SELENIUM IN WEST VIRGINIA WATERSHEDS:

A COMPREHENSIVE ANALYSIS OF THE

REVISED SELENIUM STANDARD

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Land Resources and Environmental Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

May 2022

ACKNOWLEDGEMENTS

First and foremost, thank you to all the faculty and staff at MSU for providing guidance throughout my journey in the LRES Master's program! More specifically, thank you to Dr. James Pritchard for igniting my interest in natural resource policy and for advising me throughout this project. Equally vital to this project was the availability of data and internal research made available by my employer for which I am especially grateful. Finally, my deepest thanks to the folks who took time out of their busy schedules to answer all my questions: Erin Savage, James Kotcon, Nick Baker, Christie Allen, Peter Morgan, and Autumn Crowe.

Perhaps most importantly, thank you to the family and friends in my life who have provided encouragement throughout this whole endeavor, without which I wouldn't have survived! I am forever indebted to my partner, John, for his constant support and for keeping me fed, caffeinated, and loved these past two years. Thank you to my dear friend and coworker Ashley Murphy as I wouldn't have been able to put this paper together without her willingness to be a sounding board for everything from constructing interview questions to determining how I should reward myself for finishing assignments. I can't imagine life or this grad school experience without any of y'all!

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ABSTRACT

Selenium is increasingly becoming a concern in watersheds affected by coal mining operations. Aquatic species like fish are especially vulnerable to selenium bioaccumulation as it is linked to physical deformities and disturbances to reproductive systems. Without proper monitoring and regulation, entire watersheds can be decimated by selenium pollution and human communities harmed by the loss of environmental services naturally provided by local watersheds. While previously requiring only water column concentrations of selenium, the West Virginia Department of Environmental Protection (WVDEP) recently enacted a policy allowing the monitoring of fish tissue or egg/ovary concentrations of selenium for coal mining permits with sites struggling to maintain compliance of water concentrations of selenium. According to the United States Environmental Protection Agency's guidelines, this alternative method of monitoring selenium in fish is touted as the most scientifically justified approach to tracking selenium pollution in watersheds. Due to general availability and cost effectiveness, fish tissue monitoring has been the most widely adopted method for monitoring selenium in West Virginia. My analysis concentrates on the development, implementation, and reception of the new fish tissue policy through analyses of selenium research, WVDEP regulations, industry and environmental organization interviews, and collected fish tissue data belonging to one large coal company operating in West Virginia to serve as an example of the ranges of fish selenium concentrations and risks to fish communities. This interdisciplinary approach to the West Virginia fish tissue policy provides a comprehensive examination of the consequences of employing fish tissue as the primary standard for monitoring selenium in many watersheds. Although initially positively received by coal companies, the fish tissue standard for monitoring selenium has since garnered criticism from both coal operators and environmental groups. Ultimately, WVDEP's implementation of the fish tissue standard has resulted in failures to both significantly protect water quality and assist coal operators with permit closures. The inability of coal operators to limit their own pollution in accordance with water quality standards is a failure on its own, but continuation of the fish tissue policy in its current existence would be a misguided move on the part of WVDEP.

INTRODUCTION

In the realm of water quality protection, policy analyses are pursued to inform policies intended to protect vulnerable human and aquatic communities from unnecessary pollution and irreparable harm. My policy analysis throughout this paper is driven by the requirement to protect communities vulnerable to water quality degradation by coal mining operations. Rural West Virginia communities have been subjected to many of the worst byproducts of coal mining, from the leveling of once picturesque mountaintops to the absolute ruin of water supplies and watersheds. Selenium pollution is yet another potentially devastating effect to add to the long list of coal mining consequences with which West Virginia communities must contend. The purpose of my analysis is to get beyond the "issue rhetoric," the surface-level description of selenium problems within watersheds, and to untangle how coal companies, the West Virginia Department of Environmental Protection, and community organizations interpret the new fish tissue standard and how they might alter the policy going forward if environmental protection is to be achieved (Bardach 2012).

Selenium is a naturally occurring element present in coal and sedimentary rocks and soils. Natural processes of weathering can release selenium into aquatic environments over time, whereas more immediate anthropogenic inputs stem from agricultural irrigation, surface mining, and coal-fired power plants (USEPA 2016). The main source of selenium from coal mining comes from waste rock, the disturbed strata associated with and surrounding coal seams (Neuzil et al. 2005) that is exposed by blasting and excavation and used as valley fill material, allowing otherwise inaccessible selenium to leach into the environment when it is exposed to water. Surface water runoff along such overburden deposits selenium into local watersheds (Stefaniak

et al. 2018) where it may persist for decades (English et al. 2022). Figure 1 illustrates the pathway of selenium through a valley fill. Underground mines, both active and abandoned, can also contribute selenium to groundwater and streams. Additionally, selenium occurs within coal itself but does not seem to be correlated to other parameters of concern like metals, making potential selenium input amounts especially difficult to predict (Neuzil et al. 2005).

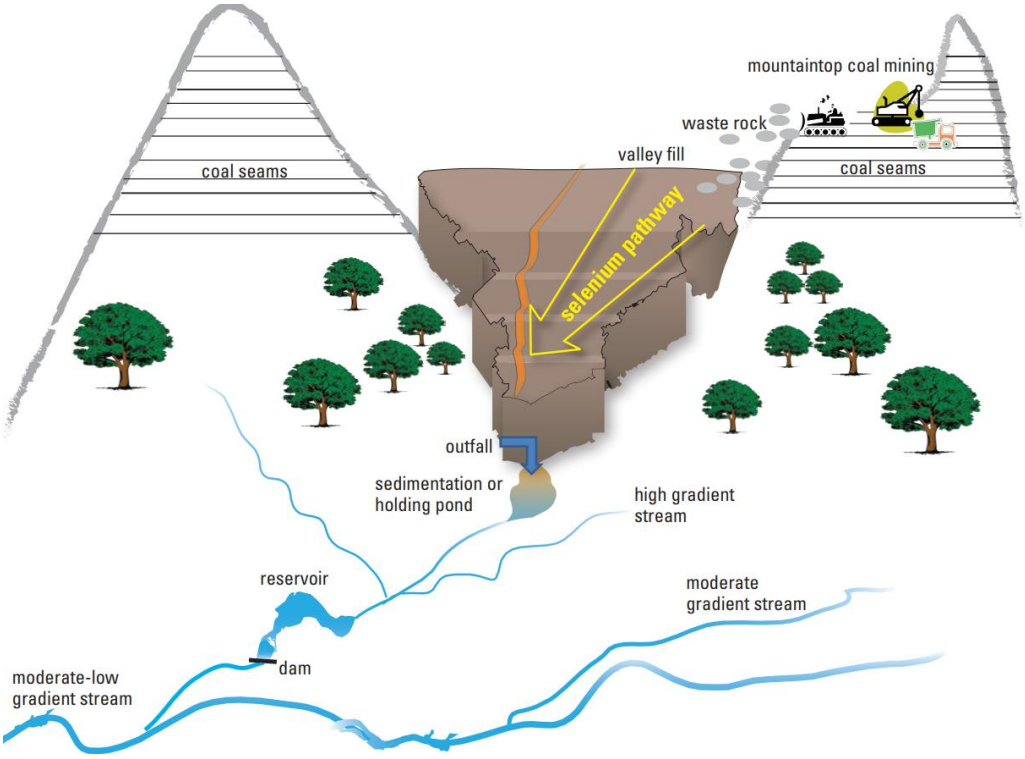

Figure 1: Schematic diagram of selenium pathways in a mined area with a valley fill. *Presser, T. S. 2013. Selenium in ecosystems within the mountaintop coal mining and valley-fill region of southern West Virginia – assessment and ecosystem-scale modeling. U.S. Geological Survey Professional Paper 1803, 86 p. http://dx.doi.org/10.3133/pp1803.*

Selenium is an essential element for animals and required in small amounts, but it is toxic above certain thresholds. In fish, this toxicity presents as reproductive impairments, deformities, and negative effects on mortality (USEPA 2016). For fish, selenium is of particular concern because of its high potential to bioaccumulate through food webs (Presser 2013). Ultrasonic

extraction is one available method for assessing bioaccessible amounts of selenium in rock that could inform coal operators in their decisions to create valley fills, but the method's use is not typical or required in coal mining operations (Pumure et al. 2010). Selenate is the most bioavailable form of selenium in water, but selenite tends to occur most commonly in coal mining effluent due to appropriate temperature, pH, and redox conditions (Etteieb et al. 2020). Both selenite and selenate are soluble in water, and both are considered teratogenic for fish species (WHO 2011) in addition to negatively affecting reproductive systems in fish (Etteieb et al. 2020). These inorganic forms of selenium have also been reported to be up to 40 times more toxic than the organic forms (Stefaniak et al. 2018). Valley fills serve as reservoirs of reduced selenium that mobilizes to selenate over time and enters watersheds with high potential to bioaccumulate within food webs (Presser 2013).

Selenium concentrations in groundwater and surface water naturally range from 0.06 µg/l to 400 µg/l (WHO 2011), but in mining wastewater, selenium concentrations can range from 3 to 12,000 µg/l (Stefaniak et al. 2018). Figure 2 presents concentrations of selenium in various water sources. While too complex to accurately predict, selenium concentrations in water are dependent on time and climate with the tendency to increase by more than twice in wet seasons (Etteieb et al. 2020, English et al. 2022). In the Appalachian basin which spans West Virginia, the average selenium concentration in coal is about 3.5 ppm (Neuzil et al. 2005). A review of Environmental Protection Agency (EPA) data found that "41 of the 50 industrial point sources with effluent limit exceedances that discharged the most selenium in 2021 were in West Virginia" (Tony 2022), two out of every three of those point sources are mines, and seven of the

ten highest point sources of selenium in the United States are located in West Virginia (Tony 2021).

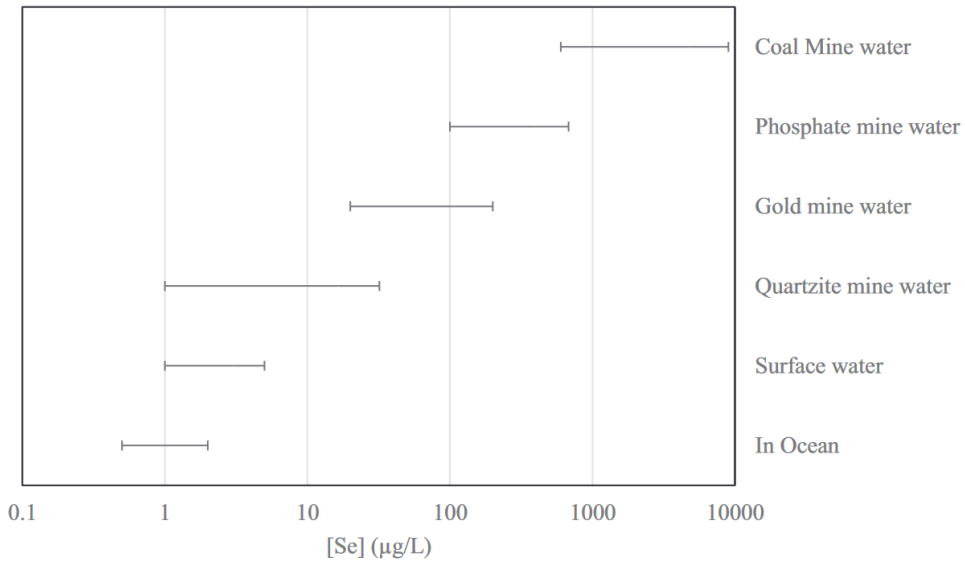

Figure 2: Range of selenium concentrations in various aquatic media. *Etteieb, Selma, Sara Magdouli, Mehdi Zolfaghari, SatinderKaur Brar. 2020. Monitoring and analysis of selenium as an emerging contaminant in mining industry: A critical review. Science of the Total Environment, 134339.*

In 2016, the EPA finalized their recommended national chronic aquatic life criterion for selenium that was developed according to section 304(a) of the Clean Water Act. Historically, the monitoring of selenium in water column concentrations, or water samples from the outfall or stream of concern, has been the primary method of water quality regulation. Because it is now better understood that selenium toxicity to aquatic life can occur as a result of bioaccumulation throughout food chains, the final EPA criterion expresses the need for fish (egg/ovary, whole-body, or muscle) concentrations of selenium to take precedence over water column concentrations where applicable (USEPA 2016).

SELENIUM MONITORING IN WEST VIRGINIA

The passage of West Virginia Legislature House Bill 2579 (HB2579) on July 12, 2013, required the West Virginia Department of Environmental Protection (WVDEP) to develop a new selenium monitoring criterion (Lowman & Seagle 2014). Water quality standards in West Virginia follow EPA guidelines, but when many coal mining wastewater outlets were unable to maintain compliance for selenium, a new policy was formulated to determine whether or not there was "reasonable potential" for these discharges to degrade the aquatic environment (Allen 2022). While not totally displacing the existing water quality criteria for selenium, the bill requires that the new selenium criterion "be implemented as a threshold standard…to trigger selenium speciation, fish population survey, fish monitoring plan and data reporting requirements of the Bill." Due to the risk of selenium toxicity to aquatic species and the complex processes driving bioaccumulation, WVDEP determined that the monitoring of selenium-sensitive fish populations would serve as "the best indicator of problematic levels of selenium exposure and facilitate the establishment of appropriate tissue-based and/or water quality standards" (Lowman & Seagle 2014). Exposure risks to aquatic life are not entirely indicated by water column concentrations of selenium due to its aforementioned variety of redox states and bioavailability, differences in diet among fish species, and movement of fish throughout selenium exposure gradients in the water since natural stream behavior can affect spatial variations in selenium (Hitt & Smith 2014). Additionally, dietary selenium "makes up 95% of tissue selenium in invertebrates and fish," making water column concentrations alone an imprecise predictor of selenium harm in aquatic systems (Presser 2013).

Per HB2579, WVDEP developed and implemented a tiered approach to selenium monitoring that is triggered by water column selenium exceedances of a 5.0 µg/L threshold, at which point coal companies should apply for assigned fish whole-body/muscle tissue or fish egg/ovary tissue monitoring requirements (Lowman & Seagle 2014). Fish egg/ovary concentrations of selenium take precedence over fish tissue or water column concentrations because egg/ovary concentrations are the best-known indicators of negative effects on fish reproduction, but egg and ovary samples are often difficult to obtain due to "limited times of year for collection, asynchronous spawning, and insufficient fish size." Because these limitations are typical, selenium monitoring via fish whole-body or muscle tissue are most widely used (WVDEP 2018). However, fish tissue is also often limited, considering some watersheds are unable to sustain fish populations conducive to responsible sampling (Allen 2022).

A sampling plan must be submitted to WVDEP for review and approval before monitoring and reporting can commence, and the plan must be based on at least 12 months of twice monthly selenium water column data at existing sites, or a minimum of 6 months twice monthly data at new sites. New water column sites are established at the site of fish tissue sampling unless an "established instream station is proximate and receives no additional inputs or dilution" (WVDEP 2018). Figure 3 provides an example of an acceptable monitoring location plan for fish. Baseline fish tissue surveys are conducted at new compliance points before permit approval in an attempt to establish pre-existing fish community composition and compliance with the standard (Seagle 2018). Site locations for fish sampling are to be "situated at the suitable locations downstream of continuous discharge that have exceeded or are currently exceeding the trigger value of 5 µg/L" with wadable, perennial conditions that support fish

populations (Lowman & Seagle 2014). The minimum sampling survey reach is 100 meters as close as practicable to the known selenium input source, and fish are to be collected by EPA-approved electroshocking methods in wadable streams or using gill nets, hook-and-line, or electroshocking methods in non-wadable streams. All captured fish are to be identified, counted, and stored appropriately for laboratory tissue analysis (WVDEP 2018). Coal operators may request WVDEP review of fish tissue monitoring data after at least two years (five samples), and approval to reduce monitoring frequency is possible if the data support it. If tissue limits are violated more than twice in a rolling 24-month period, protective water column concentration limits may be calculated and applied using the site's average water column and highest fish tissue concentrations (Seagle 2018). However, approval for fish tissue compliance reporting prohibits a return to the sole application of the original water column standard (Allen 2022).

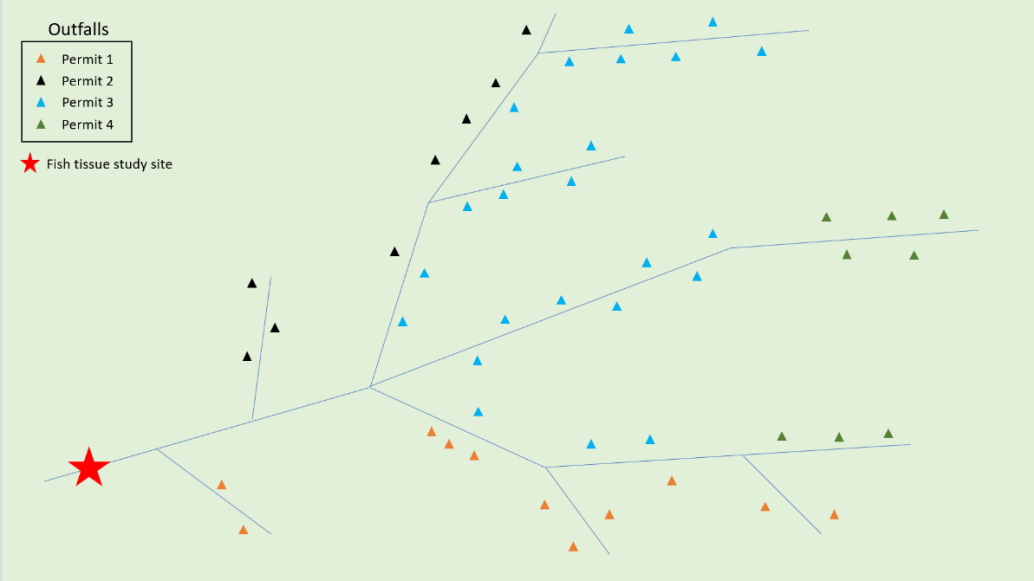

Figure 3: Example monitoring plan for adding fish tissue to permits as the monitoring approach for selenium. *Seagle, Kevin. 2018. WV Selenium Chronic Aquatic Life Standard Implementation – Revision 4: PowerPoint Presentation. West Virginia Department of Environmental Protection.*

Composite samples are required regardless of species and must each consist of 3-5 individuals of the same species that are all similarly sized adults, collected no more than one week apart within the same reach. The individual samples of each species are to be combined, thus forming a composite sample, before analysis by EPA-approved selenium animal tissue analysis methods (WVDEP 2018). Composite analysis of fish tissue has been widely adopted because it minimizes cost and generally improves estimates of mean conditions (Hitt & Smith 2014). When collecting composite samples of fish for fish tissue selenium monitoring, target species must be adhered to when possible and generally include members of the minnow and sunfish groups. In the southern coalfields of West Virginia, creek chubs (*Semotilus atromaculatus*), central stonerollers (*Compostoma anomalum*), and western blacknose dace (*Rhinichthys obtusus*) are most common and plentiful, and much selenium tissue data already exists for these species (WVDEP 2018). Creek chub and central stonerollers are also known to have high tolerance thresholds for stress in the aquatic environment, making them some of the species most likely to be present in coal mining-affected watersheds and species that serve as a "metric of disturbance in scoring the biological integrity of an ecosystem" (Presser 2013). Based on availability, some combination of these minnow species is recommended along with samples of sunfish species if possible to achieve representative composite samples (WVDEP 2018). Large predator species like sunfish have the most potential to bioaccumulate selenium, whereas generalist, insectivore, and herbivore species bioaccumulate less selenium (Presser 2013).

The expansive ranges of many fish species make it difficult to establish exposure history to selenium within the aquatic environment. Otoliths, calcified structures within the inner ears of some fish species, have the capacity to collect and incorporate trace elements from the water

column throughout their lives. Friedrich et al. (2011) analyzed otoliths in bull trout, cutthroat trout, and mountain whitefish to determine life exposure to selenium in an area with active coal mining activity. The researchers noted that otolith concentrations of selenium were low in earlier life stages but increased in later life stages, indicating that these species moved amongst areas of higher selenium throughout their lives. Fish tissue concentrations of selenium were found to be useful indicators of recent exposure but were subsequently determined to be insufficient for consideration of lifetime exposure, unlike otoliths. Hitt & Smith (2014) found that higher thresholds for selenium concentrations, like the 8 µg/L standard most regularly applied throughout West Virginia, in whole-body fish tissue are most accurately represented by large sample sizes. Their research indicated that populations are more heterogenous at higher mean selenium levels, or that higher water column concentrations of selenium equate to more variation in fish tissue concentrations of selenium. Consequently, their research recommends that at least eight individuals need to be collected to accurately reflect selenium concentrations in whole-body tissue for the EPA-defined 8.1 µg/L standard, which can reasonably be applied to West Virginia's similar 8 µg/L standard. Because selenium toxicity can occur within such a small range of excessive uptake, the need for an appropriate sample size is apparent (Hitt & Smith 2014).

WATER QUALITY VIOLATIONS IN WEST VIRGINIA

The Clean Water Act (CWA) defines penalties for violations of water quality standards, including violations of selenium. Sections 301, 302, 306, 307, 308, 318, and 405 of the CWA pertain to violations of permit conditions, stating that anyone in violation is "subject to a civil penalty not to exceed $10,000 per day of such violation." Willful or negligent violations can result in a fine of "not less than $2,500 nor more than $25,000 per day of violation, or by imprisonment for not more than 1 year, or both." These are the penalties that are applied to the reporting of West Virginia NPDES permits in the form of Discharge Monitoring Reports that reflect all required water quality data for coal-related permits (WVDEP 2022).

The West Virginia Code further describes penalties for coal mining operations in the state's Water Pollution Control Act where state regulations repeat the provision that civil penalties resulting from permit violations are not to exceed $25,000 per day. Determination of violation penalties depends on a variety of factors: the magnitude of violations, violation history, possible economic benefit or impact on the coal company that may result from the violation, consideration of any "good faith" efforts to comply with permit requirements, and the relationship of the coal company with the WVDEP secretary (West Virginia Legislature 2022). Nick Baker, Vice President of Aquatic Resources, Inc., with decades of experience in the coal industry, noted that penalty discretion is often determined by "how mad they are at the company" (2022).

The West Virginia legislature has passed bills giving coal operators more time to comply with selenium water limits, a move WVDEP regulators disagreed with considering the bioaccumulative risks of selenium. A federal judge and the West Virginia state Environmental

Quality Board even noted that the coal industry had been stalling efforts to treat selenium violations (Ward Jr. 2009). Coal companies can request a hearing to protest the imposition of a fine, but inaction on their part essentially finalizes the violation order as long as the order successfully proceeds through a public comment period and the WVDEP secretary determines it to be applicable and deserved (West Virginia Legislature 2022).

Conspicuous examples of WVDEP discretion regarding water quality violation penalties are readily available. In 2020, WVDEP fined Lexington Coal Company (LCC) $125,000 for selenium violations recorded from 2018 through 2020. Although the entire amount could have been immediately due to WVDEP, a payment plan was set up between LCC and WVDEP that simply requires the total to be paid by May 2022. Bluestone Coal Corporation, a large mining company in West Virginia owned by Governor Jim Justice, reported "paying no stipulated penalties for 31 violations of selenium limits," a failure that resulted in the continuation of a lawsuit against the company (Tony 2021). Although Gov. Justice does not directly manage his coal companies throughout Appalachia, he does have a significant conflict of interest because he oversees WVDEP appointments. The maximum potential federal penalty of $170 million for a variety of discharge violations, including selenium, at one Bluestone mine resulted in a settlement of $125,000 even though DEP had initially proposed a $2.1 million fine. When questioned as to why the amount was reduced, DEP noted that $125,000 was the maximum allowed under state law "but did not explain why it had earlier proposed a larger amount." Even though Gov. Justice appointed the DEP administrator, a lawyer representing Bluestone Coal argued that "any suggestion that the company is getting preferential treatment is completely baseless" (Ward Jr. 2020).

Aside from the notable exceptions above, most coal operators always pay the fines issued against them for water quality violations. Failure to pay results in permit blockades, and if that does not result in payment, WVDEP can collaborate with local courts to place the coal mining operations in a receivership. An appointed company or person will then manage the mining operations in a way that achieves compliance, at which point they can turn a profit or opt to sell off the properties. Considering the drastic consequences, complete failure to pay fines for violations is rare (Baker 2022).

Successful treatment of selenium in industrial wastewater is difficult and often quite expensive due to its complex chemical nature. Effective treatment requires a comprehensive understanding of a site's particular biogeochemistry and the specific state of present selenium (Etteieb et al. 2020). According to one analysis, technologies for selenium treatment "have not reached full maturity" and thus should be considered only developmental. If coal operators fail to properly treat selenium pollution in watersheds covered by their permits, clean-up costs will be passed on to WVDEP. However, a West Virginia state audit report completed in June 2021 found that "DEP mine cleanup funds are nearing insolvency" and that forfeiture of a single mining company could result in a collapse of available reclamation funds. The inability of WVDEP to accrue adequate reclamation funds in case mining companies file for bankruptcy or otherwise cannot cover reclamation costs means that taxpayers may have to make up the difference (Tony 2021). Hundreds of millions of dollars may be needed to reclaim mining properties according to federal regulations throughout West Virginia (Tony 2022).

Selenium treatment for water is becoming more effective, but because selenium is bioaccumulative and increases along trophic levels, it is more difficult to treat in fish and other affected organisms. Although significantly less toxic than the inorganic forms of selenium, the organic forms of selenium are more difficult to treat and remove due to their tendency to rapidly bioaccumulate (Stefaniak et al. 2018). Reducing selenate to selenite and then to elemental selenium "allows for its removal through conventional liquid and solid separation," but a combination of techniques may be necessary to develop a cost-effective treatment strategy (Etteieb et al. 2020).

The installment of biochemical reactors (BCRs) is one method of treating selenium-contaminated water and is a feasible option generally approved by WVDEP when water quality standards cannot be met. Figure 4 provides an example of a BCR and how it generally functions. BCR treatment of water involves the movement of contaminated water through treatment ponds that are filled with materials such as wood chips, mushroom compost, hay, manure, or limestone to induce biological and chemical reactions that transform pollutants into safer forms. BCRs typically come in the form of ponds or trenches that are situated downhill of mine effluent so that water flows through the treatment materials from the top down and are preferred at mine sites because of their gravity-driven system and low maintenance requirements. However, fill material does need to be regularly refreshed as BCRs are only effective if they function for the entirety of the wastewater treatment (USEPA 2021). However, pumping to BCRs is extremely expensive. Setting up an adequate BCR typically costs about $1 million, and pumping to the BCR can cost approximately $5,000+ per day depending on the amount of discharge needing to be pumped (Allen 2022).

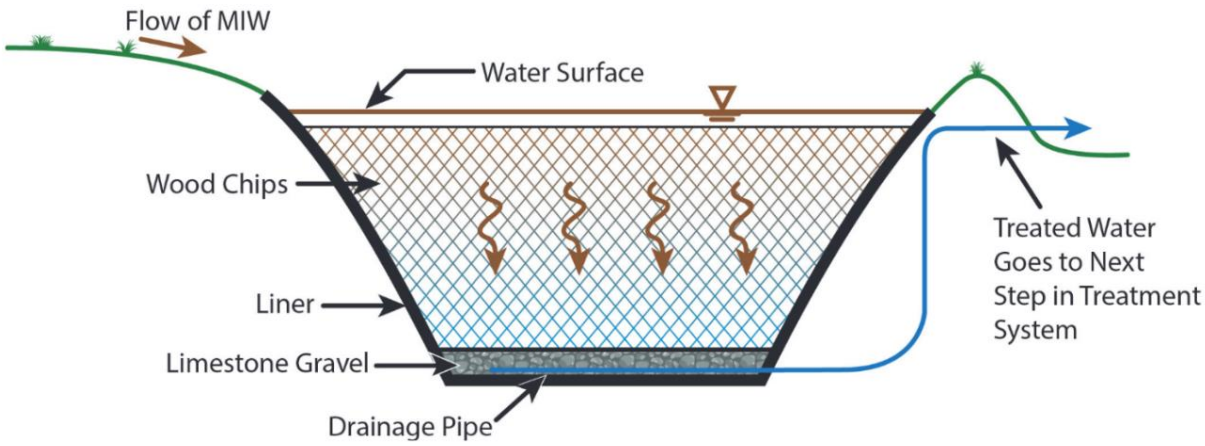

Figure 4: Diagram of a BCR (Biochemical Reactor), the coal industry's preferred method for selenium treatment. MIW equates to mine-influenced water. *United States Environmental Protection Agency (USEPA). 2021. "Community Guide to Biochemical Reactors." Office of Land and Emergency Management. https://semspub.epa.gov/work/HQ/401581.pdf. Accessed 2.15.2022*.

While BCRs tend to be the favored method of treatment for coal operators whose outlets fail to maintain selenium compliance, operators in West Virginia have recently theorized that BCRs may be causing more problems than they are solving in the biological community (Baker 2022). WVDEP is now aware that BCRs may be causing a rise in fish tissue selenium but not in the water column due to the way selenium is broken down into different forms (Allen 2022). Additionally, while BCR treatment may be successful over the long-term if properly maintained, effective treatment is often "easier said than done." Fulfillment of fish tissue selenium compliance negates the need for BCR implementation, however, as compliant fish tissue samples indicate that water column concentrations are not negatively impacting aquatic communities (Baker 2022).

If BCRs are causing an increase of selenium concentrations in fish tissue rather than successfully treating the selenium-contaminated water, something must be going wrong with the

whole process. Sierra Club senior attorney Peter Morgan noted, “It’s interesting because BCR is basically what the industry provided as an alternative to reverse osmosis filtration, which is what our experts had initially identified as the most reliable way of reducing selenium. Industry complained that [reverse osmosis filtration] was too expensive, it wasn’t cost-effective, and that there were less expensive ways like BCRs” (2022). Reverse osmosis is one of the only reliable treatment technologies capable of separating selenium compounds from water, removing 74-94% of selenium. However, scientific literature presenting the success of reverse osmosis is generally lacking, and although the EPA lists it as one of the best available technologies for treating selenium, it is typically described as a post-treatment step. This is especially true for mining-polluted water since “the solutions to be treated contain very dilute concentrations of solids,” requiring pre-treatment of the water before reverse osmosis can be used as a final “polishing step” (Stefaniak et al 2018). Nonetheless, a conclusion that BCRs are causing a rise in selenium concentrations could result in a shift to reverse osmosis filtration as it is widely agreed upon to be an effective treatment option, but that remains to be seen (Morgan 2022). Aside from treatment by BCRs or reverse osmosis, alternatives for avoiding selenium pollution altogether are to inject the water deep underground, far beneath the water table, or to pump it to an impoundment, but these solutions are expensive and labor-intensive (Baker 2022).

POLICY ACTORS

The shift from the water column standard to fish tissue and egg/ovary criteria for selenium monitoring by the WVDEP involved input from the coal industry and environmental organizations concerned with water protection, and yet the fish tissue standard continues to receive criticism from both sides. In the realm of policy analysis, a recognition of the agencies and interested groups behind the development of a policy, or the policy actors, is vital to the understanding of it (Bardach 2012). To gain a better understanding of the effects of the implementation of the fish tissue policy for monitoring selenium, I carried out interviews with coal industry professionals and environmental advocates. The interactions between these policy actors – the WVDEP, coal operators, and environmental groups – influence the trajectory of the fish tissue sampling policy for selenium monitoring.

Coal Industry

Where fish tissue concentrations of selenium are in compliance with the maximum limit of 8 µg/L and not indicating harmful levels of bioaccumulation, coal operators are generally supportive of the fish tissue policy (Baker 2022). However, the policy is garnering more concern throughout the coal industry as fish tissue concentrations regularly exceed the 8 µg/L threshold. Although the policy is scientifically justified and reasonable, WVDEP has admitted that in practice the policy is not working out as intended – watersheds are not being shielded from selenium pollution, and coal operators are still unable to release, industry terminology meaning "to cease," monitoring of many permits or achieve selenium compliance. Arguments against the validity of the policy rebut the assumption that outlets of coal wastewater act as the sole, primary

sources of selenium, especially in larger watersheds where there are multiple contributing outlets that may not belong to the same permits or companies. The natural migratory habits and movement of fish also add complexity to the policy as fish with high levels of selenium measured in their tissue may not be constant occupants of the particular streams from which they were sampled (Allen 2022).

Figure 5 presents the range of all fish tissue concentrations of selenium found in fish samples collected throughout West Virginia according to Lexington Coal Company (LCC) permits as an illustration of typical fish concentrations of selenium. Since 2018, LCC has acquired 20 permits requiring fish tissue for locations that previously required only water column monitoring of selenium (see Appendix: Table 1 for full list of permits). A total of 471 fish composite samples have been collected and tested for tissue concentrations of selenium. Of those, 79 of the samples, or ~17%, are in exceedance of the applied maximum limit of 8.0 µg/L. Reporting technicalities prevent these from all being violations, however, as the maximum values of composite samples are only reported on DMRs if multiple species are collected. If only one species is collected, the weighted average of the composite samples is reported instead, presenting the possibility that some exceedances of the 8.0 µg/L threshold may not actually be reported as exceedances meeting the criteria for proper violations (WVDEP 2020).

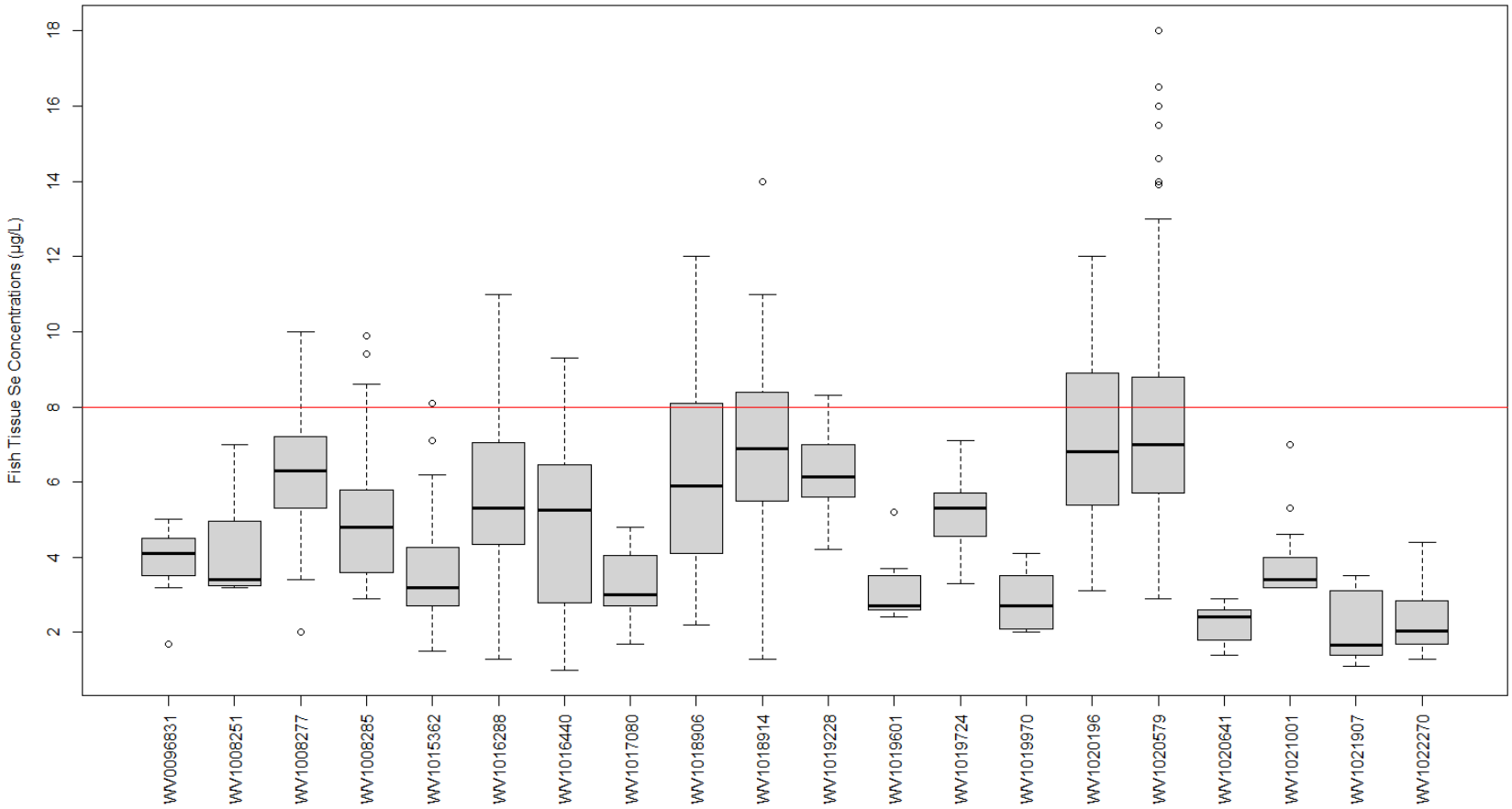

Figure 5: Boxplots illustrating collective concentrations of selenium in fish tissue according to NPDES permits operated by Lexington Coal Company (LCC). The red line indicates the maximum limit allowed, 8.0 µg/L. *Data made available by Aquatic Resources, Inc., and publicly available from WVDEP.*

In August 2019, several environmental organizations filed a lawsuit against LCC for violating selenium and conductivity limits at two mines located in the Tug Fork River watershed of West Virginia. In *West Virginia Highlands Conservancy, Appalachian Voices, & Sierra Club v. Lexington Coal Company*, the U.S. District Court for the Southern District of West Virginia determined LCC to be responsible for violating the conditions of its permits and ordered the company to submit a remediation plan to return conductivity and selenium levels to compliance within one year of submitting their plan. In addition to water column violations, exceedances of fish tissue selenium limits were noted as adequate evidence that LCC was responsible for the biological degradation of aquatic communities below the mines. LCC submitted a remediation plan in January of 2022 (Tony 2022), but it was rejected by the court. The judge found that the plan, which relied on a theory that "if you mix selenium-laden water with iron-laden water, somehow the iron would precipitate out the selenium," was inadequate because the chemistry was questionable, the plan was not formulated by an engineer, and the issue of conductivity was not addressed. Morgan (2022) stated, "If it were that easy to treat selenium, then I think that would be the treatment method employed at mines across West Virginia and other parts of Appalachia, but the chemistry, I think, does not work the way LCC consultants suggested that it would. It flies in the face of everything that the coal industry has learned about selenium treatment over the last 15 years, so it's hard to take it seriously as an earnest effort towards compliance." However, the treatment has been successfully implemented on another mine where selenium has remained in compliance (Tony 2022). The judge has since issued a follow-up order that provides more time for LCC to develop a remediation plan, this time by a certified engineer (Morgan 2022).

Treatment methods alone are proving to be insufficient for selenium compliance at some sites, requiring coal operators to apply to WVDEP for permit modifications. One particular permit at LCC provides an example of some of the permit maneuvering coal companies can employ to regain compliance with water quality standards. At a site where an installed BCR is suspected of causing fish tissue concentrations of selenium to rise, operators are planning to pump the problematic outlets to the next receiving stream and to reapply for fish tissue monitoring requirements at a new location there. In the meantime, the BCR suspected of causing the rise of selenium concentrations in fish tissue would be cut off for at least two years. After two years, fish tissue will be sampled at the original monitoring location to determine whether or not selenium concentrations in fish tissue there have reduced to levels below 8 µg/L, at which point the company would need to reapply for the fish tissue monitoring requirement once again at the original location. Strategies like this to reach selenium compliance are well within legal bounds as efforts still eventually lead back to dependence on fish tissue compliance. This entire process is time-consuming but necessary if the company wants to be released from their selenium monitoring requirements and attain eventual permit closure, or complete cessation of monitoring for entire permits (Allen 2022).

The fish tissue policy was developed with consideration for giving coal companies options for locations that were not meeting water quality standards for selenium. Though initially welcomed by operators, the fish tissue policy is not speeding up permit closures as the industry had hoped. Because selenium can cause long-term degradation to aquatic communities, monitoring requirements have generally been quite strict. Fish tissue provided a possible way out of selenium monitoring since it presents physical evidence of possible harm to fish communities,

but in reality it has not led to the removal of monitoring requirements since fish tissue selenium measurements often exceed the 8 µg/L threshold in many watersheds. WVDEP biologists are wary of signing off on the release of otherwise reclaimed permits that have high fish tissue concentrations of selenium due to the risks of both lawsuits and environmental degradation. Internal WVDEP meetings aimed at coming to some consensus about how to proceed are ongoing, but even if WVDEP makes a decision, the issue must still proceed to the EPA where it is presumed there will be even more complex discussions. In the meantime, coal operators are essentially stuck monitoring these sites (Allen 2022).

As principal actors in the policy process, coal operators have a vested interest in the fish tissue policy working in their favor by reducing selenium monitoring liability. The premise of the fish tissue policy that sites and permits could reach closure despite regular water column selenium violations was well-received. Additionally, since violation costs for fish tissue are considerably less than those incurred by water column selenium concentrations, the failure of the policy could result in a return to those higher costs if the water quality standard is reimposed or if a new policy approach is developed. Violations for selenium fish tissue and water column concentrations are issued based on what is reported on quarterly Discharge Monitoring Reports and can include both average and maximum limit violations (Baker 2022). Limit exceedances are marked on the reports prior to being uploaded to the WVDEP Electronic Submission System website where they are then submitted by the coal companies and reviewed by state inspectors. Often, inspectors allow some period of time for the operators to get a substandard discharge back into compliance before finalizing a violation (Baker 2022). As an example of the vast difference in costs, consider possible selenium violations for permit WV1020196, an LCC permit. In 2021,

if previously applied water column limits for selenium (average limit = 4.7 µg/L, maximum limit = 8.2 µg/L) had been in place for the permit's five outfalls that regularly fail to maintain selenium compliance, there would have been 86 exceedances for which WVDEP could have issued violations. Considering that violation amounts can be anywhere from $2,500 to $25,000, these exceedances could have cost the operator anywhere within the range of $215,000 to $2.15 million if WVDEP had been so inclined to pursue these exceedances as violations. However, this permit shifted to fish tissue requirements for selenium compliance in 2018, resulting in only four reported exceedances for 2021. These potential violations would accrue costs of $10,000 to $100,000, a range far lower than even the lowest estimate for the potential water column violation amounts.

Though cheaper than a selenium standard that depends on water column violations, coal companies are disillusioned with the fish tissue policy. Since the fish tissue policy is sometimes not fulfilling the industry-embraced goal of ending monitoring requirements for coal operators, it is now deemed a failure by operators who still cannot achieve selenium compliance through fish tissue monitoring. Rather than concluding that there is realistic potential for further aquatic harm and bioaccumulation of selenium in fish communities, perhaps already exceeding a toxic threshold in some cases, coal companies instead seem focused only on how it affects their long-term operational costs even with the perceptible decrease in violation costs that is certainly to their benefit.

Environmental & Community Organizations

Sierra Club of West Virginia

Environmental organizations throughout West Virginia are not satisfied with the implementation of fish tissue for selenium monitoring on many permits, either. The Sierra Club has been widely involved with monitoring water quality in coal mining affected regions throughout the state and has pursued dozens of lawsuits regarding selenium pollution. WVDEP does a respectable job regulating pH and metals, but the complexity of selenium pollution makes it harder for regulators to appropriately monitor. When the EPA first issued the selenium criterion recommendations for the monitoring of egg, ovary, or tissue concentrations in fish, the Sierra Club submitted multiple comments outlining their concerns with some of the underlying science and the 8 µg/L threshold. The primary concern was that enforcement would be much more difficult under this fish-based standard, thus making it more difficult to bring lawsuits against coal companies for water quality violations. The EPA, however, pointed to their success in effectively enforcing the water quality-based standard, especially when state regulators were unwilling or unprepared to enforce it (Morgan 2022).

While scientifically justified, the presence of selenium in fish tissue is not the ultimate indicator of harm to aquatic environments. Fish tissue selenium concentrations do not reflect impacts on other aquatic life, and the potential for selenium to move up the food chain goes unmonitored with fish tissue as the main focus. James Kotcon, Chair of the Conservation Committee for the Sierra Club of West Virginia, explained, “The coal industry argued that the selenium standard based on fish body burden was a better way of estimating true impact” (2022). However, Kotcon argued that once selenium concentrations become significant in fish tissue, it

may already be too late to mitigate adverse impacts on aquatic life. “In very severe cases, the fish disappear; they’re all dying out, so it’s hard to get fish with high levels of selenium, and the only ones left are the ones that don’t have the selenium. It underestimates the true impact” (Kotcon 2022). While this situation is feasible and anecdotal evidence may seem to confirm this, existing scientific research cannot confirm that complete fish die-offs are occurring in West Virginia watersheds due to excessive selenium inputs from coal operations. Additionally, reported concentrations of fish tissue selenium are often quite high, refuting the assumption that existing populations of fish do not exhibit such high concentrations.

Under the CWA, coal companies are required to self-monitor and self-report, making it easier for local communities to monitor selenium pollution in their watersheds by accessing public record Discharge Monitoring Reports through WVDEP’s FOIA portal or by utilizing the EPA’s database of violation history, ECHO. However, if companies are not abiding by reporting standards, as was the case for many operators early in the COVID-19 pandemic, there is no data to rely upon. Morgan (2022) noted, “That being said, a lot of the selenium suits we’ve brought over time have been unpermitted discharge suits where selenium wasn’t authorized in their permits. So, because selenium is not listed in the permit, they’re not monitoring for it. The only way to determine if it is there is to go take samples downstream. That opportunity to sort of bird-dog those cases is again limited in some ways by shifting to the tissue standard.”

It is widely agreed upon that violation costs to coal companies are significantly decreased as a result of the fish tissue policy, allowing coal companies to point to decreased violation counts as proof that their mining operations are not harming the aquatic environment if fish tissue results do not reflect high concentrations of selenium even when the water column does.

Potential clean-up costs and liabilities are similarly reduced as a result of the policy, leading to even greater savings for coal companies. Meanwhile, the coal industry and WVDEP continue to search for lower cost solutions for selenium treatment even though proven treatments exist. Kotcon (2022) said, "We think that a reverse osmosis system is the only one that has really proven to be effective consistently – that is, of course, the most expensive approach by far. We would certainly like to reduce the cost of that cleanup, but the first criterion is that they need to be able to meet water quality standards, and they're having difficulty doing that."

"Some of these areas should never have been mined in the first place," noted Kotcon (2022) in reference to regions where the coal industry struggles to maintain compliance with water quality standards. "We felt that if they cannot mine legally, then they shouldn't be mining – that's a difference of opinion." In reality, this "opinion" is legitimate considering mining *is* supposed to operate within the bounds of the CWA and state laws. WVDEP operates effectively enough in most areas, but excuses of being underfunded and overworked result in a lot of overlooked or otherwise unpursued issues. Additionally, since leadership is politically appointed and typically industry-affiliated, WVDEP tends to assist coal mining operators with issues of water quality compliance rather than consistently holding them accountable and requiring environmental remediation every time a violation occurs. "We need some fairly significant reform in our environmental agencies, but that will take some new elections" (Kotcon 2022).

The Sierra Club supports the fish standard approach for selenium if it would be used in conjunction with the water column criterion instead of being the lone requirement. Ecologically, it would be most reasonable to consider both fish tissue and water column concentrations of selenium since "they're both indicators of an adverse water quality situation" (Kotcon 2022).

Morgan (2022) explained, “We argued that it should allow for both the tissue and a water column-based standard, but if there’s a violation of the water column, that’s a violation by itself. I still think an approach like that would be appropriate.” Combined monitoring would not be an approach that would benefit the industry at all, but it would be environmentally protective. The most environmentally protective option would be drastic for the industry, however, and seems like a dramatic improbability for that reason. “I think what they should do first of all is stop issuing permits that allow disposal of mining waste in streams in West Virginia and other parts of Appalachia. That’s how you avoid a selenium problem. That’s the bigger picture of what they should do” (Morgan 2022).

Appalachian Voices

Appalachian Voices is a grassroots organization dedicated to environmental protection and maintaining the health of Appalachian communities. Their work has largely centered around holding coal companies responsible for pollution via lawsuits based on CWA violations, an extremely successful strategy. Pollutants like iron and manganese are typically easier and cheaper to control than selenium, so coal companies tend to properly address them, especially when citizen complaints occur. But with selenium, organizations like Appalachian Voices have to focus more seriously on getting coal operators to curb pollution. Erin Savage, the senior program manager for Appalachian Voices, explained, “If we can get coal companies to limit selenium pollution, that helps to internalize what has been an externality for coal mining. We are trying to improve enforcement by looking at the most costly aspects of controlling mining pollution” (2022). Much like the Sierra Club of West Virginia, Appalachian Voices maintains that the policy shift to requiring fish concentrations of selenium was a political move more than

anything. “The change to the standard was political to some extent, but it’s not that I think that the science is wrong. I do think they did this under pressure from the industry, or at least knowing the industry would appreciate it… I’m just arguing that it’s not the best way to enforce under the CWA” (Savage 2022).

Furthermore, Savage noted that the change in criterion seems to be a direct response to their lawsuits against coal companies over water column violations of selenium. With the criterion shifted to a fish tissue burden instead, community clean water advocates are now limited in terms of monitoring involvement since fish tissue collection is a much more complicated process than water sample collection. “This was essentially somewhat in response to our lawsuits – that it was a way to get around the monitoring that we were doing that led us to being able to bring those CWA lawsuits.” Regardless, organizations like Appalachian Voices tend to use the coal companies’ own data reported on Discharge Monitoring Reports to WVDEP for such lawsuits as using coal operator-reported data avoids any questions regarding proper sampling protocols and data tampering. Going forward with the fish requirement, this same approach could continue to be applied for lawsuit purposes if necessary since seasonal fish tissue concentrations of selenium are reported on Discharge Monitoring Reports (Savage 2022).

Simply filing a notice of intent to sue for possible selenium pollution in watersheds rarely affects change in coal mining operations, but intentionally pursuing a lawsuit through local West Virginia county courts often works out well for both the environmental organizations and affected communities. Appalachian Voices and their lawsuit partners tend to settle with coal companies because advocates can demand cleanup and treatment, solving the pollution issue and forcing the coal company to internalize the costs of their pollution. Instead of fighting for coal

companies to receive the maximum amounts in violation fees on a case-by-case basis, in which case all the money goes into a state fund from which directly affected communities may never benefit, settlement money from successful lawsuits can be directly applied to the problems experienced by local communities. Lawsuit settlements are generally cheaper for organizations as well since drawn-out fights over maximum penalties can be quite costly (Savage 2022).

One noteworthy exception to this selenium monitoring plan for West Virginia arguably puts the implementation of this policy at active mining locations in question:

> There is an exception to this hierarchy, and it is in regard to selenium being added to a water that previously had no significant source of selenium. In this case, selenium concentrations in fish tissues must be allowed to come to equilibrium with the water column before fish tissue concentration would be allowed to override water column concentration. When a selenium input changes, causing the water column concentration to increase or decrease, the fish tissue will not immediately reflect the changed water chemistry. Because of this, when any major changes in water column selenium concentration occur, a minimum of six months must be allowed before fish tissue may be sampled for use in this standard (WVDEP 2018).

Essentially, this exception describes how fish tissue concentrations of selenium lag behind water inputs of selenium. Due to this, at least six months must pass to allow for fish tissue concentrations of selenium to come to equilibrium with new inputs and stabilize before fish tissue monitoring can be applied as the primary monitoring criterion for selenium on a permit. What qualifies as a change in selenium input is up for debate.

Regarding interpretation of this selenium input exception, Savage (2022) said, “I would argue that you have the potential for new input at any point during the life of that mine… Basically, they need to do water column while there’s changing input.” This understanding is based on the assumption that nearby surface mines are still contributing selenium inputs as long as ground and geology are still being disturbed, preventing any true equilibrium between fish tissue and water column selenium concentrations. “My interpretation of that – and I don’t think

the state or coal companies are going to interpret this this way – is that surface coal mines need to always use the water column standard then because the conditions on the ground, and therefore the conditions in the runoff, are constantly changing… I wouldn't expect there to be equilibrium below an outfall in a West Virginia surface mine really at any point during the life of that mine" (Savage 2022). Morgan (2022) translated this exception similarly, stressing the importance that fish not be applied as the primary monitoring criterion too soon in watersheds with new mining. Failure to monitor water column concentrations of selenium as soon as mining starts and attempting to monitor only fish tissue years later could result in the loss of entire aquatic communities. "There are some watersheds that have had a lot of mining over the years, and we might see the extirpation of any species that are sensitive to selenium. If you're prioritizing a tissue standard, industry can say, 'Well, we can't find any of the organisms so we can't do the testing.' That's just a perverse result that rewards or even encourages polluting a watershed to the point where you've driven out any of the sensitive species. That is totally counter to the purpose of the CWA which is to restore the nation's waterways, not to create sacrifice zones, to say, 'We've already sufficiently polluted this that there's no point in limiting the additional introduction of more of these pollutants.'"

Indeed, the coal industry does *not* perceive the selenium input exception in this way. Instead of focusing on the status of mining (active/inactive), the focus is on the watershed's status – is the watershed totally pristine or has it had mining inputs before, either directly or indirectly from adjacent mines? In the case that a location is completely devoid of any previous mining activity, it does seem that this exception would apply since the fish communities would not have had time to come to equilibrium with any new selenium inputs. But, in watersheds

where mining has been active for a long time, fish communities have reasonably had enough time to adjust to selenium inputs. Basically, this interpretation argues that the exception simply suggests the impracticality of utilizing fish tissue as the selenium standard when mining is only just beginning in a fresh area. Another thing to take into account when it comes to increasing inputs is the fact that valley fills are liable to contribute selenium and heavy metals for a long time after mining has concluded (Allen 2022). One analysis done in 2009 found that there were 1,812 valley fills and 270 refuse fills with the potential to affect 700 miles of streams throughout West Virginia, and another study found that in five coal mining basins in West Virginia, selenium leaching into streams was greater in watersheds that had valley fills than in nonmined areas or areas without fills (Presser 2013). Going forward, this exception to the criterion will remain heavily contested between policy actors based on defensible interpretations that favor their respective purposes.

Environmental organizations are wholly dedicated to requiring coal companies to operate responsibly and legally. If selenium pollution cannot be curbed from the outset of mining, coal operators should fulfill the treatment and remediation requirements for selenium regardless of expense or time. Because selenium can exist in watersheds long after mining has ceased, it is imperative that WVDEP enforces a policy geared towards mitigation in favor of watershed health rather than the self-interested requests of coal companies. Policies developed for watershed protection, like the fish tissue criterion for selenium, are well-intentioned and scientifically justified, but they can fail if agencies fail to appropriately enforce them.

POLICY ANALYSIS

For my policy analysis of the West Virginia fish criterion for selenium, I utilize several pertinent steps of Eugene Bardach's "Eightfold Path" along with the information I obtained from my interviews and research. Defining the problem is the first step (Bardach 2012). In this case, monitoring selenium via fish tissue or egg/ovary concentrations rather than by water column concentrations is the problem because, although scientifically justified, its implementation in West Virginia has proven to be inadequate. Because WVDEP is underfunded and its employees often overworked, enforcement of the policy is lacking, and arguably too much deference is provided to coal operators when it comes to violations and mitigation requirements. Environmental organizations are similarly hampered in their attempts to hold coal companies accountable for selenium pollution since fish tissue collection methods are more complicated than those required for straightforward water samples. Most importantly, fish tissue concentrations of selenium in many watersheds of West Virginia are indicating that toxic thresholds are being reached and exceeded. The consideration that fish tissue concentrations of selenium are more reflective of aquatic harm is significant but meaningless if nothing is done to effectively enforce compliance or remediation.

The second step of Bardach's policy analysis process revolves around accumulating evidence that assesses the particular features of the current policy and the extent of the problem (2012). Evidence of the problematic fish tissue policy for selenium in West Virginia was mainly collected from interviews I recorded with both coal industry professionals and environmental group leaders. Scientific and journalistic research informed my examination of the extent of selenium pollution throughout West Virginia and the environmental degradation that can occur

as a result of it, especially when fish tissue is employed as the sole monitoring standard. Coal operators do not view the fish tissue policy as problematic as long as it is working in their favor, but when high fish tissue concentrations of selenium prohibit the termination of monitoring obligations, operators are quick to criticize the policy. Christie Allen, a senior environmental scientist for Aquatic Resources, Inc., who manages permitting for coal operators, was especially critical of the fish tissue policy's implementation since it was not fulfilling permit closures as expected and since it seemed as if WVDEP was unsure of how to proceed because of that shortcoming (2022). In this way, the policy was viewed to be a problem only to the extent that it impacts the costs to coal operators. Environmental groups take issue with the implementation of fish tissue as the main monitoring requirement for selenium in many watersheds in a different way. Interviews with Kotcon (2022), Savage (2022), and Morgan (2022) all echo the recognition that selenium monitoring in fish tissue alone allows for ultimately more selenium pollution from coal operators. While accepting the scientific feasibility of fish tissue monitoring for selenium, fish tissue concentrations alone do not represent the entirety of selenium pollution within a watershed. Additionally, these environmental organizations are aware of WVDEP's tendency of leniency with coal operators. The prioritization of fish tissue over water column concentrations of selenium deters citizen monitoring and using lawsuits to encourage enforcement of clean water standards in cases where WVDEP fails to enforce compliance with the policy they implemented.

Steps three through five of Bardach's policy process involve examining policy options, or "alternative courses of action" (2012). The simplest alternative that WVDEP could employ is to effectively enforce the fish tissue policy for selenium that they have implemented. If coal

operators are reporting fish tissue concentrations in exceedance of the 8 µg/L threshold, there should be no debate within WVDEP about how to proceed – those coal operators should simply be found in violation and required to continue monitoring and appropriately remediate the pollution. The failure of WVDEP to immediately do so is ultimately a failure of the policy as is. However, effective enforcement of the fish tissue policy as it exists still does not account for the issues regarding citizen involvement, nor does it provide a total picture of watershed health in areas with selenium pollution.

Alternatively, the environmental leaders I spoke to expressed a desire to return to water column concentrations as the main policy for monitoring selenium in West Virginia as that requirement proved effective at enforcing water quality standards in cases when WVDEP was slow to act. At the very least, a monitoring policy requiring both water column and fish tissue concentrations of selenium would be more effective both in terms of environmental protection and holding coal companies accountable for pollution. Coal operators simply seem prepared to support whichever policy will reduce their costs and monitoring workloads. The formulation of an entirely new monitoring policy alternative for selenium in West Virginia is unlikely given the options are generally limited to water and fish, but regular enforcement with clearly required remediation procedures through any of these existing alternatives would result in immediate improvements for watershed protection.

Step six of Bardach's process involves clarifying the trade-offs associated with different policy options. The outcome of any suggested policy alternative is the focus here rather than the alternative itself (Bardach 2012). In the case of the fish tissue policy and its alternatives, the intended outcome of each should be improved protection of watersheds from selenium pollution.

Continuation of the fish tissue policy in its current form would achieve this only with improved enforcement and remediation requirements which reasonably translates into more costs to WVDEP as they would need to hire more employees to responsibly spread the workload. The extension of the current policy with improved enforcement would similarly increase costs to coal companies as operators would be required to prolong monitoring and ideally devote substantial resources to costly selenium treatments. The return to a water column monitoring policy or a combination of water column and fish tissue monitoring for selenium would similarly impose greater costs on coal operators based on my own violation cost comparison included in the "Violations" section of this paper, sampling costs, and general consensus among both industry professionals and environmental groups. No policy alternative for selenium monitoring should be pursued based on the costs to coal operators, though; any considered policy should instead be based on environmental protection, regardless of the impacts increased monitoring or treatment costs may have on coal mining operations.

The final steps of Bardach's policy process are to personally determine which policy alternative is best and to describe why in the most effective manner possible. If I were actually tasked with determing the fate of the fish tissue policy for selenium monitoring in West Virginia, I would be in favor of a shift to a policy that includes both fish tissue and water column concentrations of selenium. A shift to this policy would require little in the way of practical changes since coal companies already monitor selenium in the water at locations that have shifted to requiring fish tissue. The reimposition of limits on these water column concentrations of selenium would be fairly straightforward, although I would expect coal companies to strongly fight this change seeing as they would then be responsible for violation penalties for both semi-

monthly water column *and* seasonal fish tissue exceedances at many locations. Assuming WVDEP enforcement would also improve, this dual approach would ideally encourage operators to finally invest in more costly selenium treatments that they have been foregoing in hopes of leniency from WVDEP. Based on personal experience working within the coal industry and conversations with environmental experts, it seems that the only way to make coal operators care about selenium pollution is to make the long-term expenses of reckless pollution more costly than the expenses to just treat or avoid pollution altogether.

CONCLUSION

The future of West Virginia's fish tissue criterion for selenium is debatable. Due to uncertainty on the part of regulators and expert biologists, many coal mining permits awaiting selenium approval for progress or closure are at a standstill. Community organizations dedicated to protecting local watersheds distrust the fish tissue standards implementation and enforcement, and advocates are concerned with how it will affect their own attempts to hold coal companies accountable for selenium pollution. All the while, bioaccumulation within aquatic ecosystems is likely occurring given the growing evidence of high concentrations of selenium in fish tissue. More research needs to be done going forward, especially in the realm of selenium bioaccumulation through food webs.

Though scientifically researched and formulated in a way arguably intended to protect watersheds from selenium pollution, the implementation of the fish tissue policy was rushed in a way that did not plan for complications or failure. Anytime an environmentally protective policy is applied, all possible outcomes should be considered with prepared solutions in the event of any problems, from its effect on citizen involvement to how it may impact business operations. Coal companies and their often irresponsible operations that refuse to comply with water quality laws are primarily to blame for the breakdown of the fish tissue policy since the policy would never have been created if companies had simply been willing to protect the watersheds in which they operate instead of foregoing protection for profits. Rather than simply complying with water quality regulations, coal operators pushed for a policy that would allow them to continue polluting streams with selenium and had the potential to eliminate monitoring requirements as soon as possible to end financial burdens.

Ultimately, the water quality policy in West Virginia regarding selenium monitoring via fish tissue needs to be revised in some way. It is unlikely that the fish tissue option will be entirely withdrawn with an imposed return to water column concentrations of selenium as the standard since all policy actors tout the scientific justification and rationality of the fish policy. A revision that requires water column concentrations of selenium along with fish tissue sampling is unlikely as well since that would still likely prevent most permits from moving forward, though a combined approach could achieve success for some permits. Notwithstanding the probable coal industry backlash, a combined approach would be most effective for presenting the full scope of selenium pollution in West Virginia watersheds. The relative success of the policy seems to depend on WVDEP and EPA as they determine whether or not coal companies with permits with fish tissue selenium violations can be allowed to modify monitoring requirements. Approving such permits would invariably lead to lawsuits, a reality that has already set regulators on edge (Allen 2022). Instead, expensive and novel treatment systems are likely to be required in hopes that selenium pollution can be ameliorated, though this approach would likely not suit coal operators, either, considering long-term monitoring and related expenses would be required. As with most policies, not all policy actors will achieve all of their goals when it comes to the fish tissue policy in West Virginia. However, in this case, environmental protection must be the first and foremost priority. Appeasing coal operators above all else is irresponsible if it means West Virginia watersheds continue to suffer from selenium degradation.

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APPENDIX

LCC PERMITS WITH FISH TISSUE REQUIREMENTS

Table 1: Lexington Coal Company (LCC) West Virginia coal mining permits requiring fish tissue monitoring as of December 2021.

NPDES PERMIT #	SMCRA PERMIT #	OUTFALL	FISH SITE
WV0096831	U045800	**004**	**BC-Fish-1**
WV1008251	U501091	**008**	**WFTCFISH1**
WV1008277	S505389	**003**	**WCFISH1**
		017	**WCFISH2**
WV1008285	S505489	**003**	**WCFISH1**
		016	**TFFISH1**
WV1015362	S300598 S301806	**001/002/003**	**RFFISH1**
		011/012	**TMFISH2**
		015	**TMFISH3**
WV1016288	S401395	**002**	**BCFISH5**
		019	**LFBCFISH1**
		017	**BCFISH3**
		024	**LFBCFISH4**
WV1016440	S400896	**019**	**CTBFISH1**
WV1017080	S502097	**036**	**OBFISH2**
WV1018906	S400300	**001**	**UTHCFISH1**
		002/012/021	**RBFISH1**
WV1018914	S400400	**047**	**BFFISH1**
		087	**BCFISH3**
		107	**BCFISH4**
WV1019228	S301999	**016/019**	**UBBFISH1**
WV1019601	S300702	**004**	**TM-FISH-1**
WV1019724	S503408	**021**	**CFFISH1**
		017	**CFFISH2**
WV1019970	S501609	**006/007**	**WOBFISH1**
WV1020196	S502099	**005**	**BFFISH1**
		006	**AFFISH2**
		007	**BIGFFISH1**
		010	**GCFISH1**
		011/052	**HCFISH1**
WV1020579	S501501	**045/047**	**EFBFISH1**
		004/005	**RFFISH1**
		012	**CBFISH2**
		031	**BPBFISH3**
WV1020641	S502301	**020**	**RHFISH1**
WV1021001	U500304	**001**	**WFTCFISH1**
WV1021907	S301405	**029**	**HB-FISH-1**
WV1022270	S300907	**013/014**	**RDF-FISH-1**
		018-020/026	**RDF-FISH-2**
		007/008/009	**JB-FISH-3**