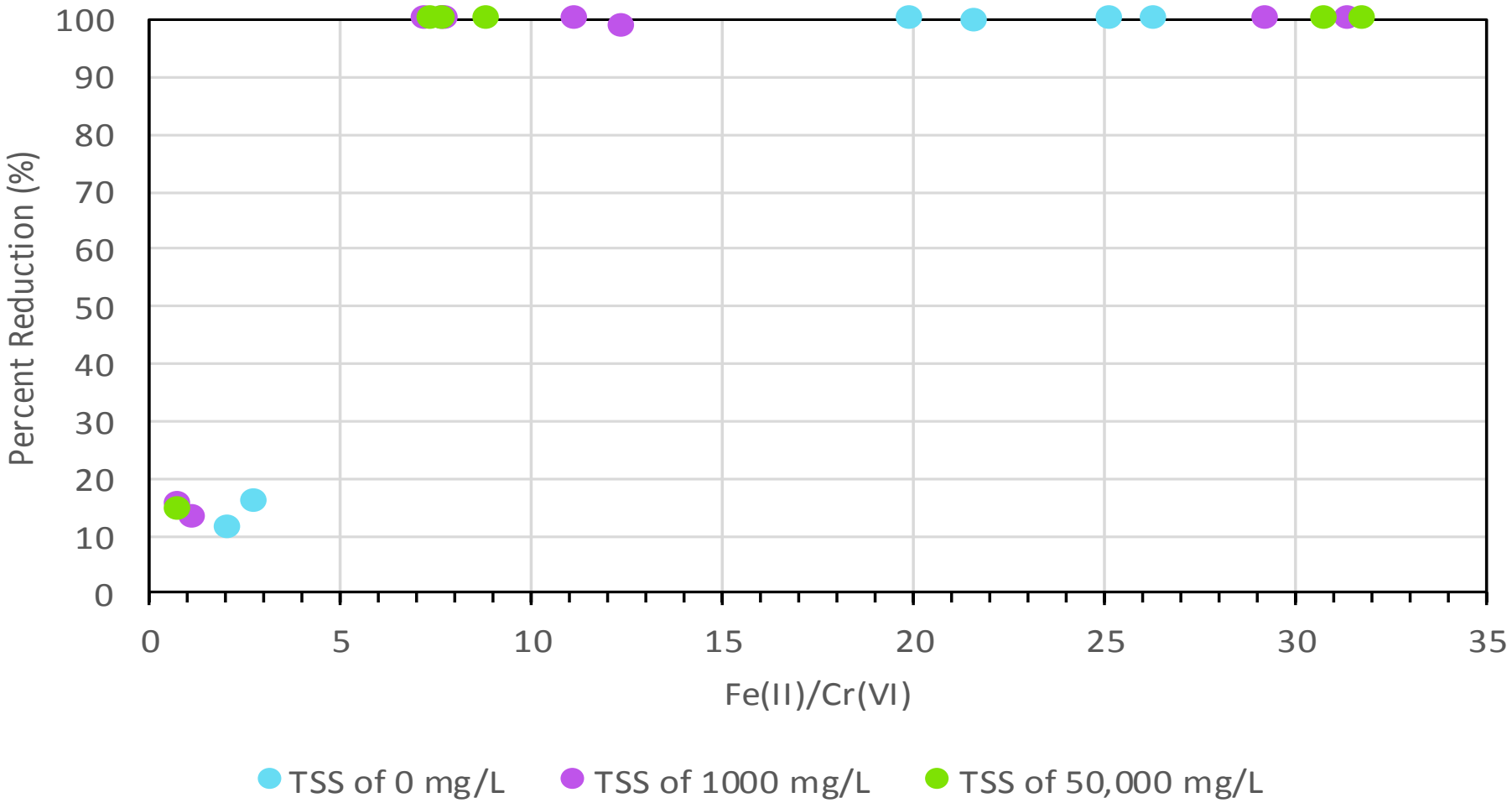
Cr INVESTIGATIONS AT BRUCEJACK GOLD MINE: MINE WATER



- Effective Cr(VI) reduction was observed under all experimental conditions when Fe(II)/Cr(VI) is > 8 (irrespective of pH, TSS or temperature)
- Treatment of mine water directly could be implemented at the mine if necessary

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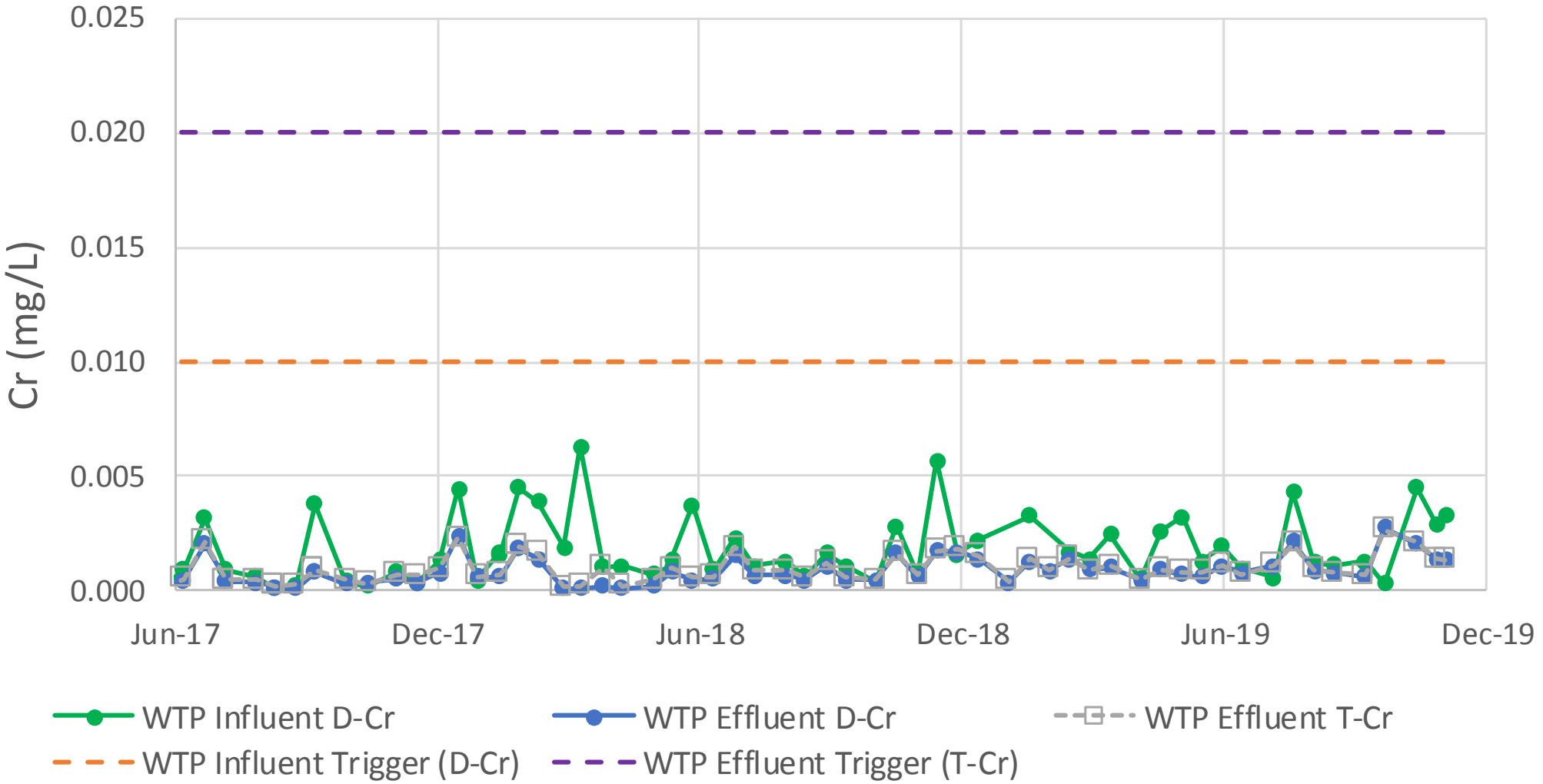
CR MONITORING RESULTS: MINE WATER



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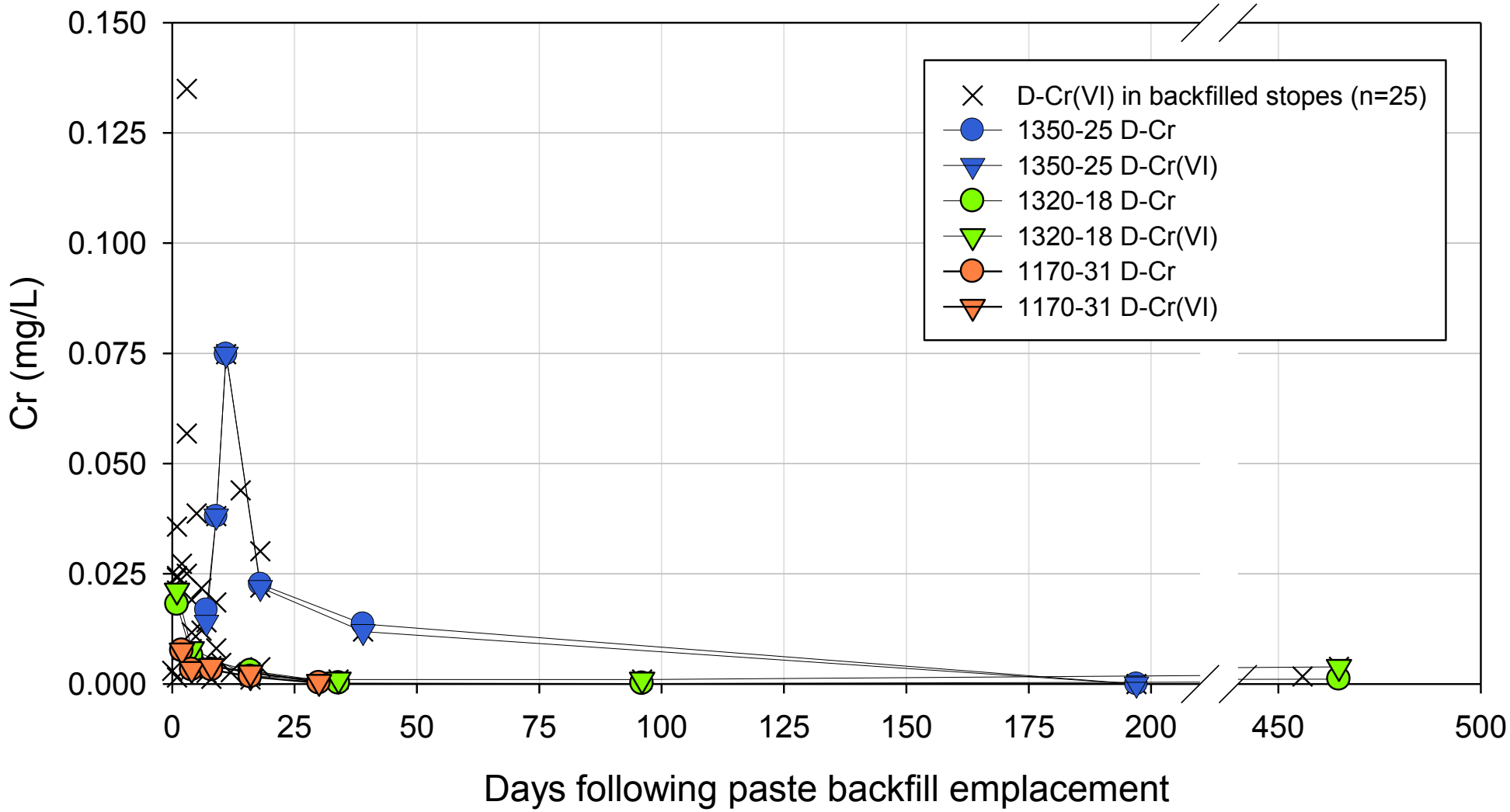
CR MONITORING RESULTS: BACKFILLED STOPES



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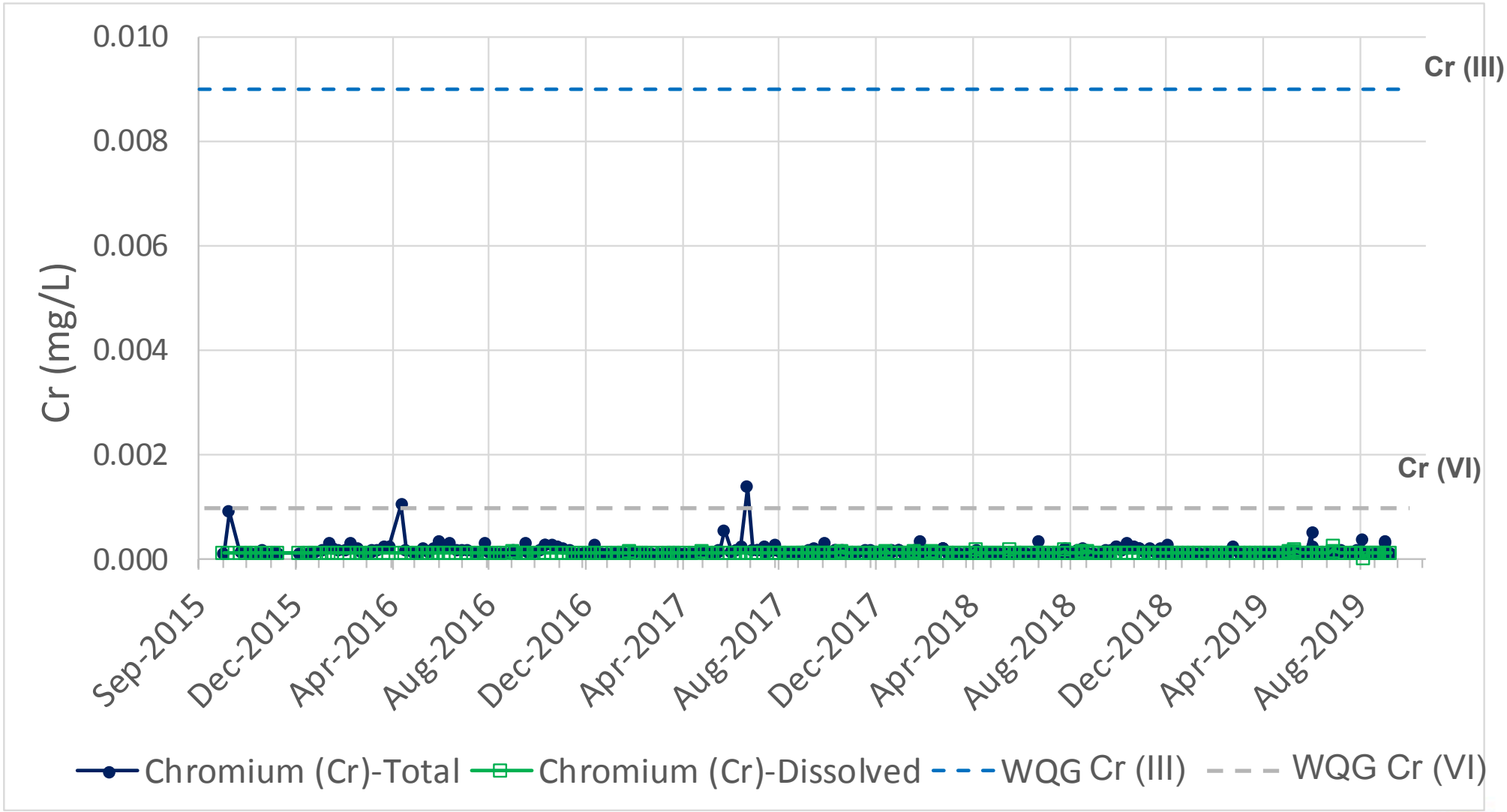
CR MONITORING RESULTS: BJ 3.10 (EFFLUENT COMPLIANCE POINT)



CONCLUDING REMARKS

- Paste backfill is generally considered to be best practice in terms of ML/ARD, but the potential risk associated with Cr(VI) leaching may need to be managed
- Humidity cell tests and paste backfill monitoring data sets confirm that Cr leaching from cement-related materials is dominantly Cr(VI)
- Recent experiments using representative tailings and cement predict lower total Cr loads than original experiments – not all cement has the same Cr content
- Experiments using site-specific materials demonstrate that addition of a reducing agent to paste backfill or mine water will be effective should mitigation be required
- The Brucejack Gold Mine Cr Management Plan is an example of effective Cr management

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