Selenium Coal Research Study

The Toxicity of Selenium and History of Emissions Controls from Conventional Coal Mining

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1.0 Introduction

Coal is one of the most largely used fossil fuels world-wide. Some primary uses for coal are electricity generation, steel production, cement manufacturing, and liquid fuel. Due to its many uses, coal is a highly sought after material, but it has many controversial issues associated with its production and extraction processes. Coal extraction requires large areas of land and the land must be cleared of trees and other obstructions before a mine can be set up (Sandlos, 2006). The extraction process is known to contaminate nearby water sources while also releasing airborne pollutants into the atmosphere. Selenium is a primary contaminant of extraction and is often released in the waste materials, especially in wastewater during coal mining (Sandlos, 2006). Selenium is a naturally occurring element that can be harmful to ecosystem health when it accumulates in high doses (Brandt, 2019). Issues resulting from selenium release include biodiversity loss for the surrounding ecosystem and human and environmental health issues. Recent publications in certain major news outlets have discussed concerns over coal mine contamination in Alberta rivers and the failure of British Columbia to address selenium pollution (Weber, 2021 & Cruickshank, 2020). The rise of public awareness has further increased the need to address selenium contamination in a prompt and responsible manner.

Selenium is an important trace element in the human diet for enzymes and proteins that regulate thyroid hormones and antioxidant defences (Health Canada, 2014). It is exposed to humans in a variety of ways including food, air, soil and drinking water that are not necessarily toxic to humans (Health Canada, 2014). However, long term chronic exposure to selenium can have serious health effects including hair loss, nail anomalies or loss, skin anomalies, garlic odour of the breath, tooth decay and nervous system disturbances (Health Canada, 2014). Recommended daily intake levels account for selenium in drinking water (which is typically non-volatile in nature), air, soil, and food which are totalled and calculated based on various age groups.

Selenium contamination is a concern in many aquatic environments ranging from urban to rural settings and affecting a broad range of ecosystems such as mountains, rainforests, deserts, and plains (Lemly, 2004). Based on the Canadian Council of Ministers of the Environment (CCME) “protection of aquatic life” protocol, standards are set for both agriculture water uses and for freshwater aquatic life. Guidelines set for agriculture are 20 mg/L if use is continuous and 50 mg/L if use is intermittent (Alberta Government, 2018). Protection of aquatic life does not have fully set guidelines, rather it states that “exceedance of the alert concentration in sensitive environments indicates the need for increased monitoring of water and other ecosystem compartments to support early detection of potential Se bioaccumulation issues and provide earilirt opportunities to commence proactive management actions” (Alberta Government, 2018). However, there is no set alert concentration given for selenium. However, there are sediment quality guidelines for the protection of aquatic life that state that the interim sediment quality guideline for selenium is 2000 mg/kg (Alberta Government, 2018). In reference to drinking water, Health Canada states that the maximum acceptable concentration for total selenium in drinking water is 0.05 mg/L (Health Canada, 2014).

The NPRI has been reporting data on selenium since 1994 in Alberta where the High River facility La Roche Ltd reported that there were zero on site releases or disposals of selenium (Government of Canada, 2019). Additionally, reporting thresholds for selenium and its compounds were changed in 2011 from 10 tonnes and 1% concentration to 100 kilograms and 0.000005% in 2011 (Government of Canada, 2019). This alteration changed the level at which selenium had to be reported as much smaller concentrations are now of concern. Other evidence from a study downstream of a mine in Saskatchewan confirms the supposition that selenium is prone to bioaccumulation in aquatic ecosystems, and that fish reproduction may be impared as a result (Muscatello et al, 2008).

2.0 Research Statement

Selenium and other harmful trace elements are released into the atmosphere and water sources due to coal mining. This report focuses on selenium in coal mines and its effects on air quality and aquatic ecosystems. Coal resource management strategies and regulations are required to prevent further ecological damage in the watersheds and atmosphere near mining operations.

3.0 Project Goal and Objectives

The purpose of this research study is to determine the effects of selenium emissions from coal mines and coal production throughout British Columbia, Alberta and Saskatchewan. Research was based on scholarly articles and regulations regarding coal emissions and selenium levels in mining waste. This study discusses the toxicity of selenium and the environmental impacts it has on human and ecosystem health. Data was obtained to better understand past and current emissions while outlining measures to reduce overexposure and aid in reaching emission targets. A review of the history of emissions controls from coal mining and combustion in Canada and the United States of America is also discussed in the report, and a case study describing an effective management strategy was analyzed to aid with future recommendations.

3.1 Project Design & Required Resources

The report discusses data acquired from the NPRI involving selenium releases from mining wastewater for coal mines in BC and Alberta, along with a Teck Resources case study for wastewater treatment. The study also presents information on how regulations help mitigate contamination while providing recommendations for future improvements. The required resources in the form of data were obtained from Environment Canada records and the extensive research focused on peer-reviewed scientific reports. A specific project timeline can be viewed in Appendix A.

4.0 Toxicity and Impacts of Selenium

4.1 Effects of Selenium on Ecosystem Health

Selenium impacts primarily aquatic ecosystems when it enters waterways such as streams, rivers and lakes. The major issue with selenium is that it bioaccumulates through aquatic organisms in the food chain, similar to the process seen in the element mercury. Elemental selenium is not extremely toxic, but becomes harmful when it is combined with other elements. Minimal concentrations of selenium in the water can lead toxic effects for aquatic life. Some of the signs of selenium toxicity include fish deformities, reproductive issues and high fatality rates of aquatic organisms (Prica, 2019). Studies have shown that as little as 0.1-1.0 parts per million (ppm) of selenium can lead to nutritional deficiencies and body abnormalities (Davis, 1988). Another pathway in which selenium can enter the food chain is through vegetation uptake. Plants are able to take up selenium through their roots and this concentrates the selenium within the plant tissues. Any organism that feeds on the vegetation is then accumulating the selenium inside their body. Invertebrates are most susceptible to selenium toxicity due to their size and body functions and selenium toxicity commonly leads to death (as seen in Figure 1).

Species	Common name	Concentration of Se compound	Effect
		ppm	
Algae:			
Ankistrodesmus falcatus		0.01 selenate	decrease in cell divisions
Selenastrum capricornutum		0.1 selenite	20% decrease in cell divisions
Scenedesmus dimorphus		40.0 selenate	100% "
"		40.0 selenite	100% "
Anabaena nidulans		50.0 selenate	24% "
"		50.0 selenite	21% "
Anabaena flos-aquae		5.0 selenate	decrease in cell divisions
"		4.0 selenite	"
"		0.3 selenomethionine	"
Invertebrates:			
Daphnia magna	water flea	2.4 selenate	96 hr. LC_{50}
"	"	0.6 selenite	"
"	"	0.04 selenomethionine	"
"	"	0.03-0.28 selenite	survival and reproduction unaffected
"	"	1.1 selenite	48 hr LC_{50}
"	"	1.0 selenite	decreased reproduction
Daphnia pulex	water flea	0.2-0.8 selenite	insignificant rise in O_2 consumption
"	"	"	decrease in filtration rate
"	"	3.87 selenite	48 hr LC_{50}
"	"	0.13 selenite	96 hr LC_{50} cellular damage
Daphnia pulicaria	water flea	0.006 selenite	96 hr LC_{50}
Chironomus decorus	midge	25.0 selenate	48 hr. LC_{50}
"	"	50.0 selenite	"
"	"	<200 selenomethionine	"
Orconectes immunis	crayfish	0.1-1.0-	osmoregulatory changes
Hyallela azteca	amphipod	1.0 selenite	96 hr LC_{50}
"	"	1.0 selenate	"
Entosiphion sulcatum	protozoan	0.003 selenite	decreased reproduction
Vertebrates:			
Lepomis machrochirus	bluegill	40.0 selenite	96 hr LC_{50}
Ictalurus punctatus	catfish	18.2 selenite	"
Carassius auratus	goldfish	36.6 selenite	"
Pimephales promelas	fathead minnow	1.1-7.3 selenite	"
Gambusia affinis	mosquitofish	76.0 selenite	"
Salmo gairdneri	rainbow trout	8.1 selenite	"
"	"	0.044 selenite	increased mortality

Figure 1: The concentration of selenium along with the effects and minimal concentration required to harm aquatic organisms (Davis, 1988)

4.2 Effects of Selenium on Human Health

Selenium in small amounts is necessary for the human body to properly function. For example, selenium is required for the thyroid to produce necessary hormones and it protects the thyroid from oxidative stress (Ventura et al., 2017). The healthy concentration of selenium in adults is 70 to 150 ng/mL, or the equivalent of 0.15 ppm (Mayo Clinic, 2021). Optimal selenium concentration is age dependent and can be different based on preexisting health conditions. Excess amounts of selenium are known to cause various health issues once ingested (primarily through drinking water). For example, common symptoms include nausea, vomiting, nail discoloration, hair loss, fatigue, irritability, reproductive issues and a foul odour coming from the individual's breath (Prica, 2019). In extreme circumstances, excess selenium may result in organ failure be fatal (Prica, 2019).

5.0 Regulatory Requirements

5.1 Alberta Coal Mining Regulations

Alberta has many regulators that are involved in coal mining in order to make sure that negative human and environmental impacts are minimized. In Alberta, coal mining is regulated by the Alberta Energy Regulator (AER) for production and extraction procedures. The AER ensures that coal mining operations are following the regulatory guidelines and safety protocols. Alberta Labour is responsible for the safety for all individuals involved in the mining activities. The Alberta Environment and Parks (AEP) are able to review reclamation activities and mining practices in order to keep the companies accountable for their actions and ongoing projects (Government of Alberta, 2021).

5.2 Saskatchewan Coal Mining Regulations

Saskatchewan has been mining coal since 1857 and is one of Canada's most prominent producers of lignite coal (Government of Saskatchewan, n.d.). Saskatchewan requires a completed land grid survey form and a cover letter in order to be approved for coal and lignite dispositions through the Lands and Mineral Tenure Branch of the Ministry of Energy and Resources (Government of Saskatchewan, n.d.). Data is also available through Saskatchewan's public website pertaining to all ownership, status, and locations of dispositions in the province. Additionally, Saskatchewan has a Crown Minerals Act which outlines regulations such as the Mineral Tenure Registry Regulation, which is a regulatory body that gives authority to the

Mineral Administration Registry Saskatchewan (MARS) to issue mineral dispositions throughout the province (Government of Saskatchewan, n.d.). The Mineral Resources Act of 1985 outlines developmental and conservation issues surrounding mineral resources and will also be addressed in this study.

5.3 British Columbia Coal Mining Regulations

In British Columbia, mining activities are liable to various regulations, including the Environmental Assessment Act, the Mines Act, and the Environmental Management Act and are subject to both provincial and federal directives (Government of British Columbia, n.d.). The Environmental Assessment Act is a provincial statute that reviews any major mining projects to help assess possible environmental impacts and includes the Reviewable Projects Regulation to help manage certain large-scale projects (Government of British Columbia, n.d.). The Mines Act focuses on the health and safety of both the environment and workers by minimizing risk through various approvals (Government of British Columbia, n.d.). The Environmental Management Act includes the Waste Discharge Regulation, among others, and controls pollution, hazardous waste, and site remediation activities while encouraging compliance through fines and penalties (Government of British Columbia, n.d.).

5.4 Selenium Coal Mining Regulations

Though selenium is a major contaminant from mining wastewater, there are currently no regulations pertaining to selenium standards. The Fisheries Act has some guidelines set to prevent excess pollutants from entering water bodies, however there is no specific regulation pertaining to selenium and standards for pollutants are often not strict enough to prevent contamination. An in depth look at the lack of selenium regulations in Alberta, British Columbia and Saskatchewan can be found under the ENVS 4419 report, *Regulations Regarding: The*

Toxicity of Selenium and History of Emissions Controls from Conventional Coal Mining written by Kate Winterford, Stuart Rushbrook, Adam Fyten and Shelby Hansen.

6.0 Data Collected from Environment Canada

The data for this study was obtained from Amelie Pelletier on behalf of Karole-Ann Roy-Chretien who are Science Officers that work for Environment Canada under the Science and Technology Branch regarding Environment and Climate Change Canada. They provided the details on how the data was organically obtained. Annually, companies are required to report to the NPRI if they meet certain criteria. This criteria is related to the number hours worked or the types of activities carried on site. This is often the case for oil, gas and all mining practices (Pelletier, 2021). This information is then used to help the government set priorities and monitor environmental performance. The requirements for each company are published in the Canada Gazette, and are explained through the Guide of reporting to the NPRI (Pelletier, 2021).The data values are estimated by the companies through their monitoring and research.

As demonstrated in Table 1, the greatest amounts of selenium emissions from coal mining in both Alberta and British Columber for the 2019 year were into water bodies. Selenium releases into air were not of large concern, therefore the majority of data discussion and recommendations are made on the basis of water bodies being affected. Continued analysis should be completed to ensure selenium releases to air do not increase in the coming years.

Table 1: 2019 selenium emissions (kg) for British Columbia and Alberta based on the source of pollution into either air or water bodies

Province	Source of Selenium	Amount of Selenium (kg)
British Columbia	Release to Air	1.956664
	Release to Water Bodies	7081.13262
Alberta	Release to Air	4.2984
	Release to Water Bodies	504.0422

The data collected from Environment Canada consisted of a Microsoft Excel spreadsheet of all the mining operations across Canada. Most of the data was from mining operations that were not coal mines and this can be seen in Appendix B. The focus of this study is coal mines in Alberta, BC and Saskatchewan, however there was no available data regarding selenium emissions for Saskatchewan for coal mining operations. Table 2 compares the companies within the provinces and how they differ based on the number of mines and by statistical analysis of selenium content released.

Table 2: Data collected from Environment Canada is displayed in the table below showing the average selenium amounts in kilograms for 2019, as well as the standard deviation and variance values for the participating coal mines.

Year	Province	Company Name	Number of Mines included	Selenium Averages (kg)	Standard Deviation (kg)	Variance (kg)
2019	British Columbia	Teck Coal Limited	15	29078.02	2895.577	2797.39
2019	British Columbia	Conuma Coal Resources	4	247.72	349.28	246.98
2019	Alberta	Teck Coal Limited	3	858.296	1075.80	878.385
2019	Saskatchewan	No data available	No data available	No data available	No data available	No data available

Table 3: Data collected from Environment Canada for all of the applicable coal mining operations in Alberta and BC showing the sources of selenium and the type of source with the emissions in kilograms.

Year	Company Name	Operation	Location	Province	Source of Selenium	Type of Source	Amount of Selenium (kg)	
2019	Teck Coal Limited	Elkview Operations	Sparwood	BC	Releases to Water Bodies	Direct Discharges	380.6132	kg
2019	Teck Coal Limited	Elkview Operations	Sparwood	BC	On-site Disposal of TWR	Tailings Management	6090.3727	kg
2019	Teck Coal Limited	Elkview Operations	Sparwood	BC	Releases to Air	Stack / Point	0.0026	kg
2019	Teck Coal Limited	Line Creek Operations	Sparwood	BC	Releases to Water Bodies	Direct Discharges	1221.94091	kg
2019	Teck Coal Limited	Line Creek Operations	Sparwood	BC	Releases to Air	Stack / Point	0.000786	kg
2019	Teck Coal Limited	Line Creek Operations	Sparwood	BC	On-site Disposal of TWR	Tailings Management	4486.5584	kg
2019	Teck Coal Limited	Greenhills Operations	Elkford	BC	Releases to Water Bodies	Direct Discharges	699.758	kg
2019	Teck Coal Limited	Greenhills Operations	Elkford	BC	Releases to Air	Stack / Point	0.002811	kg
2019	Teck Coal Limited	Greenhills Operations	Elkford	BC	On-site Disposal of TWR	Tailings Management	2303.1451	kg
2019	Teck Coal Limited	Coal Mountain Operations	Sparwood	BC	Releases to Air	Stack / Point	0.000166	kg
2019	Teck Coal Limited	Coal Mountain Operations	Sparwood	BC	Releases to Water Bodies	Direct Discharges	179.92489	kg
2019	Teck Coal Limited	Coal Mountain Operations	Sparwood	BC	On-site Disposal of TWR	Tailings Management	152.604	kg
2019	Teck Coal Limited	Fording River Operations	Elkford	BC	Releases to Air	Stack / Point	0.7718	kg
2019	Teck Coal Limited	Fording River Operations	Elkford	BC	Releases to Water Bodies	Direct Discharges	3859.54	kg
2019	Teck Coal Limited	Fording River Operations	Elkford	BC	On-site Disposal of TWR	Tailings Management	9702.79	kg
2019	Conuma Coal Resources Ltd.	Dillon / Brule Mine	Chetwynd	BC	Releases to Water Bodies	Direct Discharges	494.46	kg
2019	Conuma Coal Resources Ltd.	Dillon / Brule Mine	Chetwynd	BC	Releases to Air	Fugitive	0.74	kg
2019	Conuma Coal Resources Ltd.	Willow Creek Mine	Chetwynd	BC	Releases to Air	Fugitive	0.438501	kg
2019	Conuma Coal Resources Ltd.	Willow Creek Mine	Chetwynd	BC	Releases to Water Bodies	Direct Discharges	244.895616	kg
2019	Teck Coal Limited	Cheviot Mine (Cardinal River Operations)	Hinton	AB	Releases to Water Bodies	Direct Discharges	504.0422	kg
2019	Teck Coal Limited	Cheviot Mine (Cardinal River Operations)	Hinton	AB	Releases to Air	Stack / Point	4.2984	kg
2019	Teck Coal Limited	Cheviot Mine (Cardinal River Operations)	Hinton	AB	On-site Disposal of TWR	Tailings Management	2066.549	kg

Data from Table 3 was created into a pie chart (Figure 2) to exhibit the sources that produce the highest levels of selenium pollution, based on the company and types of source. Data was also organized into a bar graph (Figure 3) to compare the emission levels of each different operation from the varying companies.

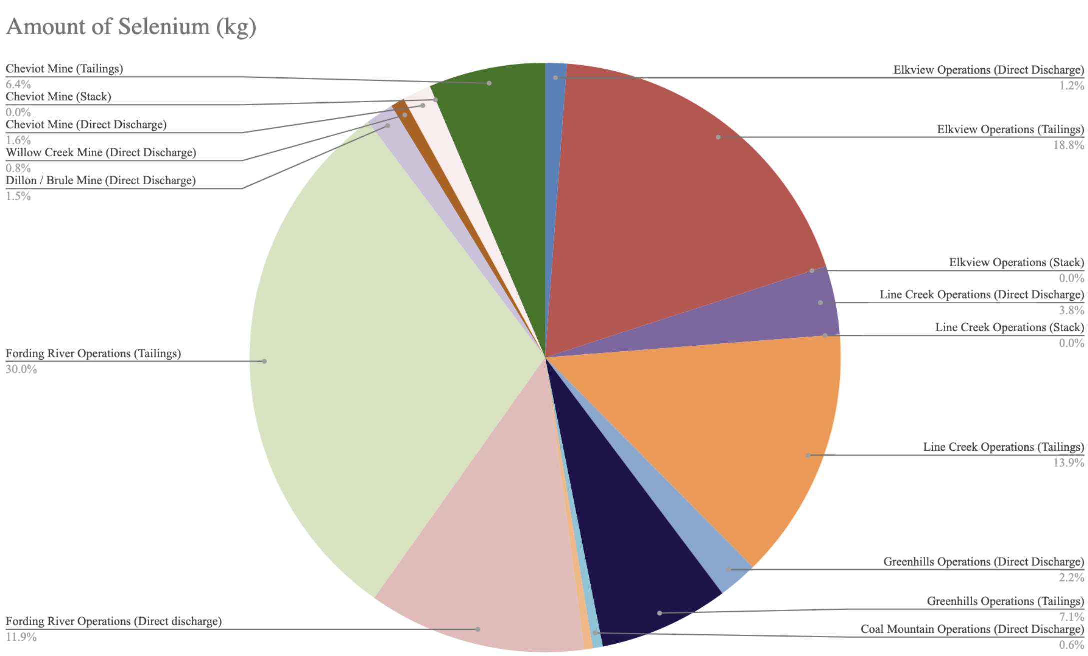

Figure 2: Pie chart showing the comparison among operations and their selenium emissions by direct discharge, tailings and stacks among coal mines in BC and Alberta.

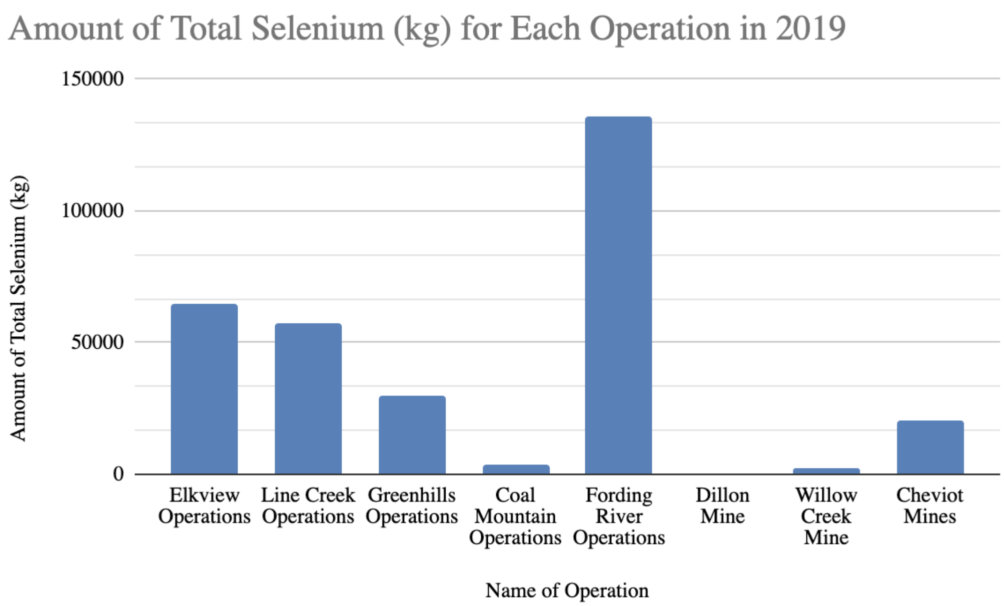

Figure 3: Bar graph showing the total selenium emissions for each operation based on the cumulative sum of direct discharge, stack emissions and tailings

Data from the mine with the highest pollution levels was reviewed over the period of eight years to determine whether any trends occurred over time (Figure 4).

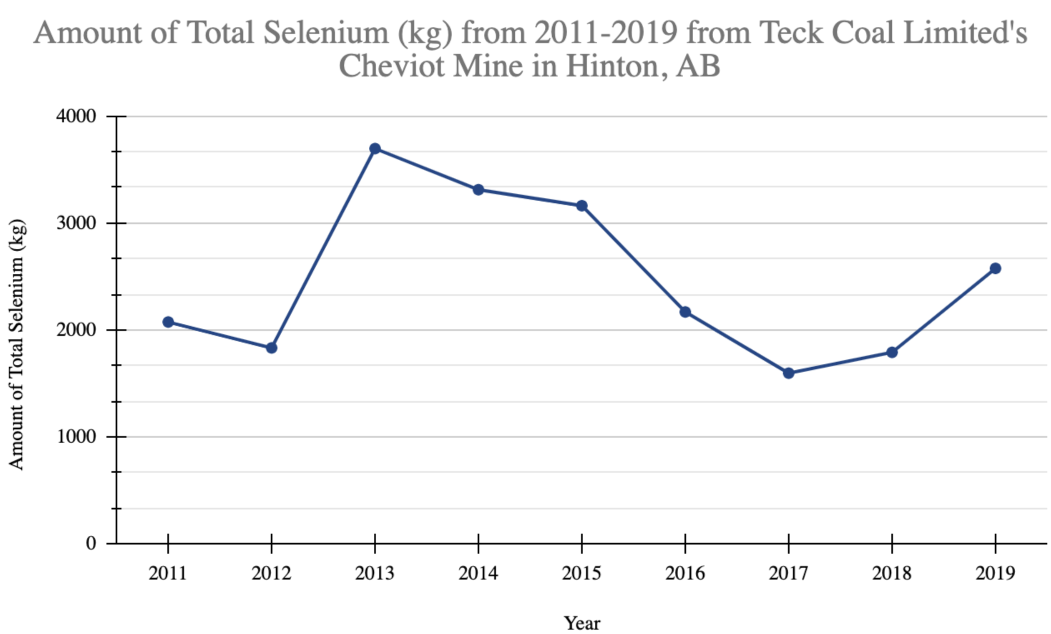

Figure 4: Line graph showing the trends from 2011 to 2019 for the Cheviot Mine Operation in Hinton, Alberta using cumulative sums of selenium emissions (direct discharge, stack emissions and tailings)

7.0 Data Analysis

7.1 Data Analysis and Discussion

By evaluating the data it can be determined that the size of the operation directly correlates to the amount of selenium produced. Teck Resources largest mine called Fording River Operations had the highest amounts in kilograms of selenium emitted in the year 2019 at a sum of 13563.1018kg which can be seen above in Figure 3. The smaller mines (Coal Mountain Operations, Dillon and Willow Creek) had very limited levels of selenium. An increase in coal extraction and the scale of the mining increases the amount of wastewater and burning which leads to the selenium being released into the environment. By analyzing Figure 2, it can be confirmed that tailings are the major source of selenium contamination. This is due to wastewater in tailing ponds often being difficult to contain, as well as, run-off can easily wash contaminated wastewater into the nearby water bodies (Coimbra, 2020). The stack emissions are the lowest type of selenium discharge at coal mining operations, as the burning of coal is limited due to Canada phasing out coal combustion by the year of 2030 (Government of Canada, 2019). Based on Figure 4, most of the selenium values from the data collected are close too or higher than what is toxic to most aquatic life. The data however is over a year basis, so shorter time periods would be required to address the levels and effects of the toxicity at the organisms.

There was no data available for Saskatchewan coal mining, as the only data that Environment Canada had available was based on oil and gas operations. This is likely due to there only being three smaller active open-pit coal mines in Saskatchewan which are located in Coronach and Estevan (Giannetta, 2011). After looking at data over time, it is evident from Figure 3 that there are no trends for selenium releases, as the quantity of selenium varies and is seen as unpredictable. The conclusion that can be made from the data and different mining operations is that the annual rates of selenium are not consistent and there is an increase in selenium releases for larger scale operations. These selenium releases are also not increasing over time and this can be due to an increase in wastewater treatment methods that most mining operations are implemented.

7.2 Limitations to the Data and Study

The representatives from Environment Canada gave insight to how the data was collected and mentioned that the data values are an estimate from the companies. By analyzing the data values and the significant digits it is unclear as to how accurate the data knowing that it is is based on the companies estimates. This is a major limitation to this study as the data obtained may contain some biases or be slightly skewed. Further research and reaching out to the companies would provide clarity on the specific ways the data was collected and to ensure maximum accuracy in the results. Another limitation would be the data gap for Saskatchewan coal mining operations. There was no applicable data for Saskatchewan that could be used to compare operations and selenium emissions to Alberta and BC. The type of selenium releases were not specific. If the point sources were in detail then a better understanding of how the selenium was released would have been used to determine specific mitigation strategies. The data is also based on annual levels which makes it differOverall, this study had minimal limitations which allowed for the overall study objectives to be met.

8.0 Recommendations

As selenium is becoming an increasing issue for air quality and aquatic ecosystems, recommendations and proper planning need to be implemented to create a sustainable future for Canadian selenium levels. The main recommendation that can be made is introducing strict regulations on selenium contamination that must be followed by coal mining companies. As of right now, selenium has guidelines put in place both provincially and federally that gives estimates to the amount of selenium that is safe in drinking water and ingested through air pathways. However, there are currently no national regulations that hold mining activities accountable for releasing selenium into the environment through stack burning and tailings. It is therefore most important, as in any pollution prevention model, to reduce pollution at the source through regulatory action, education, and accountability for coal companies. Reduction at the source is the most cost-effective and safe way to deal with selenium contamination.

Other recommendations of treating selenium have been made based on a study done through Alberta Environment, who hired Microbial Technologies Inc. to conduct and evaluation of different treatment options that aimed to reduce water-borne selenium at coal mines in Alberta (Government of Alberta, 2006). Treatment systems varied as being either physical, chemical, and biological in nature and were awarded on a point-based system for overall effectiveness. Though the study recognized that data was limited for Alberta mines, two of the eleven best management practices stood out as being most effective: in-situ treatment and bioreactors (Government of Alberta, 2006). Both methods were proven to work in cold climates with high levels of reliability regarding effluent selenium concentrations and overall cost-effectiveness (Government of Alberta, 2006). It is important to note that though these methods were found to be effective at the time of the study, they were based on limited data and were developed only with Alberta mountain coal mines considered. A similar research process would be recommended for British Columbia and Saskatchewan in order to find best management practices that will suit the needs of those specific environments.

Further recommendations include effective management practices such as wastewater treatment facilities and the future outlook of coal mining, transitioning to cleaner alternatives.

Implementing wastewater treatment facilities can significantly reduce selenium levels entering water systems after passing coal mining operations. This process can be done through saturated rock fills, coagulation treatments and sand filtration (Lai, 2016). Although this will create some financial burden on mining companies, responsibility needs to be higher for selenium contaminated water. Finally, a continued transition towards cleaner energy such as solar, wind and hydroelectric can help reduce the need to use coal combustion so regularly. This in turn will further reduce the amount of selenium present in aquatic ecosystems and the atmosphere in Western Canada.

8.1 Effective Case Study for Selenium Wastewater Treatment

The following case study was analyzed to determine its overall effectiveness in managing selenium wastewater from a local source. Modelling new treatment methods after previous successful strategies is an important way to continue with the development of beneficial management approaches.

Teck Resources Limited owns many different mining and energy operations throughout Canada, United States, South America, as well as, has counterparts in Asia and Europe. One case study showing effective selenium wastewater treatment is Teck's water quality management facilities in Elk Valley. Elk Valley is a region that is located near in the East Kootenays surrounding Sparwood, British Columbia. The economy in this area is driven by four metallurgical coal mines. The coal that is extracted at these mines are primarily used for making steel. In order to mitigate the effects of selenium near the watersheds of Elk Valley, Teck Resources has implemented four wastewater treatment facilities called: Line Creek, Elkview, Fording River South and Fording River North.The implementation of the water treatment facilities is in progress and is supposed to be fully completed by the year of 2031. (Teck Resources, 2019).

The first water treatment facility has been completed and is currently treating 7.5 million litres of water per day at the Line Creek Mine. Teck Resources has stated that this has led to reductions in selenium and nitrate concentrations that are located downstream of the mine (in the Elk River). The second water treatment facility to be implemented is called the Elkview Saturated Rock Fill. This facility has been nearly removing all of the selenium and nitrate from the wastewater. It pumps 20 million litres of water every 24 hours, and was finished in 2018 (Teck Resources, 2019). The third water treatment facility that Teck has implemented in the Elk Valley is called the Fording River South Water Treatment Facility. This facility is currently still under construction. This facility is expected to be fully completed by the year 2021, with a capacity to treat up to 20 million litres of water per day (Teck Resources, 2019). The fourth water treatment facility, which is called the Phase 1 Fording River North Saturated Rock Fill, is currently under construction and is expected to be completed in 2022. By late 2021-2022, Teck has stated that it is expected to have capacity to treat up to 47.5 million litres per day, making this facility the largest in the area (Teck Resources, 2019). Teck also predicts through watershed monitoring that there will be close to minimal levels of selenium and nitrate being released in the watershed once the Fording River facility is completed (Teck Resources, 2019). This effective management strategy shows that selenium emissions can be reduced substantially through extensive wastewater treatment.

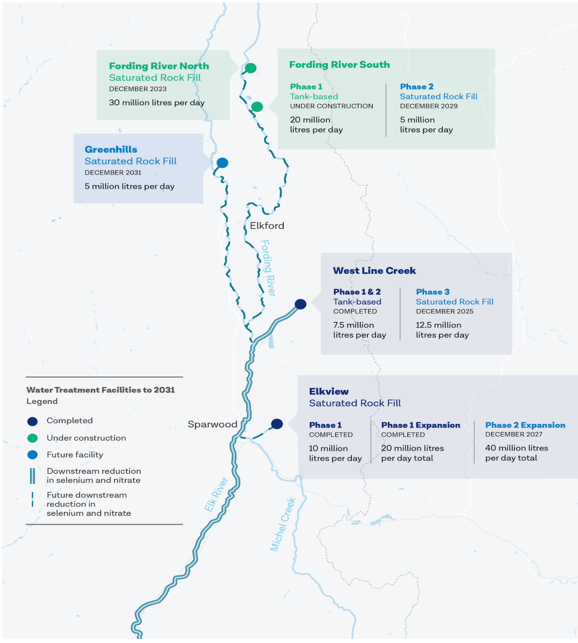

Figure 5: A map of the water treatment locations for the Elk Valley coal mines (Teck Resources, 2019).

The main technology that is used for the removal of selenium at Teck's Facilities is called saturated rock fills (SRF) (Teck Resources, 2019). SRF use naturally-occurring biological processes in former mining areas. These areas are locations at the mine that have been backfilled with rock and saturated with water to remove selenium and nitrate (Seen above in Figure 4). The first step for the water treatment is for the wastewater to be pumped into the SRF area using a series of industrial water pumps and piping. The next step is for the naturally occurring bacteria and other microbes to convert dissolved forms of selenium into a solid form which remains securely stored in the SRF. This means that the selenium becomes immobile and is not able to contaminate the surrounding environment (Lai, 2016). The bacteria converts nitrate (which is harmful to organisms and the environment) to an inert form of nitrogen gas which is safely released into the environment (Holdsworth, 2020). Once the water is treated it can be safely pumped out of the SRF and discharged back into the nearby waterways or the water can be pumped back into other areas of the mine where it is reused (Teck Resources, 2019). SRF has many benefits and is more effective than other forms of water treatment. The benefits of SRF include: the rock fill pits are fast to build, it is easier to operate for the technicians due to the simplicity of the methods, it has lower implementation and operating costs and this method can be used to treat large volumes of wastewater. (Lai, 2016).

In conclusion, selenium can be safely removed from wastewater in order to prevent it from entering aquatic ecosystems, however it can be costly and time consuming to implement the technologies to do so. Teck Resources has made it a priority to implement the water treatment facilities in order to minimize their impacts on the environment and to maintain their reputation as a reputable and responsible mining company.

9.0 Conclusion

Coal is one of the most used fossil fuels that is extracted and used across the globe it has many controversial issues associated with its potential negative environmental impacts. Overall, this report focused on impacts of selenium emissions from coal mines and coal production throughout Western Canada for the provinces British Columbia, Alberta and Saskatchewan. Monitoring and minimizing selenium releases is important as it is known to bioaccumulate through organisms in the food chain and causes health issues for wildlife and humans. Research for this study was based on peer reviewed reports and regulations regarding coal emissions regarding selenium levels in aquatic environments. The primary resource was collecting the data from the NPRI in order to obtain data for all cooperating coal mines to determine the extent of selenium emissions throughout BC, Alberta and Saskatchewan. The data was not available for Saskatechwan, however the selenium emissions for BC and Alberta coal mines throughout the last decade have been inconsistent. A conclusion can be made from looking at the results that the larger the mining operation the more selenium releases occur which is due to the volumes of the wastewater. The time periods show no trends in selenium levels or that there have been any increases over the years. By looking at the Teck Resources case study it is evident that selenium emissions can be mitigated with high capacity water treatment facilities. Because coal mining continues to be a vital industry, pollution prevention and effective wastewater treatment are required to help protect aquatic and human health.

10.0 References

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11.0 Appendix

11.1 Appendix A : Project Timeline

Below, Table 1 and Table 2 display the expected timelines for the project tasks. Most execution dates were made on time throughout the semester.

Table 1: An outline of the project tasks and deadlines for the duration of the research project

Goals	Specific Tasks	Execution Dates
Project Proposal	● Cover page ● Reference Page ● Research Goal ● Resources to be used ● Regulations to be considered ● Data to be obtained ● Intro to topic ● Project timeline	February 22nd, 2021
Interview with Tim Taylor	● Review Project Proposal ● Make any necessary changes to the report	11:45am on February 19th, 2021
Execute Research Project	● Research and report writing	Throughout March, 2021
Final Report	● Finalize all information ● Edit and review report prior to submission	TBD

Table 2: A detailed overview of all deliverables for the report throughout the research process

Deliverables	Specific Tasks	Execution Dates
Research topic	● Develop Research Statement ● Think of questions	February 20th, 2021

	associated with the topic	
In-depth review of the research question	• Analyze case studies that relate to the research question and data	February 22nd, 2021
Project design, objectives, timeline, statements and anticipated results	• Create an overview of the project • Write the project proposal	February 22nd, 2021
Detailed methodology	• Discuss processes associated with the research • Determine how and where data will be obtained from (using Environment Canada) • Determine how data will be interpreted and discussed	First Week of March, 2021
Regulatory Research	• Determine the selenium standards and any regulations regarding selenium emissions	First Week of March, 2021
Research on effects of selenium on human and environmental health	• Research how the environment is affected (effects on wildlife-primarily aquatic species) • Research how selenium could interfere with human health	First Week of March, 2021
Coal production and extraction research	• Research coal mining processes in order to determine the sources of selenium and how it can be prevented	Second Week of March, 2021

Report writing	● Gather all of the data and research ● Comprise all of the research into a scientific report	Second Week of March, 2021
Report Review and editing	● Edit the report for clarity, grammar & flow ● Ensure the report answers the research questions	TBD
Research Report Submission	● Submit the report to Professor, Tim Taylor	TBD

11.2 Appendix B: The raw data obtained from Environment Canada regarding selenium releases in 2019 for Alberta, British Columbia and Saskatchewan

ReportYear	NpriId	CompanyName	FacilityName	Latitude	Longitude	City	ProvinceEn	SectorDescriptio	SectorDescriptio	Detail_NPRI_Sub	Cas	NameFr	GroupEn	DescriptionEn	Quantity	Detail_UnitType.N
2019	30798	Copper Mountai	Copper Mountai	49.34556	-120.51	Princeton	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	5.3978	kg
2019	30798	Copper Mountai	Copper Mountai	49.34556	-120.51	Princeton	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	14507.603	kg
2019	7838	Teck Coal Limite	Elkview Operatic	49.7496	-114.865	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	380.6132	kg
2019	7838	Teck Coal Limite	Elkview Operatic	49.7496	-114.865	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	6090.3727	kg
2019	7838	Teck Coal Limite	Elkview Operatic	49.7496	-114.865	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.0026	kg
2019	6895	Teck Coal Limite	Cheviot Mine (C	53.0665	-117.4048	Hinton	Alberta	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	504.0422	kg
2019	6895	Teck Coal Limite	Cheviot Mine (C	53.0665	-117.4048	Hinton	Alberta	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	4.2984	kg
2019	6895	Teck Coal Limite	Cheviot Mine (C	53.0665	-117.4048	Hinton	Alberta	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	2066.549	kg
2019	4866	AREVA Resource	McClean Lake O	58.2501	-103.9172	Saskatoon	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	37	kg
2019	4866	AREVA Resource	McClean Lake O	58.2501	-103.9172	Saskatoon	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	4704	kg
2019	29761	K+S Potash Cana	Bethune Mine	50.647947	-105.378645	Bethune	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Land Treatment	0.1445	kg
2019	29761	K+S Potash Cana	Bethune Mine	50.647947	-105.378645	Bethune	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Underground Inj	1763.0387	kg
2019	29761	K+S Potash Cana	Bethune Mine	50.647947	-105.378645	Bethune	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Off-site Disposal	Landfill	0.0204	kg
2019	29761	K+S Potash Cana	Bethune Mine	50.647947	-105.378645	Bethune	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Off-site Disposal	Land Treatment	0.8433	kg
2019	29191	Thompson Creel	Mount Milligan I	55.12046	-124.00305	Fort St. James	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	54666	kg
2019	29191	Thompson Creel	Mount Milligan I	55.12046	-124.00305	Fort St. James	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Waste Rock man	37801	kg
2019	29191	Thompson Creel	Mount Milligan I	55.12046	-124.00305	Fort St. James	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Fugitive	23.3834	kg
2019	2960	Shell Canada Prc	Shell Scotford Re	53.7959	-113.0996	Fort Saskatchew	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	0.1078	kg
2019	2960	Shell Canada Prc	Shell Scotford Re	53.7959	-113.0996	Fort Saskatchew	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.179	kg
2019	1885	POTASH CORP	POTASH CORP - I	51.8464	-105.192	Lanigan	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	687.248	kg
2019	2372	NVI MINING LTD	Nyrstar Myra Fal	49.5772	-125.602	Campbell River	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	2232.4721	kg
2019	2372	NVI MINING LTD	Nyrstar Myra Fal	49.5772	-125.602	Campbell River	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.0055	kg
2019	2372	NVI MINING LTD	Nyrstar Myra Fal	49.5772	-125.602	Campbell River	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	13.8719	kg
2019	2372	NVI MINING LTD	Nyrstar Myra Fal	49.5772	-125.602	Campbell River	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Waste Rock man	216.9506	kg
2019	2406	POTASH CORP	Potash Corp - All	51.9386	-106.084	Allan	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	1277.741	kg
2019	19397	Cameco Corpora	Cigar Lake Opera	58.0676	-104.542	Saskatoon	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	1.339	kg
2019	19397	Cameco Corpora	Cigar Lake Opera	58.0676	-104.542	Saskatoon	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Waste Rock man	305.51	kg
2019	7839	Teck Coal Limite	Line Creek Opera	49.8844	-114.8528	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	1221.94091	kg
2019	7839	Teck Coal Limite	Line Creek Opera	49.8844	-114.8528	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.000786	kg
2019	7839	Teck Coal Limite	Line Creek Opera	49.8844	-114.8528	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	4486.5584	kg
2019	2794	THOMPSON CRE	Endako Mine	54.0332	-125.1183	Endako	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	1.076685	kg
2019	1177	Agrium Potash L	Vanscoy Potash (	52.0057	-107.0936	Vanscoy	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	780	kg
2019	20078	Conuma Coal Re	Dillon / Brule Mi	55.3658	-121.7628	Chetwynd	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	494.46	kg
2019	20078	Conuma Coal Re	Dillon / Brule Mi	55.3658	-121.7628	Chetwynd	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Fugitive	0.74	kg
2019	1303	Gibraltar Mines	Gibraltar Mine (!	52.5299	-122.2851	McLeese Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	2.8708	kg
2019	1303	Gibraltar Mines	Gibraltar Mine (!	52.5299	-122.2851	McLeese Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	29888.863	kg
2019	1303	Gibraltar Mines	Gibraltar Mine (!	52.5299	-122.2851	McLeese Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0	kg
2019	1303	Gibraltar Mines	Gibraltar Mine (!	52.5299	-122.2851	McLeese Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Fugitive	0.0701	kg
2019	403	Husky Oil Operat	Lloydminster Ref	53.2885	-110.0183	Lloydminster	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Underground Inj	0.1584	kg
2019	23273	Claude Resource	Seabee	55.6884	-103.6151	Saskatoon	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	1.65337	kg
2019	23273	Claude Resource	Seabee	55.6884	-103.6151	Saskatoon	Saskatchewan	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	140.48	kg
2019	6671	Teck Coal Limite	Greenhills Opera	50.0843	-114.87	Elkford	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	699.758	kg
2019	6671	Teck Coal Limite	Greenhills Opera	50.0843	-114.87	Elkford	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.002811	kg
2019	6671	Teck Coal Limite	Greenhills Opera	50.0843	-114.87	Elkford	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	2303.1451	kg
2019	5146	Huckleberry Mir	Huckleberry Mir	53.6793	-127.1776	Houston	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	0	kg
2019	5146	Huckleberry Mir	Huckleberry Mir	53.6793	-127.1776	Houston	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	2.37	kg
2019	3903	Suncor Energy P	Edmonton Refin	53.5505	-113.3589	Edmonton	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	1.4822	kg
2019	3903	Suncor Energy P	Edmonton Refin	53.5505	-113.3589	Edmonton	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	13.5792	kg
2019	3903	Suncor Energy P	Edmonton Refin	53.5505	-113.3589	Edmonton	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Underground Inj	150.717	kg
2019	3903	Suncor Energy P	Edmonton Refin	53.5505	-113.3589	Edmonton	Alberta	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Off-site Disposal	Landfill	22.2665	kg
2019	25434	New Gold	New Afton Mine	50.66082	-120.512424	Kamloops	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	582	kg
2019	25434	New Gold	New Afton Mine	50.66082	-120.512424	Kamloops	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Waste Rock man	642	kg
2019	4048	Consumers' Co-c	Co-op Refinery C	50.4843	-104.5794	Regina	Saskatchewan	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Underground Inj	0.01	kg
2019	4048	Consumers' Co-c	Co-op Refinery C	50.4843	-104.5794	Regina	Saskatchewan	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Off-site Disposal	Landfill	41.76	kg
2019	4048	Consumers' Co-c	Co-op Refinery C	50.4843	-104.5794	Regina	Saskatchewan	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Off-site Transfer	Municipal Sewag	134.43	kg
2019	4048	Consumers' Co-c	Co-op Refinery C	50.4843	-104.5794	Regina	Saskatchewan	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	13.94	kg
2019	4048	Consumers' Co-c	Co-op Refinery C	50.4843	-104.5794	Regina	Saskatchewan	Petroleum and C	Fabrication et ra	Selenium (and it	NA - 12	Sélénium (et ses	Off-site Transfer	Refining or Re-u	0.63	kg
2019	3356	Teck Highland Va	Teck Highland Va	50.4742	-121.027	Logan Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	0.7738	kg
2019	3356	Teck Highland Va	Teck Highland Va	50.4742	-121.027	Logan Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	2247	kg
2019	3356	Teck Highland Va	Teck Highland Va	50.4742	-121.027	Logan Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Lanc	Spills	0.00048	kg
2019	3356	Teck Highland Va	Teck Highland Va	50.4742	-121.027	Logan Lake	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.000001	kg
2019	6674	Teck Coal Limite	Coal Mountain C	49.4988	-114.6584	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.000166	kg
2019	6674	Teck Coal Limite	Coal Mountain C	49.4988	-114.6584	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	179.92489	kg
2019	6674	Teck Coal Limite	Coal Mountain C	49.4988	-114.6584	Sparwood	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	152.604	kg
2019	20175	Conuma Coal Re	Willow Creek Mi	55.6044	-122.2007	Chetwynd	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Fugitive	0.438501	kg
2019	20175	Conuma Coal Re	Willow Creek Mi	55.6044	-122.2007	Chetwynd	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	244.895616	kg
2019	6669	Teck Coal Limite	Fording River Op	50.1895	-114.8793	Elkford	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Air	Stack / Point	0.7718	kg
2019	6669	Teck Coal Limite	Fording River Op	50.1895	-114.8793	Elkford	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	Releases to Wat	Direct Discharge	3859.54	kg
2019	6669	Teck Coal Limite	Fording River Op	50.1895	-114.8793	Elkford	British Columbia	Mining and Quai	Extraction miniè	Selenium (and it	NA - 12	Sélénium (et ses	On-site Disposal	Tailings Manage	9702.79	kg