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Analysis of the Numeric Water Quality Criteria Adopted by the Ten States That Border Directly on the Mississippi River

Missouri

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The findings presented in this document are based only on what was found in final, state WQS regulations as of September 1, 2008. Hence, though the existence of proposed changes to state water quality standards may be acknowledged, typically in footnotes, the contents of such potential modifications are not reflected in the various analyses contained in the report. Likewise, associated guidance documents, policy memoranda, and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards program or how WQS are applied in other water quality programs.

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Analysis of the Numeric Water Quality Criteria Adopted by the Ten States That Border Directly on the Mississippi River

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List of Acronyms

AWS	Agricultural Water Supply
BATEA (or BAT)	Best Available Treatment Economically Achievable
BOD	Biochemical Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CALM	Consolidated Assessment and Listing Methodology
CSO	Combined Sewer Overflows
CWA	Clean Water Act
DDT	Dichloro-dephenyl-trichloroethane
DO	Dissolved Oxygen
DU	Designated Use
DW	Drinking Water Standards
DWS	Drinking Water Supply
FC	Fish Consumption
GLI	Great Lakes Initiative
HHO	Human Health Organism
HHWO	Human Health: Water and Organism
IWS	Industrial Water Supply
LA	Load Allocation
MCL	Maximum Contaminant Level
MS4	Separate Sewage System
NPDES	National Pollution Discharge Elimination System
NTU	Nephelometric Turbidity Unit
PAH	Polycyclic Aromatic Hydrocarbons
PBT	Persistent, Bioaccumulative and Toxic (EPA Program)
PCB	Polychlorinated biphenyl
PWS	Public Water System
SDWA	Safe Drinking Water Act
SRF	State Revolving Fund
SSM	Single Sample Maximum
STP	Sewage Treatment Plant
TBA	Technology-Based Approach
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TRI	Toxics Release Inventory
TSS	Total Suspended Solids
WLA	Wasteload Allocation
WQ	Water Quality
WQBA	Water Quality Based Approach
WQBEL	Water Quality Based Effluent Limits
WQC	Water Quality Criteria
WQS	Water Quality Standards

A. Introduction

This document is one of a number of state-specific reports resulting from an Environmental Law Institute (ELI) analysis of the numeric water quality criteria (WQC)[1] component of the water quality standards (WQS) of the ten states that border directly on the Mississippi River. In this report ELI compares the state numeric water quality criteria to recommended criteria and related standards[2] issued by the US Environmental Protection Agency. The findings presented in the documents produced for this report are based on the most recent version of the state's WQS regulations as of September 1st 2008. Hence, only water quality criteria contained in proposed or final state regulations were examined. Associated guidance documents, policy memoranda and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards programs or how standards are applied in other water quality standards programs.

This work was funded by a grant from the Mississippi River Water Quality Collaborative, a group of state, regional and national non-profit organizations working together to improve water quality in the Mississippi River basin.

B. Summary of Findings

The water quality criteria (WQC)[3] specified in Missouri's water quality standards (WQS) regulations[4] present a mixed picture when compared to the criteria published by EPA, in terms of: 1) pollutant /use combinations[5] covered, to the degree to which all key elements of criteria are clearly articulated, and 3) level of protection likely afforded to applicable designated uses.

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[1] The terms "water quality criteria," "WQC," and "criteria" are used interchangeably in this report. Water quality criteria are closely associated with another key element of water quality standards established under state law and the federal Clean Water Act—designated uses. Criteria describe waterbody conditions, primarily pollutant levels, associated with full support of one or more of the designated uses (e.g., aquatic life, fish consumption, water contact recreation and drinking water supply) assigned to specific waters by a state's water quality standards regulations.

[2] The "recommended EPA criteria" referred to in this report are water quality criteria (WQC) issued as guidance to states, territories, and authorized tribes by the EPA under authority of the federal Clean Water Act. The "related EPA standards" are federal regulatory requirements applicable to finished (post treatment) drinking water that is delivered to homes and businesses by a public drinking water system. These standards are established by EPA under authority of the Safe Drinking Water Act (SDWA).

[3] The terms "water quality criteria," "WQC," and "criteria" are used interchangeably in this report. Water quality criteria are closely associated with another key element of water quality standards established under state law and the federal Clean Water Act—designated uses. Criteria describe waterbody conditions, primarily pollutant levels, associated with full support of one or more of the designated uses (e.g., aquatic life, fish consumption, water contact recreation and drinking water supply) assigned to specific waters by a state's water quality standards regulations.

[4] Missouri Rules of Department of Natural Resources: Divisions 20 - Chapter 7 - 10 CSR 20 – 7.010 – 10 CSR 20-7.050 (Effective February 20, 2007).

[5] As used in this report, "pollutant/use combination" or "pollutant/use pair" refers to a designated use and a particular pollutant or other water quality parameter. Often states have just one WQC for a given pollutant and use; however, in the case of aquatic life criteria, more than one WQC per pollutant/use combination is common. This is usually due to: 1) having both acute and chronic criteria; 2) breaking aquatic life down into a number of sub-categories (e.g., cold and warm water habitat); 3) establishment of different criteria for different ecoregions within the state; and/or 4) setting waterbody-specific WQC.

Missouri has adopted numeric water quality criteria for a large array of pollutant/use combinations. There are, however, a number of instances in which the state has not established criteria for pollutant/use combinations for which EPA has issued WQC under the authority of Section 304(a) of the CWA. For example, aquatic life (Cold Water Fisheries, Cool and Warm Water Fisheries, General Warm Water Fishery, and Limited Warm Water Fishery) in the state's WQS regulations) criteria for a number of traditional[6] pollutants are missing[7] from the state's WQS regulations, including the nutrients nitrogen and phosphorous. There is also no WQC for chlorophyll a, an indicator of algal density. And, the state lacks any kind of numeric WQC related to sediments/sedimentation.

There are also a number of toxic chemicals[8] for which the state currently lacks criteria. Missouri has not adopted acute Protection of Aquatic Life criteria for more than 50% of the toxic pollutants for which EPA has issued corresponding criteria. It also lacks chronic aquatic life WQC for over one-third of the toxics for which EPA has issued such WQC. Among the pollutants with missing acute and or chronic aquatic life criteria, slightly less than half are pesticides that fall into categories frequently mentioned as possible endocrine disruptors. Missouri does, however, have "extra"[9] aquatic life criteria for a couple traditional parameters and nearly a dozen toxic pollutants.

The Missouri water quality standards regulations have specified both: 1) drinking water supply (DWS) criteria and 2) human health: fish consumption criteria for a large number of toxic pollutants.[10] In addition to adopting DWS criteria covering the pollutants for which EPA has promulgated[11] somewhat corresponding[12] drinking water standards pursuant to the Safe

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[6] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[7] For the purposes of this review, "missing criteria" are those pollutant/use combinations for which the state has not officially adopted WQC, whereas EPA has published recommended WQC of the type specified

[8] In this report, "toxic pollutant" includes not only EPA's "priority toxic pollutants" but also: a) all those toxics that EPA calls, for CWA purposes, "non-priority pollutants," and, b) all toxic chemicals not falling in either of these EPA categories (the one exception is ammonia; see footnote 6.)

[9] For the purposes of this review, "extra criteria" are those pollutant/use combinations for which the state has formally proposed or officially adopted WQC while EPA has not published recommended WQC of the type specified.

[10] Missouri has not adopted any WQC for toxic chemicals aimed at protecting humans engaged in the combination of drinking water and fish consumption uses, though EPA has issued such WQC for 113 toxic chemicals. On the other hand, the state has adopted criteria for a large number of pollutants aimed at drinking water use alone and at fish consumption alone. It also has set ground water criteria for toxics.

[11] Unlike the water quality criteria that it issues for CWA purposes, the drinking water standards EPA promulgates, via formal rulemaking, under authority of the Safe Drinking Water Act are regulatory requirements, not just recommendations.

Drinking Water Act (SDWA), the state has also established DWS criteria for more than four dozen extra toxic pollutants—ones for which there are no SDWA standards.

Missouri lacks Human Health: Fish Consumption criteria for only one-fifth (20%) of the toxic pollutants for which EPA has issued corresponding (so-called Human Health: Organisms) criteria, and has such criteria for an extra six pollutants.

In addition, the state has adopted WQC for about 126 toxic pollutants to protect its groundwater sources of water, as well as "irrigation" criteria and "livestock and wildlife watering" criteria for a few toxic pollutants. There are no EPA criteria for toxic chemicals specifically applicable these two uses, or directly applicable to groundwater.

Where Missouri has adopted aquatic life protection WQC corresponding to EPA's aquatic life WQC, the criterion-concentrations[13] in most of these state criteria are equal to the criterion-concentrations in the parallel EPA criteria, for both traditional and toxic pollutants.

The criterion-concentrations in Missouri's fish consumption WQC are, with the exception of a few, higher than those in corresponding EPA fish consumption WQC. And with the exception of a few, the criterion-concentrations in Missouri's DWS criteria are mostly equal to EPA's primary drinking water standards.

Most of the state's WQC for traditional pollutants have clearly-stated criterion-durations.[14] The majority of the criteria for toxics have well-specified criterion-durations. None of the state's WQC has an explicit statement as to a criterion-frequency.[15]

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[12] The term "somewhat corresponding" has been used because water quality criteria and drinking water standards apply to different endpoints. WQC apply to surface waters within the jurisdiction of the Clean Water Act. Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems. When a waterbody in Kentucky is designated "Domestic Water Supply," then a certain set of WQC apply, per the CWA. There also is another set of standards that apply to the "finished" water that results from "raw" water being run through treatment processes aimed at removing contaminants.

[13] According to EPA guidance, numeric water quality criteria (WQC) consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. Criterion-magnitude, is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude."

[14] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as four day average concentrations. The occurrence of one or more excursion (e.g., a four day period in which the instream concentration of cyanide was higher than the chronic criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which *excursions* occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred.

[15] In EPA WQS terminology, the criterion-frequency specifies the maximum rate at which "excursions" (see above footnote re: criterion-duration) can occur and the waterbody of concern can still fully support the designated use to which the criterion applies. For instance, EPA guidance specifies a criterion-frequency of once in three years for both its acute and chronic WQC for toxic chemicals aimed at aquatic life protection. This means that only if two or more excursions occur during any three-year period has there actually been an exceedence of the WQC in question. For example, only if the four day average concentration of cyanide in a lake were higher than the chronic criterion-

As for the level of protection provided by a state WQC for a given pollutant/use combination in comparison to that of EPA (or another state), this cannot be done with any degree of confidence unless all three elements of both WQC are clearly articulated. And, even when the criterion-concentration, criterion-magnitude, and criterion-frequency of each of the two WQC being compared are precisely stated, their comparative degree of protectivity can only be determined, simply by looking at the two WQC and nothing else, with certain combinations of relative criterion-concentration, concentration-duration, and combination-frequency. For instance, if a state and a comparable (same pollutant and same designated use) EPA criterion both have the same criterion-concentration, same criterion-duration, and the same criterion-frequency, they would provide equal levels of protection. If, however, the criterion-concentration of one of the two WQC were lower than the other, and the criterion-duration and criterion-frequency remained identical, then that WQC would provide the higher degree of protection. Likewise, if the criterion-concentrations are the same, the criterion-durations are identical, but one of the WQC has a lower acceptable criterion-frequency, then that criterion with the lower frequency would provide more protection. Also providing a higher level of protection would be a WQC with a shorter criterion-duration than a comparable WQC that had the same criterion-concentration and criterion-frequency. (Appendix C provides a set of tables that list all possible combinations, in relative terms, of criterion-concentrations, criterion-durations, and criterion-frequencies, indicating which represent higher, lower, and identical levels of protection.)

Unfortunately, the relevance of the tables in Appendix C to Missouri's WQC is significantly limited by the fact that, though a majority of the state's criteria have a specified criterion-duration, the state's WQS regulations make no mention of a criterion-frequency for any of its water quality criteria. Further complicating comparison of the level of protection afforded to applicable designated uses by a state WQC is the fact that most of EPA's criteria for traditional pollutants lack a clearly-articulated criterion-duration and criterion-frequency.

Hence, any such effort would, of necessity, involve making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually settled upon, by the entities that established each of the criteria. In turn, the results of attempts to compare the protection provided by a state versus an EPA WQC would be greatly affected by whatever assumptions were made. For instance, the state has chronic aquatic life WQC for a number of toxic chemical in which the criterion-concentration and the criterion-duration are the same as EPA's (duration of 96 hours, or four days); however none of the state's aquatic life WQC specify a criterion-frequency. If the state's silence with regard to a criterion-frequency is taken to mean an implicit frequency of zero, then all the state's chronic aquatic life criteria for toxics that have criterion-concentrations equal to EPA's would provide a somewhat greater level of protection, due to the fact that the state WQC has a lower acceptable frequency of excursions than EPA's—zero versus no more than once in three years, respectively. But, if the state intended the criterion-frequency to be a maximum of no more than once a year, for instance, then the higher criterion-frequency would make the state WQC less protective than the corresponding EPA WQC.

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concentration of 5.2 µg/L more than once in three years would there have been failure to meet the EPA chronic aquatic life WQC.

Also, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher or lower than that for the corresponding U S EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC was designed. (This would not, however, mean that the two criteria would provide equal levels of protection to the relevant use. If, for example, a state's criterion-concentration were higher than EPA's, while the duration and frequency for the two WQC were identical, then the state's criteria would provide a lower degree of protection relative to that which would be provided by application of EPA's criterion to the waterbody in question. Nevertheless, site-specific conditions would have resulted in EPA's WQC providing an even higher level of protection than that for which EPA designed it. The effect of the state's higher criterion-concentration would be to bring the level of protection back down to that intended by EPA.)

Missouri has established more than one statewide WQC for several traditional pollutants for aquatic life WQC. It has different temperature criteria for three different categories of aquatic life (Fisheries, in the state's WQS regulations), and another set for lakes, as well as different criteria for three segments of the Mississippi River. It also has two different criteria for dissolved oxygen for cold waters versus cool or warm waters; and, different WQC for sulfate plus chloride depending on streamflow. The criterion-concentration for its ammonia criteria for aquatic life can be adjusted according to the temperature and/or pH of a given waterbody, as well as periods of the year, as can the EPA WQC upon which these state WQC were based.

Turning from aquatic life to human health, safe levels of pollutants tend to vary less from waterbody to waterbody. The most obvious reason is that, unlike aquatic life WQC, human health criteria address impacts on just one species, regardless of the location of the waterbody to which the WQC apply. The most common reason for need for variation in human health criteria from one locale to another is differences in patterns of human use. For example, persons in hotter climates tend to consume more water on average than those in cooler areas. Also, the amount of fish and other aquatic life from local waters that people catch and eat differ by an order of magnitude from place to place and/or within subpopulations of humans. Patterns of swimming and other water contact recreation also can change considerably depending on difference in the climate in which one waterbody versus another is located, along with the type of waterbody (river, lake, ocean beach). Hence, Missouri has one fecal coliform criteria for Whole Body Contact Recreation (criterion-concentration of 200 colonies/100 ml) and another for Secondary Contact Recreation (criterion-concentration of 2000 colonies/100 ml). There is no evidence of the state having established site-specific WQC for any toxic chemicals, even persistent, highly-bioaccumulative ones, to account for differences in human fish consumption patterns from one part of the state to another, or on any particular waterbodies.

Returning briefly to the effects of un-addressed or imprecisely-articulatedcriterion-durations and criterion-frequencies, in addition to making comparison of levels of protection afforded relevant uses difficult, if not impossible, such ambiguities can pose challenges to the implementation of CWA programs driven by WQS—303(d) and 305(b) reporting on the condition of a state's waters, total maximum daily loads (TMDLs), and water-quality based effluent limits in National Pollutant Discharge Elimination System (NPDES) permits. For instance, if a TMDL were being developed because of exceedences of one of Missouri's Human

Health: Non-Drinking Water Supply criteria WQC, the absence of a clearly-articulated criterion-duration for this category of WQC would create a quandary. What should the time-interval for the maximum loading set forth in the TMDL be? If one assumes, as has been done in this report, a default criterion-duration of an instant in such circumstances, then it would seem logical to express the TMDL as a maximum load over a very short interval, even just a second. On the other hand, if the criterion-duration for the state's Human Health Protection: Fish Consumption WQC were twelve months, then setting a maximum twelve month total load would seem appropriate.[16]

C. Traditional Pollutants/Parameters[17]

1) *Coverage*

a) Aquatic Life / "Protection of Aquatic Life"[18]

Missouri lacks an acute and/or chronic aquatic life WQC for a substantial fraction of the traditional pollutants[19] for which EPA has published criteria, with most of the "missing"[20]

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[16] In *Friends of the Earth v EPA*, 446 F.3d.145 (2006) the federal D.C. Circuit Court ruled that because of the specific reference to "daily" in the portion of Section 303(d) of the CWA that established the Total Maximum Daily Load program, all TMDLs should include, at least, a maximum daily load. Despite this ruling, maximum loads over other time spans would also be needed, in order for the TMDL to consistent with relevant WQC, when such criteria have criterion-durations other than 24 hours.

[17] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

[18] Throughout this document, generic names (e.g., "aquatic life," and "human health: drinking water supply," and "human health: water contact recreation") are used in reference to certain categories of uses. When a state uses different wording to refer to one of the generic uses, the name the state employs is listed in quotation marks, following the generic title. In the case of Missouri, we have listed "Protection of Aquatic Life," which is the heading in Table A in the state's WQS regulations for criteria applying to a number of designated uses: Cold-Water Fishery, Cool-water fishery, General Warm-Water Fishery, and Limited Warm Water Fishery. For most pollutants and parameters, the applicable WQC does not vary from one of these sub-uses of aquatic life to another. Exceptions include temperature, dissolved oxygen, and chlorine.

[19] "Traditional pollutant" has been used by EPA in reference to a small number of parameters, including: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. EPA also has published, for Clean Water Act purposes, a list of 120 "priority toxic" pollutants consisting of heavy metals, pesticides, and other synthetic organic chemicals. In addition, EPA has labeled a number of pollutants "non-priority" or "non-traditional." This category includes a number of chemicals widely recognized as toxic (e.g., iron, parathion, and pentachlorobenzene), along with several non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen oil and grease, pH, phosphorus, temperature and turbidity. For purposes of this study, the definition of "traditional pollutant" is expanded to also include all non-toxic "non-priority" pollutants, plus one "non-priority" toxic chemical, ammonia.

criteria being chronic criteria. (The only missing acute criterion is for calcium carbonate.) Among the missing currently are several criteria corresponding to published EPA criteria related to hyper-eutrophication due to excess loadings of nutrient – chlorophyll a, total phosphorous, and total nitrogen. Missouri also lacks criteria for turbidity (either as NTUs or Secchi disk depth), for which EPA has published chronic criteria, as part of its set of criteria addressing excess nutrients.

The state lacks a chronic criterion for hydrogen sulfide to correspond to EPA's, but Missouri has an acute criterion for this pollutant, whereas EPA does not. Missouri also has not adopted a "semi-chronic" aquatic life criterion for ammonia to correspond to EPA's criteria (expressed as a four day average); though, like EPA, it has an acute criterion (one hour average) and a chronic criterion (30 day average).

Missouri does have several "extra"[21] criteria for aquatic life as well. The state has acute aquatic life criteria for temperature in streams, and an acute-chronic "quasi-numeric" criterion for temperature. (See discussion of "quasi-numeric" criteria in Subsection C(3)(a)(iii)). EPA has only narrative criteria for temperature.

The state does have an acute aquatic life criterion for total sulfate plus chloride, while EPA has no WQC for this combination of pollutants for this use (Appendix A, Table 1).

b) Human Health: Drinking Water Supply/ "Drinking Water Supply"

Missouri has criteria applicable to drinking water supply use for chlorides and sulfates, whereas EPA has promulgated standards under the Safe Drinking Water Act[22] for eight (8) traditional and selected nontraditional water quality parameters. As for both chlorides and sulfates, Missouri has an acute criterion for each pollutant while EPA does not (Appendix A, Table 2).

It should be noted that, with the exception of total coliforms, the EPA standards for the eight traditional/nontraditional parameters addressed in this section are "secondary" standards (related to taste, odor, and appearance of drinking water), rather than "primary" drinking water standards (related to health). Also, EPA standards promulgated under the SDWA apply "finished" (after treatment) drinking water; hence, they are not necessarily directly applicable to WQC established in concert with the CWA for "raw" (untreated) water from surface waterbodies like rivers and lakes.

Missouri also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. High levels of algae in the raw water supply

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[20] For the purposes of this review, "missing" criteria are those pollutant/use combinations for which the state has not officially adopted WQC, whereas EPA has published recommended WQC of the type specified.

[21] For the purposes of this report, "extra" criteria are those pollutant/use pairs for which the state has officially adopted criteria, but for which EPA has not issued corresponding criteria.

[22] EPA lacks actual drinking water supply criteria for traditional pollutants, such as specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

used by a public drinking water system can result in unpleasant taste and odor in finished drinking water, unless special care is taken in the drinking water treatment process. Such extra treatment efforts can, in turn, lead to increased costs to a drinking water utility and its customers.

c) Human Health: Water-contact Recreation / "Whole Body Contact Recreation," "Secondary Contact Recreation"

Missouri has adopted chronic criteria not only for the bacterial indicator fecal coliform bacteria, but also for E.coli, to protect persons engaged in water-based recreation. Also, Missouri has established two different criteria (Whole Body Contact-Class A and Secondary Contact Recreation) for fecal coliform, as well as different criteria for three sub-uses (Whole Body-Class A, Whole Body-Class B, and Secondary Contact) for *E. coli*.

Missouri lacks chronic criteria for Enterococci to correspond with EPA's criteria. The state also does not have a criterion corresponding to EPA's "10 percent" criterion for fecal coliforms (Appendix A, Table 3).

The state also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. Such blooms can form mats on the water surface which can interfere with a variety of water-based recreational activities.

d) Human Health: Consumption of Fish and Other Aquatic Organisms / "Human Health Protection: Fish Consumption"

EPA has issued chronic WQC for bacteria applicable to consumption of shellfish, while Missouri has not.[23]

e) Agricultural Water Supply

EPA has issued agricultural water supply criteria for boron/borates, while Missouri has not.

f) Industrial Water Supply

EPA has issued industrial water supply criteria for calcium carbonate, while Missouri has not. (Industrial water supply is not among the uses for which a waterbody can be designated under the state's WQS regulations.)

[23] The significance of the lack of such criteria depends upon whether or not any of Missouri's waters harbor shellfish that are, or could be, harvested and consumed, for either recreational or commercial purposes.

2) *Criterion-Concentration*[24]

a) Aquatic Life / "Protection of Aquatic Life"

The traditional pollutants and water quality parameters for which Missouri has specified aquatic life criteria have criterion-concentrations that are either identical or very similar to comparable criteria issued by EPA and to those of neighboring states covered by this study.

Given that EPA has adopted ecoregion- and waterbody type-specific WQC for four parameters covered by the Agency's "nutrient criteria" applicable to the three ecoregions present in Missouri – Ecoregion IV (Great Plains Grass and Shrub Llands), Ecoregion V (South-Central Cultivated Great Plains), and Ecoregion IX (Southeastern Forested Plains and Hills), comparison of state criterion-concentrations to EPA's could be useful. However, the state has not adopted nor proposed criteria for total N, total P, chlorophyll a, or turbidity.

b) Human Health: Fish Consumption/ "Human Health Protection: Fish Consumption"

Not Applicable. Missouri has no "Human Health Protection: Fish Consumption" criteria that are applicable to "traditional" pollutants/parameters.

c) Human Health: Drinking Water Supply / "Drinking Water Supply"

Comparison of Missouri's criterion-concentrations for chloride and sulfate with the concentration in EPA's secondary drinking water standards for those substances is not appropriate because Missouri's criteria for these two contaminants apparently apply to relatively short term conditions (four day averages), while EPA's standards apply to longer-term scenarios (four rolling calendar quarters/365 days). Also, the state's WQC apply to raw, untreated water while EPA's drinking water standards apply to finished (post-treatment) drinking water.

d) Human Health: Water Contact Recreation / "Whole Body Contact Recreation and "Secondary Contact Recreation"

The state's Whole Body Contact-Class A criteria for fecal coliform bacteria, which apply during the recreation season (April 1 to October 31) have the same criterion-concentration (200 organisms/100 ml) as EPA's chronic (30 day average, or perhaps longer) WQC for this indicator There is no EPA criterion comparable to Missouri's Secondary Contact Recreation criterion for fecal coliforms of 1800 colonies/100 ml, though a number of states use a criterion-concentration of 2000 colonies/100 ml. Like that for primary contact criterion, this criterion applies during the 7 month recreation season only. There is no fecal coliform criterion for Whole Body Contact – Class B.

[24] According to EPA guidance, numeric water quality criteria consist of three components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these—criterion-magnitude is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude."

The chronic criterion-concentration for Missouri's Whole Body Contact-Class A for E.coli is identical to EPA's (126 colonies/100 ml). The state's criterion-concentration for *E. coli* applicable to Whole Body Contact-Class B is 548 colonies/100 ml and for Secondary Contact Recreation, it is 1134 colonies/100 ml (both seven month averages). There are no EPA criteria for *E. coli* that would correspond to these uses or concentrations.

e) Agricultural Water Supply

Not Applicable. Missouri has no WQC for "traditionals" specifically applicable to this use.

f) Industrial Water Supply

Not Applicable. Missouri has no WQC for "traditionals" specifically applicable to this use.

3) *Articulation of Criterion-Duration*[25]

Most of Missouri's WQC for traditional pollutants have clearly-specified criterion-durations though some are ambiguously associated with the criterion-duration.

a) Aquatic Life / "Protection of Aquatic Life"

Acute criteria

Some of the state's acute aquatic life criteria are clearly stated as having durations of just a moment, second, or instant. For example, the following temperature criterion applicable to the Mississippi River is a clear statement of an instantaneous duration: "At no time shall temperature … exceed the listed limits by more than three degrees Fahrenheit (3^{o} F)" (Section 10 CSR 20-7.031(4)(D)). Another example is the state's acute ammonia criteria, set forth at (10 CSR 20-7.031(4)(B)7.A. "The acute criteria shall not be exceeded at any time….."

On the other hand, Missouri has a number of criteria that appear to have a duration of an instant, but this is not entirely clear. For example, "Water contaminants shall not cause pH to be outside the range of 6.5 to 9.0 units." Similarly, "Water contaminants shall not cause the dissolved oxygen to be lower than the levels described in Table A." Yet another example is "Water contaminant sources shall not cause or contribute to stream temperatures in excess of eighty-four degrees Fahrenheit (84^{o}F)…" Criteria for chloride, total dissolved gases, hydrogen sulfide, and sulfate plus chloride appearing in Table A are also expressed imprecisely. Section 10

[25] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as 4 day average concentrations. The occurrence of one or more excursion (e.g., a four-day period in which the instream concentration, for example, of cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred.

CSR 20-7.031(4)(B)1 of the Missouri WQS regulations states, "water contaminants shall not cause the criteria in Tables A and B to be exceeded."[26] This language appears to apply to all the aquatic life criteria in the table that are labeled "acute."

In all the above cases, there is no indication that the cited values are anything other than levels not to be surpassed for a second, but the wording does create some uncertainty.

Chronic criteria

Table A has an aquatic life criterion for chloride labeled "chronic." It seems that a criterion-duration of four days applies, given that Section 10 CSR 20-7.031 (1)(E) states "Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four-day averages."

"Acute/chronic" criteria

Missouri has several criteria for temperature stating that it "shall not raise or lower the temperature of a stream more than ___." These are examples of what this study calls "quasi-numeric" criteria—ones expressed in terms of a certain change from background conditions. Unlike the case of typical numeric WQC, determination of whether such criteria have been exceeded requires knowledge of not only current but also past water quality but also past (or current concentration above and below a discharge or point of loading of pollutants to a waterbody). Also, the wording of such criteria provides no indication as to what duration(s) of time the "no change" standard is intended to apply. It would presumably apply to the overall natural background pattern of temperature, over time and space. Hence, attention would need to be paid not only to the instantaneous minimum temperature levels, but also average temperatures over various periods of time (minutes, hours, days, etc.).

b) Human Health: Fish Consumption

Not Applicable. Missouri has no criteria for traditional pollutants for this use.

c) Human Health: Drinking Water Supply / "Drinking Water Supply"

Missouri has criteria for chlorides and sulfates applicable to this use, both of which apparently have a criterion-duration of four days, the duration applicable to all criteria for "chronic toxicity." The assumption that these are chronic, rather than acute, criteria is based upon this language: "All Table A and B criteria are chronic toxicity criteria, except those

[26] This language in Missouri's WQS regulations seems to reflect a fairly common source of ambiguity in communication about water quality criteria – conflating "criterion" and "criterion-concentration." As a consequence, saying that levels of a pollutant in a waterbody shall not be higher than the "criterion" could be read in one of two ways: 1) no higher than the "criterion-concentration; or 2) no worse than the conditions described by the combination of the three elements of numeric criteria—the concentration, the duration, and the frequency. When a state fails to explicitly specify either a criterion-duration or a criterion-frequency (as is the case with many of Missouri's criteria) it becomes difficult to read regulatory language such as that quoted in the first sentence of this subsection to mean anything other than "waterbody concentrations shall not surpass the criterion-concentration at any time, even for an instant."

specifically identified as acute" (Section 10 CSR 20-7.031 (4)(A).[27]

The four-day criterion-duration is established by this regulatory text: "Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four day averages" (Section 10 CSR 20-7.031 (1)(E)).

d) Human Health: Water Contact Recreation / "Whole Body Contact Recreation" and "Secondary Contact Recreation"

Missouri's criteria for fecal coliform and *E. coli* bacteria pertaining to water-based recreation have criterion-durations of 7 specific calendar months. (April 1 to October 31), according to Section 10 CSR 20-7.031 (4)(C): "the ____ bacteria count shall not exceed the criteria listed in Table A as a geometric mean during the recreational season…" According to Table A of the Missouri WQS regulations, "The recreation season is from April 1 to October 31."

e) Agricultural Water Supply

Not Applicable. Missouri has no WQC for "traditionals" specifically applicable to agricultural water supply.

f) Industrial Water Supply

Not Applicable. Missouri has no WQC for traditional pollutants specifically applicable to industrial water supply.

4) *Articulation of Criterion-Frequency*[28]

None of Missouri's WQC for traditional pollutants has any specification of criterion-frequency, in which case a default frequency of zero is assumed for the purposes of this report.

A criterion-frequency of once in ten years for both the acute and chronic ammonia criteria could be inferred text in Section 10 CSR 20-7.031(4)(B)7. For instance, subsection B includes the following: "Therefore, the thirty-day Q_{10} low flow of the receiving water body will

[27] Though chlorides and sulfates are addressed here under traditional pollutants, Missouri presents its criterion-concentrations for these parameters in its table of criteria for toxics.

[28] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

be used in determining chronic total ammonia nitrogen criteria."[29] Similar language referring to a Q_{10} low flow (that occurring, on average, once in every 10 years) appears in subsection A of Section 10 CSR 20-7.031(4)(B)7.

A criterion-frequency of once in ten years for an indicator of salinity could be inferred from the following text in Section 10 CSR 20-7.031(4)(L)2: "The total chloride plus sulfate concentration shall not exceed the estimated natural background concentrations by more than 20% at the 60-day Q_{10} low flow."

No such references to stream design flows applicable to other traditional pollutants appear in the MO WQS regulations.

5) ***Discussion: Traditional Parameters***[30]

Missouri has adopted numeric WQC for a relatively small portion of the traditional parameter/use combinations for which EPA has issued water quality criteria and/or related standards (e.g., MCLs under the Safe Drinking Water Act). EPA has issued such values for about two dozen pollutants and parameters, some of which have criteria for more than one designated use.

Most significant to coverage of traditional pollutants is the absence of numeric criteria for nutrients (phosphorous and nitrogen) or the related parameter chlorophyll a (an indicator of the density of algae). The algal blooms that can result from excessive loadings of nutrients can interfere not only with aquatic life, but also public drinking water supply and water-based recreation.

Despite this lack of numeric criteria relevant to eutrophication, Missouri has included on its 303(d) list of impaired waters two assessment units for "nutrients." These listings reflect the willingness of the state to put waters on the 303(d) list based on conditions considered inconsistent with one or more narrative WQC. Nevertheless, the adoption of numeric nutrient WQC would likely eventually result in the identification of additional nutrient-impaired waters. ("Nutrients" are among the five most frequently mentioned causes of impairment for waters on state 303(d) lists nationwide, along with "sediments/sedimentation," pathogens, mercury and

[29] These references to what is often called design stream flows would be more consistent with EPA guidance and actual practice, if instead of "determining chronic criteria," they read, "in setting TMDLs and water quality-based effluent limits based on the chronic criterion." Stream flows or other indicators of the volume of a waterbody are not taken into account in EPA's methodologies for establishing either aquatic life or human health criteria.

[30] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance, which includes: biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, total suspended solids (TSS), bacteria and other pathogens, and temperature. Also considered "traditional" in this document are several other non-toxic pollutants and parameters including alkalinity, chloride, chlorophyll a, color, dissolved solids, hydrogen sulfide, (total) nitrogen, oil and grease, total phosphorus, and turbidity, which are sometimes called "non-conventional" or "non-priority" in the EPA literature. Also, one "non-priority" toxic chemical, ammonia, is discussed under the heading "traditional pollutants/parameters."

metals other than mercury.[31]) The state also lacks numeric criteria for sediment, sedimentation, turbidity or any variant thereof; it also has not listed any waters as impaired by this common stressor.

Like all the ten states reviewed in this study, Missouri has numeric criteria for aquatic life for temperature, while EPA has only narrative criteria. The state also has specified acute aquatic life criteria for hydrogen sulfide and combined sulfate and chloride while EPA has not.

Missouri lacks drinking water supply criteria for six of the eight traditional parameters for which EPA has published "secondary" (pertaining to taste, odor, and appearance of finished drinking water, rather than health risk) standards under the Safe Drinking Water Act (SDWA). However, given that EPA has not issued actual water quality criteria for public water supply use and that all public water supplies serving more than 25 connections are covered by SDWA regulations applicable to finished (at the tap) drinking water, the lack of public water supply criteria probably has little effect on human health. On the other hand, high levels of contaminants in raw water supplies can increase the cost of meeting federal drinking water standards.

Most of the criterion-concentrations in Missouri's WQC for traditional pollutants and parameters are comparable to the criterion-concentrations in corresponding EPA criteria as well as those of the other nine states covered in this study.

Some of Missouri's criteria for traditional parameters have a clearly stated criterion-duration, while others do not. The state has one aquatic life criterion with a clearly-articulated criterion-duration of an instant for both temperature and ammonia. On the other hand, its temperature, dissolved oxygen, and pH criteria, while appearing to have durations of just an instant, are somewhat ambiguously worded. All of Missouri's chronic aquatic life criteria and drinking water supply criteria have a clearly stated criterion-duration of four days, and the bacterial criteria applicable to water contact recreation have a clearly stated duration of seven calendar months (April 1 through October 31).

None of the state's criteria for traditional pollutants have explicit criterion-frequencies. The lack of reference to a frequency is taken, for purposes of this report, to mean that the state concluded that no frequency of excursions would be consistent with full support of applicable designated uses. That is, frequency equals zero.

Such lack of clarity regarding criterion-duration and/or criterion-frequency renders any attempt to determine the absolute level of protection afforded to the applicable designated use(s) an exercise with an inherent high degree of uncertainty. Obviously, any attempt to perform such comparisons would require making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended by the state. The results of attempts to compare the protection provided by a state versus an EPA would, of course, be greatly affected by whatever assumptions were made. Assumption of some fairly long-term duration (e.g., 90 days), rather than a short-term (e.g., one hour), would tend to make a criterion less protective. Likewise, assumption of a higher frequency (e.g., once in six months), rather than a lower frequency (e.g.,

[31] EPA National Section 303(d) List Fact Sheet: Causes of Impairment. Available at: (http://iaspub.epa.gov/waters/national_rept.control#TOP_IMP).

once in five years) would have the same effect, and would be more protective than the alternative.

For example, Missouri's chronic Protection of Aquatic Life WQC for chloride has the same criterion-concentration (230 mg/L) and the same criterion-duration (96 hours) as the corresponding EPA WQC. EPA specifies a maximum frequency of excursions,[32] however, Missouri's WQS regulations make no mention of a criterion-frequency for this, or any other, WQC for traditionals, which this report presumes to indicate a criterion-frequency of zero. This would mean that the state's WQC, having a lower criterion-frequency, would be more protective than the EPA criterion. Of course, if one assumed the state's WQC had a higher criterion-frequency, e.g., once in six months, than EPA's WQC, then the state criterion would be less protective. In the case of its aquatic life WQC for hydrogen sulfide, the state makes no mention of a criterion-duration or a criterion-frequency. If one assumed that this means the criterion-duration is an instant, and the criterion-frequency is zero, then the Missouri WQC would provide more protection than EPA's. This is because the state and EPA criteria have identical criterion-concentrations, while the state's criterion-duration is shorter (an instant versus 96 hours, and its criterion-frequency is lower (zero versus one in three years).

Also, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC were designed.[33] Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (e.g., duration of 24 hours, frequency of zero) and the state's criterion-concentration where higher than EPA's, then the state's criterion would indeed provide less protection to aquatic organisms in the waterbody or set of waterbodies than would EPA's, in relative terms. However, due to site-specific or watershed-specific conditions, the state's WQC would provide the same absolute level of protection as that for which the EPA WQC were designed, while use of the recommended EPA WQC in such waters would actually provide greater protection than that which EPA intended.

Indeed, Missouri has established more than one statewide WQC for several traditional pollutants for Aquatic Life Protection. It has different temperature criteria for three different categories of aquatic life (Fisheries, in the state's WQS regulations), and another set for lakes, as well as different criteria for three segments of the Mississippi River. (The criteria for one of these three segments also vary from month to month.) It also has different WQC for sulfate plus chloride depending on streamflow, as well as different criterion-concentrations for its dissolved oxygen WQC pertaining to: 1) Warm and Cool Water Fisheries (5.0 mg/L), and 2) Cold Water Fisheries (6.0 mg/L).

As is the case with aquatic life, safe levels of pollutants can vary from locale to locale, from time to time, and among different types of waterbodies. The most common reason is variation in human health criteria from one locale to another is differences in patterns of human

[32] As used in this report, and in some EPA guidance documents, an "excursion" is any period equal in length to the criterion-duration of a WQC when the average waterbody concentration is higher than the criterion-concentration.
[33] Possible reasons include differences in waterbody chemistry and in species present in a given type of aquatic ecosystems, compared to what were used in studies on which EPA's criteria were based.

use. For example, regarding drinking water use, persons in hotter climates tend to consume more water, on average, than those in cooler areas. And, of course, patterns of swimming and other water contact recreation can change considerably depending on differences in the climate in which one waterbody versus another is located, along with the type of waterbody (river versus lake.)

For example, Missouri has one fecal coliform criterion for Whole Body Contact Recreation (criterion-concentration of 200 colonies/100 ml) and another for Secondary Contact Recreation (criterion-concentration of 2000 colonies/100 ml). There is also variation in the applicability of these two recreation-related criteria—they only apply from April 1 to October 31, base, presumably on the idea that water-based recreational activities tend to occur only in the warmer months of the year.

Lack of clearly-stated criterion-durations and criterion-frequencies also can render considerably more challenging the implementation of CWA programs that are driven largely by WQC (Section 303(d) and 305(b) assessment and reporting, TMDLs, and water quality-based NPDES permitting programs). It would be difficult for someone implementing one of these "downstream" CWA programs to deal with a WQC having a criterion-concentration reading, "not too high" or "levels no greater than approximately 40 mg/L - 60 mg/L."[34] Though perhaps less immediately obvious, imprecisely-stated criterion-durations and criterion-frequencies can pose similar challenges to those presented by missing or vaguely-stated criterion-magnitudes. For example, if over some 30-day period, four "grab" samples had been collected and analyzed for levels of a certain pollutant, and one of those samples had a concentration higher than a relevant criterion-concentration, the answer to the question "Was this pollutant exceeded this WQC?" would differ depending on the criterion-duration and criterion-frequency. If the duration were "instantaneous" and the frequency "zero," the WQC would have been exceeded, without question.[35] But, if the duration were 30 days and the frequency remained at zero, the mere fact that one out of four instantaneous measurements surpassed the criterion concentration would not prove that an exceedence had occurred. Rather, only if the average of the concentrations in the four samples were higher than the criterion-concentration would there be strong evidence of an exceedence of WQC in the water from which said samples were collected. And, if the criterion-frequency were "two or more times per year," then one might not conclude that WQC exceedence had occurred based on the above evidence.[36]

[34] Missouri has no WQC stated in this manner. This wording is hypothetical.

[35] This statement assumes that all four of the samples passed the state's quality assurance/quality control (QA/QC) tests.

[36] The phrase "might not conclude" was employed because it would be contrary to the laws of probability to conclude that no additional excursions 30-day periods with average bacterial concentrations about the criterion-concentration) had occurred during any twelve-month period encompassing the 30 days in which the four grab samples had been collected, based on the information presented herein. In fact, if these four individual samples were the only ones gathered during a given twelve-month period, then it is quite likely that additional excursions did occur. The reason for this inference is that given that there are 336 thirty-day periods in any twelve month period, the odds of having randomly chosen to collect samples during the only 30-day period in which an excursion occurred are very low.

D. Toxic Chemicals[37]

1) *Coverage*

a) Aquatic Life / "Protection of Aquatic Life"[38]

Acute Toxicity

Missouri has not adopted criteria for nineteen pollutants, or 61%, of the 31 toxic pollutants for which EPA has issued[39] acute criteria for aquatic life protection (Appendix B, Table 1) pursuant to Section 304(a) of the CWA. These "missing"[40] pollutants are mostly synthetic organic substances, including many organophosphate and organochloride pesticides.

On the other hand, Missouri has adopted acute aquatic life protection criteria covering five[41] "extra"[42] pollutants—pollutants for which EPA has not issued corresponding Section 304(a) criteria (Appendix B, Table 3).

Chronic Toxicity

Missouri has not adopted criteria for thirteen pollutants, or 37%, of the 35 toxic pollutants for which EPA has issued chronic criteria for the protection of freshwater aquatic life (Appendix B, Table 1). They are mostly synthetic organic substances, including several organochloride pesticides and some suspected endocrine disruptors, including DDT, chlordane PCBs, toxaphene and tributyltin.

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[37] In this report, the term "toxic pollutant" includes not only EPA's "priority" toxic pollutants but also all those toxics called – for CWA purposes – "non-priority" pollutants, as well as all toxic chemicals falling into neither of these two EPA classifications. (The one exception is ammonia, which is addressed under "traditional pollutants" in this report.)

[38] Throughout this document, generic names (e.g., "aquatic life," and "human health: drinking water supply," and "human health: water contact recreation") are used in reference to certain categories of uses. When a state uses different wording to refer to one of the generic uses, the name the state employs is listed in quotation marks, following the generic use. In the case of Missouri, we have listed "Protection of Aquatic Life," which is the heading in Table A in the state's WQS regulations for criteria applying to a number of designated uses: Cold-Water Fishery, Cool-water fishery, General Warm-Water Fishery, and Limited Warm Water Fishery. For most pollutants and parameters, the applicable WQC does not vary from one of these sub-uses of aquatic life to another. Exceptions include, chlorine, temperature and dissolved oxygen.

[39] Throughout this report, the water quality criteria (WQC) recommended by EPA under the Clean Water Act will be referred to as the EPA's "issued" or "published" criteria, interchangeably. Unlike Primary Drinking Water Standards promulgated by the Agency according to the federal Safe Drinking Water Act, EPA WQC are not regulatory requirements. Terms like "established," "promulgated," and "set" are not used because EPA criteria are guidance, issued to help the states adopt their own water quality criteria in their water quality standards (WQS) regulations.

[40] For the purposes of this review, "missing" criteria are those pollutant/use combinations for which the state has not officially adopted WQC, whereas EPA has published recommended WQC of the type specified.

[41] The remaining pollutants are selenium and 5 other pollutants are those for which EPA has not issued acute aquatic life criteria. Because the EPA criterion for selenium is expressed in the form of an equation and because the Agency is in the process of developing a more stringent criterion for selenium, direct quantitative comparison of EPA's selenium WQC to Missouri's selenium WQC was not undertaken in this review.

[42] For the purposes of this report, "extra" criteria are those pollutant/use pairs for which the state has officially adopted criteria, but for which EPA has not issued corresponding criteria.

There are also six "extra" pollutants for which the state adopted *chronic* aquatic life protection criteria whereas EPA has not (Appendix B, Table 3).

b) Human Health: Consumption of Fish and Other Aquatic Organisms/ "Human Health Protection-Fish Consumption"

Missouri has adopted human health protection-fish consumption for 94 pollutants. It lacks criteria for only 20 pollutants, or 19%, of the total 106 toxic pollutants for which the EPA has issued corresponding criteria (HHO) to address risks to human health associated with fish consumption (Appendix B, Table 1). These missing pollutants include organochloride pesticides, toxic metals, aromatic hydrocarbons, and two potential endocrine disruptors: alpha-endosulfan and beta-endosulfan.

On the other hand, the state has adopted fish consumption criteria for six pollutants for which EPA has not issued corresponding criteria pursuant to Section 304(a) of the Clean Water Act (Appendix B, Table 3).

c) Human Health: Consumption of Water plus Fish and Other Aquatic Organisms

Missouri has not adopted criteria for any of the 113 toxic pollutants for which EPA has published "human health: water and organisms" (HHWO) criteria to address human health risks associated with the combined use of fish and water consumption from surface waters.

d) Human Health: Drinking Water Supply/"Drinking Water Supply"

Missouri has not adopted drinking water supply criteria for 21%, or eighteen pollutants (Appendix B, Table 2), of the total 83 pollutants for which EPA had adopted primary and/or secondary drinking water criteria under the authority of the Safe Drinking Water Act.[43]

On the other hand, the state has adopted drinking water supply criteria for 56 pollutants for which EPA has not issued corresponding DWS criteria (Appendix B, Table 4). Most of these "extra" pollutants are synthetic organic substances, including organochloride pesticides, polycyclic aromatic hydrocarbons, and phthalate esters.

e) Human Health: Groundwater

Missouri has adopted "groundwater" WQC for 126 pollutants (Appendix B, Table 4). There are no corresponding EPA criteria for toxic pollutants for this particular designated use.

[43] EPA lacks actual drinking water supply criteria for traditional pollutants – specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

f) Human Health: Water Contact Recreation / "Whole Body Contact Recreation" and "Secondary Contact Recreation"

Not Applicable. Missouri has not adopted any water-based recreation WQC covering toxic pollutants; neither has EPA.

g) Agricultural Water Supply: Irrigation / "Irrigation Water"

Missouri has adopted "irrigation water" WQC for two pollutants: cobalt and copper. There are no corresponding EPA criteria for toxic pollutants for this particular designated use.

h) Agricultural Water Supply: Livestock / "Livestock and Wildlife Watering"

Missouri has adopted "livestock and wildlife watering" WQC for four pollutants: arsenic, beryllium, boron, and chromium (III). There are no corresponding EPA criteria for toxic pollutants aimed at this particular designated use.

i) Industrial Water Supply

Not Applicable. Missouri has not adopted any "industrial water supply" WQC for toxic pollutants.

2) *Criterion-Concentrations*[44]

a) Aquatic Life / "Aquatic Life Protection Criteria"

Acute Toxicity

Of the eighteen toxic pollutants for which Missouri has adopted acute freshwater aquatic life WQC, twelve pollutants have WQC that correspond to EPA's recommended WQC. [45] Within this subset, seven pollutants have acute freshwater aquatic life WQC for which the criterion-concentrations are the same as the corresponding EPA values; three pollutants have WQC for which the criterion-concentrations are lower than the corresponding EPA values (Appendix B, Table 5); and two pollutants have WQC for which the criterion-concentrations are higher than the corresponding EPA values (Appendix B, Table 6).

Chronic Toxicity

Of the 28 toxic pollutants for which Missouri has adopted acute freshwater aquatic life WQC, 22 pollutants have WQC that correspond to EPA's recommended WQC.[46] Within this

[44] According to EPA guidance, numeric water quality criteria (WQC) consist of 3 components: 1) a criterion-magnitude, 2) a criterion-duration, and 3) a criterion-frequency. The first of these—criterion-magnitude is usually expressed as a concentration; hence, the frequent use of "criterion-concentration" in this report. For some key water quality parameters, such as temperature and pH, quantity is not expressed as a concentration, so EPA employs the broader term "criterion-magnitude."

[45] The other six pollutants are those for which EPA has not issued acute aquatic life criteria.

[46] The other six pollutants are those for which EPA has not issued chronic aquatic life criteria.

subset, the chronic freshwater aquatic life criteria for eleven pollutants have the same criterion-concentrations as the corresponding EPA values. Eight (8) pollutants have WQC for which the criterion-concentrations are lower than the corresponding EPA values (Appendix B, Table 5); and three pollutants have WQC for which the criterion-concentrations are higher than the corresponding EPA values (Appendix B, Table 6).

b) Human Health: Consumption of Fish and Other Aquatic Organisms/ "Human Health Protection-Fish Consumption"

Of the 91 pollutants for which Missouri has adopted human health "fish consumption" criteria, 85 pollutants have WQC that correspond to the EPA's "human health: organisms only" WQC.[47] Within this subset, the "fish consumption" criterion for one pollutant has the same criterion-concentration as the corresponding EPA values. Nine pollutants have WQC for which the criterion-concentrations are lower than the corresponding EPA values (Appendix B, Table 5); and 75 pollutants have WQC for which the criterion-concentrations are higher than the corresponding EPA values (Appendix B, Table 7).

c) Human Health: Consumption of Water *plus* Fish and Other Aquatic Organisms

Not Applicable. It is not apparent from the Missouri WQS regulations that the state has adopted criteria for any of the 113 toxic pollutants for which EPA has issued "human health: water and organisms" (HHWO) criteria.

d) Drinking Water Supply (DWS)

Of the 122 toxic pollutants for which Missouri has adopted DWS criteria, 66 pollutants[48] have criteria that correspond to the Primary Drinking Water Standards (often referred to as maximum contaminant level (MCL)). EPA issued under the authority of the Safe Drinking Water Act. Within this subset, the DWS criteria for 62 pollutants have the same criterion-concentrations as the corresponding EPA values. Three pollutants have WQC for which the criterion-concentrations are lower than the corresponding EPA values (Appendix B, Table 5); and the criterion-concentration in the WQC of one pollutant, arsenic, is higher than the corresponding EPA value (Appendix B, Table 6).

e) Groundwater

The criterion-concentration for every pollutant for every "groundwater" WQC that Missouri has adopted is equal to the criterion-concentration in the drinking water supply WQC that the state has adopted for that pollutant. (See discussion of how the state's DWS criteria compare to those of EPA in subsection D(2)(d) above.)

[47] The other six pollutants are those for which EPA has not issued HHO criteria.
[48] The other 56 are those for which EPA has not issued primary and/or secondary drinking water criteria.

f) Human Health: Water Contact Recreation / "Whole Body Contact Recreation" and "Secondary Contact Recreation"

Not Applicable. Missouri has not adopted any water-based recreation criteria covering toxic pollutants; and neither has EPA.

g) Irrigation Water

Not Applicable. While Missouri has adopted "irrigation water" WQC, there are no corresponding EPA criteria for toxic pollutants for this particular designated use.

h) Livestock and Wildlife Watering

Not Applicable. While Missouri has adopted "livestock and wildlife watering" WQC, there are no corresponding EPA criteria for toxic pollutants for this particular designated use.

3) *Articulation of Criterion-Duration*[49]

The majority of Missouri's WQC for toxic chemicals have clearly stated criterion-durations – the principal exception being the state's acute aquatic life criteria.

a) Aquatic Life / "Protection of Aquatic Life"

Acute Toxicity

The criterion-duration in Missouri's acute aquatic life criteria for toxic substances appears to be an instant.

Section 10 CSR 20-7.031(4)(A) states, "All Table A and B criteria are chronic toxicity criteria, except those specifically identified as acute." And, Section 10 CSR 20-7.031(1)(E) specifies a criterion-duration of four days for chronic criteria. The only indication of a criterion-duration for acute criteria in these tables is provided by Section10 CSR 20-7.031(4)(B)1: "Water contaminants shall not cause the criteria in Tables A and B to be exceeded."[50] Since this

[49] According to terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as 4 day average concentrations. The occurrence of one or more excursion (e.g., a four-day period in which the instream concentration, for example, of cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedence of a water quality criterion occurred.

[50] As noted in this report, EPA guidance, as well as common sense, indicate that a water quality criterion (or any description of waterbody conditions at a given location over time) consists of three parts: 1) a concentration (or magnitude), 2) a duration (often expressed as an averaging period); and 3) a frequency. Failure to meet a WQC expressed in this fashion would, by definition, occur only when actual waterbody conditions are "worse than" those specified by the combination of the criterion-concentration, criterion-duration, and criterion-frequency. The term most often used in EPA publications to describe failure to meet a water quality criterion is "exceedence." It follows that, if a particular WQC has a concentration of 25 µg/L, a duration of 30 days, and a frequency of once in five

language provides no indication that the cited values for acute criterion-concentrations are anything other than levels not to be exceeded ever, even for a second, this study defaults to a criterion-duration of "instantaneous."

Chronic Toxicity

A four-day criterion-duration is established by this text in Section (10 CSR 20-7.031 (1)(E)): "Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four-day averages."

b) Human Health: Consumption of Fish and Other Aquatic Organisms/ "Human Health Protection-Fish Consumption"

Section 10 CSR 20-7.031 (4)(A) states, "All Table A and B criteria are chronic toxicity criteria, except those specifically identified as acute." A four-day criterion-duration is established by this regulatory text: "Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four-day averages" (10 CSR 20-7.031 (1)(E)).

c) Human Health: Consumption of Water plus Fish and Other Aquatic Organisms

Not Applicable. It is not apparent from the Missouri WQS regulations that the state has adopted criteria for any of the 113 toxic pollutants for which EPA has issued "human health: water and organisms" (HHWO) criteria.

d) Human Health: Drinking Water Supply/ "Drinking Water Supply"

Section 10 CSR 20-7.031 (4)(A) states, "All Table A and B criteria are chronic toxicity criteria, except those specifically identified as acute." A four-day criterion-duration is established

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years, that an "exceedence" would have occurred if, during any five-year period, there was more than one stretch of 4consecutive days in which the average concentration of the pollutant of concern were greater than 25 µg/L. But, there would *not* have been an "exceedence" according to these EPA terms, if during a given five-year period, the concentration had spiked above 25 µg/L for just a second on two or more occasions, but had never averaged 25 µg/L over any period of 4 days or more.

This hypothetical example illustrates the need for terms describing two distinct situations, neither of which is an "exceedence" according to the just-mentioned EPA terminology: 1) times when the ambient concentration goes above the criterion-concentration for just an instant; and 2) times when the ambient concentration over a period equals to the criterion-duration averages more than the criterion-concentration. The term that EPA has used in recent guidance to describe situation #1 is "digression." For situation #2, the term most frequently employed by EPA is "excursion."

The problem with language referring to an "exceedence of a criterion" is that it is often taken to mean "ambient concentration higher than the criterion-concentration for just a second." (Quite often, any grab sample with a concentration above the criterion-concentration is incorrectly referred to as "an exceedence.") This interpretation of language like that from the Missouri WQS regulations cited above is fostered by the practice of both EPA and states to present tables of "water quality criteria" that are actually just listings of criterion-concentrations. Tables A and B in the WQS regulations are examples of such—no mention of criterion-durations or criterion-frequencies are made in either the table itself or in any footnotes to said table.

by this regulatory text: “Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four-day averages” (10 CSR 20-7.031 (1)(E)).

e) Human Health: Groundwater

Section 10 CSR 20-7.031 (4)(A) states, “All Table A and B criteria are chronic toxicity criteria, except those specifically identified as acute.” A four-day criterion-duration is established by this regulatory text: “Chronic numeric criteria in Tables A and B are maximum concentrations which protect against chronic toxicity; these values shall be considered four-day averages” (10 CSR 20-7.031 (1)(E)).

f) Human Health: Water Contact Recreation / “Whole Body Contact Recreation” and “Secondary Contact Recreation”

Not Applicable. Missouri has not adopted any water-based recreation criteria covering toxic pollutants; and neither has EPA.

g) Industrial Water Supply

Not Applicable. The state has no WQC for toxic chemicals pertaining to use of waterbodies as a water supply for industrial operations.

h) Agricultural Water Supply

Not Applicable. The state has no WQC for toxic chemicals pertaining to use of waterbodies as a water supply for agricultural operations.

4) *Articulation of Criterion-Frequencies*

None of Missouri’s numeric WQC for toxic chemicals has specified criterion-frequencies. In the absence of such specificity in the state’s WQS regulations, this study employs a default criterion-frequency of zero.

5) *Discussion: Criteria for Toxic Chemicals*

Missouri has adopted drinking water supply (DWS) criteria, ground water criteria, and fish consumption criteria for a large number of toxic pollutants. Indeed, in addition to adopting DWS criteria covering the pollutants for which EPA has published drinking water criteria pursuant to the SDWA, the state has also established DWS criteria for more than four dozen “extra” pollutants for which EPA has not issued any corresponding drinking water criteria under the SDWA. Most of these “extra” pollutants are synthetic organic compounds, including many known/suspected carcinogens, persistent bioaccumulators, and several compounds that have been cited as likely endocrine disruptors. For those state DWS criteria with corresponding EPA drinking water criteria, the criterion-concentration in Missouri’s DWS criteria are mostly equivalent to the EPA’s MCL criterion values.

In addition, the state has adopted criteria for about 126 toxic pollutants to protect its groundwater sources. And where both a DWS criterion and a groundwater criterion have been established for a given pollutant, the criterion-concentration in the state's ground water WQC for that pollutant is identical to the criterion-concentration in its drinking water supply WQC.

While Missouri's coverage of Drinking Water Supply and ground water criteria is fairly comprehensive, significant gaps exist with regard to the state's coverage of Aquatic Life Protection criteria for toxic pollutants. Missouri has not adopted acute aquatic life protection criteria for more than 50% of the pollutants for which EPA has issued corresponding criteria. Among the pollutants with missing acute aquatic life criteria, slightly less than half are pesticides that fall into categories frequently mentioned as possible endocrine disruptors (aldrin, alpha-endosulfan, beta-endosufan, chlordane, DDT, dieldrin, endrin, toxaphene, heptachlor, and pentachlorophenol). A similar pattern holds for the state's chronic aquatic life protection criteria: slightly more than a dozen pollutants lack chronic criteria aimed at aquatic life protection. Of these, seven are pesticides that fall into categories frequently mentioned as possible endocrine disruptors (aldrin, alpha-endosulfan, beta-endosufan, chlordane, DDT, dieldrin, endrin, and toxaphene).

Furthermore, Missouri has not adopted criteria for any of the pollutants for which EPA has issued "human health: organism and water" (HHWO) criteria to address risks to human health associated with the combined consumption of fish and water.

The majority of these pollutants are synthetic organic chemicals, including over two dozen known or suspected carcinogens (e.g., 1,3-dichloropropene, acrylonitrile, 2,4-dinitrotoluene); persistent bioaccumulators (e.g., PCB, dieldrin, hexachlorobenzene); and a number of potential endocrine disruptors (e.g., aldrin, chlordane, endrin, endosulfan). Also among the pollutants lacking state equivalents to EPA's "Human Health: Water & Organism" criteria are several polycyclic aromatic hydrocarbons (PAHs), which are not only carcinogenic and bioaccumulative, but are also commonly found in urban stormwater. And, like phthalate esters, for which Missouri also lacks "Human Health: Water & Organism" criteria, PAHs are among those types of chemicals cited by numerous sources as likely endocrine disruptors. The state also lacks "Human Health: Water & Organism" criteria for heptachlorepoxide, hexachlorobenzene and methoxychlor, which are contaminants reported to be associated with suspended material in the Mississippi River.[51]

While Missouri has not issued "Human Health: Water & Organism" criteria for any pollutant, the state has adopted Human Health Protection: Fish Consumption criteria for 80% of the pollutants for which EPA has published corresponding criteria. As for those pollutants lacking state equivalents to EPA's fish consumption (Human Health: Organisms) criteria, many are synthetic organic compounds, and several are toxic metals. Alpha-endosulfan and beta-endosulfan, pesticides that have been cited as likely endocrine disruptors, are two of these compounds.

[51] "Polychlorinated Biphenyls and other Synthetic Organic Contaminants Associated with Sediments and Fish in the Mississippi River" Colleen E. Rostad, *et. al*. Contained in U.S. Geological Survey Circular 1133, "Contaminants in the Mississippi River" (1995).

In theory, the absence of a human health criterion for a pollutant might not be important to ensuring that people are protected from exposure (via ingestion of drinking water and/or aquatic organisms) to levels of that pollutant that pose a significant risk. In particular, if the state has an acute and/or a chronic aquatic life criterion for the pollutant with a criterion-concentration lower than that in EPA's human health criteria for the pollutant of concern, attainment of the aquatic life criterion should ensure that waterbody levels of the pollutant would remain below those specified in EPA's human health criteria.

In Missouri's case, this situation applies to the criteria for three pollutants: cyanide, nickel, and zinc—that is, the state has aquatic life criteria for the chemical, though it does not have human health criteria. The criterion-concentration in the chronic aquatic life criterion for all three pollutants is significantly lower than the lowest criterion-concentration for the pollutant between EPA's two types of human health criteria. If this study's assumption that the criterion-frequency for Missouri's aquatic life criteria is zero, as is also assumed for EPA's human health criteria, then only if the criterion-duration for EPA's human health criteria were shorter than the four-day duration of Missouri's chronic aquatic life criteria might there be any reason to doubt that the state's aquatic life criteria provide equal or greater protection to human health than do EPA's criteria. (As noted previously, EPA's guidance regarding the criterion-duration for its human health criteria has been subject to various interpretations, ranging from one instant to 70 years.)

Where Missouri has adopted Aquatic Life Protection WQC comparable to EPA's aquatic life WQC, the criterion-concentrations in most of these state criteria are equal to the criterion-concentrations in the corresponding EPA criteria. The criterion-concentrations in the remaining WQC are either slightly higher or slightly lower than that of EPA's WQC.

Regarding criterion-durations in Missouri's WQC for toxics, the state's chronic Aquatic Life Protection, as well as both of its types of human health WQC (Drinking Water Supply and Human Health Protection: Fish Consumption, have a clearly-articulated criterion-duration of four days. However, the acute Aquatic Life Protection WQC lack a specified criterion- durations, which this report takes to mean a duration of an instant.
No mention is made of a criterion-frequency pertaining to any of the WQC for toxic substances in Missouri's WQS regulations.

Given that none of Missouri's WQC for toxic chemicals have clearly stated criterion-frequencies, and that its acute aquatic life criteria do not have a clearly stated criterion-duration, simple comparison of the state's criterion-concentrations to those of EPA's is not a reliable means of determining the relative protectiveness of their WQC. If for purposes of discussion, one assumes a criterion-frequency of zero for all the state's WQC for toxics, applicable to aquatic life and human health, then reliable judgments about the protectivity of a given state WQC versus the comparable EPA WQC can be rendered. For instance, those nineteen chronic Aquatic Life Protection criteria for toxic substances with criterion-concentrations lower than that of EPA's chronic aquatic life WQC would presumably be more protective that the corresponding EPA WQC, given that the criterion-duration for the state and federal EPA WQC are both four days, and the state has a lower (zero versus once in three years) criterion-frequency. On the other hand,

it would difficult to determine, just from looking at the WQC themselves, whether the three state WQC of this type with higher criterion-concentration's than EPA's would be more or less protective. That is, would the tendency toward lower protection resulting from the state's higher criterion-concentration be offset by the lower frequency, with the criterion-durations being the same? For each of these WQC, data showing the toxic effects on several different aquatic species of the lower level of the pollutant specified in Missouri's higher criterion-concentration over four days would need to be gathered and/or generated and compared to available data on the effect of exposure to EPA's lower criterion-concentration over the same period would be needed, along with some analysis on the effect of the repeated, though infrequent, periods of exposure accepted (criterion-frequency) by the EPA criterion, in order to determine which of the two criteria would be more protective.

However, if one assumes that the criterion-frequencies for Missouri's aquatic life WQC are the same as those for EPA's aquatic life criteria (once in three years), then it is reasonable to conclude that those eleven Missouri chronic aquatic life criteria for toxics with criterion-concentrations equal to that of the corresponding EPA criteria would likely provide essentially the same level of protection, while those eight with lower criterion-concentrations would seem to be more protective, and those three with higher criterion-concentrations than EPA's are less protective than EPA's.

Such concentration-to-concentration comparisons would not be as valid with regard to the state's acute aquatic life criteria. Whereas Missouri's chronic aquatic life criteria have a clearly-articulated criterion-duration that is identical to EPA's chronic criterion-duration (four days), the duration for the state's acute aquatic life criterion is somewhat unclear. For the purposes of this study, an instantaneous duration has been assumed, which is substantially shorter than the one-hour duration in EPA's acute aquatic life criteria. If this indeed were the case, then Missouri's criteria for the seven pollutants having criterion-concentrations equal to EPA's corresponding criteria would be more protective, as would the three with criterion-concentrations lower than EPA's. More difficult to determine would be the relative protectiveness of those state WQC with criterion-concentrations higher than those in the corresponding EPA criteria. In theory, the considerably shorter criterion-duration could offset the somewhat higher criterion-concentration, making the state criterion the more protective. Careful analysis of available, and perhaps newly generated, toxicity data would be needed to determine whether this was the case.

There could be, however, state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still be equally protective of aquatic life.[52] Missouri has not, however, developed any such WQC for toxics—the same criterion-concentration for a given pollutant/designated use combination applies throughout the state.

Where Missouri has adopted Human Health Protection: Fish Consumption, the criterion-concentrations in these WQC are, with only a few exceptions, higher than those in corresponding EPA fish consumption WQC. From this, one might conclude that most of Missouri's human

[52] Possible reasons include differences in waterbody chemistry and in species present in a given type of aquatic ecosystems, compared to what were used in studies on which EPA's criteria were based.

health fish consumption criteria for toxic pollutants are less protective than EPA's, if the criterion-durations and criterion-frequency for Missouri's and EPA's human health fish consumption criteria are identical. However, this conclusion would be questionable because of uncertainty regarding the criterion-duration and/or criterion-frequency in Missouri's and/or EPA's criteria. On one hand, Missouri has a clearly-stated criterion-duration of four days; on the other hand EPA guidance is not clear as to the duration applicable to its "Human Health: Organisms Only" criteria, with possible interpretation running all the way from one second to 70 years.[53] If the EPA duration was just an instant, or anything up to four days, then the Missouri criteria having higher criterion-concentrations than the corresponding EPA criteria would appear to be less protective. (Confidence in this conclusion would be very high if it were assumed that the criterion-frequency for both the Missouri and EPA criteria were zero, which is a fairly reasonable assumption given that neither the state nor EPA has indicated anything about a criterion-frequency for their fish consumption criteria.) On the other hand, if the duration of EPA's criteria were one of the longer possibilities, such as 365 days or 70 years, then the relative degree of protection provided by the criteria from the state versus EPA would be impossible to infer from the information at hand. Likewise, if the criterion-frequencies were different for the state and EPA criteria, conclusions about the relative protectiveness of the two criteria would become most difficult.

Safe levels of toxic chemicals with regard to human health tend to be less variable from one waterbody to another, one reason being that the species of concern, Homo sapiens, is the same everywhere.[54] The most common cause of variation in human health criteria from one waterbody to the next is differences in patterns of human use. For example, differences in the rates of human consumption of local aquatic foodstuffs from one waterbody to the next can result in the need for different criterion-concentrations, in order to provide the same level of protection.[55] EPA's human health criteria dealing with fish consumption (alone or in combination with consumption of drinking water) assume a daily intake of 17.5 grams of fish (and other aquatic organisms) per person. This estimate is based on national data, and represents the average rate of fish consumption. However, there are subpopulations that consume locally-caught "fish" at considerably higher rates. (Native Americans, Cajuns, immigrants from Southeast Asia, and low income persons of all ethnic racial backgrounds are widely-recognized examples.) For such subsistence fisherpersons, the EPA estimates that the fish consumption rate can be as high as 10 times the 17.5 g/day national average. If a state simply adopts a EPA "human health: organisms" (HHO) or a "human health: water and organisms" (HHWO) criteria for a waterbody that is used by subsistence fishers, those people will face a higher risk of illness than that upon which EPA's human health criteria are based. In order to compensate for this situation, the criterion-concentrations for these kinds of criteria ("Human Health-based aquatic

[53] Some EPA text strongly suggests an instantaneous duration, while other portions of relevant EPA guidance seem to indicate durations of either a year (365 days, not a calendar year), or even 70 years (average human life span).
[54] Of course, within the human population in a given locale, there will be certain sub-populations that are more sensitive to certain pollutants than the average members. Small children, pregnant women, and the elderly are examples of such groups. Other groups worthy of special attention are persons who engage in hard physical labor and those who participate in vigorous outdoor exercise. In most cases, this fact would not, however, indicate a need for different human health WQC for one waterbody versus another, as the proportion of the total population represented by each of these subgroups would most likely not vary substantially from one location to another.
[55] Rates of consumption of drinking water and frequency of water contact recreation also can vary from one climate zone to another—being higher in hotter areas.

life" criteria, in Missouri's case) would need to be set at lower levels than that which has been set by EPA.

There is nothing in Missouri's WQS regulations that indicates that the state has established site-specific Human Health-based aquatic life criteria, in order to account for differences in rates of fish consumption from one waterbody to another.

A further confounding factor pertaining to criteria aimed at risks associated with consuming contaminants in drinking water is the fact that most states' water quality criteria for public water supply apply to the untreated water from a river or lake that is used as a "raw" water supply for a public drinking water system, while EPA's standards established under the Safe Drinking Water Act (SDWA) apply to "finished" drinking water at the tap, which usually has undergone some form of treatment to remove contaminants. Hence, for those 62 pollutants with a Missouri Drinking Water Supply WQC with a concentration equal to that specified in the EPA drinking water standard for that pollutant could actually provide greater protection to consumers of finished drinking water. (This assumes that the same durations and frequencies apply to the state criteria and the federal standard.) For instance, if the drinking water treatment process to which the raw water is subjected removes 50% of a certain pollutant, then the level of the pollutant in the raw water could be two-times the concentration specified by the SDWA standard, and still meet that standard in the finished drinking water. For example, both the Missouri Drinking Water Supply criteria and EPA's Drinking Water Standard for styrene are both 100 mg/L, so if a public water supply utility was using a river or lake with water meeting the state's water quality criterion for its raw drinking water supply, then finished drinking water supply with a concentration equal to half that of the drinking water standard (50 mg/L) should emerge from the treatment process. And, if the drinking water treatment system could remove more than 50% of the styrene, e.g., 80%, then finished drinking water with a styrene level of 100 mg/L.

Only if the drinking water treatment system had the effect of increasing levels of a given pollutant found in the raw water supply, rather than achieving the reductions for which the treatment is intended, would there be any chance that raw water meeting state water quality criteria would end up providing finished water that failed to meet EPA drinking water standards. Though this is apparently not the case with most contaminants, it does happen with one set of chemicals, trihalomethanes, such as trichloromethane and bromodichloromethane, which are formed as a byproduct of the use of halogens (chlorine and/or bromine) to disinfect drinking water, whereby the halogen(s) combine with natural organic compounds in the raw water supply to create trihalomethanes.

Returning, briefly to the problems associated with vaguely articulated WQC, lack of clearly-stated criterion-durations and criterion-frequencies can result in lack of consistency in the application of Clean Water Act programs that are "driven by" water quality criteria. For instance, if one assumes that the criterion-duration for the human health criterion is an instant and the frequency is zero, then any waterbody from which just one valid (meets QA/QC requirements/guidelines) grab sample, out of several such samples, with a concentration of a pollutant higher than the criterion-concentration should be included in the state's Section 303(d) list. On the other hand, if the criterion-duration for human health criteria were 365 days, then

exceedence of WQC would not be indicated by having just one sample out of several collected over any 365 day period with a concentration above the criterion-concentration. In this latter case, the appropriate determinant of criterion exceedence would be having a set of samples collected over some 365-day periods with an average concentration higher than the criterion-concentration.

Other possible ways in which different outcomes could result from different assumptions regarding the criterion-duration for the state's human health criteria could be manifested in the TMDL and NPDES programs. For instance, it would seem that meeting TMDL wasteload allocation or an NPDES permit limit of "no higher than 10 µg/L for an instant, at any time" would be considerably more difficult, and presumably more expensive, than keeping the 365 day average concentration at or below 10 µg/L.

Appendix A

Missing and Extra Criteria for Conventional Pollutants: MISSOURI

Table 1 - Aquatic Life

i) MISSING[56] POLLUTANTS

	ACUTE	CHRONIC
warm water/cold water[57]	calcium carbonate	ammonia (4d) chlorophyll a hydrogen sulfide nitrogen (total) phosphorous (total) turbidity (NTU) turbidity (Secchi)

ii) EXTRA[58] POLLUTANTS

	ACUTE	CHRONIC
warm/cold water streams	hydrogen sulfide sulfate and chloride temperature	
lakes	temperature[59]	

[56] For the purpose of this review, "missing pollutants" means those pollutants for which EPA has issued WQC while the state has neither adopted nor officially proposed corresponding criteria. In situations where a state has adopted and submitted to EPA a set of state-adopted changes but EPA has either not acted on the changes or has disapproved the changes, this fact is noted in this document.

[57] EPA's criteria do not distinguish between warm and cold water habitats.

[58] For the purposes of this review, "extra pollutants" are pollutants for which the state has formally proposed or officially adopted WQC, while EPA has not published recommended WQC of the type specified.

[59] This criterion is neither clearly an acute nor a chronic criterion, as its criterion-duration is unspecified. For counting purposes, it has been listed just once, under "acute."

Table 2 - Drinking Water Supply [60]

i) MISSING POLLUTANTS

ACUTE	CHRONIC
total coliforms	color foaming agents odor (dissolved) solids sulfate

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
chlorides sulfate	---

Table 3 - Water-Based Recreation

i) MISSING POLLUTANTS

ACUTE	CHRONIC
Fecal coliform	Enterococci

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC

[60] EPA lacks actual drinking water supply criteria for conventional pollutants – specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply to "finished" water that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable.

APPENDIX B

Table 1

	Aquatic Life Protection		**Human Health Protection**	
	Acute	*Chronic*	*Fish Consumption (HHO)*	*Water & Organisms (HHWO)*
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Missouri Has Not	4,4'-DDT Aldrin alpha-Endosulfan Arsenic beta-Endosulfan Chlordane Diazinon Dieldrin Endrin gamma-BHC Heptachlor Heptachlor Epoxide Nonylphenol Parathion Selenium Toxaphene Tributyltin Pentachlorophenol Chlorpyrifos	4,4'-DDT alpha-Endosulfan Aluminum Diazinon Dieldrin Endrin Heptachlor Epoxide Nonylphenol Polychlorinated Biphenyls PCBs Toxaphene Tributyltin beta-Endosulfan Chlordane	1,3-Dichloropropene[61] 2-Chloronaphthalene alpha-Endosulfan Arsenic beta-Endosulfan Cyanide Dinitrophenols Endosulfan Sulfate Ethylbenzene Hexachlorocyclo-hexane-Technical Hexachlorocyclopentadiene Methylmercury Nickel Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Phenol Selenium Zinc Manganese	Missouri has not adopted criteria for any of the 113 toxic pollutants for which EPA has published "human health: water and organisms" (HHWO) criteria to address human health risks associated with the combined use of fish and water consumption from surface waters.
Total # of Pollutants	19	13	20	113

[61] Missouri has a human health WQC for dichloropropene.

Table 2

	Drinking Water Supply
MISSING POLLUTANTS: Pollutants for which EPA Has Adopted WQC where Missouri Has Not	Alpha particles Beta particles & photon emitters Bromate Chloramines Chlorine Chlorine dioxide Chlorite Chromium (total) Cyanide (as free cyanide) Haloacetic acids (HAA5) Nitrite PCBs Radium 226 and Radium 228 (combined) Total Trihalomethanes Uranium Aluminum (s) Iron (s) Manganese (s)
Total # of Pollutants	18

Note: Pollutants labeled with the "(s)" notation are those for which EPA has issued secondary drinking water criteria.

Table 3

	Aquatic Life Protection		**Human Health Protection**	
	Acute	*Chronic*	*Fish Consumption (HHO)*	*Water & Organisms (HHWO)*
EXTRA POLLUTANTS: Pollutants for which Missouri Has Adopted WQC where EPA Has Not	2,4-Dichlorophenol Endosulfan[62] Guthion Methoxychlor Mirex	2,4-Dichlorophenol Beryllium Endosulfan[63] Ethylbenzene Hexachlorocyclo-pentadiene Phenol	delta-BHC Dichlorodifluoromethane Dichloropropene Methoxychlor Methyl Chloride Trichlorofluoromethane	N/A
Total # of Pollutants	5	6	6	

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[62] While EPA has no criterion for "endosulfan," it has separate, though identical, *acute* and *chronic* aquatic life criteria for alpha- and beta-endosulfan.
[63] Ia. at 6

Table 4

	Drinking Water Supply	**Groundwater**
EXTRA POLLUTANTS: Pollutants for which Missouri Has Adopted WQC where EPA Has Not	1,1,2,2-Tetrachloroethane 1,2-Diphenylhydrazine 2,4,6-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2-Chlorophenol 2-Methyl-4,6-Dinitrophenol 3,3'-Dichlorobenzidine 3,4-benzofluoranthene 4,4'-DDD 4,4'-DDE 4,4'-DDT Acenaphthene Acrolein Acrylonitrile Aldrin alpha-BHC Anthracene Benzo(a)Anthracene Benzo(k)Fluoranthene beta-BHC Bis(2-Chloroethyl)Ether Bis(Chloromethyl)Ether Bromoform Butylbenzyl Phthalate Chlorodibromomethane Chloroform Chromium (III) Chrysene delta-BHC Dibenzo(a,h)Anthracene Dichlorobromomethane Dichloropropene Dieldrin Dimethyl Phthalate Di-n-Butyl Phthalate Endrin Aldehyde Fluoranthene Fluorene Hexachlorobutadiene Hexachloroethane Ideno(1,2,3-cd)Pyrene Isophorone Methyl Bromide	1,1,1-trichloroethane 1,1,2,2-tetrachloroethane 1,1,2-trichloroethane 1,1-dichloroethylene 1,2,4,5-tetrachlorobenzene 1,2,4-trichlorobenzene 1,2-cis-dichloroethylene 1,2-dichloroethane 1,2-dichloropropane 1,2-diphenylhydrazine 1,2-trans-dichloroethylene 2, chlorophenol 2,4,5-TP 2,4,5-trichlorophenol 2,4,6-trichlorophenol 2,4-D 2,4-dichlorophenol 2,4-dimethylphenol 2,4-dinitrophenol 2,4-dinitrotoluene 2-methyl-4,6-dinitrophenol 3,3'-dichlorobenzidine Acenaphthene Acrolein Acrylonitrile Alachlor Aldrin Alpha-BHC Anthracene Antimony Arsenic Atrazine Barium Benzene Benzidine Benzo(a)pyrene Beryllium beta-BHC Bis (2-chloroethyl) ether Bis (chloromethyl) ether Bis(2-ethylhexyl) phthalate Bis-2-chloroisopropyl ether Boron Bromoform Butylbenzyl phthalate Cadmium

(Table 4 continues onto the next page.)

Table 4 (cont.)

	Drinking Water Supply	**Groundwater**
EXTRA POLLUTANTS: Pollutants for which Missouri Has Adopted WQC where EPA Has Not	Methyl Chloride Methylene Chloride Nickel Nitrobenzene N-Nitrosodimethylamine N-Nitrosodiphenylamine Pentachlorobenzene Phenol Pyrene Tetrachlorobenzene,1,2,4,5-	Carbofuran Carbon Tetrachloride Chlordane Chlorobenzene Chlorodibromomethane Chloroform Chlorpyrifos Chromium III Cobalt Copper Dalapon DDD DDE DDT delta-BHC di (2-ethylhexyl) adipate Dibromochloropropane Dichlorobromoethane Dichloropropene Dieldrin Diethyl phthalate Dimethyl phthalate Di-n-butyl phthalate Dinoseb Dioxin Diquat Endothall Endrin Endrin aldehyde Ethylbenzene Ethylene dibromide Fluoranthene Fluorene Fluoride Glyphosate Heptachlor Heptachlor epoxide Hexachlorobenzene Hexachlorobutadiene Hexachlorocyclopentadiene Hexachloroethane Iron Isophorone Lead Lindane Manganese Mercury

(Table 4 continues onto the next page.)

Table 4 (cont.)

	Drinking Water Supply	**Groundwater**
EXTRA POLLUTANTS: Pollutants for which Missouri Has Adopted WQC where EPA Has Not		Methoxychlor Methyl Bromide Methyl Chloride Methylene Chloride Mirex Nickel Nitrate-N Nitrobenzene n-nitrosodimethylamine n-nitrosodiphenylamine Other Dichlorobenzenes other polynuclear aromatic hydrocarbons Oxamyl (vydate) Para(1,4)-dichlorobenzene PCBs pentachlorobenzene Pentachlorophenol Phenol Picloram Pyrene Selenium Silver Simazine Styrene Tetrachloroethylene Thallium Toluene Toxaphene Trichloroethylene Trihalomethanes Vinyl chloride Xylenes (total) Zinc
Total # of pollutants	56	126

Table 5

	Aquatic Life Protection		Human Health Protection		Drinking Water Supply
	Acute	*Chronic*	*Fish Consumption (Organisms Only)(HHO)*	*Water & Organisms (HHWO)*	
Pollutants with a state criterion-concentration **lower** than EPA's	Chromium (VI) Nickel Zinc	Arsenic Chlorine Chlorpyrifos Chromium (VI) Copper Cyanide Pentachlorophenol Mercury	1,1-Dichloroethylene beta-BHC Bis(2-Chloroisopropyl)Ether Chlordane Endrin Endrin Aldehyde gamma-BHC PCBs (total) Toxaphene	N/A	Copper (s) Methylene chloride Tetrachloroethylene

Note: Pollutants labeled with the "(s)" notation are those for which EPA has issued secondary drinking water criteria.

Table 6

	Aquatic Life Protection		Drinking Water Supply
	Acute	*Chronic*	
Pollutants with a state criterion-concentration **higher** than EPA's	Cadmium Mercury	Cadmium Lead Parathion	Arsenic

Table 7

	Human Health Protection	
	Fish Consumption (HHO)	*Water & Organisms (HHWO)*
Pollutants with a state criterion-concentration **higher** than EPA's	1,1,2,2-Tetrachloroethane 1,1,2-Trichloroethane 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Dichloroethane 1,2-Dichloropropane 1,2-Diphenylhydrazine 1,2-Trans-Dichloroethylene 1,3-Dichlorobenzene 1,4-Dichlorobenzene 2,3,7,8-TCDD (Dioxin) 2,4,6-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2-Chlorophenol 2-Methyl-4,6-Dinitrophenol 3,3'-Dichlorobenzidine 4,4'-DDD 4,4'-DDE 4,4'-DDT Acenaphthene Acrolein Acrylonitrile Aldrin alpha-BHC Anthracene Antimony Benzene Benzidine Benzo(a)Anthracene Benzo(a)Pyrene Benzo(b)Fluoranthene Benzo(k)Fluoranthene Bis(2-Chloroethyl)Ether Bis(2-Ethylhexyl)Phthalate Bromoform Butylbenzyl Phthalate Carbon Tetrachloride Chlorobenzene Chlorodibromomethane Chrysene Dichlorobromomethane Dieldrin Diethyl Phthalate Dimethyl Phthalate	N/A

(Table 7 continues onto the next page.)

Table 7 (cont.)

	Fish Consumption (HHO)	*Water & Organisms (HHWO)*
Pollutants with a state criterion-concentration **higher** than EPA's	Di-n-Butyl Phthalate Ether, Bis(Chloromethyl) Fluoranthene Fluorene Heptachlor Heptachlor Epoxide Hexachlorobenzene Hexachlorobutadiene Hexachloroethane Ideno(1,2,3-cd)Pyrene Isophorone Methyl Bromide Methylene Chloride Nitrobenzene Nitrosopyrrolidine,N N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Pentachlorobenzene Pentachlorophenol Pyrene Tetrachlorobenzene,1,2,4,5- Tetrachloroethylene Thallium Toluene Trichloroethylene Trichlorophenol,2,4,5- Vinyl Chloride	N/A
Total # of pollutants	75	

APPENDIX C

SITUATIONS IN WHICH STATE WQC ARE CLEARLY LESS PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vs. EPA[i]	**higher**	**longer**	**higher**
“ “ “	equal	**longer**	**higher**
“ “ “	**higher**	equal	**higher**
“ “ “	**higher**	**longer**	equal
“ “ “	**higher**	equal	equal
“ “ “	equal	equal	**higher**
“ “ “	equal	**longer**	equal

SITUATIONS IN WHICH STATE WQC ARE CLEARLY MORE PROTECTIVE THAN EQUIVALENT EPA WQC

	Concentration	Duration	Frequency
State vs. EPA	**lower**	**shorter**	**lower**
“ “ “	equal	**shorter**	**lower**
“ “ “	lower	equal	**lower**
“ “ “	**lower**	**shorter**	equal
“ “ “	**lower**	equal	equal
“ “ “	equal	equal	**lower**
“ “ “	equal	**shorter**	equal

SITUATIONS IN WHICH COMPARATIVE LEVEL OF PROTECTION CANNOT BE DETERMINED BY SIMPLY LOOKING AT THE TWO CRITERIA

	Concentration	Duration	Frequency
State vs. EPA	**lower**	**shorter**	**higher**
“ “ “	equal	**shorter**	**higher**
“ “ “	**lower**	equal	**higher**
“ “ “	**lower**	**longer**	equal
“ “ “	**higher**	equal	**lower**
“ “ “	**higher**	**shorter**	equal
“ “ “	equal	**longer**	**lower**

[i] The state WQC’s component (e.g., duration) compared to the component for corresponding EPA WQC.

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