THE IMPLICATIONS OF SCIENCE COMMUNICATION IN REPORTING OF THE RISKS POSED BY SELENIUM IN CANADIAN COAL MINE EFFLUENTS

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ABSTRACT

The future of the coal mining industry is receiving intense scrutiny in western Canada. Among the issues discussed by opponents of coal mining are environmental concerns about the significance of elevated selenium in surface water bodies near mine sites. This paper briefly reviews the current understanding of selenium ecotoxicology and risk to aquatic life and the communication on risk that the news media and opponents have adopted with the public when addressing the selenium issue. Canadian coal mining policy has been influenced by the public's misunderstanding of the threat of selenium in coal deposits, coal processing, and releases to the aquatic environment. We find that the claims made by opponents when reporting scientific information about selenium in western Canada have unnecessarily alarmed the public and raised fears unwarranted by the current scientific understanding of selenium. Most claims are not supported by scientific research and environmental monitoring studies. In the absence of accurate communication of selenium science and environmental risks, there is a high possibility that misinformation, intentional or otherwise, will unduly influence decisions about the future of Canadian mining policy. While several environmental concerns associated with coal mining, including selenium, need open and public debate, we advocate for the implementation of regulatory decisions informed by credible scientific evidence. In this paper, we review several key concerns raised about selenium releases from coal mining from a scientific viewpoint.

KEYWORDS: Aquatic Effects, Coal Mining, Effluents, Public Opinion, Selenium.

INTRODUCTION

Selenium is a naturally-occurring metalloid in the Earth's crust and is found in sedimentary bedrock worldwide (Sobolev et al. 2020); it has long been recognized as particularly concentrated in the soils of arid regions where the soil tends to be more alkaline. In North America, selenium has been reported in high concentrations across the Great Plains, the Prairie Provinces of Canada, westward to the Pacific, and south into Mexico (NRC 1983). It is especially concentrated in the soils of Wyoming and South Dakota,

and the western provinces of Canada. Selenium naturally finds its way into the soil and surface water ecosystems, then into plants and animals, and eventually into the people who eat those plants and animals. Selenium is a trace mineral widely considered by public health organizations as an essential dietary supplement at trace levels for human and animal health (Rayman 2000; Pecoraro et al. 2022). Selenium treatment of crops and grazing lands is encouraged in some agricultural regions in which selenium is naturally low to guard against selenium deficiency (Gupta and Gupta 2000).

Selenium occurs in coal in small amounts (Coleman et al. 1993; Yudovich and Ketris 2006). The potential for selenium to enter the environment principally occurs when coal-bearing strata, associated ore, and waste rock are exposed to air and water during mining and processing (Gearson et al. 2022). As a result, coal mines typically generate leachates from ore bodies and the waste rock that can mobilize selenium. These waste streams currently require treatment prior to release. The fate and effects of selenium in aquatic environments have been well studied following historical releases from agricultural drainage and fly ash that resulted in bird and fish kills (Ohlendorf et al., 2011; Cumbie and Van Horn, 1978). Comprehensive reviews of selenium physical and chemical properties, environmental behavior, ecotoxicity, and treatment technologies are available elsewhere (Hamilton 2004; Yudovich and Ketris 2006; Tan et al. 2016; Saha et al. 2017).

Coal mining has a long history in Canada, beginning with the excavation of seaside cliffs in Nova Scotia in the 1600s (Muise and Macintosh 1996). Alberta's first commercial coal mine opened in 1864 on the Oldman River near present-day Lethbridge and by the early 1900's, coal mining was a major industry in Alberta and British Columbia (Piper and Green 2017). The first government policies addressing environmental and land use considerations applicable to coal mining were developed by the western provinces and the federal government in the 1970s (e.g., Alberta's 1976 Coal Policy).

Canada's coal mining industry is under intense scrutiny. Policy pronouncements by the Canadian government in 2021 indicate a reluctance to approve permits for new thermal coal mines (ECCC 2021). Alberta's recommendations for the future management of coal resources emphasize the need for public consultation on coal mining along the province's Eastern Slopes and other regions in which mining significantly impacts local communities and the economy (Coal Policy Committee 2021). Tens of thousands of Western Canadians spoke up when the Alberta Government rescinded the 1976 Coal Policy in May of 2020. In February of 2021, when its long-standing policy was reinstated, the provincial government announced the formation of a committee representing a cross-section of stakeholders charged with engaging Albertans on the future of coal mining in the province (Coal Policy Committee 2021). The committee's final Coal Policy Consultation Report released in December 2021 contained eight principal

recommendations for the long-term management of Alberta's coal resources (Coal Policy Committee 2021). Throughout the Committee's public engagement process and deliberations, the public's attention has been repeatedly drawn to the environmental and cultural issues that led to the provincial government's rejection in 2021 of an Environmental Certificate supporting the Grassy Mountain Metallurgical Coal Project. Opponents cited concerns for surface water quality (Lemly 2019), the impacts on key aquatic and terrestrial species such as the westslope cutthroat trout, whitebark pine, and little brown bat, as well as the loss of lands used for traditional activities by First Nations. Similar environmental concerns related to elevated selenium levels in surface waters downstream of coal mines, have led to the rejection of the environmental assessment certificate for the Sukunka Metallurgical Coal Project in 2023, and have impeded the progress on approvals of other coal mine development projects.

During this same period, selenium and other environmental issues involving coal mining operations have been the focus of the Canadian federal government's proposed *Coal Mining Effluent Regulations* (*CMERs*) – the first of their kind in Canada (ECCC 2022). The CMERs will specify national effluent quality limits for selenium, nitrate and total suspended solids, in addition to requirements for environmental effects monitoring. Once promulgated, the regulations will apply to the 28 existing coal mines in Canada and all future mine expansions and new coal mine projects.

The Alberta and British Columbia governments' rejections of the Grassy Mountain and Sukunka metallurgical coal mining projects and the federal government's deliberations on national *CMER*s have prompted considerable news reporting about selenium, which have had a significant impact on Canadian environmental policy and regulations affecting the future of coal mining in Canada. Among the issues receiving a high level of attention was the renewed focus on the environmental significance of elevated selenium in surface water bodies near coal mine sites. Selenium was only one of many issues associated with these rejections. This issue was studied extensively in the early 2000s when concerns were first raised by both the provincial and federal governments (Chapman et al. 2009).

This paper briefly reviews the current understanding of selenium aquatic ecotoxicology and the risk communication approach that coal mine opponents, including the news media, have adopted in their reporting. The accuracy of science communications in the news reporting about selenium and its environmental risks has the potential, intentional or otherwise, to influence decisions about the future of Canadian mining policy. This brief review concludes that credible and accurate scientific reporting is needed to inform the regulatory decision-making process.

SELENIUM MANAGEMENT AT COAL MINING SITES

The main issue associated with coal mining and selenium is the oxidation of selenium in rock piles to soluble forms (primarily $Se0_3$ and SeO_4) and leaching into nearby surface waters (Ziemkiewicz et al., 2011). Most coal mining practices, including those conducted in Alberta and British Columbia, involve the collection and treatment of leachate and wastewater containing elevated selenium (Golder 2020). Several technologies for controlling metal leaching and acid rock drainage apply to selenium management at coal mines (Naidau et al. 2019; Skousen et al. 2019). Collection systems to capture surface water runoff and leachate from historical waste rock piles are common, and new approaches involve landform design to manage mining rock piles and improve the collection and treatment of water, and, in some cases, can entirely avoid or minimize runoff (McKenna 2009; McKenna and Gilron 2021).

Potential adverse effects can be avoided if adequate steps are taken to prevent or reduce hazards by controlling or treating the source. The approach that Lemly (2007) has described for assessing selenium hazards and developing environmental management plans for coal mining in the US is comparable to the approach followed more recently in Canada (Lemly 2014, 2019). This involves conducting a detailed environmental baseline assessment at proposed coal mining sites, preparing a comprehensive water management plan, and then matching the mine's operational parameters with environmental protection measures.

SELENIUM IN THE ENVIRONMENT

Much is known about selenium in soils, surface waters, and plants in aquatic and terrestrial ecosystems surrounding coal mines in Canada and the US (Chapman et al. 2010; Etteieb et al. 2020). A large body of knowledge and considerable progress has been made in mine management and selenium control and treatment technologies (Tan et al. 2016).

Two incidents of selenium contamination have received the most attention in news reporting and opposition analysis of coal mining. Selenium in freshwater fish at Belews Lake in North Carolina represents one of the most extensive and prolonged incidents of contamination associated with the release of coal-fired power plant wastewater (Lemly 2002; Browne and Lutz 2010). The second incident, at Kesterson Reservoir and Kesterson National Wildlife Refuge in California, involved high levels of selenium that leached from irrigated soils and accumulated in agricultural drainage water and evaporation ponds as the primary cause of the high rates of mortality and deformities among aquatic birds (Ohlendorf et al. 1989; Ohlendorf et al. 2020).

In both cases, selenium concentrations exceeded 100 µg/L in surface water, resulting in high concentrations in aquatic plants and prey consumed by fish and wildlife, and elevated concentrations in fish and aquatic bird eggs. The primary route of exposure determined from field studies was dietary consumption of prey in the food chain, rather than direct exposure to the surface water (Chapman et al. 2010). This is consistent with research reported by Presser and Luoma (2010) and Adams et al. (2000), concluding that diet is the main route of exposure to selenium in aquatic ecosystems.

NEWS REPORTING ON SELENIUM

During the past ten years, the coal mining industry has been the focus of nearly 1,000 news stories published in Canada. Of those news stories, nearly one-third (i.e., 225) have focused on the presence of selenium in the Canadian environment and its relationship to coal mining. The remaining two-thirds of news reports have focused on the impacts of the industry on regional and national economies, environmental quality, social and cultural issues, climate change, and energy consumption. Examples of news stories addressing selenium in the coal mining industry in western Canada are presented in Table 1.

Table 1. Examples of recent media articles citing issues regarding selenium that are not adequately supported by scientific information.

Article Title	Reference	Statements/Assertions	Issue
How pollution from Canadian coal mines threatens the fish at the heart of communities from B.C. to Idaho	Cruickshank (2022)	"For fish, the effect of selenium on reproduction is one of its most insidious threats. When female fish transfer the contaminant through their eggs, their larvae may be born with deformities - curved spines, misshapen skulls, abnormal gills - or fail to hatch at all. These impacts have already been observed in the Fording River."	**"These impacts have already been observed in the Fording River."** While these effects have been shown to occur in controlled multi-generational laboratory studies, evidence of these effects in fish populations in the Fording River has not been reported.
Alberta government knew bighorn sheep contaminated with coal-mine selenium: scientist	Weber (2021)	" 'They're getting it from the coal mines,' Kneteman said. "We found no evidence of elevated selenium in Alberta in any of the other populations that we sampled."	**" 'They're getting it from the coal mines……'"** There is no specific evidence that Alberta bighorn sheep are exposed to selenium downstream of coal mines. **"We found no evidence of elevated selenium in Alberta in any of the other populations that we sampled."** Kneteman (2016) only sampled one other bighorn sheep herd in Nevada.
Recent data spell trouble for Koocanusa fish	McLaughlin (2022)	"Data over the past nearly four decades show a steady uptick of selenium concentrations, initially breaching Canada's current 2 µg/L guideline during the early 1990s, in the Elk River near its confluence with Koocanusa waters, according to the DEQ[1]."	**"…..past nearly four decades show a steady uptick of selenium concentrations….."** **"……breaching Canada's current 2 µg/L guideline during the early 1990s……"** The data do not show an upward trend (only over two decades), but rather, steady concentrations that approximate 1 µg/L (see Figure 1 below), which is 50% of the British Columbia guideline of 2 µg/L, and 66% of the USEPA lentic criterion of 1.5 µg/L.
Selenium from open-pit coal mining may pose downstream risk to ag	Whelan (2021)	"In studying the impacts of open-pit coal mining in B.C.'s Elk Valley …… devastated fish populations before flowing south into Montana and Idaho with levels of selenium significantly higher than state regulations allow."	**"……devastated fish populations…."** Despite elevated aqueous concentrations of selenium, there is no evidence of devastated fish population or even population-level impacts in the Elk Valley. "**levels of selenium significantly higher than state regulations allow**." Selenium are below all state and federal criteria in the United States.

[1]Montana Department of Environmental Quality.

Article Title	Reference	Statements/Assertions	Issue
The Case Against Coal Mining in Alberta	Atwood (2021)	"So even if there is a fairly low concentration of selenium up the water if it's above that threshold, it can seriously impede the development of different aquatic species and then that obviously can also make it way up the food chain," they said.	**"…..seriously impede the development of different aquatic species and then that obviously can also make it way up the food chain."** There is not always a correlation between aqueous and tissue concentrations.

Relative to the economic and climate-related issues confronting both Canada and the coal mining industry, the current state of the science regarding environmental impacts and technologies for controlling and treating selenium at coal mines would suggest that the focus of nearly one-third of news reporting during the past ten years has been excessive and misplaced. While stakeholder concerns are certainly crucial in any deliberations considering environmental protection, such concerns should always be informed by credible scientific evidence. News stories reporting on selenium and coal mining have tended to focus on five environmental concerns. These are discussed below.

Concern # 1 - "Historical data describing elevated selenium conditions at a coal mine are relevant to other coal mining sites."

This argument is most common in arguments opposing new coal mining in western Canada. At five active coal mines in the province, coal mine effluents have been discharged to the Elk Valley watershed for over 120 years. Historically, high volumes of exposed rock piles, some used in cross-valley fills, have weathered over several decades, and have contributed substantially to selenium loadings into the Elk River watershed. However, Teck Resources Ltd.'s (Teck) implementation of the Elk Valley Water Quality Plan (Teck, 2014) during the past decade has reduced selenium concentrations in surface water and biota. New leachate and surface water bodies downstream of the mines. This situation has led to advances in the understanding of selenium behavior and environmental management, and the implementation of the Elk Valley Water Quality Plan (https://www.teck.com/media/2015-Water-elk_valley_water_quality_plan_T3.2.3.2.pdf), and Teck's recent focus on mitigation measures and treatment technologies, including Saturated Rock Fill (SRF) technology (Mackie et al. 2022), have contributed to substantial declines in selenium concentrations.

Thus, historical mining practices are no longer indicative of current and future mining practices and environmental consequences. Modifications to operations at active coal mines and mine management plans at proposed/new coal mines throughout western Canada reflect the current state-of-practice involving the implementation of mine design features, mitigation opportunities, treatment methods,

monitoring and adaptive management measures and strategies to minimize and control selenium in mine wastewaters (McKenna and Gilron 2021).

Concern # 2 – "Selenium impacts on aquatic life can be extrapolated to humans, livestock, and terrestrial wildlife."

The use of scientific studies relevant to determining the potential for adverse effects of selenium on aquatic organisms should not be used in news reporting to describe the potential impacts to humans, wildlife (Kneteman, 2016) and livestock (Whelan, 2021). There are fundamental differences in the biological mechanisms of action associated with selenium exposure to fish, birds and mammals (Chapman et al., 2010; Gilron et al., 2021). Studies used to derive health benchmarks for selenium in drinking water applicable to livestock and human consumption support 50 ppb (parts-per-billion) as the relevant drinking water guideline, nearly 25 times higher than the surface water guideline applicable to aquatic life in Canada (*i.e.,* 1-2 ppb) (CCME, 2009; Health Canada 2014).

Concerning wildlife, Kneteman's (2016) work has prompted claims in Canadian news reporting that selenium has adverse effects/impacts to Bighorn sheep. These concerns rely on data indicating that selenium concentrations in blood serum near Alberta coal mines are higher than in Bighorn sheep in another part of Alberta and in the US state of Nevada. An increase in blood serum is an indicator of exposure, but not necessarily effects (Ohlendorf et al. 2020).

Concern # 3 – "Selenium is adversely impacting fish populations in western Canada."

News reports describing that elevated selenium concentrations in surface water near coal mines adversely affects fish populations throughout Canada have often been attributed to publications by Lemly (2014, 2019). Statements cited in news reports attributed to Lemly's work, are based on the author's opinions about selenium impacts originating from different industries, not coal mines. Further, the statements refer to several decades-old environmental data and observations from the U.S. and are not based on data relevant to surface waters adjacent to developing coal mines in Canada.

Several studies have shown that fish species differ in their sensitivity to selenium (DeForest et al., 2012; USEPA, 2016). A recent critical review of selenium in fish indicates there is significant variability in fish tissue concentrations and consequences to fish populations (Gilron et al. 2021). Bioaccumulation and effects of selenium have been demonstrated to vary significantly in different geology and geographic areas and different fish species (Presser and Luoma 2010; Chapman et al. 2010). It is most appropriate to match exposure data with the toxicity data for resident species.

Concern # 4 – "Transboundary selenium pollution is evident in Lake Koocanusa, situated downstream of the Elk Valley watershed."

Numerous news reports on both sides of the Canada-US border suggest that selenium pollution has migrated from BC's Elk Valley watershed to Lake Koocanusa. For many years, the state of Montana and the province of British Columbia have monitored the lake's aquatic environment. The available monitoring data do not support news media reports. Lake Koocanusa selenium concentrations have been stable for the past decade at a mean concentration of approximately 1 µg/L, which is below the British Columbia guideline value of 2 µg/L (Beatty & Russo, 2014), and below the USEPA (2016) criterion for slow-flowing (lentic) waters (1.5 µg/L) (see Figure 1). Fish egg and ovary tissue data collected from Lake Koocanusa indicates that the selenium concentrations are below the USEPA (2016) egg/ovary threshold of 15.1 mg/kg, which is established to protect the most sensitive aquatic species.

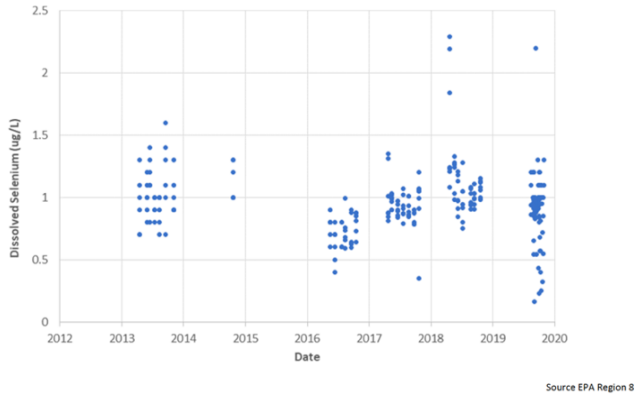

Figure 1. Dissolved selenium concentrations in Lake Koocanusa, 2013-2020. Source: Montana Department of Environmental Quality (via e-mail; August 27, 2021).

Concern # 5 – "Selenium treatment technologies are unproven."

Assertions have been made that current selenium treatment methods are unproven technologies and have not been demonstrated to be workable in operating coal mines and for post-closure mine reclamation. However, technology reviews conducted by Golder (2020) and Gilron and McKenna (2021) do not concur with this viewpoint; these authors describe the efficacy and readiness of several available treatment technologies used at active coal mining sites and proposed for use in future mining operations. Several technologies are already currently in full-scale operation (Golder, 2020).

SUMMARY

Claims in news media reports and by stakeholders during recent environmental policy reviews and assessments related to coal mining in western Canada have unnecessarily caused public alarm about the potential impacts of selenium in the aquatic environment. The science is well understood. Moreover, several environmental management strategies developed collaboratively by governmental agencies and the mining industry have the capability of limiting the release of mine leachate and liquid wastes containing selenium to the aquatic environment. The results of extensive monitoring of stream, river, and lake surface waters, fish populations and tissues, and ecosystems indicate these strategies can, and do, protect Canadian (and US) aquatic environments. Because Canada's environmental policy with respect to coal mining has significant ramifications to the national economy, it is paramount that decisions regarding the future of coal mining be informed by an accurate understanding and communication of the science and technology associated with selenium management at coal mining sites and the need to protect the environment. We strongly advocate for the application of scientific evidence to inform regulatory decisions.

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