Adding Error Estimates to EPA's NH_3 Recalculation Criteria

Addendum to Richards 2016 Draft Report.

Version 1.2

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Justification

EPA reported Final Acute Values (FAVs) and chronic values as point estimates without any error associated in their ammonia water criteria (USEPA 2013b). Richards 2016 discussed that including error estimates was crucial for useful ammonia criteria and that omission of error estimates was cause for concern. Subsequently error estimates were made using EPA's sensitivity values reported by EPA in Appendix A (USEPA 2013b) in this addendum.

Methods

Species toxicity values were compiled from Appendix A (USEPA 2013b). Geometric means and standard errors and 90% confidence intervals (CIs) of the means were calculated, as was the sample size. One standard error and 90% CIs as opposed to more commonly used two standard errors and 95% CIs were calculated to avoid the extremely large variability estimates associated with the dataset and which would have resulted in essentially useless wide intervals. Discrepancies between calculated values presented here and by EPA for several taxa are noted and discussed. Final Acute Values (FAVs) were then calculated at one standard error less than the mean and one standard error greater than the mean. Chronic values were calculated by using results from the error estimates for FAVs.

Results

Geometric means, standard errors, 90% CIs, and sample sizes (N) are in Table 1. It was evident that there was a wide range in error estimates and that a simple geometric mean was not likely to reflect sensitivity values with any precision. Many species had been only tested on one occasion (N = 1) and no error estimates were obtainable. 90% CIs for species with few tests (N < 5 or so) had very large intervals. For example, *Hyalella azteca* (N = 3 test scores) 90% CIs were between 53.40 and 694.44 mg TAN/L (Table 1). Cursory examination showed a trend that increased sample size resulted in less error estimation, whereas fewer test samples tended to have wider error estimates.

Table 1. Species Mean Acute Values (mg TAN/L), +/- 1 standard error (S.E.), lower and upper 90% confidence intervals (CIs), and number of tests (N) used in EPA 2013b, Appendix A.

Species	**SMAV (mg TAN/L)**	- 1 S.E.	+ 1S.E.	Lower 90% CI	Upper 90% CI	N
Acipenser brevirostrum	156.7	NA	NA	NA	NA	1
Actinonaias ligamentina	63.89	52.96	74.82	42.71	95.55	4
Actinonaias pectorosa	79.46	75.71	79.46	58.99	107.03	2
Alasmidonta heterodon	>109.0	NA	NA	NA	NA	1
Asellus aquaticus	378.2	333.99	422.41	304.31	470.03	9
Caecidotea racovitzai	387	313.50	460.50	222.26	673.86	3
Callibaetis skokianus	364.6	302.16	427.04	123.64	1075.08	2
Callibaetis sp.	166.7	NA	NA	NA	NA	1

Campostoma anomalum	115.9	NA	NA	NA	NA	1
Catostomus commersonii	157.5	123.27	191.73	105.16	235.97	9
Catostomus platyrhynchus	136.2	124.14	148.26	105.16	176.39	3
Ceriodaphnia acanthina	154.3	NA	NA	NA	NA	1
Ceriodaphnia dubia	134.2	114.03	154.37	102.81	175.09	14
Chasmistes brevirostris	69.36	45.32	93.40	7.77	618.79	2
Chironomus riparius	1029	NA	NA	NA	NA	1
Chironomus tentans	451.8	340.17	563.43	361.84	824.53	6
Chydorus sphaericus	162.6	NA	NA	NA	NA	1
Cottus bairdii	222.2	NA	NA	NA	NA	1
Crangonyx pseudogracilis	270.5	201.87	339.13	97.75	397.61	6
Crangonyx sp.	122.2	78.08	166.32	12.49	1194.65	2
Cyprinella lutrensis	196.1	186.30	205.90	143.01	268.77	2
Cyprinella spiloptera	83.8	77.48	90.12	67.23	104.46	3
Cyprinella whipplei	80.94	NA	NA	NA	NA	1
Cyprinus carpio	106.3	84.64	127.96	58.60	192.68	3
Daphnia magna	157.7	127.09	188.31	111.57	222.86	13
Daphnia pulicaria	99.03	NA	NA	NA	NA	1
Deltistes luxatus	56.62	42.88	70.36	12.23	262.17	2
Dendrocoelum lacteum	119.5	NA	NA	NA	NA	1
Drunella grandis	442.4	389.96	494.84	312.94	625.36	3
Enallagma sp.	164	NA	NA	NA	NA	1
Epioblasma capsaeformis	31.14	21.23	41.05	12.29	78.88	3
Erythromma najas	2515	1824.38	3205.62	1127.79	5607.37	3
Etheostoma nigrum	71.45	61.64	81.26	54.17	94.23	6
Etheostoma spectabile	77.17	70.87	83.47	46.08	129.25	2
Fluminicola sp.[2]	> 62.15	NA	NA	NA	NA	1
Fusconaia masoni	47.4	NA	NA	NA	NA	1
Gambusia affinis	219.3	182.33	256.27	147.53	326.12	4
Gasterosteus aculeatus	281.5	225.97	337.03	191.86	413.00	7
Hyalella azteca	192.6	108.01	277.19	53.40	694.44	3
Hybognathus amarus	72.55	NA	NA	NA	NA	1
Ictalurus punctatus	142.4	133.06	151.74	130.15	162.08	27
Lampsilis abrupta	19.57	13.99	25.15	3.23	118.58	2
Lampsilis cardium[1]	89.79	59.84	119.74	40.96	196.86	4
Lampsilis fasciola	48.11	37.38	58.84	28.47	81.33	4
Lampsilis higginsii	41.9	38.31	45.49	24.41	71.92	2
Lampsilis rafinesqueana	69.97	61.40	69.97	48.85	99.99	3

Lampsilis siliquoidea[1]	49.75	41.62	41.62	37.40	66.18	17
Lasmigona subviridis	23.41	22.60	24.22	21.15	25.91	3
Lepomis cyanellus	150.8	136.02	165.58	110.20	180.46	4
Lepomis gibbosus	77.53	48.11	106.95	31.75	189.34	4
Lepomis macrochirus	104.5	97.03	111.97	87.04	112.46	31
Limnodrilus hoffmeisteri	170.2	NA	NA	NA	NA	1
Lumbriculus variegatus	218.7	148.51	288.89	123.07	412.79	7
Lymnaea stagnalis	88.62	NA	NA	NA	NA	1
Micropterus dolomieu	150.6	119.86	181.34	93.19	243.50	4
Micropterus salmoides	86.02	81.44	90.60	61.47	120.37	2
Micropterus treculii	54.52	NA	NA	NA	NA	1
Morone chrysops	144	NA	NA	NA	NA	1
Morone saxatilis	246.2	203.05	289.35	170.21	329.50	11
Morone saxatilis x chrysops	**70.22**	65.21	75.23	61.78	79.81	12
Musculium transversum	89.36	78.53	100.19	62.72	127.30	3
Notemigonus crysoleucas[1]	114	79.99	148.01	47.71	272.42	3
Notropis topeka	96.72	75.32	118.12	50.69	184.54	3
Oncorhynchus aguabonita	112.1	NA	NA	NA	NA	1
Oncorhynchus clarkii	78.92	67.53	90.31	60.04	103.73	8
Oncorhynchus gorbuscha	180.7	163.87	197.53	100.35	325.27	2
Oncorhynchus kisutch	87.05	81.98	92.12	77.95	97.20	8
Oncorhynchus mykiss[1]	91.64	88.49	94.79	86.58	97.00	149
Oncorhynchus mykiss[2]	82.88	79.95	85.81	78.17	87.89	118
Oncorhynchus tshawytscha	82.39	72.51	92.27	62.14	109.24	4
Orconectes immunis	1550	1355.51	1744.49	701.71	3422.79	2
Orconectes nais	303.8	NA	NA	NA	NA	1
Oreochromis mossambicus	185.2	NA	NA	NA	NA	1
Pachydiplax longipennis	233	159.67	306.33	31.95	1699.59	2
Philarctus quaeris	994.5	957.71	1031.29	787.36	1256.18	2
Physa gyrina	164.5	154.47	174.53	145.44	185.98	6
Pimephales promelas	159.2	150.10	168.30	125.75	156.15	73
Planorbella	211.6	200.46	222.74	151.70	295.04	2
Pleurocera uncialis	68.54	NA	NA	NA	NA	1
Poecilia reticulata	74.66	26.31	123.01	16.27	342.74	4
Potamilus ohiensis	>109.0	NA	NA	NA	NA	1
Procambarus clarkii	138	109.16	166.84	36.90	516.29	4
Prosopium williamsoni	51.93	34.81	69.05	19.83	135.98	3

Pseudacris crucifer	61.18	47.65	74.71	15.14	247.29	2
Pseudacris regilla	83.71	55.88	111.54	41.20	170.07	5
Pyganodon grandis	70.73	69.00	72.46	60.59	82.58	2
Rana pipiens	96.38	65.13	127.63	12.44	746.73	2
Salmo salar	183.3	162.17	204.43	150.13	223.70	20
Salmo trutta	101.99	98.71	105.27	92.84	112.05	3
Salvelinus fontinalis	156.3	149.55	163.05	119.01	205.28	2
Salvelinus namaycush	159.3	149.81	168.79	138.50	183.32	4
Sander vitreus	117.1	86.90	147.30	61.57	197.76	5
Simocephalus vetulus	142.9	126.57	159.23	109.22	187.00	4
Skwala americana	192.4	186.60	198.20	159.07	232.74	2
Stenelmis sexlineata	735.9	NA	NA	NA	NA	1
Tubifex tubifex	216.5	NA	NA	NA	NA	1
Utterbackia imbecillis	46.93	39.90	53.96	35.52	62.00	9
Venustaconcha ellipsiformis	23.12	NA	NA	NA	NA	1
Villosa iris	34.23	26.41	42.05	22.52	52.03	10
Xenopus laevis	122.5	88.55	156.45	72.42	204.44	9

[1] Geometric means calculated in this table were different than EPA (2013b) values

[2] Using EPA 'bolded' test values (USEPA 2013b, Appendix A).

Golden shiner (*Notemigonus crysoleucas*)

There were three tested values reported by EPA for Golden shiner (*Notemigonus crysoleucas*): 162.2, 144.6, and 63.02 mg TAN/L (EPA 2013b, Appendix A. page 124). However, EPA reported the lowest value, 63.02 as the final SMAV not the geometric mean of 114 (Table 1, this document). The only explanation I can determine for EPAs use of lowest value and not geometric mean is from the Guidelines Deriving Numerical …. Document, Page 15, Section IV. G.

> "If the available data indicate that one or more life stages are at least a factor of two more resistant than one or more other life stages of the same species, the data for the more resistant life stages should not be used in the calculation of the Species Mean Acute Value because a species can only be considered protected from acute toxicity if all life stages are protected."

However, in EPA (2013b) page 21, EPA states that, "Data that were suitable for the derivation of a freshwater FAV are presented in Appendix A.", including all three Golden shiner toxicity values. Alternatively, in Appendix A, page 124 (EPA2013b), the lowest value of 63.02 is also accompanied by a value of 8.7 g which apparently represents the weight of the tested shiner. There is no statement regarding whether this test was on a different life stage (e.g. egg, larvae, or juvenile) than the other two entries. Juvenile Golden shiners appear to weigh much less than 8.7 g (Hickman and Kilambi 1974, Melandri date unknown, Pearson et al. 2012) so it seems likely a weight of 8.7 g is not an early life stage. Contrarily, the mean standard weight of 8.3 g is typically used for stocking (Pearson et al. 2012). Therefore, the geometric mean of 114 should have been used for the SMAV and not the lowest value of 63.02 for EPAs ammonia criteria.

The Golden shiner was one of the four most sensitive genera used in the Richards (2016) recalculation process for Mill Creek using the questionable 63.02 SMAV (mg TAN/L). Further investigation is critical to determine EPAs rational for use of lowest test value of 63.02 instead of the geometric mean of 114 derived from the three test values that EPA (2013b) suggested as 'suitable'.

Fluminicola sp.(Pebblesnail)

The pebblesnail, *Fluminicola* sp. had the lowest GMAV, >62.15 mg TAN/L in the Richards 2016 recalculation report and EPA 2013b document. The use of the 62.15 values is questionable. In the EPA guidelines document IV. Final Acute Value, E. 5, page 15 EPA states,

"If the tests were conducted properly, acute values reported as "greater than" values and those which are above the solubility of the test material should be used, because rejection of such acute values would unnecessarily lower the Final Acute Value by eliminating acute values for resistant species."

This rational for inclusion of a species reported with "greater than" values was actually reversed of the above EPA quote for *Fluminciola* sp. because the **inclusion** not rejection of this taxon unnecessarily lowered the Final Acute Value by including acute values for a **sensitive** species not a **resistant** species.

In addition, as reported in Richards 2016 recalculation, *Fluminicola* sp. likely doesn't occur in the Mill Creek site and was used as a surrogate for the highly invasive, ecosystem altering New Zealand mudsnail, *P. antipodarum*, which does occur in the Mill Creek site.

Lampsilis cardium (Plain pocketbook mussel)

EPA (2013b) used and SMAV of 50.51 mg TAN/L for *Lampsilis cardium* based on four toxicity test results (Appendix A., page 125 and 126). It appears EPA elected to use the two lowest of the four values to calculate the geometric mean possibly because the two lowest values were from tests on 1-2 day old juveniles as opposed to 3-5 day old juveniles. However, all four tested values were juveniles and were not different life stages even though there was > 2 times differences. Therefore, the geometric mean of 89.79 should have been used on all four values. In many instances in EPA 2013b Appendix A, within species differences can exceed two times the lowest and highest values and EPA chooses to include all these values in calculation of the SMAV. These EPA discrepancies need to be investigated.

Lampsilis siliquoidea (Fatmucket mussel)

Similarly to *Lampsilis cardium*, EPA excluded several test values that were included in Appendix A for calculating *L. siliquoidea* SMAVs. These exclusions were apparently because, "[d] The EC50s reported in this study were based on nominal concentrations. Percent nominal concentrations of measured ammonia concentrations on exposure days 0 and 4 declined from 104 to 63. EC50s based on measured concentrations were estimated from the reported EC50s based on nominal concentrations by multiplying by 0.835 or the average of the percent nominal concentrations of measured concentrations from ammonia measurements made on exposure days 0 and 4 in the study." (USEPA 2013b, Appendix A).

EPA calculated an SMAV for *L. siliquoidea* of 55.42 mg TAN/L by omitting several values, whereas, the inclusion of all the tested values resulted in an SMAV of 49.75 mg TAN/L.

Oncorhynchus mykiss (Rainbow trout)

EPAs final SMAV for rainbow trout was 82.88 mg TAN/L (EPA 2013b, Appendix A., page 120) after their deletion of several test values. Inclusion of these values resulted in an SMAV of 91.64 mg TAN/L. Error estimates for both estimates (EPAs and this addendums) are in Table 1.

Final Acute Values based on Error

Final Acute Values (FAVs) were calculated using error estimates from Table 1 for the four most sensitive taxa, *Fluminicola*, *Notemigonus*, *Pseudacris*, and *Hybognathus*. A FAV for the mean minus one standard deviation was made (Table 2) as was a FAV for the mean plus one standard deviation (Table 3). *Fluminicola* and *Hybognathus* GMAVs had only one test value therefore error estimates were simply calculated as +/- 10% of the mean for *Hybognathus* and the low error estimate for *Fluminicola* was kept as the GMAV reported by EPA because it was reported as > 62.15. The high error estimate for *Fluminicola* was +10% of the GMAV. Error estimated FAVs were 66.13 for low estimate and 88.79 for the high estimate.

Table 2

-1 S.E. (-10% mean for GMAVs with only one test value, i.e. Fluminicola and Hybognathus)

Rank	GMAV	ln(GMAV)	$\ln(\text{GMAV})^2$	P=R/(n+1)	√P
1	60.34101	4.100012	16.8101	0.0217391	0.147442
2	62.15	4.129551	17.05319	0.0434783	0.2085144
3	65.295	4.178916	17.46334	0.0652174	0.255377
4	79.99	4.381902	19.20106	0.0869565	0.2948839
Sum		16.790381	70.52769	0.2173913	0.9062173

$S^2 = [70.52769 - (16.790381)^2/4] / [0.\ 0.2173913 - (0.9062173)^2/4] = 4.0108$

$S = 2.0027$

$L = [16.790381 - (2.0027)(0.9062173)]/4 = 3.7439$

$A = (2.0027)(\sqrt{0.05}) + 3.7439 = 4.1917$

FAV = $e^{4.1917}$ = 66.13

Table 3

+1 S.E. (+10% mean for GMAVs with only one test value, i.e. *Fluminicola* and *Hybognathus*)

Rank	GMAV	ln(GMAV)	$\ln(\text{GMAV})^2$	P=R/(n+1)	√P
1	68.35	4.224641	17.8476	0.0217391	0.147442
2	79.0795	4.370454	19.10086	0.0434783	0.2085144
3	82.779	4.416174	19.5026	0.0652174	0.255377
4	148.01	4.99728	24.97281	0.0869565	0.2948839
Sum		18.008549	81.42387	0.2173913	0.9062173

$S^2 = 28.7086$

$S = 5.3580$

$L = 3.2882$

A = = 4.4863

FAV = $e^{4.4863}$ = 88.79

Chronic Values based on Error Estimates

The Final Chronic Value (FCV) with error estimates for Mill Creek recalculation was derived in Richards (2016) report and was equal to the FAV divided by the geometric mean (with error estimates). The FCV reported in Richards (2016) was 5.319 (3.248, 8.712, 95% CIs). The Criterion Continuous Concentration (**CCC**) continued to be equal to the FCV = 5.319 (3.248, 8.712). The Criterion Maximum Concentration (**CMC**) was equal to one-half the Final Acute Value = 0.5*66.13 **= 33.07** for lower estimate and 0.5*88.79 **= 44.40** for upper estimate. The mean CMC reported by Richards (2016) was from 33.45 to 37.64, depending on which taxa were included.

Discussion

It was obvious that although geometric means are likely the most appropriate point estimate method for toxicity testing because sensitivity values are often on a log scale; using only a single value (geometric mean) could be uninformative and possibly misleading. Relying on values based on only one or two tests on a species also led to large error estimation or in the case of one test on a species, no error estimation could be made. This is disconcerting because geometric means used in criteria development based on one or two tests on a species could be far from precise. In addition, the error estimates in this addendum were very conservative. Typically, in ecological studies, error estimates include two standard deviations and 95% CIs (see Figures 1 and 2).

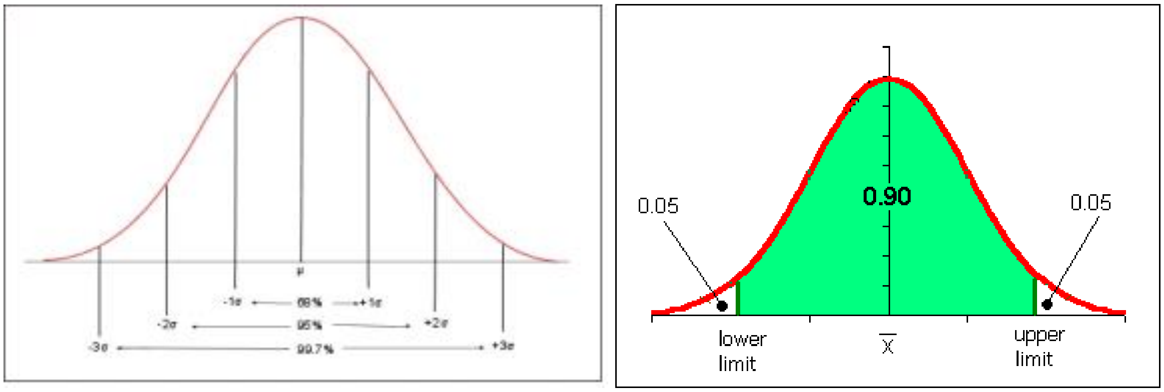

Figure 1. Example of standard errors (left graph) and 90% confidence intervals (right graph) around the mean of a normal distribution. 1 SE = 68% of the values around the mean estimate, 2 SEs = 95% of the values around the mean. 90% confidence intervals around the mean are in green (right graph), 5% on each side of the mean. SMAVs in this addendum were based on geometric means assuming log sensitivities, therefore the transformed data should approximate the normal distribution shown above.

Conclusion

By calculating and reporting error estimates, a better understanding of the values that should be used in ammonia criteria development for Mill Creek and Central Valley Water Reclamation Facility can be employed. Error estimates were not made for other Genus Mean Acute Values (GMAVs) in the recalculation procedure for Mill Creek (Richards 2016) but the error estimates reported in this addendum suggest further calculations may be necessary.

Literature Cited

Hickman, G. D. and R.V. Kilambi. 1974. Growth and production of golden shiner, *Notemigonus crysoleucas*, under different stocking densities and feeding rates.

Melandri, M. unknown date. The effects of temperature and density on the growth of golden shiners (*Notemigonous crysoleucas*). MS thesis. University of Arkansas at Pine Bluff. 52pp.

Pearson, P. R., Beecham, R. V. and C. D. Minchew. 2012. The golden shier grading assessment model. International Journal of Agriculture and Forestry 2012, 2(5): 199-202.

Richards, D. C. 2016. Numeric water quality criteria recalculation for several toxicants related to Central Valley Water Reclamation Facility discharge into Mill Creek, Salt Lake County, UT. Part 1: Ammonia. Draft Version 1.1. Submitted to Jordan River/Farmington Bay Water Quality Council. Salt Lake City, UT. 69 pages.

United States Environmental Protection Agency. 1985. Ambient water quality criteria for ammonia - 1984. EPA-440/5-85-001. National Technical Information Service, Springfield, VA

United States Environmental Protection Agency. 1999. 1999 Update of ambient water quality criteria for ammonia. EPA-822-R-99-014. National Technical Information Service, Springfield, VA.

United States Environmental Protection Agency. 2009. Draft 2009 update aquatic life ambient water quality criteria for ammonia – freshwater. EPA-822-D-09-001. Office of Water, Office of Science and Technology, Washington, DC.

United States Environmental Protection Agency. 2010. Guidelines for deriving numerical national water quality criteria for the protection of aquatic organisms and their uses. EPA-PB85-227049.

United States Environmental Protection Agency. 2013a. The revised deletion process for the site- specific recalculation procedure for aquatic life criteria. EPA 823-R-13-001. National Technical Information Service, Springfield, VA.

United States Environmental Protection Agency. 2013b. Aquatic life ambient water quality criteria for ammonia-freshwater. EPA 822-R-13-001.

United States Environmental Protection Agency. 2013c. Technical support document for conducting and reviewing freshwater mussel occurrence surveys fo the development of site-specific water quality criteria for ammonia. EPA 800-R-13-003.

U.S. Environmental Protection Agency (EPA). 2005. Methods/indicators for determining when metals are the cause of biological impairments of rivers and streams: species sensitivity distributions and chronic exposure-response relationships from laboratory data. Cincinnati, Ohio, U.S. EPA, Office of Research and Development, National Center for Environmental Assessment.