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Ambient Aquatic Life Criteria For Chloride

I. Background

Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/l; however, calcium or magnesium chloride is not usually detected by taste until levels of 1000 mg/l are reached.

Chloride may get into surface water from several sources including:

(1) rocks containing chlorides;
(2) agricultural runoff;
(3) wastewater from industries;
(4) oil well wastes;
(5) effluent wastewater from wastewater treatment plants, and;
(6) road salting.

Chlorides can corrode metals and affect the taste of food products. Therefore, water that is used in industry or processed for any use has a recommended maximum chloride level. Chlorides can contaminate fresh water streams and lakes. Fish and aquatic communities cannot survive in high levels of chlorides.

The current Iowa water quality standard for chloride is 250 mg/l for drinking water use only. There are no chloride standards for aquatic life protection in Iowa.

II. National Criterion

The national criterion was derived based on the toxicity test data of sodium chloride since it is the only chloride composition with enough data available to allow derivation of a water quality criterion. The acute toxicity data of chloride are available for 12 different species (genus). The following national criteria for Chloride are recommended by the EPA (EPA, 1988).

Table 1. National Aquatic Life Criteria for Chloride

Parameter	National Criteria (mg/l)	
	Acute	Chronic
Chloride	860	230

For acute toxicity to aquatic life, invertebrates are generally more sensitive than vertebrates. Cladoceran (Daphnia pulex) is the most sensitive among the tested species. When compared on the basis of mg of chloride/L, the chlorides of potassium, calcium, and magnesium are generally more acutely toxic to aquatic life than sodium chloride. Since the national criteria for chloride shown in Table 1 were derived from sodium chloride, these values should be protective of aquatic life if the discharge mainly consists of sodium chloride.

III. Other Toxicity Information

Birge et al. (1985) whose toxicity data were used in the U.S. EPA (1988) chloride criteria document, conducted field toxicity tests on chloride. Birge et al (1985) found that chloride was twice as toxic using standard laboratory water than that using natural water (or from field studies). The study recommended the following aquatic life criteria for chloride:

In each 30 consecutive days:
a. The average concentration of chloride should not exceed 0.6 g/l;
b. the maximum concentrations should not exceed 1.2 g/l; and
c. the concentration may be between 0.6 g/l and 1.2 g/l for up to 48 hours.

These values had been adopted by Kentucky Natural Resources and Environmental Protection Cabinet. The chronic criterion 0.6 g/l for chloride is close to the chloride value of 0.5 g/l promulgated by the Illinois Pollution Control Board to regulate general stream quality in the state (Birge et al., 1985).

EPA Region VII provided some laboratory toxicity test data for Potassium Chloride (KCL). The following table lists the results of Potassium Chloride toxicity tests for two fresh water species.

Table 2. Toxicity Test of KCL

Species	Mean LC50 (mg/l)	Standard Deviation	Coefficient of Variance	No. of Tests
Ceriodaphnia dubia	343	104	30.4%	4
Fathead minnow	1056	206	19.5%	5

The toxicity test results for KCL indicate that KCL is more toxic to aquatic life than Sodium Chloride, which is consistent with some other studies.

IV. Discussion of Chloride Toxicity and Criteria

As listed in Table 1, the national acute and chronic criteria for Chloride are 860 mg/l-Cl/L and 230 mg-Cl/L, respectively. The national acute criterion for Chloride was derived based on the acute toxicity data for 12 species. The national criteria are not specific to any one geographic area or ecosystem. Thus, some of the species in the database are not present in Iowa streams. EPA allows the State to recalculate site-specific criteria based on species only present locally. However, in this case, the acute toxicity data set is relatively small. The use of the recalculation procedure by deleting species that are not present in Iowa streams will result in the total number of species less than 8 (which is the minimum number of species allowed in the criterion calculation). As a result, the recalculation procedure cannot be used to derive site-specific acute criterion of Chloride for Iowa.

The national chronic criterion for Chloride was derived based on three acute-to-chronic ratios. The acute-to-chronic ratio (ACR) is the ratio of the acute toxicity of a toxicant to its chronic toxicity. It is often used as a factor for estimating chronic toxicity on the basis of acute toxicity data since chronic toxicity data are often limited. The three acute-to-chronic ratios are listed in Table 3.

Table 3. Acute-to-Chronic Ratio (ACR) for Deriving Chronic Chloride Criterion

Species	Hardness (mg/l as CaCO3)	Acute Value (mg/l)	Chronic Value (mg/l)	Ratio	Reference
Cladoceran Daphnia pulex	100	1,470	372.1	3.951	Birge et al. 1985
Rainbow trout Salmo girdneri	46	6,743	922.7	7.308	Spehar (1987)
Fathead minnow Pimephales promelas	100	6,570	433.1	15.17	Birge et al. (1985)
				Final ACR=7.594	

Using this ACR value of 7.594, the calculated chronic criterion for Chloride would be about 230 mg-Cl/L.

However, Pickering et al. (1996) provides more recent and published data on the fathead minnow. Using the seven-day fathead minnow larval survival and growth test, they found a subchronic value for Chloride of 3432 mg-Cl/l that is above the value of Birge et al. (1987). If the original ACR for fathead minnows is replaced with the one derived from Pickering et al. (1996), the final ACR is 3.809. The value is shown in Table 4.

Table 4. New Acute-to-Chronic Ratio (ACR) for Deriving Chronic Chloride Criterion

Species	Hardness (mg/l as CaCO3)	Acute Value (mg/l)	Chronic Value (mg/l)	Ratio	Reference
Cladoceran Daphnia pulex	100	1,470	372.1	3.951	Birge et al. 1985
Rainbow trout Salmo girdneri	46	6,743	922.7	7.308	Spehar (1987)
Fathead minnow Pimephales promelas	~~100~~ 200	6,570	~~433.1~~ 3432	~~15.17~~ 1.914	Birge et al. (1985) Pickering et al. (1996)
				Final ACR=3.809	

If the ACR of 3.809 were applied to calculate the chronic criterion, we would obtain chronic criteria of 450 mg-Cl/l for Chloride.

If the geometric mean of the chronic data provided by Birge et al. (1985) and the chronic data provided by Pickering et al. (1996) are used to calculate the ACR, the final ACR will be 5.378. If the ACR of 5.378 were applied to calculate the chronic criterion, we would obtain a chronic criterion of 320 mg-Cl/l for Chloride.

Table 5. New Acute-to-Chronic Ratio (ACR) for Deriving Chronic Chloride Criterion

Species	Hardness (mg/l as CaCO3)	Acute Value (mg/l)	Chronic Value (mg/l)	Ratio	Reference
Cladoceran Daphnia pulex	100	1,470	372.1	3.951	Birge et al. 1985
Rainbow trout Salmo girdneri	46	6,743	922.7	7.308	Spehar (1987)
Fathead minnow Pimephales promelas	100 200	6,570	1219	5.389	Birge et al. (1985) Pickering et al. (1996)
				Final ACR=5.378	

State of Wisconsin developed new chloride criteria in February 2000 based on its own new toxicity test data. Wisconsin State Lab of Hygiene did toxicity tests on three species in 1995: Fathead minnows, Daphnia magna and Ceriodaphnia dubia. The toxicity test results are shown in Table 6.

Table 6. Chloride Toxicity Test Data from State of Wisconsin

Species	Acute Toxicity	Chronic Toxicity	Acute-Chronic Ratio
Fathead Minnows	4600	None	None
Daphnia Magna	4071	None	None
Ceriodaphnia dubia	1596	458	3.4847

State of Wisconsin (Personal Communications, 2003) combined its new toxicity test data shown in Table 6 with the national criteria database for chloride and recalculated both the acute and chronic criteria. For chronic criterion recalculation, only two acute-chronic ratios (ACRs) were used, ACR for Daphnia pulex (national data) and Ceriodaphnia dubia (Wisconsin data). The recalculated acute and chronic criteria for chloride in Wisconsin are: acute criterion – 757 mg Cl/l and chronic criterion 395 mg Cl/l. Thus, if the toxicity test data from Wisconsin are used, the acute and chronic criteria for chloride are shown in Table 7.

Table 7. New Chloride Criteria Using Wisconsin Toxicity Test Data

Species	Acute Value (mg/l)	Chronic Value (mg/l)	Ratio	Chloride Criteria
Cladoceran Daphnia pulex	1,470	372.1	3.951	757 (acute)
Cladoceran Ceriodaphnia dubia	1,596	458	3.484	408[a] (chronic)
			Final ACR=3.71 FAV = 1,515	

[a] Corrected the error in Wisconsin's calculations

V. Alternatives for Chloride Criteria in Iowa

Option #1:
To adopt the criteria derived from the toxicity data provided by Birge et al. (1985), which takes into account the water-effect ratio effect. The water-effect ratio is an appropriate measure of the toxicity of a material obtained in site water divided by the same measure of the toxicity of the same material obtained simultaneously in lab dilution water. The Chloride criteria will be as shown in Table 6.

Table 6. Recommended Aquatic Life Criteria for Chloride

Parameter	Option #1: Chloride Criteria (mg/l)	
	Acute	Chronic
Chloride	1200	600

Option #2:
To adopt the national criteria for chloride as shown in Table 7 as the aquatic life criteria for chloride for cold water and warm water streams. First, these criteria values are derived based on reconstituted water. Thus, they are more stringent than that required in natural stream conditions. Also, they do not reflect Iowa's local stream conditions.

Table 7. National Aquatic Life Criteria for Chloride

Parameter	Option #2: Chloride Criteria (mg/l)	
	Acute	Chronic
Chloride	860	230

Option #3:
To adopt the recalculated criteria (chronic criterion) using Pickering et al. (1996) chronic toxicity test data. These criteria are shown in Table 8.

Table 8. Aquatic Life Criteria of Chloride for Iowa

Parameter	Option #3: Chloride Criteria (mg/l)	
	Acute	Chronic
Chloride	860	450

Option #4:
To adopt the recalculated criteria (chronic criterion) using both the chronic toxicity data of Pickering et al. (1996) and Birge et al. (1985). These criteria are shown in Table 9.

Table 9. Aquatic Life Criteria of Chloride for Iowa

Parameter	Option #4:Chloride Criteria (mg/l)	
	Acute	Chronic
Chloride	860	320

Option #5:
If the Wisconsin toxicity data were used, the aquatic life criteria for chloride are shown in Table 10.

Table 10. Aquatic Life Criteria of Chloride
Using Wisconsin Toxicity Data

Parameter	Option #4:Chloride Criteria (mg/l)	
	Acute	Chronic
Chloride	757	408

All the above values only apply to designated streams.

At their meeting on March 24, 2003, the TAC decided that Options #2 and #5 are the only viable options.

VI. Further Discussion of Alternatives for Chloride Criteria in Iowa

The new chloride aquatic toxicity data from Wisconsin supports adjustment of the EPA National Chloride criteria. No effort was made to modify the EPA Acute criterion, rather the Chronic criterion was considered for modification. The Department has presented two options to consider in how this new data is integrated with the 1988 EPA national criteria data to establish specific chronic criterion. The options are:

1) Incorporate the new fathead minnow and ceriodaphnia toxicity data from the Wisconsin Hygiene Lab and delete the poorly documented rainbow trout data used by EPA, resulting a new Chronic criterion of 564 mg/l, or
2) Incorporate the fathead minnow and ceriodaphnia new toxicity data and assure that all chronic toxicity data used in the recalculation be protected by a new Chronic criterion. This results in a criterion of 372 mg/l.

Table 11 presents the chronic toxicity data that was used to derive these two alternative Chronic criterion. (Further explanation of the use of the data will be made at the TAC meeting.)

It is staff's recommendation that the rainbow trout toxicity data not be discounted in the consideration of the chronic criterion. However, it is more significant that any chronic criterion be protective of the species mean chronic value used in establishing the ACR. This assures that each individual species chronic value will be protected by the Final Chronic Value. Both options are clearly defensible in their own right, however, staff believes that setting a final chronic value that protects the species with chronic data and not discounting the rainbow trout chronic toxicity data is environmentally prudent and protective.

Staff evaluation of the new aquatic toxicity data concluded that the Wisconsin State Laboratory of Hygiene (Aquatic Life Toxicity Testing Laboratory) provided defensible acute and chronic chloride toxicity testing results (from 10/00 to 1/03) for both the fathead minnow and ceriodaphnia following the basic approaches published by EPA and ASTM. In addition, the EPA's National Exposure Research Laboratory in Cincinnati, Ohio, developed defensible chronic chloride aquatic life toxicity data (Pickering, 1996) for the fathead minnow using Potassium Chloride as the reference toxicant. The EPA laboratory did not generate corresponding acute toxicity data.

The use of the new chloride data could be applied to both the EPA 1988 acute and chronic criteria, however, it is staff's recommendation that the EPA Chloride acute criterion of 860 mg/l remain unchanged with no attempt to integrate the new acute toxicity data from Wisconsin. Only one new species would be added to the eleven species used by EPA in calculating the national acute criterion with little anticipated change in the criteria.

The new chronic toxicity data has potential merit in association with the EPA national chronic chloride criterion. The 1988 EPA national chronic criterion used only data from three aquatic species and their representative Acute/Chronic Ratio (ACR) to calculate the 230 mg/l value. The chronic criterion could be recalculated by (Option A in Table 11, below):

1) including the new Wisconsin-based ACR for ceriodaphnia,
2) replacing the fathead minnow data with new Wisconsin-based ACR, and
3) deleting the rainbow trout ACR.

The Pickering fathead minnow chronic toxicity data is not recommended to be integrated into these recalculations primarily due to the lack of acute data to determine a corresponding ACR.

The following table shows in summary the alternatives (by comparison to the EPA criterion and basis of calculating the various Chloride criteria.

Table 11.
Summary of Chloride Criteria Alternatives

EPA Acute Criterion Summary	EPA Chronic Criterion Summary		Option A: Chronic Criterion Summary		Option B: Chronic Criterion Summary	
11 species	3 species	ACR	3 species	ACR	4 species	ACR
• FAV = 1720 mg/l (Final Acute Value) • Acute Criterion = FAV/2 = **860 mg/l**	Rainbow Trout SMCV = 923 mg/l	7.308	Rainbow Trout SMCV = 923 mg/l	x	Rainbow Trout SMCV = 923 mg/l	7.308
	Fathead Minnow SMCV = 433 mg/l	15.17	Fathead Minnow* SMCV = 1876 mg/l	2.17	Fathead Minnow* SMCV = 1876 mg/l	2.17
	Daphnia pulex SMCV = 372 mg/l	3.951	Daphnia pulex SMCV = 372 mg/l	3.951	Daphnia pulex SMCV = 372 mg/l	3.951
			Ceriodaphnia* SMCV = 461 mg/l	3.32	Ceriodaphnia* SMCV = 461 mg/l	3.32
	Geometric Mean	7.594	Geometric Mean	3.05	Geometric Mean	3.797
					Calculated CCC (FAV/Geo Mean)	453 mg/l
	Chronic Criterion (FAV/Geo. Mean)	230 mg/l	Chronic Criterion (FAV/Geo. Mean)	564 mg/l	Chronic Criterion (lowered to protect daphnia)	372 mg/l

* New Wisconsin data
SMCV is Species Mean Chronic Value

As noted in the above table, Option B differs slightly from Option A, regarding establishing a Chronic criterion that is protective of all species included in the recalculation and not discounting the applicability of the rainbow trout chronic toxicity data. Clearly, it is a valid point that the rainbow trout study (by Spehar, 1987), while used in development of the 1988 EPA criteria, does not meet the basic requirements of EPA guidance documents for acceptable test data documentation. It appears that the Spehar data documentation provided to EPA was on a single hand-written page from a

lab notebook. However, it is staff's recommendation that this toxicity data not be automatically excluded in any recalculation.

It is also important to note that the calculation of a Chronic Criterion using the geometric mean of only the three species (not including rainbow trout) results in a criterion not protecting the chronic testing data of two species. In other words, the calculated Chronic Criterion of 563 mg/l is not chronically protecting Ceriodaphnia dubia (SMCV = 461 mg/l) and Daphnia pulex (SMCV = 372 mg/l). This appears to be a mathematical anomaly because of the use of the Acute Chronic Ratio (ACR) approach in calculating a chronic criterion from the Final Acute Value (FAV/ACR=FCV, example: 1720 mg/l/3.05 = 564 mg/l). To date staff has not uncovered any EPA guidance that attempts to address this phenomenon, but it only appears logical that it is not a defensible and approvable method to establish a chronic criterion. At least two parameters for which EPA has established national criteria have limited discussions where the criterion has been lowered to assure protection of important species.

VII. Protection of General Use Streams

In recent months, several sources have provided the Department with literature information on the effects to various livestock types of elevated Chloride in their water. Poultry appear to be a more sensitive animal with research noting that laying hens experience increased incidents of damaged egg shells when provided water with NaCl as low as 600 mg/l (360 mg/l of Cl). Additional studies found that as the NaCl was increased to 2000 mg/l (1213 mg/l of Cl), greater than 50% of the egg shells were damaged or shell-less. No clear cut drinking water threshold was established for poultry in these series of Australian studies nor was any association to wild bird egg viability been attempted. However, there is no reason to expect that similar physiological responses may not occur to wild bird populations when water sources contain elevated NaCl levels. Research and documentation is clearly lacking in this area.

As was noted for poultry, it is clear that the numerous literature sources demonstrate numerous levels of NaCl tolerance for cattle, dairy cows, swine and sheep. Many studies relate the ability of these livestock types to either become accustomed to or tolerate levels at or above 4000 mg/l Chloride. One study on Holstein cows did note a decrease in milk production (5.5%) when supplied with drinking water at 2500 mg/l (1517 mg/l of Cl). Another study on Holstein heifers noted a diminished water consumption at 2500 mg/l NaCl and 50% drop in water consumption at 3500 mg/l NaCl (2124 mg/l of Cl). While scattered, the data does indicate a lower tolerance to some livestock consuming elevated NaCl waters.

Considering the current and potential types of livestock using general streams, any wasteload allocation for general streams should consider the literature information. Past WLA have assumed that the protection of aquatic life from acutely toxic conditions was more limiting and protective of the basic livestock watering needs. However, additional research information indicates that some types of livestock may have lower tolerances. Thus, to assure that the WQS's General Use definition is attained, it is suggested that the Chloride level not exceed 1500 mg/l in general use streams.

REFERENCES

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