MDAG.com Internet Case Study 90

Dangerous Confusion in Canada on Water-Quality Guidelines and Benchmarks for Fluoride

by K.A. Morin
© 2026 Kevin A. Morin
www.mdag.com/case_studies.html

Summary

A safe and widely reliable water-quality guideline for fluoride in Canada is important because:

> "Aquatic animals bioaccumulate fluoride from water and food, with the majority accumulating in bones and teeth rather than soft tissue..." (McPherson et al., 2014)

Thus, any ongoing exposure to fluoride can lead to ongoing and increasing bioaccumulation. To manage this, the current interim guideline (benchmark) by the Canadian Council of Ministers of the Environment (CCME) is 0.12 mg/L.

In 2014, a Canadian study compiled and re-interpreted previous published and unpublished toxicity studies of various types including acutely toxic tests (McPherson et al., 2014). This led the authors to derive a much higher, yet "conservatively protective" benchmark for chronic toxicity of 1.94 mg/L that was 16 times higher than the CCME guideline. However, despite several unreliable and wrong calculations and interpretations in the original work, one valid interpretation shown here is that the CCME guideline of 0.12 mg/L is in fact appropriate and not overly safe. To summarize, a reasonable benchmark for fluoride, (1) corrected from statistically invalid curve fitting, (2) applied to an incorrectly converted categorical variable, (3) extended into the sensitive but unmeasured range at and below 5%, (4) based on unreliably interpreted data, and (5) including ambiguous or incorrect confidence limits, could in reality be at least as low as ~0.4 mg/L and possibly ~0.1 mg/L with confidence limits. This is within a factor of 3 to 4 of the current CCME guideline. Comparisons of Spain and Canada further support the safe and reliable CCME guideline of 0.12 mg/L.

1. Introduction

As with the previous MDAG Case Study #88 on molybdenum (Morin, 2026), this MDAG Case Study #90 focuses on a natural element in the Periodic Table. The statements here may not apply to human-made and organic contaminants.

Wikipedia (2026) provides a helpful overview on the meaning of toxicity, touching on its true complexity:

> "Toxicity is the degree to which a chemical substance or a particular mixture of substances can damage an organism. Toxicity can refer to the effect on a whole organism, such as an animal, bacterium, or plant, as well as the effect on a substructure of the organism, such as a cell (cytotoxicity) or an organ such as the liver (hepatotoxicity). Sometimes the word is more or less synonymous with poisoning in everyday usage.

> "A central concept of toxicology is that the effects of a toxicant are dose-dependent; even water can lead to water intoxication when taken in too high a dose, whereas for even a very toxic substance such as snake venom there is a dose below which there is no detectable toxic effect. Toxicity is species-specific, making cross-species analysis problematic."

There are many types of toxicity, such as acute toxicity, reproductive toxicity, and neurotoxicity (e.g., Morin, 2025).

One way that toxicity is simplified is through water-quality guidelines and criteria expressed in units such as mg/L, as total (unfiltered) or dissolved (filtered) aqueous concentrations. This simplification is not highly accurate, but provides a relatively simple and approximate way to estimate whether a water sample may be toxic in some way.

Interestingly, the toxicities of some natural elements are so poorly defined that there are no well-established water-quality guidelines for them. As a result, many natural elements are "emerging" contaminants, such as platinum, ruthenium, rhodium, palladium, osmium, and iridium (Morin, 2022).

In Canada, the federal government, through its Canadian Council of Ministers of the Environment (CCME), has created a list of water-quality guidelines designed to be safe for all lifeforms at all life stages. Additionally, some Canadian provinces have created water-quality guidelines differing somewhat from CCME values and/or including potential contaminants not listed by CCME. Some guidelines can be higher than CCME due to their unreliable assumption of "additional safety factors" incorporated into CCME values.

These federal and provincial water-quality guidelines are often developed for specific ecosystems like freshwater or marine aquatic life, agriculture (vegetation), ruminant and non-ruminant animals, and subsurface groundwater. Guidelines for drinking water by humans are often developed separately from the other "ecosystems".

2. The Errors and Ambiguity

In Canada, the federal long-term CCME guideline for fluoride in freshwater ecosystems is 0.12 mg/L (https://ccme.ca/en/summary-table), considered an interim value when developed in 2002. A Canada-based literature review in 2014 (McPherson et al., 2014) compiled and re-interpreted fluoride-toxicity studies to develop a much higher chronic effect benchmark of 1.94 mg/L. These authors explained:

> "The proposed fluoride chronic effects benchmark of 1.94 mg/L F is approximately 10-fold higher than the 2002 Canadian WQC for fluoride of 0.12 mg/L inorganic fluoride [1] but similar to the 2003 North Carolina (USA) benchmark of 1.8 mg/L [8]. It was developed based on the most appropriate data available, including both studies used in those previous benchmarks and newer studies, using the recognized and accepted species sensitivity distribution approach [9]. However, it does not consider the potential for toxicity modifying factors to reduce fluoride toxicity... The proposed generic fluoride freshwater chronic effects benchmark of 1.94 mg/L F should be regarded as conservatively protective because it does not consider the above-noted factors that can reduce fluoride toxicity (i.e., lower water temperature, higher water hardness, higher chloride concentrations)."

Despite such strong findings of a higher, "conservatively protective" benchmark of 1.94 mg/L, McPherson et al. (2014) contains questionable and incorrect re-interpretations and, in the end, a major flaw. These show that the interim CCME guideline for fluoride of 0.12 mg/L is in fact generally within the range of probable values for fluoride toxicity based on the literature compilation of McPherson et al. (2014).

A safe and widely reliable water-quality guideline for fluoride in Canada is important because (McPherson et al., 2014):

> "Aquatic animals bioaccumulate fluoride from water and food, with the majority accumulating in bones and teeth rather than soft tissue..."

Thus, any ongoing exposure to fluoride can lead to ongoing and increasing bioaccumulation.

All interpretations of fluoride toxicity in McPherson et al. (2014) come from the authors' Table 1 copied below, which the authors explain as:

> "A total of 10 chronic studies representing 16 species (5 fish, 7 invertebrates, and 4 algae/aquatic plants) were used to derive a chronic effects benchmark..."

Table 1. A copy of Table 1 from McPherson et al. (2014).

Table 1. Chronic toxicity data used to generate the species sensitivity distribution for fluoride

Citation	Test species	Common name	End point	Concentration (mg/L F)	Species mean chronic value	Rank	Percent affected
Pearcy et al.[a]	*Hyalella azteca*	Amphipod	IC10	1.8	1.8	1	3%
[25]	*Musculium transversum*	Fingernail clam	MATC	2.25	2.25	2	9%
[15]	*Oncorhynchus mykiss*	Rainbow trout	LC20	2.0	3.1	3	16%
[14]	*Oncorhynchus mykiss*	Rainbow trout	LC10	4.8	3.1	3	16%
[23]	*Potamopyrgus antipodarum*	New Zealand mud snail	MATC	6.6	6.6	4	22%
[17]	*Acipenser baerii*	Siberian sturgeon	IC10	7.7	7.7	5	28%
Pearcy et al.	*Chironomus dilutus*	Midge	IC20	8.2	8.2	6	34%
Pearcy et al.	*Ceriodaphnia dubia*	Water flea	IC10	10.6	10.6	7	41%
[15]	*Cyprinus carpio*	Common carp	LC20	25	25	8	47%
[21]	*Daphnia magna*	Water flea	IC10	27.7	27.7	9	53%
[15]	*Pimephales promelas*	Fathead minnow	IC25	72	32.4	10	59%
Pearcy et al.	*Pimephales promelas*	Fathead minnow	IC10	14.6	32.4	10	59%
[29]	*Synechococcus leopoliensis*	Algae	EC13	50	50	11	66%
[24]	*Alasmidonta raveneliana*	Unionid mussel	IC10	91	91	12	72%
[30]	*Chlorella vulgaris*	Algae	IC11	95	95	13	78%
Pearcy et al.	*Lemna minor*	Duckweed	IC10	125	125	14	84%
Pearcy et al.	*Salvelinus namaycush*	Lake trout	IC10	>134	134	15	91%
Pearcy et al.	*Pseudokirchneriella subcapitata*	Algae	IC10	195	195	16	97%

[a]K.L. Pearcy, Nautilus Environmental, Burnaby, British Columbia, Canada, unpublished manuscript.
IC20 = 20% inhibitory concentration; MATC = maximum acceptable toxicant concentration; LC20 = 20% lethal concentration; EC13 = 13% effective concentration.

Based on this Table 1, the authors then created Figure 1 also copied below, which includes a fitted statistical Gumbel curve to derive a fluoride benchmark of 1.94 mg/L. This includes 95% confidence limits that show that 1.94 mg/L is the most-probable central tendency in a range of ~0.5 to ~4 mg/L. Note the anomalous near-horizontal "steps" in the distribution of the datapoints in Figure 1.

Of note, a later letter to the editor (Sinclair and MacDonald, 2015), and the authors' subsequent response (Chapman et al., 2015), explained that a more reliable statistical curve shows a lower fluoride benchmark of 1.03 mg/L, instead of 1.94 mg/L, using a normal distribution. The confidence limits indicated the corrected 1.03 mg/L is the most-probable central tendency within confidence limits of ~0.6 mg/L to ~2 mg/L. This revised curve is copied as Figure 2 below, with this new curve based on the original datapoints except for two adjustments discussed below.

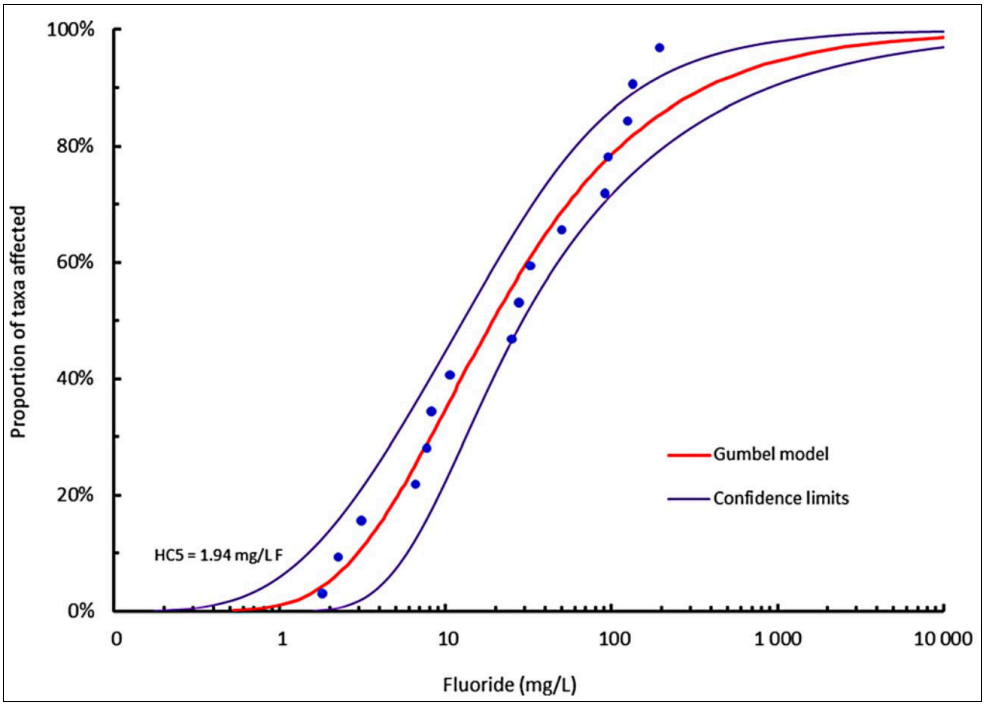

Figure 1. A copy of Figure 1 from McPherson et al. (2014).

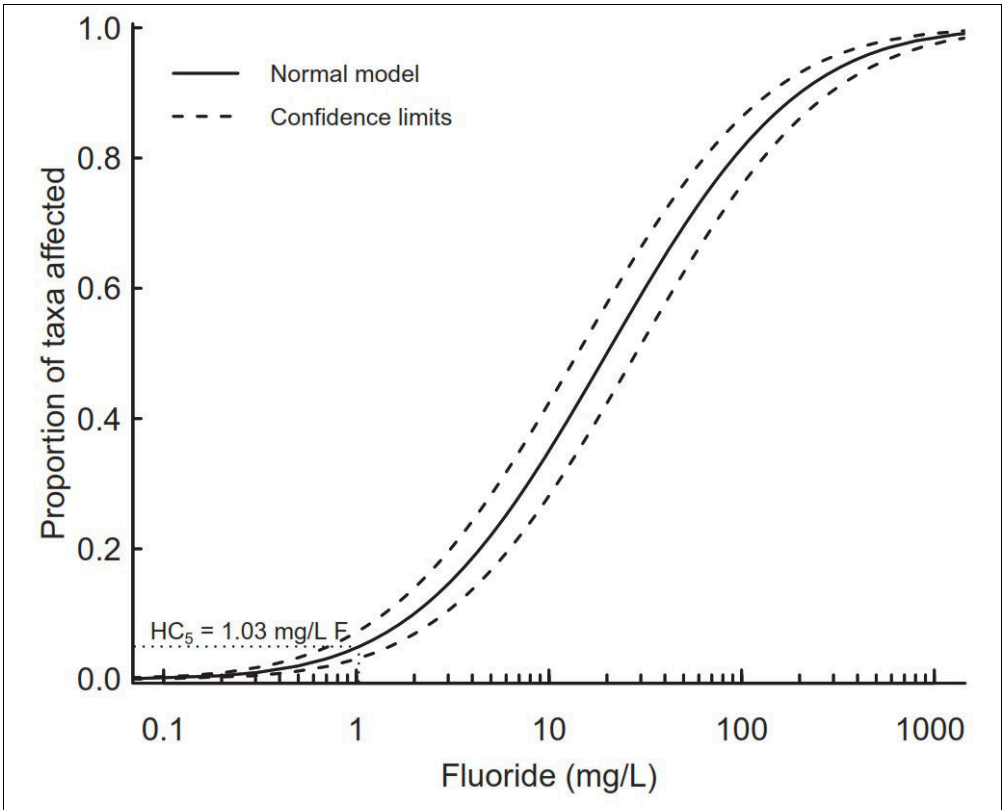

Figure 1. Results of the species sensitivity distribution (SSD) for fluoride described using the normal model. HC5 = 5% hazardous concentration.

Figure 2. A copy of Figure 1 from Sinclair and MacDonald (2015); datapoints mostly the same as Figure 1 were not plotted in the original reference.

However, neither of these benchmark values and their confidence limits recognize the major errors that invalidate these two benchmark values of 1.94 and corrected 1.03 mg/L plus their confidence limits.

McPherson et al. (2014) explained cryptically and not fully:

> "For example, if both an EC10 and an EC20 were reported for an end point, then the EC10 was selected; and if both lethal and sublethal effects were assessed, then only the more sensitive end point was selected. If end points from multiple studies were available for a particular species, then a species mean chronic value was calculated as the geometric mean of the most suitable end point from each study."

These authors did much more than this in manipulating the toxicity data.

McPherson et al. (2014) mixed many types of acutely toxic and chronic toxicity data in an unreliable attempt to estimate only chronic toxicity. For example, McPherson et al. (2014) explained (and watch for LC vs. EC vs. IC vs. NOEC vs. LOEC vs. MATC)

> "Test end points are expressed in terms of the concentration of fluoride, not the inorganic salt (i.e., mg/L F, not mg/L [NaF]). The LCx is the concentration of test material estimated to be lethal to x% of the test organisms (e.g., LC20); the ECx is the concentration of test material estimated to cause a specified nonlethal effect to x% of the test organisms (e.g., EC20). The ICx is the concentration of test material estimated to cause x% inhibition in a sublethal end point such as growth or reproduction. The no-observed-effect concentration (NOEC) is the highest concentration tested for which there was no statistically significant response compared with the negative control. The LOEC is the lowest concentration tested for which there was a statistically significant response relative to the negative control. The maximum acceptable toxicant concentration (MATC) is the geometric mean of the NOEC and LOEC."

Toxicity tests like LC and EC are conducted during fixed, predetermined time intervals, but these differing time intervals are not considered by McPherson et al. (2014) in their Table 1 of data, and their resulting Figure 1. Interestingly, despite the stated importance of NOEC and LOEC given in the quotation above, the authors' Table 1 and Figure 1 show only two MATC values averaged from NOEC and LOEC values. Instead, their Table 1 and the figure show a mixture of several types of toxicity tests, like the proverbial "comparing apples and oranges". McPherson et al. (2014) avoid explaining all these confusing and likely unreliable approaches by explaining only the non-acutely-toxic studies:

> "Because the objective of the present study was to develop a chronic effects benchmark for fluoride, only the chronic and subchronic toxicity studies are summarized below."

Nevertheless, acutely lethal LC data were obviously used in their Table 1 and Figure 1.

The authors' Table 1 includes 3 LC values, along with 12 IC values, 1 EC value, and 2 MATC values. These are all mixed on a single diagram by manipulating acute and chronic toxicity data to create a "Species mean chronic value" (the third column from the right in Table 1).

For example, for common carp fish, the LC20 concentration for fluoride was 25 mg/L, meaning 20% of fish died after an unstated but predetermined time. The authors convert this 25 mg/L, unchanged, over to a non-acutely-lethal "Species mean chronic value". So a non-acutely-lethal chronic value is the same as acutely toxic concentration that killed 20% of the fish? If a lower value had been used for this and other species, the slope of the curve in Figure 1 would have been changed. This would

lead to a significantly different fluoride benchmark based on the 5% line on the y-axis representing the most sensitive 5% of species compiled by McPherson et al. (2014).

The authors' Table 1 lists two different species twice: rainbow trout and fathead minnow. For rainbow trout, two different studies yielded an LC10 value of 4.8 mg/L and an LC20 value of 2.0 mg/L, so these were averaged together geometrically to obtain 3.1 mg/L. It is logically unreliable to estimate a non-acutely-toxic chronic level that is the average of two acutely toxic levels. Meanwhile, note the higher concentration for the lower toxicity of LC10, likely representing differences between studies that McPherson et al. (2014) do not explain:

> "Because the objective of the present study was to develop a chronic effects benchmark for fluoride, only the chronic and subchronic toxicity studies are summarized below."

When this discrepancy was pointed out (Sinclair and MacDonald, 2015), the authors' response was to brush it off by stating at least they did not use the LC10 value but the averaged value (Chapman et al., 2015). Sinclair and MacDonald used the lower of the two LC values.

Similarly, the two values for fathead minnow were IC10 of 14.6 mg/L and IC25 of 72 mg/L from two separate studies, which were averaged together to obtain 32.4 mg/L. At best, the lowest LC and lowest IC values should be used for Table 1 and Figure 1, as Sinclair and MacDonald (2015) did, rather than a higher, averaged value of two toxicities.

Seven of 18 chronic values (~40%) in the authors' Table 1 came from an unpublished, and thus non-peer-reviewed, manuscript. As a result, nearly half (~40%) of the values used by McPherson et al. (2014) were unverified, not peer reviewed, and thus should not be relied on for calculating a chronic benchmark for fluoride. Nevertheless, McPherson et al (2014) concluded:

> "The proposed generic fluoride freshwater chronic effects benchmark of 1.94 mg/L F should be regarded as conservatively protective..."

These authors later explained in Chapman et al. (2015) that the non-published data were later published in Pearcy et al. (2015).

It is important to note that McPherson et al. (2014) is <u>not</u> recommending the CCME guideline of 0.12 mg/L be raised. Nevertheless, the authors still stand by their chronic benchmark of 1.94 mg/L, not the corrected one of 1.03 mg/L (Chapman et al., 2015):

> "We continue to believe that our proposed chronic effects benchmark of 1.94 mg/L F^-, which is almost the same as the chronic effects benchmark of 1.9 mg/L F^- developed by Pearcy et al. (K.L. Pearcy, unpublished data), is adequately protective. We are not proposing that it become a Canadian Council of Ministers of the Environment water quality guideline..."

3. The Major Error That Invalidates the Published Fluoride Benchmarks

As explained in the previous section, McPherson et al. (2014) determined the chronic-toxicity benchmark for fluoride based on more than a dozen toxicity studies in published literature (with ~40% of the results from a single study). Their benchmark is 1.94 mg/L, based on their Table 1 and Figure 1 copied above. There is later discussion that the benchmark should instead be 1.03 mg/L (Sinclair and MacDonald, 2015; Chapman et al., 2015), as shown with a revised fitted curve in Figure 2 above.

As explained in the previous section above, there are several issues with data manipulation and interpretation including averaging of toxicity data and mixing LC, EC and IC results. Even under the best-case assumption that all data in Table 1 of McPherson et al. (2014) and of Sinclair and MacDonald (2015) are highly reliable and valid, there is still a major error that shows both benchmarks are unreliable and that the current CCME guideline of 0.12 mg/L is reasonable.

McPherson et al. (2014) explained that their Figure 1 for fluoride is based on:

> "A total of 10 chronic studies representing 16 species (5 fish, 7 invertebrates, and 4 algae/aquatic plants) were used to derive a chronic effects benchmark..."

The second-from-right column of Table 1 sorts the 16 species according to Rank, counting from 1 to 16, obviously given as a whole integer. Rank is a "categorical variable". It is not a numerical variable including non-integer values such as 2.25 or 34.2 as exists for the authors' "Species mean chronic value" in the column to its left. As a result, most correlations and curve fittings have no reliable quantitative meaning with Rank on one axis and Species mean chronic value on the other axis.

To get around this problem, and to nominally meet the "5% of most sensitive species" rule for CCME, McPherson et al. (2014) and Sinclair and MacDonald (2015) converted Rank into the numerical variable of "Percent affected" in the rightmost column. Note in Table 1 that the most sensitive species of Rank 1 is given as 3% of "Percent affected" out of the 16 evaluated species.

With 16 species, each species mathematically represents 6.25% (1/16) of the total species/taxa, plotted on the y-axis of Figure 1. Under the CCME requirement of 5% of species rule, this work by McPherson et al. (2014) and Sinclair and MacDonald (2015) fails and cannot be used because there were no 5% of sensitive species, only one that is 6.25% most sensitive. Also, there were no no-observable-effect concentrations (NOEC) and lowest-observable-effect concentrations (LOEC) for the most-sensitive 5% of species to identify and constrain the benchmark more reliably.

Undaunted, McPherson et al. (2014) and Sinclair and MacDonald (2015) manipulated the results for the y-axis using the following equation to get a value of 3.125% for the most sensitive species and other values for the other species:

> "Percent affected = (X - 0.5)/N
>
> where X is the species rank, with 1 being the most sensitive species, and N is the total number of species in the database."

Therefore, the most sensitive species assigned Rank #1 in this equation (leftmost datapoint in Figure 1) represents 6.25% of the total species/taxa. However, the authors plot it at 3.125% of species as if there were 32 or more species studied, thus allowing a seemingly valid assessment under the CCME 5% rule.

In other words, the entire first vertical interval on the-axis for the most sensitive species on the left can be plotted anywhere in the interval of ~0 to 6.25% and remain valid. A more formal way to explain is: the categorical variable of Rank has a flat probability distribution function across its possible values of ~0 to 6.25% and there is no more-probable central tendency such as at 3.125% - all values in that interval of ~0% to 6.25% are equally probable.

To be clear, extending a curve to lower values in order to obtain a 5% value on the y-axis is

unreliable when the single lowest measured value is up to 6.25%. This is why McPherson et al. (2014) had to manipulate the leftmost datapoint to a value less than 5%.

This means the curves in Figures 1 and 2 can conceptually "slide" up and down vertically by 6.25% on the y-axis, leading to substantially different benchmarks and confidence limits for fluoride each time.

Upon conceptually vertically "sliding" the curve in Figure 1 and the corrected curve in Figure 2 up from 3.125% to just-as-valid 6.25%:

a) the resulting fluoride benchmark of Figure 1 becomes ~1.3 mg/L instead of the now incorrect 1.94 mg/L, and the benchmark of Figure 2 becomes ~0.4 mg/L instead of the now incorrect "corrected" value of 1.03 mg/L, and
b) the lower confidence levels decrease to ~0.5 mg/L and ~0.2 mg/L, respectively.

Therefore, the corrected benchmark (Figure 2) of 1.03 mg/L, using statistically invalid curve fitting, applied to an incorrectly converted categorical variable, extended into the sensitive but unmeasured range at and below 5%, based on unreliable data, could in reality be ~0.4 mg/L with a lower confidence limit of ~0.2 mg/L.

This leads to the next part of the error. Figure 1 above from McPherson et al. (2014) shows a best-fit "Gumbel model" with upper and lower "Confidence limits" (95%?), with no detailed explanation of how these were calculated and what they mean. However, Figure 2 above taken from Sinclair and MacDonald (2015) shows a best-fit "Normal model" with upper and lower "Confidence limits" (95%?). In fact, four statistical models were examined in Table 2 of Sinclair and MacDonald: Normal, Logistic, Extreme Value, and Gumbel, including their Anderson-Darling statistic and their "MSE [mean-square-error] lower tail".

For both the original data of McPherson et al. (2014) and the few adjustments of Sinclair and MacDonald (2015), the Normal model has only a slightly better statistical fit than the Logistic model according to the Anderson-Darling statistic, within 8% which is likely within the range of uncertainty based on the questionable data discussed above. Nevertheless, this is why the preferred "Normal model" is shown in Figure 2 above. However, this next-best and close-match Logistic model estimates a fluoride benchmark of 0.81 mg/L with a lower confidence limit of 0.39 mg/L, compared with the benchmark of 1.03 mg/L with a lower confidence limit of 0.72 mg/L for the Normal model.

Next, the Anderson-Darling statistic for the third, Extreme value model is within 15% of that for the Normal model which is likely within the range of uncertainty based on the questionable data discussed above. For the close-match Extreme value model, the fluoride benchmark is 0.35 mg/L (only three times higher than the CCME guideline) with a lower confidence limit of 0.12 mg/L (the same as the CCME guideline!). This shows how sensitive the benchmark value and confidence limits are to the statistical models having relatively small differences in their best-fit statistics. Additionally, a visual comparison of Figures 1 and 2 above reveals that the Normal model in Figure 2 does not visually match the datapoints as well as Figure 1 due to its lower slope.

Finally, both Figure 1 and Figure 2 show symmetrical lower and upper confidence limits on either side of the solid line, with the x-axis on a logarithmic scale. Thus, the symmetry of the confidence limits implies that a lognormal rather than normal distribution was assumed for calculating the confidence limits, but this is not explained or justified. As a result, the meaning and calculation of

confidence limits in both Figure 1 (McPherson et al., 2014) and Figure 2 (Sinclair and MacDonald, 2015) are ambiguous at best and could well be wrong for the data.

Because the current interim CCME guideline is 0.12 mg/L, within approximately a factor of 3 to 4 of some of the reasonably alternative benchmarks and their lower confidence limits, there is no significant justification to raise the current CCME level of 0.12 mg/L. Therefore, McPherson et al. (2014), Sinclair and MacDonald (2015), and Chapman et al. (2015) offer no statistically valid reasons to accept their chosen water-quality benchmarks in Figures 1 and 2 despite their strong but incorrect belief:

> "We continue to believe that our proposed chronic effects benchmark of 1.94 mg/L F^-, which is almost the same as the chronic effects benchmark of 1.9 mg/L F^- developed by Pearcy et al. (K.L. Pearcy, unpublished data), is adequately protective. We are not proposing that it become a Canadian Council of Ministers of the Environment water quality guideline..."

4. Other, International Views on the Validity of the Canadian CCME Guideline of 0.12 mg/L

Others have emphasized that a CCME level of 0.12 mg/L for fluoride is safe and appropriate based on comparisons with Spain:

> "It should be evident that the best and most reasonable national water quality criteria for fluoride would be those that match natural levels of fluoride in the fresh waters of each country. A less restrictive but still reasonably valid alternative is to establish water quality guidelines for fluoride that essentially protect the most sensitive native species, especially if those species contribute significantly to the structure and function of aquatic ecosystems. This is the case of freshwater caddisflies, mayflies, amphipods, and upstream migrating salmons. Therefore, in the event that the interim Canadian water quality guideline of 0.12 mg F^-/l (Environment Canada, 2001) must be revised upwards, I recommend raising it to a maximum level of 0.2 mg F^-/L." (Carmago, 2022) *[MDAG Note: a maximum of 0.2 mg/L is about the same as the lower confidence interval at 5%-of-species in the corrected Canadian fluoride study of Sinclair and MacDonald, 2015.]*

> "Although anthropogenic fluoride (F^-) pollution is a serious worldwide environmental problem, only a few countries have currently established national water quality criteria for the protection of freshwater biota. Since Canada is a global leader in biodiversity conservation that exhibits restrictive water quality benchmarks, I carry out a comparative analysis of water quality guidelines for fluoride in Canada and Spain. The Canadian water quality benchmark of 0.12 mg F^-/l (maximum allowable concentration) prevents Canada's fresh waters from significant adverse events of fluoride pollution, thereby protecting sensitive native aquatic invertebrates and adult-migrating Pacific salmon. By contrast, the Spanish water quality benchmark of 1.7 mg F^-/l (annual mean concentration) allows not only continuous levels of fluoride pollution more than six times higher than natural fluoride concentrations in the fresh waters of mainland Spain, but also much higher discontinuous levels of fluoride pollution (> 15 mg F^-/l). This unacceptable scenario is contrary to the current environmental goal of 'zero pollution' in the European Union. In view of the existing toxicological data, a Spanish water quality guideline of 0.15-0.3 mg F^-/l (maximum allowable concentration) seems much more reasonable. The recommended water quality guideline for fluoride would much better protect sensitive native fish and invertebrate species, and prevent significant bioaccumulation of fluoride in tolerant freshwater

organisms." (Carmago, 2024) *[MDAG Note: a range of 0.15 to 0.30 mg/L is within the lower 5%-of-species confidence interval of the corrected Canadian fluoride study of Sinclair and MacDonald, 2015, and close to the current CCME guideline.]*

5. Conclusion

Due to several unreliable and wrong calculations and interpretations in the original work of McPherson et al. (2014), Sinclair and MacDonald (2015), and Chapman et al. (2015), one valid interpretation shown here is that the CCME guideline of 0.12 mg/L is in fact reasonable and not overly safe. To summarize, a reasonable water-quality benchmark for fluoride, (1) corrected from unreliable curve fitting, (2) applied to an incorrectly converted categorical variable, (3) extended into the sensitive but unmeasured range at and below 5%, (4) based on unreliably interpreted data, and (5) including ambiguous or incorrect confidence limits, could in reality be at least as low as ~0.4 mg/L and possibly ~0.1 mg/L. This is within a factor of 3 to 4 of the current CCME guideline. Comparisons of Spain and Canada further support the safe and reliable CCME guideline of 0.12 mg/L.

6. References

Carmago, J.A. 2024. A comparative analysis of water quality guidelines for fluoride in Canada and Spain. Limnetica, 43, p. 229-237. DOI: 10.23818/lim.43.15

Carmago, J.A. 2022. Letter to the Editor on Parker et al. 2022 "Development of Fluoride Protective Values for Aquatic Life Using Empirical Bioavailability Models". Environmental Toxicology and Chemistry, 41, p. 2045-2047. DOI: 10.1002/etc.5408

Chapman, P.M., C.A. McPherson, D.H.Y. Lee. 2015. Author's Reply. Environmental Toxicology and Chemistry, 34, p. 1944-1945. DOI: 10.1002/etc.3095

McPherson, C.A., D.H.Y. Lee, and P.M. Chapman. 2014. Development of a fluoride chronic effects benchmark for aquatic life in freshwater. Environmental Toxicology and Chemistry, 33, p. 2621-2627. Doi: 10.1002/etc.2724

Morin, K.A. 2026. Dangerous Confusion in Canada on Water-Quality Guidelines and Criteria for Molybdenum. MDAG Internet Case Study #88, www.mdag.com/case_studies.html

Morin, K.A. 2025. Oversimplification of Toxicity and Bioavailability in ML-ARD Studies. MDAG Internet Case Study #84, www.mdag.com/case_studies.html

Morin, K.A. 2022. Platinum Group Metals as Water-Borne Contaminants at Mining Operations. MDAG Internet Case Study #74, www.mdag.com/case_studies.html

Pearcy, K., J. Elphick, and C. Burnett-Seidel. 2015. Toxicity of Fluoride to Aquatic Species and Evaluation of Toxicity Modifying Factors. Environmental Toxicology and Chemistry, 34, p. 1642-1948. DOI: 10.1002/etc.296

Sinclair, J.A., and D.D. MacDonald. 2015. Letter to the Editor. Environmental Toxicology and Chemistry, 34, p. 1942-1943. DOI: 10.1002/etc.3094

Wikipedia.org. 2026. Toxicity. Accessed June 2026 at: https://en.wikipedia.org/wiki/Toxicity