BEFORE
HEALTH CANADA AND ENVIRONMENT CANADA

COMMENTS OF THE
NORTH AMERICAN METALS COUNCIL-SELENIUM WORK GROUP
IN RESPONSE TO ENVIRONMENT CANADA/HEALTH CANADA
DRAFT SCREENING ASSESSMENT FOR SELENIUM AND ITS COMPOUNDS

Canada Gazette)
Part 1: Vol. 149, No. 29)
July 18, 2015)

William J. Adams, Ph.D.
Chairman, North American Metals Council
Selenium Work Group
2200 Pennsylvania Avenue, N.W.
Suite 100W
Washington, DC, USA 20037

Kathleen M. Roberts
Executive Director
North American Metals Council
2200 Pennsylvania Avenue, N.W.
Suite 100W
Washington, DC, USA 20037

Peter M. Chapman, Ph.D., Fellow SETAC
North American Metals Council
Selenium Work Group
2200 Pennsylvania Avenue, N.W.
Suite 100W
Washington, DC, USA 20037

Dated: September 16, 2015

EXECUTIVE SUMMARY

The North American Metals Council (NAMC) submits these comments in response to the Environment Canada request for public input on the document, Draft Screening Assessment, Selenium and Its Compounds (Draft Selenium Assessment). This document comprises integrated comments provided by individual Members and Associates of the North American Metals Council-Selenium Work Group (NAMC-SWG). NAMC-SWG is engaged in technical research on issues pertaining to selenium.

In these comments, NAMC identifies the following major concerns regarding the findings of the Draft Selenium Assessment:

- Data show that the calculated predicted no effect concentrations (PNEC) for fish whole body and egg/ovary are unreasonably low and will not discriminate between reference and anthropogenically affected areas.

- Environment Canada and Health Canada did not utilize appropriate data or follow the Canada Council of Ministers of the Environment's (CCME) protocols when deriving the calculated PNEC values.

  - The calculated PNEC for fish eggs/ovaries is flawed because incorrect values were used for 50 percent of the species used in the sensitive species distribution analysis, and because Environment Canada did not follow CCME protocols concerning geometric means.

  - The fish whole body PNEC is derived from technically questionable non-reproductive effects from studies that are not fully reliable, and does not make use of conversion factors and computations developed by the U.S. Environmental Protection Agency (EPA).

- There is no need for a PNEC for benthic organisms, as data show that invertebrates are less sensitive than fish and, as such, appropriate PNECs for fish will protect benthic invertebrates as well.

- The calculated soil PNEC of 1 µg/g dry weight (dw) is not scientifically justifiable and does not take into account the documented benefits of enhancing selenium in soils, especially in areas with selenium deficiency.

- The Upper Tolerance Limit in the Draft Selenium Assessment should be reconsidered because it is based on questionable Chinese studies and does not take into account additional relevant data. The limit also does not reflect that population studies showing consumption of elevated selenium in traditional foods do not result in selenosis, and that selenium is an essential micronutrient for human health.

For all the reasons noted above, NAMC urges Environment Canada and Health Canada to reconsider and to revise the elements in the Draft Selenium Assessment as outlined above, such that they are technically defensible and not overly protective. With implementation without revision, the resulting high rate of false alarms will result in a serious misallocation of resources, thereby reducing rather than enhancing Canada's ability to address environmental problems and unnecessarily penalizing industrial activities with concomitant economic costs but without concomitant environmental benefits.

TABLE OF CONTENTS

TABLES

INTRODUCTION

The North American Metals Council (NAMC)[1] submits these comments in response to the Environment Canada request for public input on the document, Draft Screening Assessment, Selenium and Its Compounds (Draft Selenium Assessment).[2] Our organization has worked closely with federal and international agencies to address risk assessment issues that are unique to metals at various stages of their lifecycle -- sourcing, production, engineering, use, recycling, and recovery. We advocate policy based on good science.

NAMC's comments are comprised from input of the North American Metals Council-Selenium Work Group (NAMC-SWG) members. NAMC-SWG is engaged in technical research on issues pertaining to selenium. Activities include the development of water quality tissue-based standards for selenium, the implementation of such standards, development of effects thresholds, and the identification of analytical methods pertinent to such standards. As part of its ongoing efforts, NAMC-SWG develops papers on these topics and shares them publicly.

---

1 NAMC is an unincorporated, not-for-profit group formed to provide a collective voice for North American metals producers and users (*i.e.*, the North American "metals industry") on science- and policy-based issues that affect metals in a generic way. NAMC members include trade associations as well as individual companies. NAMC does not engage in lobbying.

2 Environment Canada and Health Canada (2015). Draft Screening Assessment, Selenium and its Compounds (Draft Selenium Assessment).

NAMC's comments below highlight critical errors in the calculation of the selenium predicted no effect concentrations (PNEC) for fish eggs/ovaries and fish whole bodies. In particular, as further described below, the calculated PNECs are inappropriate because (1) they are below background selenium concentrations for reference areas and (2) there are flaws in the derivation approach used, resulting in unreasonably low values that are not technically defensible. In addition to identifying concerns with PNEC values, NAMC also provides feedback on the Draft Selenium Assessment findings on harm to benthic and soil organisms, and on risks to subsistence fishers consuming fish with elevated selenium concentrations around mining operations.

I. ERRORS IN PNEC DERIVATION

A. Background Fish Selenium Concentrations Exceed the Calculated PNECs

In the Draft Selenium Assessment, Environment Canada and Health Canada have calculated a whole body PNEC of 2.9 µg/g dry weight (dw) and a fish egg/ovary PNEC of 11.8 µg/g dw. As highlighted below, these calculated PNECs are below reference values and, thus, provide no discrimination between reference and potentially impacted fish.

In deriving the PNEC values, Environment Canada relied on concentrations of selenium in minimally impacted areas, stating in its supporting documentation, "[t]hese data are a better indication of natural background, or minimally or un-directly impacted areas."[3] Table 4.12-A in that supporting documentation provides summary information including *n* (the number of samples) and the 95th percentile of the data. A comparison of the fish whole body or fillet dw from the supporting documentation, and the calculated PNEC for fish whole body in the Draft Selenium Assessment[4] is provided in Table 1 below.

Table 1. Comparison of Selenium Concentrations in Fish Whole Body or Fillet (*i.e.*, Muscle) from Minimally Impacted Areas (from Environment Canada (2014a), Table 4.12-A) to Calculated PNEC.

Region	**N (sample size)**	**95th percentile (µg/g dw)**	**Greater than calculated PNEC of 2.9 µg/g dw (%)**
Atlantic	101	3.1	Yes – by ~10%
Pacific and Yukon	299	4.52	Yes – by ~ 60%
Quebec	152	2.84	No – just under
Ontario	8,302	3.44	Yes – by ~ 20%
Prairie Northern	838	13.56	Yes – by ~ 470%

This comparison clearly shows that the calculated fish whole-body PNEC is unrealistically low compared to reference data, and thus not technically defensible or useful for making assessments of risk. We note in particular that the 95th percentile for selenium in fish whole body/muscle for Prairie Northern was 13.56 µg/g dw.

---

3 Environment Canada (2014a). Supporting Documentation: Exposure Level in Minimally Impacted Areas. Information in support of the Screening Assessment for Selenium and its compounds, Section 4.12.

4 Draft Selenium Assessment, Figure 6-2, page 28.

In addition, in the Draft Selenium Assessment, Environment Canada and Health Canada state "Selenium concentrations in fish whole-body that were associated with no toxic effects in fish ranged from 3.3-15.1 µg/g dw."[5] This language further supports the conclusion that that the calculated fish whole-body PNEC of 2.9 µg/g dw is unrealistically low, relative to reference conditions.

In addition, Carmichael and Chapman measured reference concentrations of selenium in whole bodies of sculpin (*Cottus cognatus*) in British Columbia (BC).[6] Whole body selenium concentrations usually ranged between ~4 and ~8 µg/g dw, although lower and higher values (up to ~9 µg/g dw) were recorded. These values exceeded the calculated Environment Canada and Health Canada whole body PNEC of 2.9 µg/g dw by up to ~310 percent in reference areas.

DeForest (2009) documented fish tissue selenium reference data for North America, including both Canada and the U.S.[7] The 90th percentiles were as follows: 6.8 µg/g dw, whole body; 4.8 µg/g dw, muscle; 15.2 µg/g dw, eggs; 24.0 µg/g dw, ovaries. All of these

---

5 Draft Selenium Assessment, page 27.

6 Carmichael NB, Chapman PM (2006). Baseline Selenium in Sculpins Related to the Northeast Coal Zone, Proceedings of the 30th Annual British Columbia Mining Reclamation Symposium "Case Studies of Reclamation and Environmental Protection," British Columbia Technical and Research Committee on Reclamation, Smithers, BC, Canada, June 19-22, 2006. *See* https://www.for.gov.bc.ca/hfd/library/documents/bib97331.pdf.

7 DeForest D (2009). Database of Selenium Concentrations in Fish Tissues from Reference Sites. Prepared for NAMC by Parametrix, Bellevue, WA, USA. *See* http://www.namc.org/docs/00043670.PDF.

reference values exceed the calculated whole body PNEC of 2.9 µg/g dw by ~230 percent, and the calculated fish egg/ovary PNEC of 11.8 µg/g dw by ~130 to ~200 percent.

DeForest (2009) also included reference data from Elk Valley, BC.[8] More recent reference fish muscle and whole body selenium concentrations data from the Elk Valley, provided on BC's government website, ranged up to 12 µg/g dw, exceeding the calculated whole body PNEC of 2.9 µg/g dw by ~410 percent.[9] The 95th percentile of these reference data was 8 µg/g dw, exceeding the calculated whole body PNEC of 2.9 µg/g dw by ~280 percent.

Additional reference data from various sources are provided in DeForest (2012).[10] Mean egg and ovary selenium concentrations in fish from reference sites range to ~ 19 µg/g dw, exceeding the calculated fish egg/ovary PNEC of 11.8 µg/g dw by ~160 percent.

As outlined above, multiple scientific sources, including data from Environment Canada itself, clearly document that the calculated fish whole body and egg/ovary PNECs are below concentrations found in fish from reference areas. The calculated PNECs are, thus, too

---

8 *Id.*

9 Teck Coal Limited (2014). Elk River Watershed and Lake Koocanusa, BC -- Aquatic Environment Synthesis Report. Sparwood, BC, Canada. *See* http://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/area-based-man-plan/annexes/elk_river_aquatic_env_synthesis_report_oct_2014.pdf.

10 DeForest DK, Gilron G, Armstrong SA, Robertson EL (2012). Species Sensitivity Distribution (SSD) Evaluation for Selenium in Fish Eggs: Considerations for Development of a Canadian Tissue-Based Guideline. *Integr. Environ. Assess. Manage.* 8:6-12. (Abstract, data tables, SSDs, and references available at http://www.namc.org/docs/00083457.PDF).

low as they do not provide discrimination between selenium in fish from reference and anthropogenically affected areas. As calculated, the PNECs would inappropriately identify background areas as having unacceptable selenium concentrations in fish populations, causing additional and unnecessary regulatory burdens for impacted industries and creating confusion among the general public.

B. The Calculated PNECs are Technically Flawed

In addition to concerns regarding the calculated PNECs being below reference values, NAMC also notes that the calculated PNEC values for fish eggs/ovaries and fish whole body were not developed using appropriate data, nor following Canada Council of Ministers of the Environment (CCME) protocols.[11]

1. Fish Eggs/Ovaries Calculated PNEC

The following flaws were identified in the fish eggs/ovaries calculated PNEC,[12] based on a review of the supporting documentation:[13]

---

11 CCME, Canadian Environmental Quality Guidelines: A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life. 2007. Winnipeg, MB, Canada.

12 Draft Selenium Assessment, Section 6.3.1.1, pages 25-26 including Figure 6-1.

13 Environment Canada (2014b) Supporting Documentation: Effects Data Collection. Information in Support of the Screening Assessment for Selenium and its compounds, Section 6.1.

- The lowest endpoint used in the species sensitivity distribution (SSD) in the supporting documentation is incorrectly reported at 10.92 µg/g dw, for fathead minnows. The actual endpoint for the cited study was not a bounded but rather an unbounded value of >10.92 µg/g dw, which was the no observed effects concentration (NOEC) determined by Ogle and Knight (1989).[14] This NOEC had less than a 2 percent effect on reproductive endpoints, and included a positive effect, as well as being unbounded in an upward direction. The data point used in the SSD should have been the lowest observed effects concentration (LOEC) of < 23.6 µg/g dw determined by Schultz and Hermanutz (1990),[15] which was associated with 24.6 percent larval edema, and used by DeForest *et al.* (2012)[16,17] in their SSD.

- The next lowest endpoint used in the SSD is for bluegill. This, too, is incorrectly reported. The value in the supporting documentation is 12.68 µg/g dw,[18] but the correct endpoint reported by Hermanutz *et al.* (1992) was 30 µg/g dw.[19] DeForest *et al.* (2012) did not use 30 µg/g dw in their SSD; instead DeForest *et al.* (2012) reported a value of 21.5 µg/g dw, which was a species mean derived from the Doroshov *et al.*[20] value 21 µg/g dw and the Coyle *et al.* value of 22 µg/g dw.[21]

---

14 Ogle RS, Knight AW (1989). Effects of Elevated Foodborne Selenium on Growth and Reproduction of the Fathead Minnow (*Pimephales promelas*). *Arch. Environ. Contam. Toxicol.* 18: 795-903.

15 Schultz R, Hermanutz R (1990). Transfer of Toxic Concentrations of Selenium from Parent to Progeny in the Fathead Minnow (*Pimephales promelas*). *Bull. Environ. Contam. Toxicol.* 45: 568-573.

16 DeForest *et al.* (2012).

17 Environment Canada (2014b) cites DeForest *et al*. (2011), the accepted article, not the final published paper. NAMC notes that there were no significant differences between the accepted article and published paper.

18 *Id*.

19 Hermanutz RO, Allen KN, Roush TH, Hedtke SF (1992). Effects of Elevated Selenium Concentrations on Bluegills (*Lepomis macrochirus*) in Outdoor Experimental Streams. *Environ. Toxicol. Chem*. 11: 217-224.

20 Doroshov S, Eenennaam JV, Alexander C, Hallen E, Bailey H, Kroll K, Restreppo C (1992). Development of Water Quality Criteria for Resident Aquatic Species of the San Joaquin River. University of California-Davis, Davis, CA, USA.

21 Coyle JJ, Buckler DR, Ingersoll CG, Fairchild JF, May TW (1993). Effect of Dietary Selenium on the Reproductive Success of Bluegills (*Lepomis macrochirus*). *Environ. Toxicol. Chem.* 12: 551-565.

- The endpoint for Westslope cutthroat trout used in the SSD is also incorrectly reported at 17 µg/g dw. DeForest *et al.* (2012) considered two additional references that were not included in the Environment Canada supporting document, with a calculated value of 21 µg/g dw in their SSD. Subsequently, Teck Coal (2014) conducted extensive testing and analysis, and developed a 10 percent effect level of 25 µg/g dw for Westslope cutthroat trout eggs.[22]

- The brown trout endpoint of 17.7 µg/g dw used in the SSD is also incorrect. The correct value, reported by Formation Environmental (2011), is 20.8 µg/g dw.[23] Environment Canada (2014a) used an earlier reference with preliminary values for brown trout, but correctly used Formation Environmental (2011) for Yellowstone cutthroat trout.

- The largemouth bass endpoint of 20.35 µg/g dw used in the SSD is also incorrectly reported. It should be 22 µg/g dw, per Carolina Power and Light (1997),[24] a citation used by both Environment Canada (2014a) and DeForest *et al.* (2012).

- The rainbow trout endpoint of 21.1 µg/g dw used in the SSD should be 23 µg/g dw, based on all work done by Holm (Holm (2002),[25] Holm *et al.* (2003),[26] and Holm *et al.* (2005)[27]), not just Holm *et al.* (2005), which was the only reference cited in the Draft Selenium Assessment supporting documentation.

---

22 Teck Coal (2014).

23 Formation Environmental (2011). Brown Trout Laboratory Reproduction Studies Conducted in Support of Development of a Site-Specific Selenium Criterion. Prepared for JR Simplot Company, Smoky Canyon Mine, Pocatello, ID, USA.

24 Carolina Power and Light (1997). Largemouth Bass Selenium Bioassay. Roxboro, NC, USA.

25 Holm J (2002). Sublethal Effects of Selenium in Rainbow Trout (*Oncorhynchus mykiss*) and Brook Trout (*Salvelinus fontinalis*). MA Thesis, University of Manitoba, Winnipeg, MN, Canada.

26 Holm J, Palace VP, Wautier K, Evans RE, Baron CL, Podemski C, Siwik P, Sterling G (2003). An Assessment of the Development and Survival of Wild Rainbow Trout (*Oncorhynchus mykiss*) and Brook Trout (*Salvelinus fontinalis*) Exposed to Elevated Selenium in an Area of Active Coal Mining. In: *The Big Fish Bang: Proceedings of the 26th Annual Larval Fish Conference*, July 22-26, 2003, Bergen, Norway, pages 257-273.

27 Holm J, Palace V, Siwik P, Sterling G, Evans R, Baron C, Werner J, Wautier K (2005). Developmental Effects of Bioaccumulated Selenium in Eggs and Larvae of two Salmonid Species. *Environ. Toxicol. Chem.* 24: 2373-2381.

The Draft Selenium Assessment states, "[w]hen more than one endpoint was available for an individual species, the lowest preferred endpoint was chosen, following the CCME (2007) protocol."[28] This is inconsistent with the protocol. The 2007 CCME guidance states in Part II, Sections 1-10 and 1-11: "[m]ultiple comparable records for the same endpoint are to be combined by the geometric mean of these records to represent the average species effect endpoint," and in Part II, Section 3.1-2: "[i]f there is more than one comparable record for a preferred endpoint, then the species effect endpoint is to be represented by the geometric mean of these records."[29] Further guidance on the use of the geometric mean in developing SSDs is provided by Chapman (2015).[30]

The following values used in the supporting documentation for the fish egg/gonad calculated PNEC, which are all ≥ 20 µg/g dw, match the values used by DeForest *et al.* (2012):

- Brook trout, 20 µg/g dw.
- Northern pike, 20.4 µg/g dw.
- Yellowstone cutthroat trout, 25 µg/g dw.
- White sucker, 26 µg/g dw.
- Razorback sucker, 41.9 µg/g dw.
- Dolly Varden, 54 µg/g dw.

---

28 Draft Selenium Assessment, Page 25.

29 CCME (2007).

30 Chapman PM (2015). Including or Excluding Toxicity Test Data for Development of a Geometric Mean. *Environ. Toxicol. Chem.* 34: 1691-1692.

The U.S. Environmental Protection Agency (EPA) developed chronic benchmarks for eight of the twelve fish species for which PNECs were developed by Environment Canada and Health Canada in the Draft Selenium Assessment.[31] Species excluded by EPA were brook trout, razorback sucker, and white sucker; data for Westslope and Yellowstone cutthroat trout were combined. As outlined in Table 2, the EPA (2015) benchmarks are more similar to DeForest *et al.* (2012) than those included in the Draft Selenium Assessment. For five of the eight fish species, the EPA (2015) values are greater than those calculated by Environment Canada and Health Canada. The EPA (2015) document is generally similar to the EPA (2014)[32] document, which Environment Canada and Health Canada (2015) qualitatively considered in calculating their PNECs. Most of the values shown in Table 2 are the same in both EPA documents; thus, the two documents provide egg/ovary chronic benchmarks that only differ by 0.6 µg/g dw.

---

31 EPA (2015). Draft, Aquatic Life Ambient Water Quality Criterion for Selenium -- Freshwater 2015. EPA 822-P-15-001. Washington, DC, USA. *See* http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/selenium/.

32 EPA (2014). External Peer Review Draft, Aquatic Life Ambient Water Quality Criterion for Selenium -- Freshwater 2014. EPA 822-P-14-001. Washington, DC, USA. *See* http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/selenium/upload/seleniumdraft2014.pdf.

Table 2. Comparison of Environment Canada and Health Canada (2015) Calculated PNECs with EPA (2015) Chronic Benchmarks and DeForest *et al.* (2012) PNECs -- all values are in µg/g dw.

Fish	Environment Canada and Health Canada (2015)	EPA (2015)	DeForest *et al.* (2012)
Fathead minnow	10.92	<23.85	<23.6
Northern pike	20.4	34.00	20.4
Rainbow trout	21.1	21.1	23
Cutthroat trout[33]	17-25	22.71-24.45	21-25
Dolly Varden	54	56.22	54
Brown trout	17.7	18.09	20.8
Bluegill	12.68	17.95	21.5
Largemouth bass	20.35	20.35	22

The Draft Selenium Assessment's calculated PNEC for fish eggs/ovaries is technically flawed because incorrect values were used for 50 percent of the species considered, and because Environment Canada did not follow CCME protocols concerning geometric means, resulting in a calculated value that is not technically defensible. These issues must be addressed and the PNEC recalculated in the final assessment report. In particular, we request that the data for fathead minnows be reassessed.

2. Fish Whole Body PNEC

In addition to being below reference concentrations, the calculated fish whole body PNEC is unreasonably low compared to the calculated PNEC for fish egg/ovaries. As documented by DeForest *et al.* (2012), mean ratios between egg/ovary selenium concentrations and whole body selenium concentrations range from 2.0 to 2.4 for bluegills, 2.1 for fathead

33 EPA combined data for both Cutthroat and Westslope cutthroat trout.

minnow, and 1.3 for cutthroat trout.[34] EPA (2015) notes the ratio of egg/ovary selenium concentrations to whole body selenium concentrations ranges from 1.2 to 2.4 and sets conversion factors varying from 1.4 to 2.4.[35] Thus, even if the calculated Draft Selenium Assessment egg/gonad PNEC were appropriate, which NAMC does not believe to be the case, the corresponding whole body PNEC should be on the order of two-fold higher than currently calculated, based on the egg/gonad reproductive effects. At the egg/ovary PNEC of 20 µg/g dw derived by DeForest *et al.* (2012), whole body selenium concentrations would typically vary between 8.3 and 9.3 µg/g dw depending on the egg to whole body selenium ratio; this ratio should ideally be species- and site-specific.[36]

In the Draft Selenium Assessment, Health and Environment Canada have chosen to calculate a whole-body PNEC based on "<u>non</u>-reproductive chronic toxicity" rather than calculating a whole-body selenium PNEC based on reproductive effects. This approach ignores the scientific consensus that the most sensitive selenium toxicity endpoint for fish should be based on reproductive effects.[37] EPA states, "[s]elenium toxicity occurs primarily through transfer to the eggs and subsequent reproductive effects."[38] A selenium benchmark based on non-reproductive chronic toxicity has not been previously developed. Indeed, EPA (2014, 2015)

---

34 DeForest *et al.* (2012).

35 EPA (2015), Tables 3.5 and 3.12. Similar ratios appear in EPA (2014), Tables 7a and 8a.

36 DeForest *et al.* (2012).

37 Chapman PM, Adams WJ, Brooks ML, Delos CG, Luoma SN, Maher WA, Ohlendorf HM, Presser TS, Shaw DP (eds.) (2010). Ecological Assessment of Selenium in the Aquatic Environment. SETAC Press, Pensacola, FL, USA.

38 EPA (2015), page xi. The same wording appears in EPA (2014), page 1.

states that, although acceptable data on fish non-reproductive effects are available for seven fish species, "[t]he fish non-reproductive effects data were not used to calculate tissue criterion elements because they were more variable and less reproducible than the data on reproductive effects."[39]

In the Draft Selenium Assessment and the supporting documentation,[40] Environment Canada and Health Canada used ten studies to determine the "non-reproductive chronic toxicity." As noted above, EPA only considered seven studies to have acceptable data and used none of those data in its draft assessment.[41] Only four of the studies used in the Draft Selenium Assessment were listed as "reliable with restrictions" in the supporting documentation.[42] Although the wording "reliable with restrictions" suggests a Klimisch[43] rating of the studies, there is no evidence this was done and the restrictions, as noted below, are generally too significant for the studies to be considered reliable using a Klimisch rating. Review of the data sheets for the ten studies provided by Environment Canada indicates that the Hilton and Hodson (1983)[44] and the Tashjian *et al.* (2006)[45] studies should have been labeled in

---

39 *Id.*, Section 3.1.5, page 46. Similar wording appears in EPA (2014), page 57.

40 Environment Canada (2014b).

41 EPA (2015) and EPA (2014).

42 Environment Canada (2014b).

43 Klimisch HJ, Andreae M, Tillmann U (1997). A Systematic Approach for Evaluating the Quality of Experimental Toxicological and Ecotoxicological data. *Regul. Toxicol. Pharmacol.* 25:1-5.

44 Hilton JW, Hodson PV (1983). Effect of Increased Dietary Carbohydrate on Selenium Metabolism and Toxicity in Rainbow Trout. *J. Nutrition* 113:1241-1248.

the supporting document as "reliable with restrictions" in accord with the corresponding Environment Canada data sheets. The Hilton and Hodson (1983) study is labeled in the Environment Canada data sheets as "reliable with restrictions." Data from Tashjian *et al.* (2006) were specifically labeled "acceptable with restrictions" in the Environment Canada data sheets. The Thomas *et al.* (2013) study should have been considered unreliable due to lack of quality assurance/quality control data.[46] The Environment Canada data sheet for that study is incomplete and, in particular, does not justify or explain study reliability or data acceptability.

The term "reliable [or acceptable] with restrictions" includes the following problems that are not insignificant in a risk assessment process and not in accord with a Klimisch rating using that wording: lack of negative control; uncertainty whether statistical analyses were conducted; uncertainty whether the selenium concentration was actually measured in whole body; excessive loading densities causing stress; uncertain quality assurance/quality control (*e.g.*, photoperiod, water quality); and, uncertainty in the endpoints measured (per the Environment Canada data sheets). The reasons for considering any of these studies' data in the Draft Selenium Assessment are unclear.

---

45 Tashjian DH, The SJ, Sogonyan A, Hung SSO (2006). Bioaccumulation and Chronic Toxicity of Dietary l-Selenomethionine in Juvenile White Sturgeon (*Acipenser transmontanus*). *Aquat. Toxicol.* 79: 401-409.

46 Thomas JK, Wiseman S, Giesy JP, Janz DM (2013). Effects of Chronic Dietary Selenomethionine Exposure on Repeat Swimming Performance, Aerobic Metabolism and Methionine Catabolism in Adult Zebrafish (*Danio rerio*). *Aquat. Toxicol*. 130-131:112-122.

The data from the three remaining studies considered "reliable" in the supporting documentation[47] are also questionable. For example, Ogle and Knight (1989) exposed 60-d-old fathead minnow for ~135-d to a spiked diet of 25 percent seleno-L-methionine, 25 percent selenate, and 50 percent selenite at concentrations from 0.4 µg/g dw (control diet) to 29.5 µg/g dw.[48] This is problematic, as the diet was not primarily organic selenium as would occur in the natural environment.

The supporting documentation cited Beyers and Sodergren (2001) as two separate studies demonstrating no effect on survival or growth of flannelmouth suckers with 28-d exposure via diet at 10.2 µg/g dw, or razorback suckers via diet at 12.9 µg/g dw.[49] This publication, however, is not listed by either Beyers or Sodergren on their websites, nor could it be found by extensive web searches. Given that the existence of the Beyers and Sodergren (2001) study is in question, it is inappropriate for Environment Canada to classify it as "reliable."

Beyer and Sodergren (2002), an available, peer-reviewed publication that was neither cited nor used by Environment Canada (2014b), exposed larval razorback suckers for 28-

---

47 Environment Canada (2014b).

48 Ogle and Knight (1989).

49 Beyers DW, Sodergren C (2001). Assessment of Exposure of Larval Razorback Sucker to Selenium in Natural Waters and Evaluation of Laboratory-based Predictions. (Cited by Environment Canada (2014b) with only authors and title; could not be found via extensive web searchers for the authors and the title; not listed as a publication by either author on their website)**.**

d to site waters contaminated with selenium and measured survival and growth.[50] The overall conclusion of Beyer and Sodergren (2002) was that no selenium-related effects on survival or growth were observed at the highest dietary selenium concentration of 21.8 µg/g dw. Flannelmouth suckers breed (hybridize) with the razorback sucker (*Xyrauchen texanus),* and the white sucker (C*atostomus commersoni*)[51]; therefore, it is reasonable that the conclusions of Beyer and Sodergren (2002) likely apply to both flannelmouth and razorback suckers. As noted, the existence of the cited Beyer and Sodergren (2001) study is in doubt. Furthermore, it is not technically defensible to use an unbounded (*i.e*., a greater than) no effects value as a benchmark immediately above which effects occur. This is a further demonstration that the Beyers and Sodergren (2001) study cited by Environment Canada does not provide appropriate data points for two fish species for the development of the "non-reproductive chronic toxicity" PNEC.

The rationale provided in the Draft Selenium Assessment for a "non-reproductive chronic toxicity" endpoint is the fact that "selenium in adult fish muscle or whole-body is much more frequently available, and is an indicator of exposure of selenium in fish."[52] To accomplish this rationale, the Draft Selenium Assessment needs to be revised so it is based on technically defensible reproductive effects, using actual data in addition to conversion factors and computations available in EPA, rather than the current calculated approach based on technically questionable non-reproductive effects that are based on studies that are not fully reliable.

---

50 Beyers DW, Sodergren C (2002). Assessment of Exposure of Larval Razorback Sucker to Selenium in Natural Waters. *Arch. Environ. Contam. Toxicol.* 42:53-59.

51 The IUCN Red List of Threatened Species, *Catostomus latipinnis,* available at http://www.iucnredlist.org/details/202060/0.

52 Draft Selenium Assessment, page 27.

II. HARM TO BENTHIC AND SOIL ORGANISMS

A. Benthic Organisms

Data show that invertebrates are less sensitive than fish. As such, appropriate PNECs for fish will protect benthic invertebrates as well.

EPA found that invertebrates were less sensitive to selenium than fish, and amphibians were about as sensitive as fish to selenium.[53] Specifically, EPA states "[t]he studies that have been done with invertebrates (Table 3.3, Section 3.1.3) have shown them to be more tolerant than most of the tested fish species" and "amphibians have a similar sensitivity to fish."[54] EPA further states that "[t]he relative insensitivity of invertebrates when compared with the fish whole-body concentrations demonstrates that invertebrates are generally protected by selenium criterion values derived from fish."[55]

Gallego-Gallegos *et al.* found "little risk of direct Se (selenium) toxicity to benthic invertebrates in Se-contaminated sediments in northern Saskatchewan."[56] Rosabal *et al.*

---

53 EPA (2014) and EPA (2015).

54 EPA (2015), page 46. Similar wording appears in EPA (2014), page 57.

55 *Id.*, page 45. The same point is made in EPA (2014), page 2.

56 Gallego-Gallegos M, Doig LE, Tse JJ, Pickering IJ, Liber K (2013). Bioavailability, Toxicity and Biotransformation of Selenium in Midge (*Chironomus dilutus*) Larvae

found that "larvae exposed to low ambient concentrations… [are] able to manage higher concentrations…as well as insects that have been chronically exposed to high concentrations."[57] Kuchapski and Rasmussen (2015) found that “Waterborne Se concentration…did not have a significant relationship with Ephemeroptera density” and that selenium alone could not be implicated in shifts in macroinvertebrate assemblages related to surface coal mining; other factors that needed to be considered included ionic toxicity and physical habitat changes.[58]

As outlined above, because benthic invertebrates are less sensitive than fish to selenium, an appropriate PNEC to protect fish will also protect benthic invertebrates.

B. Soil Organisms

There is no robust scientific evidence to support the calculated soil PNEC of 1 µg/g dw in the Draft Selenium Assessment. This value is unrealistically low, relative to the documented benefits of enhancing selenium in soils, which is routinely done in areas of Canada and elsewhere. The calculated value is also below background for many parts of North America.

Exposed via Water or Diet to Elemental Selenium Particles, Selenite, or Selenized Algae. *Environ. Sci. Technol.* 47: 584-592.

57 Rosabal M, Ponton DE, Campbell PGC, Hare L (2015). Uptake and Subcellular Distributions of Cadmium and Selenium in Transplanted Aquatic Insect Larvae. *Environ. Sci. Technol.* 48: 12654-12661.

58 Kuchapski KA, Rasmussen JB (2015). Surface Coal Mining Influences on Macroinvertebrate Assemblages in Streams of the Canadian Rocky Mountains. *Environ. Toxicol. Chem.* doi 10.1002/etc.3052.

In the Draft Selenium Assessment, Environment Canada and Health Canada cite CCME (2009)[59] and state: "[t]he data indicate that selenium species found in soil generally have a moderate potential to cause harm to soil organisms."[60] Because there were insufficient data for derivation of an SSD, Environment Canada and Health Canada used the lowest observed effects concentration (LOEC) from Carlson *et al.* (1991) for ~60 percent reduced shoot growth in broomcorn (*Sorghum vulgare*), which was 1 µg/g soil.[61,62] The Draft Selenium Assessment indicates that this value is similar, but not identical, to one determined by Singh and Singh (1979) for cowpea (*Vigna sinensis*).[63]

NAMC is concerned because this calculated benchmark to protect soil organisms is based on a single study with a single plant species (broomcorn, a sorghum species originating from Africa), and the reliability of the study does not appear to have been assessed. As noted by Chapman and Elphick, PNECs should not be based on a single toxicity test.[64] Other studies, not cited by Environment Canada and Health Canada in the Draft Selenium Assessment, have shown the positive effects of selenium in soil and further suggest that the calculated soil PNEC is

59 CCME (2009). Canadian Soil Quality Guidelines: Selenium. Winnipeg, MN, Canada.

60 Draft Selenium Assessment, page 32.

61 Carlson C, Adriano DC, Dixon PM (1991). Effects of Soil-Applied Selenium on the Growth and Selenium Content of Forage Species. *J. Environ. Qual.* 20: 363-368.

62 Presumably the calculated soil value is in the units µg/g dw, but dw is not stated.

63 Singh M, Singh N (1979). The Effect of Forms of Selenium on the Accumulation of Selenium, Sulphur, and Forms of Nitrogen and Phosphorus in Forage Cowpea (*Vigna sinensis*). *Soil Sci.* 127: 264-269.

64 Chapman PM, Elphick JR (2015). Predicted No Effect Concentrations (PNECs) Should Not Be Based on a Single Toxicity Test. *Environ. Toxicol. Chem.* 34(5): 1088-1090.

inappropriate, relative to beneficial effects. For instance, Nawaz *et al.* (2015) found that the addition of selenium optimized the production of wheat under drought stress.[65] De Temmerman *et al.* (2014) recommend fertilizers enriched with selenium.[66] The Draft Selenium Assessment generally acknowledges that in areas of Canada, "soil supplementation [with selenium] and feed supplements are common practices to prevent nutritional deficiencies in grazing livestock."[67]

The calculated soil PNEC of 1 µg/g dw is not scientifically defensible and does not recognize the potential benefits of selenium in the soil.

III. RISKS TO SUBSISTENCE FISHERS

The Upper Tolerance Limit of 400 µg/L Se/d, as proposed in the Draft Selenium Assessment, is based on questionable Chinese studies and there is no recognition in the Draft Selenium Assessment that selenium is an essential micronutrient for human health. Environment Canada and Health Canada should consider the study by Lawrence and Chapman (2007), which is a peer-reviewed scientific publication that reports on a risk assessment of subsistence and other fishers consuming fish with elevated selenium concentrations around mining operations.

---

65 Nawaz F, Ahmad R, Ashraf MY, Waraich EA, Khan SZ (2015). Effect of Selenium Foliar Spray on Physiological and Biochemical Processes and Chemical Constituents of Wheat under Drought Stress. *Ecotoxicol. Environ. Saf.* 113: 191-200.

66 De Temmerman L, Waegeneers N, Thiry C, Du Laing G, Tack F, Ruttens A (2014). Selenium Content of Belgian Cultivated Soils and its Uptake by Field Crops and Vegetables. *Sci. Tot. Environ.* 468-9: 77-82.

67 Draft Selenium Assessment, page 62.

That study used a conservative value of 700 µg/L Se/d, and noted that clinical signs of selenosis only occur at intakes of 900 µg/L for sensitive subjects, not the general population.[68]

Further, as noted in the Draft Selenium Assessment, the Inuit have naturally elevated selenium as a result of eating traditional foods, with no evidence of selenosis. Aboriginal tribes in the Amazon also have naturally elevated selenium concentrations as a result of their traditional diet with no evidence of selenosis, rather, beneficial effects of elevated selenium status on motor functions.[69,70]

Finally, as noted in the Draft Selenium Assessment, selenium ameliorates the toxicity of mercury (and other substances). Relative to this, the document should reference the following two citations related to this benefit of selenium – Jones *et al.* (2013), which considers the implications to human health of selenium and mercury to fishers,[71] and Zhang *et al.* (2014), which proposes a new criterion for selenium and mercury exposure assessment, the Benefit Risk Value or Benefit-Risk Ratio that "considers not only the toxicological consequences of Hg

---

68 Lawrence GC, Chapman PM (2007). Human Health Risks of Selenium-Contaminated Fish: a Case Study for Risk Assessment of Essential Elements. *Human Ecol. Risk Assess.* 13: 1192-1213.

69 Lemire M, Philibert A, Fillion M, Passos CJS, Guimarães JRD, Barosa F Jr, Mergler D (2012). No Evidence of Selenosis from a Selenium-Rich Diet in the Brazilian Amazon. *Environ. Intl.* 40: 128-136.

70 Lemire M, Fillion M, Frenette B, CJS Passos, JRD Guinarães, F Barbosa Jr, D Mergler (2011). Selenium From Dietary Sources and Motor Functions in the Brazilian Amazon. *NeuroToxicology* 32: 944-953.

71 Jones HJ, Butler ECV, Macleod CK (2013). Spatial Variability in Selenium and Mercury Interactions in a Key Recreational Fish Species: Implications for Human Health and Environmental Monitoring. *Mar. Pollut. Bull.* 74: 231-236.

exposure but also the benefits and/or adverse effects of Se intake, especially the adverse effects related to a Se deficiency/excess."[72]

IV. RECOMMENDATIONS

Below is a summary of NAMC's recommended changes to the Draft Selenium Assessment. The scientific bases for these recommendations are articulated in the preceding sections.

Fish Egg/Ovary PNEC

NAMC strongly recommends that Environment Canada adopt the egg/ovary PNEC developed by DeForest *et al.* (2012) of 20 µg/g dw, which is above the highest documented reference concentration of ~ 19 µg/g dw. That PNEC in DeForest *et al.* (2012) was based on a species sensitivity distribution (SSD) following CCME (2007) guidance, was published in an international peer-reviewed journal, and as the authors note "should be considered a conservative, broadly applicable guideline to Canadian species, as no species mean toxicity thresholds lower than this value have been identified to date."

Fish Whole Body PNEC

The fish whole body PNEC should be based on reproductive impairment and, as such, should be generically between about 42 and 47 percent of the egg/ovary PNEC, although ideally determined on a species- and site-specific basis (DeForest *et al.* 2012).

Benthic Organisms

The Draft Selenium Assessment should conclude that benthic organisms are not at risk from selenium if an appropriate, protective fish egg/ovary PNEC is developed.

72 Zhang H, Feng X, Chan HM, Larssen T (2014). New Insights into Traditional Health Risk Assessments of Mercury Exposure: Implications of Selenium. *Environ. Sci. Technol.* 48: 1206-1212.

Soil Organisms

A PNEC for soil organisms should not be calculated because the available data are insufficient to provide the technical justification for such a benchmark.

Risks to Subsistence Fishers

The Draft Selenium Assessment should include Lawrence and Chapman (2007), and other relevant publications noted herein when revising the Draft Screening Assessment.

For all the reasons noted above, NAMC urges Environment Canada and Health Canada to reconsider and to revise the elements in the Draft Selenium Assessment as outlined above such that they are technically defensible. If implemented without revision, the resulting high rate of false alarms will result in a serious misallocation of resources, thereby reducing rather than enhancing the Canada's ability to address environmental problems and unnecessarily penalizing industrial activities with concomitant economic costs, but without concomitant environmental benefits. NAMC is hoping we will have a continuing dialogue as Canada goes forward with its actions under the Canadian Environmental Protection Act (CEPA).