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Progress on Understanding Decline in Selenium Leaching Rates in the Elk Valley – Regional Analysis of Monitoring Data

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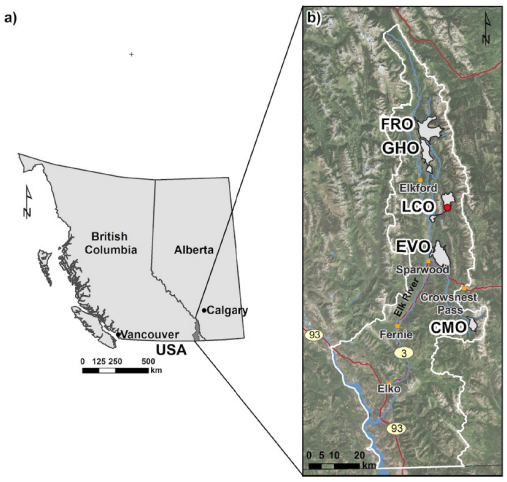
Regional Setting



- EVR mines metallurgical coal at four operations (EVO, LCO, GHO and FRO) located in the Elk Valley, southeastern British Columbia
- Coal was formerly mined at Coal Mountain Mine which is currently in care and maintenance
- The company has a regulatory requirement to predict constituent of interest (COI) concentrations in the Elk River downstream of its sites using the Regional Water Quality Model (RWQM)
- The RWQM has undergone three major updates since its development in 2014
- It is used to plan and evaluate the effectiveness of mitigation measures implemented to reduce COI concentrations.

Modelling of Selenium Leaching in the RWQM

- Selenium (Se) is released from coal mine wastes in the Elk Valley due to the oxidation of pyrite (FeS_2).
- Se leaching rates are an input into the RWQM
- Since the first iteration of the RWQM, Se leaching rates have been estimated using the extensive mine records and drainage chemistry monitoring records maintained by past and current owners of the mining operations.
- A key assumption has been that Se leaching rates are constant but in fact they will decrease.
- EVR convened a series of workshops since 2020 attended by subject matter experts (SMEs) to evaluate evidence for the decline in Se release rates to refine the inputs into the RWQM.

Why Do Selenium Release Rates Decline?

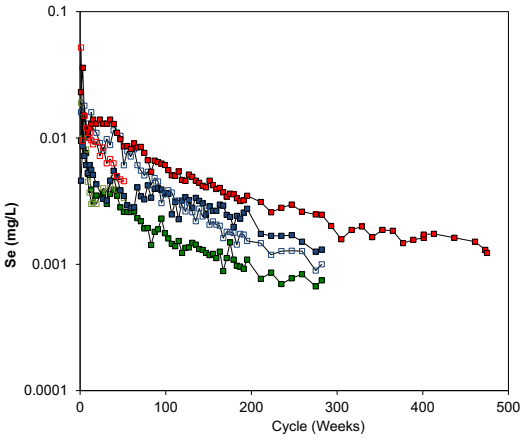
General Reasons:

- The mass of Se is finite and not all Se is available. Leaching cannot persist indefinitely.
- The oxidation process occurs on pyrite surfaces. As particles shrink, the available pyrite for oxidation decreases ("shrinking core model").
- As pyrite oxidizes, it becomes coated with secondary minerals which slow down the delivery of oxygen to the particles.
- Attenuation of leached Se can increase as wastes age.

Site Specific Reasons:

- The availability of oxygen decreases at large scales as waste facilities increase in size and geometery.
- Locally suboxic conditions develop resulting in environments where Se is converted to less mobile forms.

Trend Observed in Laboratory Tests



- Laboratory tests on EVR waste rock clearly show that Se release decreases providing small-scale evidence of the expected trends.
- The SMEs considered evidence for declining release rates in the Elk Valley and at other mining operations.
- In the Elk Valley, this included evaluation of the regional dataset.

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These are trends in Se leaching shown by humidity cells operated from for nearly 10 years. Samples tested are from LCO.
Note log axis
Note that lines are in different positions relatively but in the long term the slopes are very similar. Gives confidence that leaching processes are well constrained at this scale.

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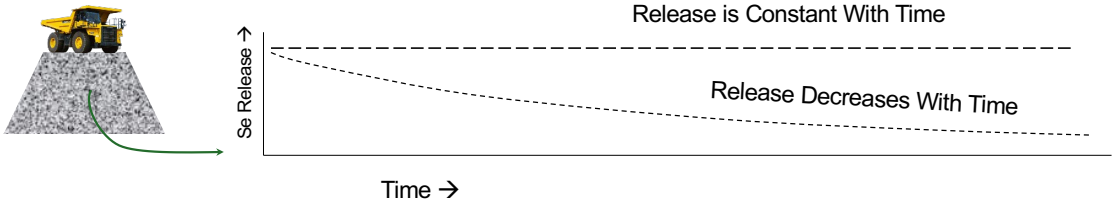
Regional Data Evaluation

Hypothesis Statement

- Large-scale open pit mining has been occurring in the Elk Valley for over 50 years.
- We expect that older waste rock is leaching Se at lower rates than when it was first placed.
- Due to the long duration of mining, the additive effect of Se leaching from all waste rock placed since 1970 should be reflected in monitoring data downstream of all the operations

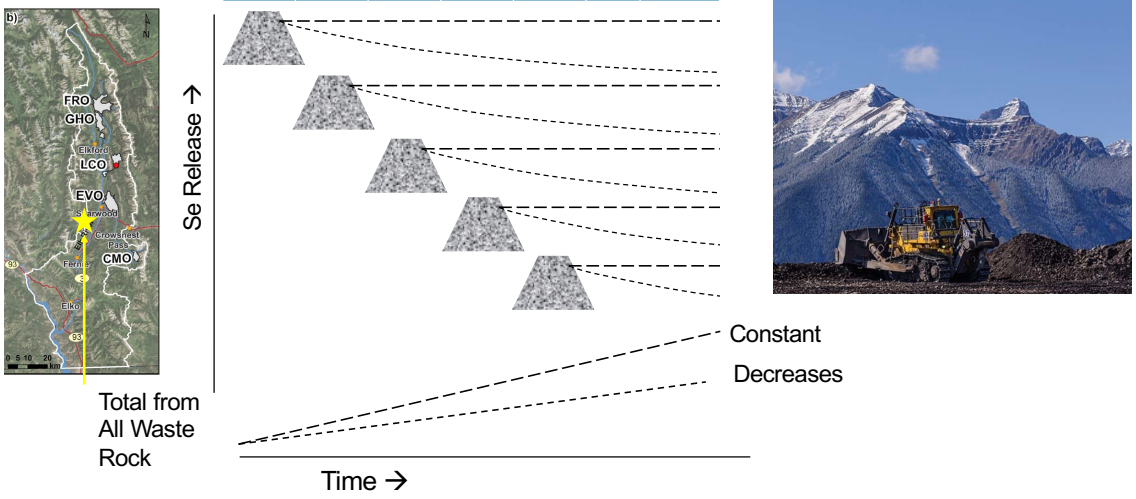
Concept



As soon as waste rock is placed, Se in the rock is converted to soluble forms that can be leached by infiltrating snowmelt and rainwater.

- In the past, we have assumed that the conversion occurs constantly with time.
- However, we know this is not the case. Conversion slows down with time.

Expected Additive Effect



Rock placed in 1970 starts to leach as soon as it is placed.
Rock placed in 1971 adds to the load from the rock placed in 1970 and so on.

Testing the Hypothesis

We expect that older waste rock is leaching Se at lower rates than when it was first placed

- Step 1: Model the trend in Se release from waste rock.
  - Calculate for constant annual Se release and decreasing annual release
- Step 2: Compare these model trends to the observed Se in the Elk River downstream of all mining operations.
- Step 3: Evaluate uncertainty.

Inputs to the Model

- Annual waste (bank m^3, BCM) produced by all mines since 1970 from mining records.
- Se release from rock (mg/BCM/year) as indicated by monitoring at the operations.
- Trend in decline in Se release indicated by multi-year laboratory weathering tests on waste rock.
- Effect of difference in temperature between laboratory and field conditions. Chemical reactions happen slower at lower temperatures.
- Delayed release to Elk River due to hydraulic effects.
- Effect of water treatment for Se in recent years. This Se is leached from waste rock but does not reach the Elk River.

Calculations

- Calculate the total mass of Se released each year (kg/year) from waste rock placed in each preceding year.
- Calculate the total mass of Se moving in the Elk River each year (kg/year).
- Compare Se on cumulative mass basis (kg). This smooths out inter-annual variability.

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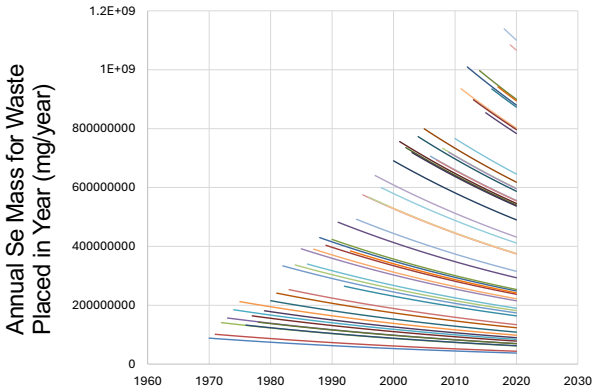
Results

Individual Year Curves Models



- Annual waste production was low in early years resulting in lowest annual Se release.
- Annual waste production has generally increased over the years leading to higher overall Se release.

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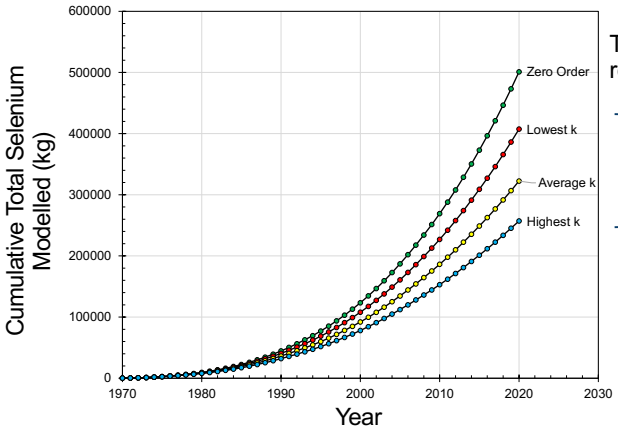
Note each line starts at the year the waste is placed
These lines are then added to obtain total load released (next slide)

Model Results



This model is for constant annual Se release. Note this is the steepest line.

These models are for decreasing annual Se release. k refers to slopes observed in the laboratory tests. High k means most rapid decline.

Conclusion: There is sufficient difference between the model trends that declining Se release should be reflected in the Elk River.

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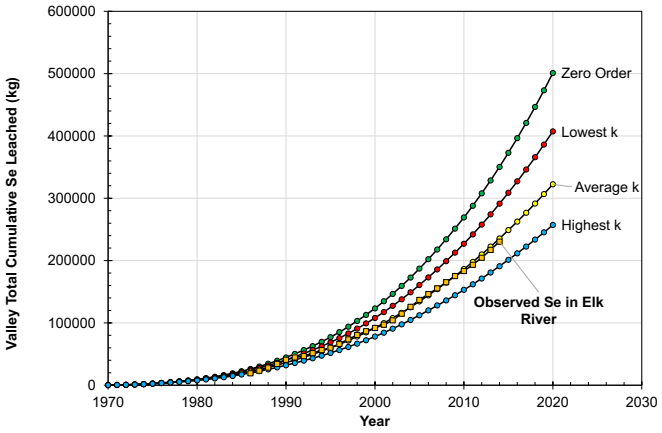
Zero order means constant release.
k value indicates the slope of the declining curve. Higher k means steeper decline.
Will explain on graph about how greater annual decline leads to lower total Se by picking a year.
Note the difference between constant release model and highest k is about 50% in 2020.

Comparison of Models with Observed Se in the Elk River



- The trend for Se in Elk River aligns with the average model trend.
- This conclusion was evaluated by varying the model inputs.
- It was not possible to align the observed Se in the Elk River with the “constant release” model using credible model inputs.

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Conclusions

- This analysis concluded that Se in the Elk River is consistent with models for declining Se leaching from waste rock.
- Inclusion of declining Se in the RWQM is appropriate and consistent with the overall well-established expectation that Se release will decrease over the long term.

Thank you

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