

**Translation and Guidance on Application of the Montana Narrative Water Quality Criterion for Sulfate**

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| 2 | 2016 | ? | ? |
| 3 | 1/8/2019 | Table 1, Reference section | Minor typo edits to both |
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# Introduction

Neither the state of Montana nor the United States Environmental Protection Agency (USEPA) has established numeric water quality criteria for sulfate. However, there are numerous studies that demonstrate sulfate’s negative health effects to aquatic life (USEPA, 2014), humans (USEPA, Office of Water, 2003), and animals (Illinois EPA, 2006).

Although there are no numeric water quality criteria for sulfate in Montana, surface waters are protected from the harmful effects of toxic substances through narrative water quality criteria. The Administrative Rules of Montana 17.30.637 sets a general prohibition against discharge of substances that will create concentrations or combinations of materials which are toxic or harmful to human, animal, plant, or aquatic life.

In this document, the Montana Department of Environmental Quality (DEQ) translates Montana’s narrative criteria to establish water quality targets for sulfate in Montana surface waters. The targets are based on the most recent scientific information available, and may be used in water quality assessments and total maximum daily load calculations. The targets may be applied to A and B class waters in Montana. They may be applied to C class waters on a case by case basis, if appropriate, based upon site-specific information. As new sulfate toxicity studies become available, these targets are subject to change to reflect the most current information.

There are some areas in Montana that have naturally high levels of sulfate. The sulfate targets herein only apply where anthropogenic sources of sulfate are present that have caused or may cause sulfate levels that are potentially toxic or harmful to human, animal, plant, or aquatic life. There may be site-specific situations where aquatic life, plants, and animals have adapted to the levels of sulfate present. In these situations, regardless of use class, sulfate targets may not apply or may be different than those proposed in this document.

# Sulfate toxicity to humans

## Drinking water use

In 1979, USEPA set a secondary maximum contaminant limit (SMCL) for sulfate of 250 milligrams per liter (mg/L) (USEPA, Office of Water, 2003). Unless adopted as a criterion by states, the SMCL is not an enforceable standard, and is set to protect taste and odor thresholds (USEPA, 2012).

A study conducted by USEPA and the National Center for Environmental Health Centers for Disease Control and Prevention concluded that sulfate concentrations below 600 mg/L would be unlikely to cause diarrhea in adults. In addition to a focus on adults, the study objectives included a focus on infants (USEPA, 1999a). There was difficulty obtaining subjects for the study, so a panel of experts sponsored by CDC reviewed available literature. The experts concluded that there was not enough scientific evidence on which to base regulation, but suggested health advisories for drinking water sources with sulfate levels exceeding 500 mg/L (USEPA, 1999b).

Sulfate in drinking water at concentrations greater than 500 mg/L may cause a laxative effect that is limited and acute. Available data do not indicate developmental or reproductive effects from long-term exposure of sulfate, and carcinogenicity cannot be determined from available health effects data (USEPA, Office of Water, 2003).

Most healthy people exposed chronically to water high in sulfate typically adjust within a week of initial exposure, or reduce their intake because of taste in the water (USEPA, Office of Water, 2003). However, to protect sensitive populations such as infants, the elderly, and travelers, DEQ recommends USEPA’s guidance of 500 mg/L sulfate in drinking water as the sulfate target. Because USEPA found insufficient evidence to promulgate a water quality criterion, 500 mg/L sulfate is to be used as guidance rather than an enforceable water quality target. For assessment purposes, the recommended frequency and duration of exposure is based on a 96-hour exposure and can be exceeded only once, on average, in a three year period. The “once in a three-year period” exceedance frequency may be translated to a 10% exceedance rate (DEQ, 2012).

## Recreational use

There are no studies available on skin contact with sulfate in water.

# Sulfate toxicity to animals

## agricultural use

Illinois Environmental Protection Agency (Illinois EPA) reviewed literature on sulfate impacts to livestock. Like humans, livestock experience a laxative effect when exposed to high levels of sulfate in their drinking water. The major concern with livestock is the chronic effects of drinking water with high sulfate levels. Exposure of cattle to water with 2,500 mg/L sulfate results in poor conception, chronic exposure of cattle to water with 2,600 mg/L sulfate can result in weight loss and decreased body condition, and as sulfate concentrations approach 3,000 mg/L, cattle drink less water and become more prone to a neurological disorder that leads to anorexia, blindness, seizures, and eventually death (Illinois EPA, 2006).

Illinois did not find enough studies to calculate a chronic livestock criterion for sulfate, but determined that a chronic standard of 2,000 mg/L is protective of livestock watering, as that level will not lead to adverse effects on livestock or economic effects to livestock operations. We will apply a surface water target of 2,000 mg/L, not to exceed the four-day average more than once in a three-year period, to protect livestock. As with the drinking water target, the agricultural target is guidance only. The “once in a three-year period” exceedance frequency may be translated to a 10% exceedance rate (DEQ, 2012).

# Sulfate toxicity to plants

## agricultural use

Sulfate is an essential nutrient for plants. Sulfate toxicity in plants is usually is not an issue, except at very high concentrations where high sulfate can interfere with uptake of other nutrients (Bauder et al., 2011). Sulfate salts affect sensitive crops by limiting calcium uptake and increasing the absorption of sodium and potassium (Fipps, 2003). Because of the reduction of calcium uptake and increased sodium and potassium uptake, “the harmful effects of sulfate are likely related to a disturbance in the ionic balance within the plant rather than a direct injury.” (Pick, 2008)

None of the aforementioned sources provided any sulfate toxicity data nor established a sulfate concentration at which undesirable effects are observed, nor were we able to locate studies that have this information. Because these sources assert that very high concentrations of sulfate are necessary to cause undesirable effects, we propose that the human health target, aquatic life target, or livestock target for sulfate will always or nearly always be protective of plant life.

# Sulfate toxicity to aquatic life

## Salmonid and non-salmonid aquatic life use

In 2009, USEPA approved sulfate criteria promulgated by the Illinois EPA (USEPA, 2009). Illinois EPA had worked with the USEPA Duluth Toxicity Laboratory over several years to search and review available aquatic life toxicity data for sulfate. They found about 30 acute toxicity studies with data for over 30 organisms in the literature, but most of those organisms were fish and zooplankton crustaceans. In order to round out the dataset for the aquatic life water quality criteria derivation, Illinois EPA, USEPA, and the Illinois Coal Association sponsored toxicology studies for five additional aquatic organisms (Illinois EPA, 2006).

Because previous studies had shown a relationship between hardness and chloride concentrations and sulfate toxicity, Illinois EPA considered hardness and chloride in the derivation of their aquatic life criterion. The following table shows their derived sulfate acute aquatic life criteria.

Table 1. Acute Sulfate Criteria in mg/L for Illinois Waters Based on Hardness and Chloride

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Cl < 5mg/L** | **5 mg/L ≤ Cl < 25 mg/L** | **25 mg/L ≤ Cl < 500 mg/L** |
| **Hardness < 100 mg/L** | 500 | 500 | 500 |
| **100 mg/L ≤ Hardness ≤ 500 mg/L** | 500 | [-57.478 + 5.79 (hardness) + 54.163 (chloride)]\*0.65 | [1276.7 + 5.508 (hardness) - 1.457 (chloride)] \* 0.65 |
| **Hardness > 500 mg/L** | 500 | 2,000 | 2,000 |

In addition to the acute toxicity testing, limited chronic toxicity testing was conducted on *Ceriodaphnia dubia*. These tests showed that a chronic exposure period would not result in reduced survival compared to acute exposures.

A 2010 study conducted by Elphick, et al concluded that the available chronic sulfate toxicity studies were insufficient, so they carried out their own sulfate chronic toxicity studies on multiple species at varying hardness levels.

Among the species tested was *C. dubia*. The study found that the levels of sulfate that caused chronic toxicity in reproduction was significantly lower in soft water than in hard water, and was significantly lower than sulfate levels causing reduced survival at the same hardness. The lowest observed effect concentration (LOEC) of sulfate for *C. dubia* reproduction at a hardness of 40 mg/L was 150 mg/L. This was the most sensitive LOEC of all the organisms tested at all of the different hardness levels. With one exception (*C. dubia* at hardness 320 mg/L and LOEC 480 mg/L sulfate), there were only two other LOECs below 500 mg/L, and both were at hardness 15 mg/L. All 31 of the other LOECs were above 950 mg/L.

Based on the research conducted by Illinois EPA (2006) and Elphick et al (2011), it is reasonable to have different sulfate targets at varying hardness. The only hardness range for which DEQ is identifying a chronic sulfate target is from 0 to 50 mg/L hardness. For hardness below 50 mg/L, DEQ will use the less conservative of two soft water guidelines derived by Elphick et al. Their more conservative target was calculated by using the lowest LOEC divided by a safety factor of two, giving a target of 75 mg/L sulfate. The other calculation method was to use the hazard coefficient associated with the 5th percentile of the species sensitivity distributions (SSD). For purposes of this guidance, this lower level of conservatism is appropriate because sulfate is a natural salt compound and not a true toxic substance. This method calculated a target of 129 mg/L. Because this number protects against chronic toxicity, the four day average is not to be exceeded more than once in a three year period, or in more than 10% of samples.

For acute toxicity, DEQ will use Illinois’s adopted sulfate criteria, shown in Table 1 above, and capped at 2,000 mg/L. Because these targets protect against acute toxicity, the one hour average is not to be exceeded more than once every three years, or in more than 10% of samples. Acute targets are shown for a wide range of hardness and chloride concentrations in Table 1 in Appendix A.

These aquatic life targets can be applied to all waters with either salmonid or non-salmonid aquatic life uses.

# Summary

The sulfate target applied to a specific water body must protect the most sensitive use for that water body. Based on these targets and Montana’s use class system, the maximum sulfate target for any use class without a drinking water use is 2,000 mg/L—the sulfate target for hard waters will be limited by the aquatic life use and/or livestock use. The maximum sulfate target for a water body with a drinking water use is 500 mg/L. Finally, the minimum sulfate target for any water body in Montana is the chronic target for aquatic life of 129 mg/L, only to be applied when hardness is less than 50 mg/L.

Before determining if a sulfate target is appropriate for a surface water body, geology and anthropogenic activities should be considered. These sulfate targets should only be applied where anthropogenic sources of sulfate are present that have caused or may cause sulfate levels that are potentially toxic or harmful to human, animal, plant, or aquatic life. Depending on the geologic formation, sulfate levels in some surface water are naturally higher than others. In naturally high sulfate waters, aquatic life, plants, and animals present are adapted to the high levels of sulfate. In these situations, sulfate targets may not apply or may be different than those proposed in this document based upon site-specific conditions.

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Appendix A

Table 1. Maximum allowable acute\* concentrations of sulfate in mg/L at various concentrations of hardness and chloride.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Chloride** |  |  |  |  |  | **Hardness (mg/L)** |  |  |  |  |  |
| **(mg/L)** | **<100** | **100** | **150** | **200** | **250** | **300** | **350** | **400** | **450** | **500** | **>500** |
| **0-5** | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| **5** | 500 | 515 | 703 | 891 | 1,080 | 1,268 | 1,456 | 1,644 | 1,832 | 2,000 | 2,000 |
| **10** | 500 | 691 | 879 | 1,067 | 1,256 | 1,444 | 1,632 | 1,820 | 2,000 | 2,000 | 2,000 |
| **15** | 500 | 867 | 1,055 | 1,243 | 1,432 | 1,620 | 1,808 | 1,996 | 2,000 | 2,000 | 2,000 |
| **20** | 500 | 1,043 | 1,231 | 1,419 | 1,608 | 1,796 | 1,984 | 2,000 | 2,000 | 2,000 | 2,000 |
| **25** | 500 | 1,164 | 1,343 | 1,522 | 1,701 | 1,880 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| **50** | 500 | 1,141 | 1,320 | 1,499 | 1,678 | 1,857 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| **100** | 500 | 1,093 | 1,272 | 1,451 | 1,630 | 1,809 | 1,988 | 2,000 | 2,000 | 2,000 | 2,000 |
| **150** | 500 | 1,046 | 1,225 | 1,404 | 1,583 | 1,762 | 1,941 | 2,000 | 2,000 | 2,000 | 2,000 |
| **200** | 500 | 998 | 1,177 | 1,356 | 1,535 | 1,715 | 1,894 | 2,000 | 2,000 | 2,000 | 2,000 |
| **250** | 500 | 951 | 1,130 | 1,309 | 1,488 | 1,667 | 1,846 | 2,000 | 2,000 | 2,000 | 2,000 |
| **300** | 500 | 904 | 1,083 | 1,262 | 1,441 | 1,620 | 1,799 | 1,978 | 2,000 | 2,000 | 2,000 |
| **350** | 500 | 856 | 1,035 | 1,214 | 1,393 | 1,572 | 1,751 | 1,930 | 2,000 | 2,000 | 2,000 |
| **400** | 500 | 809 | 988 | 1,167 | 1,346 | 1,525 | 1,704 | 1,883 | 2,000 | 2,000 | 2,000 |
| **450** | 500 | 762 | 941 | 1,120 | 1,299 | 1,478 | 1,657 | 1,836 | 2,000 | 2,000 | 2,000 |
| **500** | 500 | 714 | 893 | 1,072 | 1,251 | 1,430 | 1,609 | 1,788 | 1,967 | 2,000 | 2,000 |
| **>500** | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |

Adapted from Illinois EPA Preliminary Technical Justification for Changing Water Quality Standards for Sulfates, Total Dissolved Solids and Mixing Zones, 2006

\*These acute values are calculated from equations proposed as water quality targets in Table 1 in the document and capped at 2,000 mg/L. The only chronic sulfate water quality target is 129 mg/L sulfate, applicable only where surface water hardness is less than 50 mg/L.