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

Overview

November 2009

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Environmental Law Institute
September 2009

Acknowledgements

This publication is a project of the Environmental Law Institute (ELI). Funding for this project was provided 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. The findings and conclusions of this report do not, however, necessarily represent the views of the Mississippi River Water Quality Collaborative or its individual members.

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.

This report was written by Bill Painter and Yen Hoang, with oversight by John Pendergrass, of ELI. Mr. Painter was at the time of the research and writing of this report a Visiting Government Scholar at ELI under the Inter-governmental Personnel Act Mobility Program from the U.S. Environmental Protection Agency where he has since returned. This report has not been reviewed by the U.S. Environmental Protection Agency and does not represent the views of the Agency and no official endorsement should be inferred. The authors gratefully acknowledge the review and guidance provided by Judith Petersen, Albert Ettinger, Dana Wright, Jill Witkowski, Jon Devine, Jeff Grimes, Susan Heathcote, and Betsy Lawton. Drafts of the state Overviews were sent to the water quality standards staff of the respective state environmental agencies for comment. ELI received responses from Illinois, Kentucky, Louisiana, and Missouri and sought to correct all errors that were identified, but neither the Overviews nor the report represent the views of any of the states and no official endorsement by any state should be inferred. The Environmental Law Institute is responsible for the views and information contained in this publication.

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ELI Project No. 063101

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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

I. EXECUTIVE SUMMARY

This report summarizes findings from an Environmental Law Institute (ELI) analysis of the numeric water quality criteria (WQC) formally adopted, as of September 1, 2008, [1] by the ten states that border directly on the Mississippi River—Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kentucky, Arkansas, Tennessee, Louisiana, and Mississippi. This report compares state numeric water quality criteria to recommended criteria and related standards issued by the United States Environmental Protection Agency (US EPA).

Overall, the numeric water quality criteria that the ten states covered in this report have adopted in their regulations vary substantially from recommended US EPA criteria, in terms of:

1) coverage of pollutants for which EPA has developed criteria,
2) inclusion and clear articulation of the three key components of a water quality criterion (concentration, duration, and frequency),
3) the specified criterion-concentration, and
4) where such comparison is feasible, the relative degree of protection provided.

There is quite significant variation among the states studied in this report with regard to each of these touchstones. This is true not only in comparison to US EPA's criteria, but also among the WQC adopted by the ten states.

Perhaps the most remarkable finding of this study is the degree to which states are missing numeric WQC. In fact, none of the Mississippi River states have numeric WQC for the full array of pollutant/use combinations for which US EPA has issued WQC, and some of the states lack WQC for the majority of certain types of pollutants for certain designated uses.

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[1] The findings reported herein refer to the contents of the following state WQS regulations:

- Arkansas Pollution Control and Ecology Commission - #014.00-002, Regulation No. 2 - Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas (*adopted October 26, 2007*)
- Chapter 61, "Water Quality Standards," Iowa Administrative Code (*as amended in Notice of Intended Action ARC 6352B in IAB 10/24/07*)
- Illinois Administrative Code, Part 302.100 to 302.410 and Part 302.601 to 302.669
- 401 Ky. Admin Regs. 5:031 (2003)
- Louisiana Administrative Code, Title 33 Environmental Quality Part IX - Proposed Rule/December 20, 2006, Water Quality Standards Triennial Revision (*Notice of Intent WQ054*); Fiscal Office Draft - Title 33 Environmental Quality Part IX. Water Quality. Chapter 11. Surface Water
- Minnesota *State Register*, Volume 32, Number 4, pages 87-217, July 23, 2007 (32 SR 87), Minnesota *State Register*, Volume 32, Number 5, pages 250-255, July 30, 2007 (32 SR 250), and Minnesota *State Register*, Volume 32, Number 37, pages 1699-1728, March, 2008 (32 SR 1699);
- 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*). Available at: http://www.epa.gov/waterscience/standards/wqslibrary/mo/mo_7_wqs.pdf
- Mississippi Commission on Environmental Quality Regulation WPC-2: State of Mississippi – Draft – Water Quality Criteria for Intrastate, Interstate, and Coastal Waters. (*Modified for Public Review and Comment: October 6, 2006)*
- Rules of Tennessee Department of Environment and Conservation Tennessee Water Quality Control Board Division of Water Pollution Control, Chapter 1200-4-3, October 2007. Available at: http://www.state.tn.us/sos/rules/1200/1200-04/1200-04-03.pdf;
- Wisconsin Administrative Code, Chapter NR 105 – Surface Water Quality Criteria and Secondary Values for Toxic Substances (in *Register*, February, 2004, No. 578); and Wisconsin Administrative Code, Chapter NR 102 – Water Quality Criteria for Wisconsin Surface Waters (in *Register*, February, 1998, No. 506).

For example, four states (MN, IL, AR, and MS) have numeric WQC addressing risk to human health resulting from consumption of fish and other aquatic organisms for less than one-third of the toxic substances for which US EPA has recommended corresponding WQC. Likewise, five of the ten states (IL, MO, KY, AR and MS) have WQC addressing risk resulting from intake of toxics resulting from consumption of the combination of fish consumption and drinking water for fewer than one-third of chemicals for which the federal EPA has issued corresponding WQC. Furthermore, Minnesota and Louisiana have adopted aquatic life criteria for a number of toxic substances for which US EPA has not issued recommended WQC.

By contrast, four states (WI, MO, KY, and TN) have formally adopted numeric WQC for more than two-thirds of the toxics for which US EPA has adopted "fish consumption" (called Human Health: Organism [HHO]) WQC. Also, all but three of the states (WI, AR, and LA) have established, for at least a few toxics, WQC applicable to surface waters used as a raw water supply by drinking water utilities, even though there are federal regulations governing levels of toxic contaminants in finished drinking water. In fact, Missouri and Kentucky have adopted drinking water supply criteria for some two dozen toxic substances for which US EPA has not issued Primary Drinking Water Standards.

Among the pollutants for which states have not adopted human health WQC are several known or suspected carcinogens and mutagens, as well as ones though to cause disruption of endocrine, nervous, and/or other organ systems. In addition some of the toxic substances are highly bioaccumulative, which can result in problematic concentrations in the flesh of fish and other forms of aquatic life consumed by humans. Several of the states lack equivalents to EPA's human health criteria for polycyclic aromatic hydrocarbons (PAHs) and various phthalate esters, which are not only carcinogenic and bioaccumulative (they accumulate in body tissues), but are also commonly found in urban storm water.

In comparison to their coverage of human health WQC for toxics, the ten states have adopted aquatic life WQC for a higher percentage of the toxic substances for which US EPA has issued such criteria. With regard to acute aquatic life WQC, the states (WI and MO) with the lowest number of criteria (18) still have such WQC for sixty percent (60%) of the toxics for which US EPA has WQC. For chronic aquatic life criteria, these two states have WQC for 43% of the thirty-five toxic substances for which there are US EPA criteria. Also, three states (MN, IA, and LA) have adopted numeric acute aquatic life WQC for more toxics than the thirty-one (31) for which US EPA has issued such criteria, and Louisiana has chronic aquatic life WQC for more pollutants than the thirty-five for which there are US EPA WQC. Among the chemicals for which one or more states lack aquatic life WQC are ones recognized as adversely affecting hormonal systems in fish and/or humans.

As for traditional pollutants and other water quality parameters, though the ten states have numeric WQC for several common ones, including dissolved oxygen (DO), temperature, pH and pathogens, none of the states currently have a comprehensive set of WQC for the nutrients phosphorous and nitrogen. Currently, only Minnesota and Illinois have numeric criteria for phosphorous, and those apply only to lakes and reservoirs, even though phosphorous is known to sometimes adversely affect rivers and streams as well. None of the states have numeric WQC for nitrogen, which negatively impacts aquatic life in the Gulf of Mexico, and may also affect inland waters. (Tennessee has published a set of numeric thresholds for nitrogen [nitrates+nitrites]. Though published in 2001, they have not been formally incorporated as numeric WQC in the state's WQS regulations. It also has a set of such thresholds for phosphorous. Wisconsin is in the process of developing an extensive set of phosphorous WQC, for not only lakes and reservoirs, but also streams and rivers.)

Five states - Minnesota, Iowa, Arkansas, Louisiana, and Mississippi have established criteria for turbidity, an indicator of suspended sediments and other problems such as excess algal growth. None of the states have numeric WQC indicative of benthic sedimentation. "Sediments" and/or "sedimentation" is one of the five most commonly cited stressors in state 303(d) listings of "impaired" waters among the ten states, as well as all states nationwide, along with nutrients, mercury, metals other than mercury, and pathogens.

Several states (IA, AR, LA, and MS) have WQC for traditional parameters/pollutants that seem to intend to apply only when lower water quality is caused by certain types of sources of pollutants—most often point sources. These restrictions apply to one or more of several traditional pollutants (chlorides, sulfates, and total dissolved solids) and other water quality parameters (pH, turbidity, and temperature). Given that numerous types of nonpoint sources are known to affect levels in surface waters of parameters such as these, these exemptions would likely result in waters with uses impaired by nonpoint sources not being included on the 303(d) lists of one or more of these states.

Turning to the first of the three key elements of a numeric WQC—the criterion-concentration, most of the WQC specified by the ten Mississippi River states have criterion-concentrations that are identical to, or fairly close to, those of corresponding WQC published by EPA. In some instances, such comparison can not be made because EPA has not issued numeric WQC for pollutants or other water quality parameters for which states have adopted WQC.

The range of criterion-concentrations of the WQC for most pollutant/use combinations among the ten states is fairly narrow. There are no states for which a large majority of the WQC have criterion-concentrations higher (or lower) than the criterion-concentration for corresponding US EPA WQC. Nor are there any categories of WQC (e.g., those for a certain designated use) for which most of the states had WQC with criterion-concentrations higher (or lower) than US EPA's.

There are a number of traditional pollutants/water quality parameters for which one or more of the ten states have established more than just one aquatic life WQC for the entire state. Such WQC specific to ecoregion, water body type, watershed, or waterbody are designed to account for differences in native species of aquatic life and/or other factors such as water chemistry. In such instances, there is often a considerable range of criterion-concentrations among the WQC within the state. Such WQC are most frequently encountered for temperature, dissolved oxygen, chlorides, sulfates, and total dissolved solids. By contrast, US EPA aquatic life WQC for traditional pollutants/parameters often consist simply of one threshold value for the entire nation. (The major exception is the federal WQC for nutrients.) Likewise, neither the federal EPA nor any of the ten states have adopted significant numbers of site-specific aquatic life WQC for toxics.

The ten states have done relatively little with regard to adjusting human health WQC criterion-concentrations to account for conditions unique to a given waterbody or set of waters. The most frequently-encountered example is having bacterial WQC with different criterion-concentrations for waters designated for primary/full-body contact recreation and those designated secondary/partialbody contact recreation. Two states (MN and WI) have WQC for toxics related to human consumption of fish and other aquatic organisms that vary depending on the types of consumable organisms found in various categories of waterbodies, such as warm water verses cold water. None of the states have adopted site-specific or regional WQC reflecting differences in people's rates of consumption of fish and other aquatic life from waterbody to waterbody within the state.

A substantial number of the WQC adopted by the ten states lack clear specification of the other two basic components of numeric WQC, criterion-durations and criterion-frequencies. In fact, all of the states have one or more groups of WQC that say nothing about one or both of these WQC components. Absence of a criterion-frequency is more common than absence of a criterion-duration, and absence of both is not uncommon. In addition, several states articulate criterion-durations in an unclear fashion. For instance, WQC stated as a "monthly average concentration" could be interpreted to mean a calendar month or any block of time roughly equal to a month (30 days). The difference is important because biological systems, from the sub-cellular to the ecosystem level, are not attuned to the time-keeping systems adopted by humans.

Absence of clearly articulated criterion-duration or criterion-frequency renders comparison of the level of protection provided by two or more WQC a guessing game, just as a vaguely stated criterion-concentration does. That is, not knowing whether the criterion-duration is 24 hours or 240 hours creates just as much uncertainty as being unclear as to whether the criterion-concentration were 24 μg/L as opposed to 240 μg/L. Likewise, uncertainty regarding one or more of key components of numeric WQC creates challenges when the WQC are used in programs, such as 303(d) lists of impaired waters, total maximum daily loads (TMDLs), and national pollutant discharge elimination system (NPDES) permits.

Where it is possible to discern the relative degree of protection provided by two WQC merely by looking at the criteria themselves (see Table 1, p. 18), there were no striking patterns among the ten states. That is, it is not the case that substantially more of the WQC established by the ten states provided a greater (or lesser) level of protection than would application of the corresponding US EPA criteria. In quite a few instances, the state and US EPA WQC would result in identical levels of protection to the designated uses to which they apply.

II. BACKGROUND

A. Water Quality Standards: Their Important Roles

Water quality standards are vital to the implementation of several aspects of the federal Clean Water Act (CWA).[2] In effect they serve as forcing mechanisms—and, ultimately, measures of success—of key CWA programs such as: 1) impaired waters listings under section 303(d) of the CWA; 2) total maximum daily loads; 3) NPDES regulation of point sources; 4) the nonpoint source program under section 319 of the CWA; and 5) the CWA State Revolving Fund (SRF) program. WQS can also be used to measure the efficacy of water quality programs other than those established under the CWA.

[2] 33 U.S.C. §§1251–1387 (2006) (Originally enacted as the Federal Water Pollution Control Act Amendments of 1972.)

The role and the importance of water quality standards in the context of the CWA are reflected in the following statements from various sources.

> "**Purpose of water quality standards.** A water quality standard defines the water quality goals of a water body …" (40 CFR 131.2)
>
> "Such standards shall be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this Act." (Clean Water Act, Section 303(c)(2)(A))
>
> "Such standards . . . serve as the regulatory basis for the establishment of water-quality-based . . . strategies beyond the technology-based levels of treatment required by . . . the Act." (40 CFR 131.2)
>
> "Under the Clean Water Act . . . water quality standards . . . define the goals and pollution limits for all waters. . . . standards give the Act much of its meaning—and its force. . . . They determine which healthy waters need protection, and which waters must be restored and how much . . . . they set a course for restoring and protecting a watershed over the long term." *The Clean Water Act: An Owner's Manual, 2nd Edition*, River Network (2005), page 15.
>
> "State water quality standards play a central role in a State's water quality management program, which . . . States use to integrate the various Clean Water Act . . . requirements into a coherent management framework." *Water Quality Standards Handbook. 2nd Edition*. EPA EPA-823-B-94-005 (Aug. 1994), page Intro-13.

B. Water Quality *Criteria*: Key Components of Water Quality Standards

The two core elements of all water quality standards are: 1) designated uses and 2) water quality criteria (WQC).[3] Together, designated uses and WQC describe, at various levels of detail, the characteristics and capabilities that the state and federal governments have decided they want an individual water body, or portion thereof, to exhibit.

Designated uses are defined in EPA's regulations in the following two passages:

> "A water quality standard defines the . . . goals of a water body . . . by designating the use or uses to be made of the water." 40 CFR 131.2
>
> "Designated uses are those uses specified in water quality standards for each water body . . . whether or not they are being attained." 40 CFR 131.3(f)

[3] EPA literature includes antidegradation policies as a third basic component of WQS, and requires all states to include specified antidegradation language in their WQS regulations. Nevertheless, antidegradation is very much its own program, in which designated uses (DUs) and WQC play important roles. This report deals only with DUs and WQC, and focuses largely on the latter.

Thus, designated uses are not, despite what their name might imply, the equivalent of posting a stream or lake to inform the public as to which uses said water body is presently capable of supporting, given current water quality and other aspects of the water body's condition. Rather, the designated uses assigned to a specific water body in a State's WQS regulations are an indication of the uses which society wants the water body to be capable of supporting—if not now, then some time in the future. That is, designated uses are desired uses. If in its current state, a water body cannot fully support one or more of the designated uses assigned to it, then those uses are "impaired," and the water will have to be placed in either Category 4 or 5 in the EPA listing system.[4]

Once designated uses are assigned to a water body, the need arises for a way to determine whether or not current water body conditions are capable of supporting a given use. This is when WQC become important to water quality standards. Their role is to describe, as clearly as possible, those conditions that, according to current scientific understanding, should be able to fully support a given use. Ideally, for any given use (e.g., using a lake as a source of raw water for a community's drinking water supply system), there needs to be one or more WQC for every contaminant which—if present in the area of the lake where the drinking water supply intake is located—could have the potential to harm those who depend on that water body for that particular use.

As defined by EPA, water quality criteria are:

- "elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use When criteria are met, water quality will generally protect the designated use;"[5]

- "levels of individual pollutants or water quality characteristics, or descriptions of conditions of a water body that, if met, will generally protect the designated use of the water body;"[6] and

- "specify concentrations of water constituents which, if not exceeded, are expected to support an aquatic ecosystem suitable for higher uses of water. Such criteria are derived from scientific facts obtained from experimental or in situ observations that depict organism responses to a defined stimulus or material under identifiable or regulated environmental conditions for a specified time period."[7]

As just noted, according to federal regulations and guidance, the determination of appropriate WQC for a given designated use is to be based entirely on scientific considerations. Concerns about the potential technical difficulty and/or economic impact of achieving a WQC in one or more waterbodies are not to be addressed when developing WQC. Rather, such factors can be taken into account, on a waterbody-specific basis, when deciding what designated uses to assign to a waterbody.

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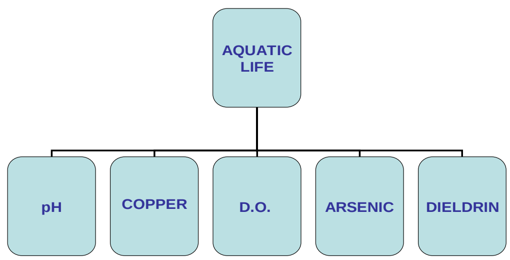
[4] Category 5 is the equivalent of the 303(d) list—those impaired waters needing one or more TMDLs to be developed. Category 4 also includes impaired waters, but ones for which TMDLs are not needed because: a) all necessary TMDLs have been completed and approved; 2) an EPA-approved alternative approach to meeting WQS is being implemented; or 3) the impairment of designated use(s) is caused solely by one or more non-pollutant types of pollution, such as altered stream flow, channel modification, and removal of native riparian zone vegetation.
[5] Water Quality Standards—Definitions, 40 C.F.R. 131.3(b) (2008).
[6] Water Quality Standards Regulation, Advanced Notice of Proposed Rulemaking, 63 Fed. Reg. 36,761 (July 7, 1998).
[7] U.S. EPA, Quality Criteria for Water ("Red Book") 1 (1976).

The following diagram illustrates this basic relationship between WQC and designated uses. Here, the designated use is Aquatic Life. For that one designated use, water quality criteria have been developed for five water quality parameters, represented by the bottom row of boxes. (In a real set of WQS, there typically would be WQC for several times as many pollutants as shown here.) If ambient water quality were worse than that specified by any of the WQC for these 5 parameters, then the water would be judged incapable of fully supporting aquatic life, and would be reported as impaired for aquatic life in the state's Integrated Sections 305(b)/303(d) list.

WQS: DU and WQC



Some water quality criteria are expressed in broad statements such as, "waters should be free from toxic pollutants at levels harmful to humans and/or aquatic life." These are referred to as "narrative" water quality criteria. Such criteria typically apply to all waters within a state, regardless of the designated uses. Knowledge of the effects of different levels of a pollutant on humans and aquatic life is needed to apply such "no toxics in toxic amounts" WQC for purposes of implementing programs established by the CWA, or other water quality programs created under federal, state, or local law.. Other examples of narrative WQC make reference to "nuisance levels of aquatic plants" or "objectionable odors". An obvious problem with use of such criteria in the context of regulatory programs is the subjectivity of words like "nuisance," "objectionable," and "undesirable."

This report focuses on criteria stated in a quantitative format—numeric water quality criteria. Though states sometimes have numeric WQC that apply to all waters, or to certain large sets of waters, regardless of those waters' designated uses, a given numeric criterion usually applies to just one designated use—hence the terms "pollutant/use combination" and "pollutant/use pairs" are used throughout this document. Sometimes, a given pollutant will have one or more criterion that applies to a certain designated use, and another criterion (or set thereof) related to another use. For instance, a given pathogen indicator (e.g., fecal coliform bacteria, *E. coli*, or enterococci) could have one set of criteria for water contact recreation, another for shellfish consumption, and yet a third for drinking water supply. Another common example is metals, for which a state may have WQC for aquatic life, drinking water supply, and fish consumption.

On occasion, US EPA documents and other literature reference the need to ensure that, if met, WQC will ensure protection of the "most sensitive use." Considerable confusion surrounds the term "most sensitive use." US EPA has been clear that this is not intended to reflect a measure of the relative importance of one use over another (e.g., aquatic life over drinking water supply). Rather, it appears that US EPA intends for "most sensitive use" to mean that use whose protection requires a level of water quality that will also ensure full protection of all other uses for which a given waterbody is designated. (This might be taken as the use that requires the "cleanest" water.) Though at first it might seem simple to determine, for a given pollutant, which level would be "cleaner" or "more protective," this is not always the case. For example, suppose one WQC were expressed as a one-hour average concentration of 25 μg/L, never to be surpassed, and another WQC for the same pollutant with a different use was expressed as a 365-day average concentration of 9 μg/L, never to be surpassed. Though one might think that the designated use with the WQC having a criterion-concentration of 9 μg/L would be the "most sensitive use," this is not necessary the case, because it is possible to have a 365-day average concentration of only 9 μg/L and still have, during that 365 period, one or more hours in which the average concentration of the pollutant was above 25 μg/L. Hence, the use with the WQC criterion-concentration of 9 μg/L is not necessarily more sensitive that the use with the WQC having a criterion-concentration of 25 μg/L, since attainment of the first WQC does not guarantee attainment of the second.

Also, for a given pollutant/use combination, more than one WQC may be needed, in order to account for different exposure scenarios, i.e., short term verses long term. For example, with regard to WQC related to protection of aquatic life from the effects of toxic compounds, US EPA has usually published both an acute (one hour average) and chronic (96 hour average) criterion.

In adopting WQC for given pollutant/use pairs, states have the choice of:1) adopting the criterion published by US EPA; 2) modifying US EPA's criterion to reflect state-specific, water basin-specific, or water body-specific factors, or 3) developing criteria based on a scientifically defensible method different from that employed by US EPA. All state water quality criteria, as well as all other aspects of state WQS regulations, are subject to review and approval (or disapproval) by the US EPA. If US EPA disapproves a given feature of a state's WQS regulations, and the state is unwilling to modify its proposal to address US EPA's concerns, then US EPA can go through formal rulemaking, and thereby promulgate what it believes are appropriate WQC. By law, US EPA is required to use only state WQC that it (US EPA) has approved or promulgated when implementing Clean Water Act regulatory programs in which WQS play a role.

C. Components of Numeric Water Quality Criteria

A common misconception of "water quality standard" or "water quality criteria" is that the terms refer solely to a concentration, such as 26 milligrams of lead per liter of water. As noted above, however, that value alone is not a water quality standard because it says does not say anything about a waterbody use (e.g., support of a healthy community of aquatic organisms composed largely, if not exclusively, of species native to the waterbody in question). Likewise, a clearly-specified concentration of a given water quality constituent is not, in and of itself, a water quality criterion either. This is because it does not provide an adequate description of the levels of the constituent that are needed to support a certain use. First, the concentration alone does not answer the question: for how long can the average concentration remain at 26 milligrams per liter (mg/L) without impairing one or more designated use? Second, it does not indicate how often such "averaging above 26 mg/L" events can occur—once per year, for example—without actually impairing the relevant DU.

To be useful, a WQC has to provide a complete description of a pattern of pollutant levels consistent with fully supporting the DU to which that criterion applies. Consequently, a fully articulated WQC must include three elements: 1) criterion-magnitude (usually a concentration); 2) criterion-duration; and 3) criterion-frequency.

EPA made this point in the preamble to an announcement seeking comments on an array of possible changes to the Agency's regulations governing state water quality standards:

> Water quality criteria to protect aquatic life[8] consist of three components—magnitude, duration and frequency. Magnitude refers to the acceptable concentration of a pollutant. Duration is the period of time (averaging period) over which the ambient concentration is averaged for comparison with criteria concentrations. Frequency is how often the [combined] criteria [magnitude and duration] can be exceeded to allow the aquatic community sufficient time to recover from excursions of aquatic life criteria and to thrive after recovery.[9]

Consequently, this study analyzed not only whether a state had a WQC for a given pollutant use combination—and, if it did, what concentration of that pollutant that WQC specified—but also the criterion-duration and criterion-frequency. In fact, as will be explained later in this report,[10] these latter two elements of numeric WQC are just as important as the criterion-magnitude with respect to:

1) Determining whether one entity's WQC for a given pollutant/use combination provides more, less, or equal protection to that designated use, compared to a WQC established by another jurisdiction; and,
2) Properly implementing Clean Water Act programs that are driven by state water quality criteria.

D. Level of Protection Provided by Water Quality Criteria

In this report, the term "level of protection" means the degree to which attainment of a given WQC can be expected to fully support a given designated use. In the case of aquatic life uses, a "more protective" WQC would support a healthier (i.e., closer to natural) community of aquatic organisms than would a "less protective" criterion. Likewise, a "more protective" human health WQC is one that, if attained, would result in a healthier (lower rates of illness and death) population of persons using a waterbody for a given purpose.

"Level of protection" is not intended herein to be synonymous with "level of stringency," a topic which this report does not address. The authors take "stringency" to mean how difficult a given level of water quality would be to attain, in a given waterbody. "Difficulty," in turn, could refer to: 1) technological feasibility and/or 2) economic cost. Though in many instances, the more protective of two criteria would also be more "stringent," but this is not always the case because achieving a certain pattern of pollutant levels coming from a given type of source depends on several factors, including: 1) characteristics of the source itself, and 2) the unique features of available pollutant reduction techniques.

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[8] Though EPA discusses the three components of WQC in terms of criteria for aquatic life in this particular excerpt, the same concept applies to criteria for human health.
[9] Water Quality Standards Regulation, Advanced Notice of Proposed Rulemaking, 63 Fed. Reg. 36,761 (July 7, 1998).
[10] *See infra* Part IV.D.

As for the level of protection provided by a state WQC for a given pollutant/use combination in comparison to that provided by a WQC from US EPA (or another state), this cannot be determined with any degree of confidence unless all three elements of both WQC are clearly articulated. And, even when the criterion-concentration, criterion-duration, 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, in certain situations. For instance, if a WQC from "Entity A" and a comparable (same pollutant and same designated use) criterion from "Entity B" 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 the Entity A WQC were lower than that of the WQC of Entity B, and the criterion-duration and criterion-frequency remained identical, then the Entity A WQC would provide the higher degree of protection. Likewise, if the criterion-concentrations are the same, the criterion-durations are identical, then the WQC with the lower acceptable criterion-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.

Table 1 provides a set of tables that list all possible combinations—in relative terms—of criterion-concentrations, criterion-durations, and criterion-frequencies, with the exception of the situation in which the two WQC being compared are identical—same concentration, same duration, and same frequency. Table 1-a lists combinations which result in the WQC of hypothetical Entity A being less protective than the corresponding (same designated use and pollutant) WQC of hypothetical Entity B. For example, in the situation represented in the first row of Table 1-b, Entity A's WQC has a higher criterion-concentration than that of the corresponding Entity B WQC, along with a longer criterion-duration and a higher criterion-frequency than Entity B's. Table 1-c lists those combinations in which the respective criterion-concentration, criterion-duration, and criterion-frequency of Entity A's WQC, in comparison those of Entity B's corresponding WQC, result in the WQC of Entity A providing a higher level of protection to the relevant designated use(s) than does Entity B's.

Table 1-c lists those combinations for which the relative degree of protection provided by one WQC verses another cannot be determined simply by looking at the two WQC. For instance, in the situation presented by the first row in Table 1-c, one cannot tell whether the tendency for greater protection resulting from Entity A's WQC having a lower criterion-concentration and shorter criterion-duration would, or would not, be offset by the tendency for lesser protection resulting from Entity A's WQC having a higher criterion-frequency.

Also, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons (different native species and/or differences in waterbody chemistry) that a state criterion can have a criterion-concentration higher or lower than that for the corresponding US EPA criterion and still provide aquatic life protection equal to that for which the US EPA WQC were 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 US 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 US EPA's criterion to the waterbody in question.[11]

Turning from aquatic life to human health, safe levels of pollutants tend to vary less from waterbody to waterbody: 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 are caught and eaten by people can differ by an order of magnitude from place to place and/or within subpopulations of humans. Of course, patterns of swimming and other water contact recreation can change considerably depending on difference in the climate in which one waterbody verses another is located, along with the type of waterbody (river, lake, ocean beach).

[11] Nevertheless, site-specific conditions would have resulted in US EPA's WQC providing an even higher level of protection than that for which US EPA designed it. The effect of the state's higher criterion-concentration would be to bring the level of protection back down to that which the US EPA WQC was designed to provide.

Table 1

Table 1-a: SITUATIONS IN WHICH ENTITY A's WQC ARE CLEARLY LESS PROTECTIVE THAN EQUIVALENT ENTITY B's WQC

	Concentration	Duration	Frequency
Entity A WQC vs. Entity B WQC	**higher**	**longer**	**higher**
" " "	equal	**longer**	**higher**
" " "	**higher**	equal	**higher**
" " "	**higher**	**longer**	equal
" " "	**higher**	equal	equal
" " "	equal	equal	**higher**
" " "	equal	**longer**	equal

Table 1-b: SITUATIONS IN WHICH ENTITY A's WQC ARE CLEARLY MORE PROTECTIVE THAN EQUIVALENT ENTITY B's WQC

	Concentration	Duration	Frequency
Entity A WQC vs. Entity B WQC	**lower**	**shorter**	**lower**
" " "	equal	**shorter**	**lower**
" " "	lower	equal	**lower**
" " "	**lower**	**shorter**	equal
" " "	**lower**	equal	equal
" " "	equal	equal	**lower**
" " "	equal	**shorter**	equal

Table 1-c: SITUATIONS IN WHICH COMPARATIVE LEVEL OF PROTECTION CANNOT BE DETERMINED BY SIMPLY LOOKING AT THE TWO CRITERIA

	Concentration	Duration	Frequency
Entity A WQC vs. Entity B WQC	**lower**	**shorter**	**higher**
" " "	equal	**shorter**	**higher**
" " "	**lower**	equal	**higher**
" " "	**lower**	**longer**	equal
" " "	**higher**	equal	**lower**
" " "	**higher**	**shorter**	equal
" " "	equal	**longer**	**lower**

III. FINDINGS

A. Coverage: Pollutant/Use Combinations for which States Have Specified Water Quality Criteria

1. Coverage for "Traditional" Pollutants/Water Quality Parameters[12]

a. Overview

The ten Mississippi River states present a mixed picture with regard to adoption of WQC for "traditional" pollutants and water quality parameters. All have at least one criterion (acute or chronic) covering at least one designated use for: 1) dissolved oxygen; 2) pH, 3) temperature, and 4) pathogens (see Table 2). None have both an acute and a chronic criterion for all four of these parameters.[13] Only Illinois has acute and chronic WQC for three of the parameters, lacking only a chronic criterion for pH. By contrast, Louisiana has both acute and chronic for pathogens only and Missouri does not have both types of criteria for any of the four parameters. The remaining seven states have both acute and chronic WQC for two of these four traditional parameters.

As Table 2 shows, of a possible total of forty acute criteria (four parameters, ten states), the states have thirty-eight.[14] On the other hand, the states have just nineteen of the possible forty chronic criteria for the four parameters. The most commonly addressed category of uses for temperature, dissolved oxygen, and pH is aquatic life, whereas most of the WQC for pathogens address water-based recreation, though some states have pathogen WQC related to shellfish consumption and/or drinking water supply.

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[12] 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 US 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."

[13] Ideally, criteria for a given use and pollutant/parameter would consist of a graph, with concentration plotted on the x-axis and duration of exposure on the y-axis. The line on the graph, representing a given biological response, such as death of 5% of exposed individuals, would slope from the upper left corner downward to the lower right corner, reflecting the well-known fact that short-term exposure to extremely stressful conditions can be equally harmful as long-term exposure to only moderately stressful conditions. (See Figure A, page 69.) EPA and the states have not published WQC in this format simply because of lack of sufficient data upon which to base such a graph. Meanwhile, these agencies typically have compromised, publishing just one criterion for short-term exposures (acute) and another for longer terms (chronic). One exception is EPA's aquatic life WQC for ammonia, which include values for three exposure durations—one hour, four days, and 30 days.

[14] Although Minnesota lacks a "true" acute criterion for temperature, the state does have a "quasi-numeric" criterion for this parameter, which could serve, to some degree, as a type of acute criterion.

None of the ten states have set numeric criteria addressing the contribution of nitrogen compounds to excessive algal blooms and resulting lowering of oxygen levels in the Gulf "Dead Zone," or anywhere in the ten states themselves. As of August 1, 2008, only two states, Minnesota and Illinois, have adopted any numeric criteria for phosphorous, and these water quality criteria apply only to one subset of waters—lakes and reservoirs. Minnesota has water quality criteria applying to virtually all lakes and reservoirs, while the Illinois phosphorous criteria apply only to such water bodies greater than 20 acres in size. Just two states, Minnesota and Tennessee, have criteria for chlorophyll a, a direct means of quantifying algal blooms, though not an indicator of the cause of those blooms. Furthermore, Tennessee's criteria apply only to one reservoir in the state.

The lack of numeric WQC for sediments/sedimentation is worthy of comment, given that sediment-related pollution is among the top five reasons for water body impairment cited in recent state Integrated 305(b)/303(c) reports on the condition of surface waters. Minnesota, Arkansas, and Louisiana are the only of the 10 states that have "true" numeric criteria for turbidity. None of the states have numeric WQC for total suspended solids (TSS) or for sedimentation of benthic zones.

b. Temperature

All of the states except Minnesota have acute criteria for temperature. On the other hand, Minnesota is one of three states (Wisconsin and Illinois are the others) with chronic temperature criteria, and Wisconsin has a chronic WQC covering temperature only for the Mississippi River itself. Eight states (exceptions are Iowa and Arkansas) have "quasi-numeric" criteria for temperature. Most of these are worded like this Illinois criterion, "[t]he maximum temperature rise above natural temperatures shall not exceed 2.8^{o}C (5^{o}F)." Another common version of such "quasi-numeric" WQC is illustrated by this Kentucky WQC, "[w]ater temperatures shall not be increased through human activities above natural seasonal temperatures." Unlike "regular" numeric WQC, determining whether or not a "quasi-numeric" WQC is being exceeded at a given waterbody location requires not just: 1) the WQC itself, and 2) data on current ambient water quality in at least one location. To determine what the quantitative water quality threshold for a given waterbody to which a quasi-numeric WQC applies, one also needs information about levels of the water quality parameter: 1) in the past, and/or 2) at two or more locations in the waterbody. Such information is needed in order to determine what "natural" or "background" levels of the parameter would be, for that particular waterbody unit.

Iowa and Missouri have temperature criteria that vary by calendar month, as does Kentucky, but Kentucky goes further by breaking each of the months except January, February, July, and August into two distinct halves. Though Arkansas' temperature criteria do not vary by season, the state does have specific criteria for each of six eco-regions, plus six individual large rivers. (One of these is the Mississippi River, for which Wisconsin, Iowa, and Missouri also have water body-specific temperature criteria.) As might be expected, all the states except Mississippi and Louisiana have separate criteria for warm water habitats and coldwater habitats (or "trout waters"). Iowa, Missouri, Arkansas, Tennessee, and Louisiana have WQC for temperature that are specific to lakes, reservoirs, and impoundments.[15]

[15] In December 2007, Wisconsin formally proposed a substantial set of changes to its temperature criteria. As of the time of this writing, the changes have not been finalized. If adopted, this new set of acute, sublethal, and chronic temperature WQC would go farther in the direction of tailoring temperature criteria according to 1) duration of exposure; 2) time of

US EPA has not issued numeric temperature water quality criteria.

c. Dissolved Oxygen (DO)

Every one of the ten main stem states have acute WQC for dissolved oxygen, while just half of them (Iowa, Illinois, Kentucky, Tennessee, and Mississippi) have chronic WQC for dissolved oxygen. Most of the states have more than one dissolved oxygen criterion, the one exception being Mississippi, which has one acute and one chronic WQC that apply to all waters in the state. Wisconsin has one criterion (acute) for fish and aquatic life-general and another for fish and aquatic life found in cold waters. Illinois has an acute criterion that applies to all waters except a group in the Chicago area. Missouri has distinct criteria for: 1) all cold water fisheries and 2) all cool or warm water fisheries. Minnesota has a dissolved oxygen criterion (chronic) for all cold waters, while warm waters are divided into: 1) cool or warm water/ sport or commercial fish; 2) indigenous fish and associated aquatic life; and 3) wetlands. Kentucky has a similar system, except that it breaks down waters with lower temperatures into: 1) cold water habitats in general and 2) lakes and reservoirs that support trout. Kentucky also has dissolved oxygen criteria specific to the main stem of the Ohio River. Iowa, on the other hand, has just one set of criteria for cold water aquatic life, but breaks warm waters down into three types of rivers and streams, plus another category for wetlands and upper layers of lakes. Tennessee has a default acute criterion that applies to all waters except for: 1) naturally reproducing trout streams; 2) other trout streams; 3) lakes and reservoirs; and 4) streams in three specific sub-eco-regions. The state has distinct dissolved oxygen criteria for each of these four categories of waters.

Arkansas and Louisiana have considerably more extensive sets of dissolved oxygen criteria than those of the other seven states. More specifically, Arkansas has adopted acute dissolved oxygen criteria for six eco-regions: Ozark Highlands; Boston Mountains; Arkansas River Valley; Ouachita Mountains; Gulf Coastal; and Delta. Within each of these eco-regions, different criteria apply depending on a number of factors, including: 1) size of a water body's watershed; 2) time of year; and 3) whether or not the water body in question is influenced by spring water (for Gulf Coastal waters only). There also are criteria applicable to trout streams, regardless of where they are located. As noted previously, Arkansas does not have any chronic dissolved oxygen criteria). Louisiana has three sets of Fish and Wildlife Propagation WQC that apply to: 1) fresh waters; 2) estuarine waters, or 3) coastal and marine waters; however these default criteria do not apply to some 500 water bodies to which site-specific dissolved oxygen criteria apply.

US EPA has issued just one acute criterion for all types of fresh water in the nation.

d. pH

All of the Mississippi River states have acute pH criteria while none have chronic pH criteria. Six states (Wisconsin, Kentucky, Arkansas, Tennessee, Louisiana, and Mississippi) have quasi-numeric pH criteria. Mississippi, for instance, has a pH criterion stating that pH "shall not be caused to vary more than 1.0 unit." Louisiana and Wisconsin have similarly worded criteria. Tennessee, Arkansas, and Kentucky also set a limit of the amount the pH can change, but go further in specifying that such

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year; 3) type of waterbody; and 4) location of waterbody than those of any of the other nine states' WQC examined for this report.

changes shall not take place within a 24-hour period. Most of the states apply the same acute and quasi-numeric criteria to all waters in the state, while Louisiana, Iowa, and Minnesota have pH criteria that vary according to water body type and/or location. Louisiana has WQC applicable to all waters in the state, except for certain waters for which water body-specific pH criteria have been established. Tennessee is unique in that it has a specific set of pH criteria applicable to water-contact recreation. None of the 10 states have pH criteria that are specific to drinking water supply.

EPA has one set of acute pH criteria applicable to fresh water aquatic life (range of 6.5 to 9.0 units), and one to marine aquatic life (6.6 to 8.5 units). The Agency also has a recommended secondary drinking water standard for pH of 6.5 to 8.5 units. This is a chronic value.

e. Pathogens

There is considerable variation in what the ten states have done regarding criteria intended to indicate acceptably safe levels of waterborne pathogens, but there are also similarities. All states have chronic pathogen WQC and all but one (Missouri) have some sort of acute criterion for pathogens. Six of the ten states (Minnesota, Iowa, Missouri, Kentucky, Arkansas, and Tennessee) have adopted *E. coli* criteria for freshwaters—a significantly higher percentage than that for all the states and territories nationwide. The other four states still are using fecal coliform bacteria as their pathogen indicator for freshwaters. There are Enterococci WQC that apply to recreational waters in the coastal zones of Louisiana and Mississippi, promulgated by EPA under the 2000 BEACH Act amendments to the Clean Water Act.

Most of the criteria related to pathogens address potential risk to people engaged in water-contact recreation. Only Louisiana and Mississippi have bacterial WQC aimed at protecting those who consume shellfish harvested from state waters. Only Minnesota has a bacterial WQC specific to drinking water supply, one that incorporates, by reference, EPA's Primary Drinking Water Standard for total coliform bacteria to its Class 1A waters.[16] Illinois, Tennessee, and Mississippi have bacterial WQC that apply to drinking water supply, but these same criteria apply to other uses (recreation and/or aquatic life) and seem to be designed primarily to protect water-contact recreation. Iowa has acute and chronic fecal coliform criteria that apply to all waters that either: 1) enter a sinkhole or 2) are a losing stream segment.[17] This provision is apparently designed to protect persons who rely on well water from contamination by surface waters pathogens.

Five states (Iowa, Missouri, Kentucky, Arkansas, and Louisiana) have distinct WQC for "primary" and "secondary" contact recreation. The "primary" criteria apply during specified periods that represent the warmer part of the year and the "secondary" contact criteria apply during the remainder of the year. Mississippi also has two sets of bacterial WQC, one applicable to warmer months (May through October) and the other during the cooler months (November through April), but the state's WQS regulations do not label them "primary contact" and "secondary contact."

[16] For the remainder of its Class 1 subcategories (1B, 1C, and 1D), Minnesota has what are essentially narrative WQC, in that they specify that levels of bacteria in raw water supply shall be such that after various types of treatment, the "finished" drinking water will meet the SDWA standard for total coliform bacteria.
[17] A "losing stream segment" is one where the flow of water from the stream to connected groundwater is greater that the flow in the other direction. A "gaining segment" is one with a net flow from groundwater to surface water.

Tennessee takes a somewhat different approach. It has one acute *E. coli* WQC for recreational uses, which is applicable to all lakes and reservoirs and to certain categories of rivers and streams (e.g., State Scenic Rivers and Tier 3 antidegradation waters), and a second criterion that applies to all other waters. Tennessee's chronic *E. coli* WQC is the same for all waters.

An unusual feature of Iowa's standards related to recreational uses of waters is the establishment of bacterial criteria for Children's Recreational Use. These apply to waters that might not have sufficient depth and/or volume to support activities that involve total body immersion, but are still used by children for wading, sitting, splashing, and similar water contact activities.

EPA has issued recommended acute and chronic WQC for fecal coliform, as well as chronic WQC for E.coli and enterococci, pertaining to water-contact recreation. The Agency has not issued acute WQC for *E. coli* or enterococci. EPA's fecal coliform criteria date is from the 1970s. The WQC for *E. coli* and enterococci were issued in 1986.[18] The more recent criteria are thought to better reflect the possible presence of human pathogens. US EPA is currently working on even more targeted indicators of human pathogens.

f. Nutrients

Only three states (Minnesota, Illinois, and Tennessee) have numeric criteria for phosphorous or chlorophyll a, the key parameters, in addition to nitrogen, dissolved oxygen, and turbidity, related to excessive nutrient enrichment/human-caused eutrophication of surface waters. Excessive eutrophication is one of the five most frequently listed causes for impairment of waters put on state 303(d) lists nationwide.[19] This phenomenon not only can have adverse effects on aquatic life, but can also impair recreational use of water bodies, and also create problems for public water supply systems. None of the ten Mississippi River states have WQC for total nitrogen—the pollutant seen as the primary cause of the Gulf of Mexico "dead zone," a large area in which oxygen levels are so low that virtually nothing can live there.

Minnesota and Illinois do have numeric criteria for total phosphorous that apply to lakes and reservoirs, but none of the states have WQC applicable to rivers and streams for this pollutant.[20] Minnesota has developed phosphorous criteria specific to several different types of lakes and reservoirs in each of four different eco-regions; Illinois has one criterion that applies to all lakes having a surface area of 20 acres or more. Minnesota also has eco-regional chlorophyll a criteria for different

[18] There is considerable confusion about EPA's "Single Sample Maximum" (SSM) values. Many take these to be bacterial densities that should never be surpassed. This interpretation of the EPA criterion document and associated guidance leads one to the conclusion that the SSM values are acute criteria with a criterion-duration of an instant and frequency of zero. In fact, the SSM values published by EPA are components of an assessment methodology, and address only those situations in which just one single grab sample has been collected in a 30-day period. In essence, EPA's SSM values were derived by constructing a bell-shaped distribution centered on 126 organisms/mL (EPA's criterion-concentration for its chronic WQC, which is stated as a 30-day geometric mean) with an assumed log standard deviation of 0.4, and marking the points on the concentration distribution curve above which only 25%, 18%, 10% and 5% of the *E. coli* levels in the distribution fall. EPA refers to these as the upper 75%, 82%, 90% and 95% confidence levels.

[19] Also in the top-five causes of impairment are: 1) sediments/sedimentation, 2) pathogens, 3) mercury, and 4) heavy metals other than mercury. For further information, see National Section 303(d) List Fact Sheet: http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T#causes_303d

[20] Wisconsin has formally proposed an extensive set of water quality criteria for phosphorous that include WQC not only for lakes and reservoirs, but also rivers and streams. These had not been finalized as of December 2008.

kinds of lakes, while Tennessee's one chlorophyll a criterion applies to just one particular reservoir. Wisconsin is currently in the process of developing what could be the most comprehensive set of nutrient-related WQC among the ten states.

Tennessee has published a set of threshold concentrations for: 1) total phosphorous and 2) nitrate + nitrite. Thresholds applicable to rivers and streams in 15 different subecoregions in the state have been issued. The state has not published any such thresholds for lakes and reservoirs. These numeric water quality goals have not been formally adopted as components of the state's WQS regulations. A document containing these values is mentioned in the state's WQS regulations, in the section covering WQC for aquatic life, but they are not incorporated by reference into the regulations. Rather, the regulations simply state that the document could be used for purposes of interpretation of the state's narrative WQC for nutrients. Hence, these numeric WQ goals are not treated as actual WQC in this report.

US EPA has published eutrophication-related criteria for total phosphorous, total nitrogen, turbidity and chlorophyll a for two types of waters (rivers and streams/lakes and reservoirs) in each of fourteen major eco-regions nationwide. For further information, see US EPA, Ecoregional Criteria, http://www.epa.gov/waterscience/criteria/nutrient/ecoregions.

g. Sediments

Another cluster of pollutants/parameters that is frequently cited as a cause of impairment of section 303(d) listed waters is sediment/sedimentation. Minnesota, Arkansas, and Louisiana have true numeric criteria for turbidity. Minnesota's turbidity WQC for rivers and streams are expressed in Nephelometric Turbidity Units (NTUs), while its turbidity criteria for lakes and reservoirs are expressed as the maximum depth of visibility of a Secchi Disk. Minnesota also varies its criteria depending on whether the waterbody to which they apply harbor warm water species or cold water organisms such as trout. Furthermore, Minnesota's turbidity criteria for lakes and reservoirs are subdivided according to the four eco-regions within the state. Arkansas also has turbidity criteria (expressed as NTU) for streams that vary according to a number of factors, including: 1) location (by eco-region); 2) stream flow ("base flow" periods vs. all other flows); 3) aquatic community (trout waters vs. all others); 4) alteration (whether a water body has been channelized); and 5) degree of influence by spring water. It also has a special set of criteria for lakes and lakes/reservoirs. Louisiana has a set of default turbidity (NTU) criteria that apply to all waters that: 1) are not of a certain type (freshwater lakes, reservoirs and oxbows, estuaries, bayous, and canals); 2) lack special designation (e.g. State Scenic Streams, Outstanding Natural Resource Waters); or 3) have not been assigned water body-specific WQC.

Iowa and Mississippi have "quasi-numeric" criteria for turbidity. Iowa's turbidity criterion states, "the turbidity of the receiving water shall not be increased by more than 25 [NTU]." Mississippi's criterion specifies, "turbidity . . . shall not exceed background turbidity . . . by more than 50 [NTU]." Tennessee's quasi-numeric WQC for sediment/sedimentation differs from other states in that it addresses total suspended solids, rather than turbidity. It also applies only to "wadeable streams."

None of the ten states have numeric WQC for total suspended sediments (TSS), nor do any have numeric WQC that address buildup of excessive levels of sediments in the benthic zone.

The ten states also differ as to which designated uses their sediment/sedimentation criteria apply. The sediment/sedimentation criteria specified by Iowa, Arkansas, Louisiana, and Mississippi apply to water bodies regardless of the designated uses assigned in the state's WQS regulations. Tennessee's narrative total suspended solids criterion applies only to aquatic life uses. Minnesota has one set of sediment/sedimentation criteria that apply to aquatic life, as well as one criterion each for drinking water and water-based recreational uses.

US EPA has issued recommended dozens of ecoregion-specific numeric criteria for turbidity, as part of its package of WQC related to the impacts of excess nutrients on two categories of surface waters: 1) rivers and streams, and 2) lakes and reservoirs. Decades ago, the federal EPA published the following quasi-numeric WQC related to turbidity, "Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than ten percent, from the seasonably established norm for aquatic life."

h. Other Traditional Pollutants/Parameters

All of the Mississippi River states except Louisiana have aquatic life criteria for ammonia. Similarly, all of the ten states except Louisiana and Tennessee have adopted criteria for chlorides, with drinking water supply and aquatic life being the uses to which these criteria most often apply.[21] Four states (Louisiana, Arkansas, Illinois, and Minnesota) have criteria for sulfates, most of which are related to water supply uses of one type or another. Illinois and Minnesota are the only states with numeric criteria for oil and grease. Missouri is the only state with a numeric criterion for total dissolved gases.

i. Limiting Application of WQC to Effects of Certain Categories of Sources

Several states (Iowa, Arkansas, Louisiana, and Mississippi) have WQC for traditional parameters/pollutants that the state appears to intend to apply only when lower water quality is caused by certain types of sources of pollutants—most often point sources. For example, Iowa has a WQC that states, "[t]he turbidity of the receiving water shall not be increased by more than 25 Nephelometric Turbidity units by any point source discharge." Arkansas has a set of eco-region-specific criteria for "mineral quality" (chlorides, sulfates, and total dissolved solids) that are similarly limited in application. The table listing "eco-region reference stream data" in the state's WQS regulations upon which these WQC are based is prefaced by, "[m]ineral quality shall not be altered by municipal, industrial, other waste discharges . . . so as to interfere with designated uses." Another part of Arkansas' WQS regulations defines "discharge" as a "discrete point source waste or wastewater entering into waters of the state."

Iowa's pH criterion is expressed in a similar manner: "[t]he maximum change permitted as a result of a water discharge shall not exceed 0.5 pH units." Louisiana has a pH WQC that begins with "[n]o discharge of waste shall cause pH of a water body to vary more than one pH unit within the specified pH range for the subsegment where the discharge occurs," as well as a NTU criterion with very similar wording. Mississippi has a temperature WQC that reads, "the discharge of any heated waters to a

[21] Some of the states have adopted criteria for other indicators of salts/salinity. Minnesota has WQC for total salinity, specific conductance, and total dissolved solids (TDS). Arkansas, Missouri, Kentucky, and Iowa also have TDS criteria. Most often, these apply to water supply uses—domestic, agricultural, and/or industrial.

stream, lake, or reservoir shall not raise temperatures more than 5 degrees F (2.8 degrees C) above natural conditions for temperatures." The intent to limit application of a WQC just to effects of point sources is somewhat less clear in the case of these pH, NTU, and temperature criteria because they refer to "waste discharges" rather than "point sources" and because unlike Arkansas, neither Iowa, Louisiana, nor Mississippi specifically define "discharge" as "point source" in their WQS regulations.

An intent to limit application of a WQC to instances where water quality declines are caused by point sources could be read into the phrasing of certain of the temperature WQC for Iowa and Arkansas. For instance, Iowa's table listing criterion-magnitudes for temperature criteria is prefaced by this language: "[n]o heat shall be added to the Mississippi River that would cause an increase of more than 3°C." Arkansas also makes reference to addition of heat in its temperature WQC. Though these criteria lack reference to "point sources" or "discharge," use of terms related to addition of heat could be interpreted to mean actual addition of heated water, which would typically come from a point source discharge, in contrast to increased temperatures resulting from removal of streamside tree canopy or widening, and therefore reducing the depth of, a stream's channel. Arkansas' "mineral quality criteria" (Cl^-, SO_4, TDS) restricts application to effects of point sources and also "instream activities."

TABLE 2: Presence of Acute and Chronic WQC for Key Traditional Pollutants

	Temperature	Dissolved Oxygen	pH	Pathogens
MN	---, q-n, chr	---, chr	acu, ---	acu(%-s), chr
WI	acu, q-n, chr*	acute, ---	acu,q-n., ---	acu(%-s),chr
IA	acu, ---	acu, chr	acu, ---	acu, chr
IL	acu, q-n, chr	acu, chr	acu, ---	acu(%-s), chr
MO	acu, q-n, ---	acu, ---	acu, ---	---, chr
KY	acu, q-n, ---	acu, chr	acu, q-n, ---	acu(%-s), chr
AR	acu, chr	acu, ---	acu, q-n, ---	acu, chr
TN	acu, q-n, ---	acu, chr	acu, q-n, ---	acu, chr
LA	acu, q-n, ---	acu, ---	acu, q-n---	acu(%-s) , chr
MS	acu, q-n, ---	acu, chr	acu, q-n, ----	acu(%-s), chr

Legend

acu = state has acute criterion

chr = state has chronic criterion

--- = no criterion of this type (acute or chronic) has been adopted

***** = state has chronic temperature criteria only for the main stem Mississippi River

acute(%-s) = Criterion expressed as a certain percentage (e.g., 10%) of samples having a concentration above the criterion-concentration. If WQC had been worded as "concentration shall be higher than the criterion-concentration no more than ___ percent of the time," it would have been labeled "acute(%-t)."

q-n = "Quasi-numeric" criteria: a hybrid between a numeric and narrative WQC. Application of "quasi-numeric" criteria depends upon having certain knowledge of the relatively undisturbed levels of a specific water quality parameter in a water body, or group of similar waters. Such criteria are expressed in terms of a specified change from "natural conditions," "natural background," or simply "background. For example, a quasi-numeric criterion would contain language such as "temperature shall not be increased more than 1^0 C above natural background." By contrast, "true" numeric criteria, as the term is used herein, do not require having a historic or spatial perspective regarding conditions in the water body of concern, and would contain language such as "temperature shall never go above ___ degrees C, at any time."
All of the quasi-numeric criteria encountered in this study lacked a clearly-specified duration, in which case the default usually would be an "instantaneous, never to surpass" duration. However, in situations where a quasi-numeric criterion was paired with a true acute or chronic criterion, ELI listed the quasi-numeric criterion as the alternative of the true criterion. Hence, if a state had a true acute criterion for a given parameter, the quasi-numeric criterion was listed as chronic.

2. Coverage for Toxic Chemicals

a. Aquatic Life Criteria

Acute Toxicity

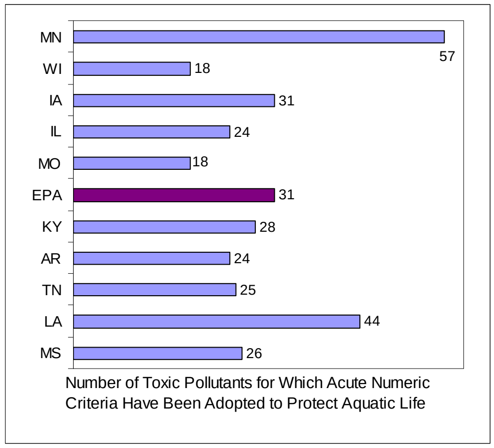

TABLE 3

Among the ten states along the Mississippi River, Minnesota has the highest number (57) of toxic pollutants for which acute numeric criteria have been adopted for aquatic life protection, substantially more than the total number of pollutants (31) for which EPA has issued acute freshwater aquatic life criteria, Missouri and Wisconsin have the lowest number (18) of pollutants for which acute numeric criteria applicable to toxic substances have been adopted for aquatic life protection.[22] Minnesota (32) and Louisiana (26) have the highest counts of "extra" acute aquatic life WQC for toxics. Illinois has, by far, the largest number of toxics for which it has threshold concentrations addressing acute exposure of aquatic life—two hundred and seventeen (217). However only 24 of these have been formally established as WQC, in the state's WQS regulations, the remaining 198 values, referred to by the state as "derived criteria," have not been incorporated into regulation.

Chronic Toxicity

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[22] Included in the count of acute WQC for Illinois are WQC for seven toxics (barium, fluoride, iron, manganese, phenols, selenium, and silver) set forth in Section 302.208(g) of the state's WQS regulations, though it is not at all clear that these "general use" WQC apply solely to aquatic life, and not also to human health-related uses. Because state typically assign aquatic life use designation to more waterbodies than the number of waters to which they assign one or more human health-related uses (fish consumption, drinking water supply, body contact recreation), these "general use" WQC are assumed to apply to aquatic life uses.
Also, Illinois has published "derived" aquatic life criteria (acute and chronic) for 193 toxic compounds. These have not been counted as WQC is this report because they have not been formally adopted into the State's WQS regulations. The state document listing these "derived criteria" indicates that some of them have been used in setting water quality-based effluent limits in NPDES permits for point source dischargers. However, such use appears to be optional, while use of formally adopted state numeric WQC in this manner is mandatory, under the CWA. Also, no mention is made of their possible, or actual, use in other CWA programs that are driven by WQS—303(d) listing and total maximum daily loads.

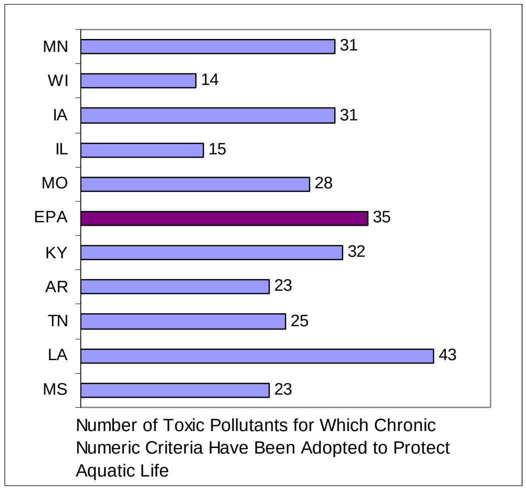

TABLE 4

Among the ten states on the Mississippi River, Louisiana has the highest number of toxic pollutants (43) for which chronic numeric criteria have been adopted for aquatic life protection. With 15 pollutants, or 40%, of the total number of pollutants for which EPA has issued chronic freshwater aquatic life criteria (35), Wisconsin and Illinois have the lowest number of pollutants for which chronic aquatic life criteria applicable to toxic substances have been adopted. Louisiana (26) and Minnesota (17) have the highest number of "extra" chronic aquatic life WQC. Illinois has, by far, the largest number of toxic substances for which it has published threshold concentrations for protection of aquatic life from chronic exposure—two hundred and eight (208). However only fifteen of these have been formally established as WQC, in the state's WQS regulations, the remaining 198 values, referred to by the state as "derived criteria," have not been incorporated into regulation.

b. Human Health Criteria

Consumption of Fish and Other Aquatic Organisms

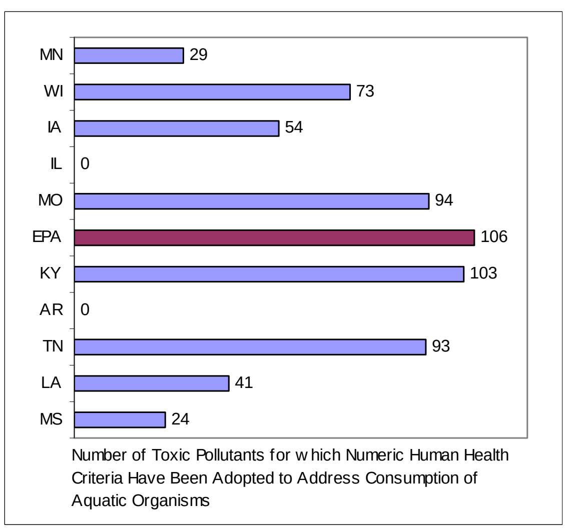

TABLE 5

The above bar chart displays the number of WQC each of the ten states have adopted, and the US EPA has issued, focused exclusively, or largely, on risk to humans resulting from consumption of fish and other forms of aquatic life contaminated by toxic substances. US EPA refers to this set of this type of WQC as Human Health: Organisms (HHO) criteria, and has published such WQC for 106 toxic substances. Only five (MN, IA, MO, KY, and MS) of the ten states have WQC that correspond exactly to these US EPA criteria. Of these, Kentucky has the most of this type of WQC (103), while Missouri has slightly fewer (94). Iowa has 54 such criteria, whereas Minnesota has just 29 and Mississippi has 24. Illinois and Arkansas have no such WQC. Illinois has published "derived" human health criteria for a total of 75 toxic pollutants, which if they had been incorporated into the state's WQS regulations as WQC would fall into this category, because they primarily address human consumption of fish and other aquatic organisms.

The states with the highest number of "extra" WQC for "fish consumption" are Louisiana and Wisconsin, with 13 and 12, respectively. Illinois (7), Missouri (6), Mississippi (5) and Louisiana (4) also have a few "extra" WQC of this type.

The above counts include not only those state WQC with titles that include "fish consumption," "consumption of aquatic organisms," "organisms," or similar wording. Also included is a set of Minnesota WQC called "Human Health-based aquatic life criteria," applicable waterbody classes 2B, 2C, and 2D in the state WQS regulations. Like the criteria from the other four states mentioned in the previous paragraph, these Minnesota criteria address risk to humans resulting solely from intake of toxic chemicals resulting from eating fish and other forms of aquatic life.

Three states (WI, TN, and LA) have a set of WQC that address the situation in which a waterbody is being used not only as a source of food, but also a place for water-contact recreation. Though technically, none of these five states have any WQC that clearly correspond to US EPA's Human Health: Organisms (HHO) WQC, it seems reasonable to treat these WQC as sufficiently similar to US EPA's HHO criteria to include them in this set of counts. Treating these sets of WQC as almost the same as US EPA's "fish consumption only" (Human Health: Organisms) criteria seems reasonable because, in comparison to the amount of a toxic substance (particularly if it is highly bioaccumulative) ingested by consumption of fish and other aquatic organisms, the amount likely to be taken in accidentally during water contact recreation is probably quite small. Wisconsin has seventy-three (73) "Human Threshold (and Non-Threshold) Criteria: Non-Public Water Supply WQC."[23] Tennessee has 93 Human Health: Organisms WQC, and Louisiana has 41 "Human Health Protection: Non Drinking Water Supply" WQC.

Illinois has "Protection of Human Health" criteria for' two toxic substances and Arkansas has "All Waterbodies-Human Health Criteria for seven toxics. Neither state specifies which of the possible exposure routes (drinking water supply, fish consumption, water contact recreation, combinations of these three). These have been counted as "drinking water and fish consumption" criteria, for purposes of this report. (The decision to count these WQC in that category was largely arbitrary, though it could be argued that, for purposes of comparison with

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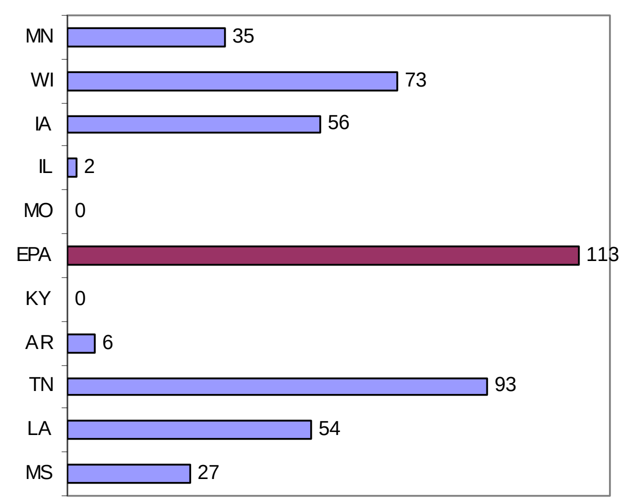
[23] Wisconsin presents its "Non-Public Water Supply criteria in two different tables, one dealing with human threshold chemicals (not carcinogenic) and the other with human non-threshold chemicals (carcinogens). A total of seventy-three (73)chemicals are covered, between the two tables.

US EPA's two types of human health WQC (Human Health: Organisms *verses* Human Health: Water and Organisms) that it is better to err on the side of the type of WQC that covers the most (two) exposure routes. Hence, the above bar chart indicates that neither Illinois nor Arkansas has any "fish consumption alone" WQC.

Illinois also has published "derived" Human Health criteria for 75 toxic compounds. These threshold values address the combined exposure pathways of: 1) fish consumption, and 2) water contact recreation. These have not been counted as WQC is this report because they have not been formally adopted into the State's WQS regulations. The state document listing these "derived criteria" indicates that some of them have been used in setting nearly 60 water quality-based effluent limits in NPDES permits for point source dischargers. However, such use appears to be optional, while use of formally adopted state numeric WQC in this manner is mandatory, under the CWA. Also, no mention is made of their possible, or actual, use in other CWA programs that are driven by WQS—303(d) listing and total maximum daily loads.

Consumption of: i) Water, plus ii) Fish and Other Aquatic Organisms



Number of Pollutants for Which Numeric Human Health Criteria Have Been Adopted to Address the Consumption Pattern of Water Plus Aquatic Organisms

TABLE 6

The above bar chart displays the number of WQC each of the ten states have adopted, and the US EPA has issued, focused exclusively, or largely, on risk to humans resulting from two pathways combined: 1) intake of drinking water contaminated by toxic substances, and 2) consumption of fish and other forms of aquatic life contaminated by toxic substances. US EPA refers to this set of this type of WQC as Human Health: Water and Organisms (HHWO) criteria, and has published such WQC for 113 toxic substances. Only three (MN, IA, and MS) of the ten states have WQC that correspond exactly to these US EPA criteria. Of these, Iowa has the most of this type of WQC (56), whereas Minnesota has 35, and Mississippi has 27. Missouri and Kentucky have no WQC that correspond to US EPA's HHWO WQC.

The above counts include not only those state WQC with titles that include “water and fish consumption” (IA), “water and organisms,” or something very similar. Also included is a set of Minnesota WQC called “Human Health-based aquatic life criteria,” applicable to waterbody classes 2A and 2Bd in the state WQS regulations. Like the criteria from the other states mentioned in the previous paragraph, these Minnesota criteria address risk to humans resulting solely from intake of toxic chemicals resulting from eating fish and other forms of aquatic life.

Three states (WI, TN, and LA) have a set of WQC that address the situation in which a waterbody is being used not only as a source of drinking water and food, but also a place for water-contact recreation. Though technically, none of these three states have any WQC that clearly correspond exactly to US EPA’s Human Health: Water and Organisms (HHWO) WQC, it seems reasonable to treat these slightly different WQC as sufficiently similar to US EPA’s HHO criteria to include them in this set of counts, given that the amount of toxics taken into the body by accident during occasional whole body contact with a surface water is likely to be considerably less that that resulting from intentional consumption of drinking water and aquatic organisms combined.

Unfortunately, none of the three states name this set of WQC in such a way that it is immediately obvious that they apply to the combination of three exposure routes: 1) drinking water, 2) consumption of fish and other aquatic organisms, and 3) water contact recreation. In fact the word “recreation” does not appear in the title of any of these sets of criteria; rather; reference to this use appears in footnotes to the tables in which these criteria are listed in the state’s WQS regulations. Also, only Tennessee’s WQC of this type, which the state has for 93 toxic pollutants, have the phrase “water and organisms” in its title. Wisconsin has a total of 73 such criteria, in two sets, one called “Human Threshold Criteria: Public Water Supply” and another named “Human Non-threshold Criteria: Public Water Supply,” and Louisiana has 54 Human Health Protection: Drinking Water Supply WQC. Though the titles of these Wisconsin and Mississippi WQC suggest they apply only to drinking water supply, careful reading of the WQS regulations reveals they apply also to: 1) fish consumption, and 2) water contact recreation.

Illinois has “Protection of Human Health” criteria for’ two (2) toxic substances and Arkansas has “All Waterbodies-Human Health Criteria for seven (7) toxics. Neither state specifies the possible exposure routes (drinking water supply, fish consumption, water contact recreation, combinations of these three). Both of these IL criteria and six of the seven AR criteria have been counted here as “drinking water and fish consumption” criteria, for purposes of this report. The decision to count these WQC in that category is largely arbitrary, based on the theory that it would be best to assume they are comparable to the more inclusive of the two types of US EPA human health WQC—those called “water and organisms” (HHWO). Arkansas “All Waterbodies-Human Health Criteria” for beryllium has been assumed to apply just to intake through the drinking water route, simply because its criterion-concentration is equal to that US EPA’s Primary Drinking Water Standard for this substance.

Drinking Water Supply

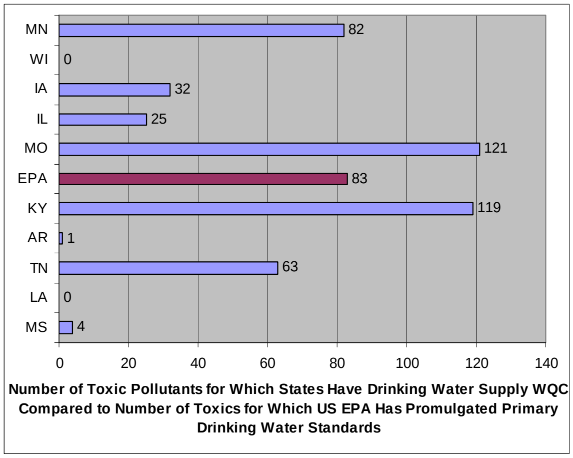


TABLE 7

Seven of the ten states have sets of WQC that are clearly aimed at defining levels of toxic chemicals in surface water used by drinking water utilities as a source of raw water; of these seven, only Missouri has WQC called "Drinking Water Supply," of which there are one hundred and twenty one (121). Minnesota's 82 criteria for this use are called Domestic Consumption". Kentucky has 119 "Domestic Water Supply" criteria, while Tennessee has 63 by the same name. Illinois' has a set of 25 WQC called "Public and Food Processing Water Supply." Iowa has 32 WQC that appear to be aimed just at drinking water supply use. These Iowa criteria appear in Table 1 in the WQS regulations and apply to waters the state designates as Class C raw water source of potable water supply. Mississippi has Public Water Supply for four toxic constituents. Arkansas has a set of "Human Health: All Waterbodies" WQC for a small number of toxic substances, but does not specify the human health related uses—drinking water supply, fish consumption, or water contact recreation—to which these criteria apply. Since the WQC for beryllium has a criterion-concentration equal to that of the US EPA Primary Drinking Water Standard, it has been counted here, as a drinking water supply WQC.

US EPA has not issued any WQC pursuant to the Clean Water Act for toxic chemicals that apply to drinking water supply, i.e., the raw water that a drinking water utility draws from surface water. (As mentioned earlier, US EPA has issued a set of WQC that apply to drinking water supply and fish consumption uses, in combination. These are called Human Health: Water and Organisms [HHWO] criteria.) The Agency has, however, promulgated, under authority of the Safe Drinking Water Act, Primary Drinking Water Standards for 83 toxic contaminants. Sometimes referred to as Maximum Contaminant Levels (MCLs), these standards are regulatory requirements that apply to the "finished" drinking water that all but very small drinking water utilities supply to their customers. Although EPA's Primary Drinking Water Standards are not directly comparable to state Drinking Water Supply WQC, they are used for comparison purposes in this report. (US EPA's Human Health: Water and Organisms WQC are like "true" drinking water supply water quality criteria in that they address levels of pollutants in raw water supplies; but, they are different in that they also incorporate ingestion of toxics resulting from consumption of fish and other aquatic life. US EPA's drinking water standards established as required by the Safe Drinking Water Act are, on the other hand, like these state drinking water supply WQC in that they address only one human exposure route—ingestion of water; but, they differ in that they apply to levels of contaminants in finished drinking water, rather than levels in raw water supplies.)

The states with the highest numbers of "extra" drinking water supply criteria are Kentucky (68) and Missouri (56). The next highest count is Minnesota, with just five "extra" drinking water supply criteria.

It should be noted that a couple of states have sets of WQC with titles that, taken alone, indicate they apply to drinking water supply. Wisconsin has two sets of WQC, one for non-threshold chemicals (carcinogens) and one for threshold chemicals (non-carcinogens) called "Human…Criteria: Public Water Supply". Louisiana has a set of "Human Health Protection: Drinking Water Supply criteria. Despite their titles, these sets of state criteria and LA "public water supply" criteria address not only drinking water supply, but also both fish consumption and recreation. As explained above, in this report, these criteria have been compared to US EPA's Human Health: Water and Organisms WQC.

B. Criterion-Concentration

1. Criterion Concentration: Traditional Pollutants/Parameters

Most of the WQC for traditional pollutants/water quality parameters that the ten mainstem Mississippi River states have adopted for aquatic life protection have criterion-concentrations identical or fairly close to the criterion-concentrations of the corresponding EPA criteria. Similarly, when states have a WQC for a parameter for which EPA has not published criteria (e.g., temperature) nearly all of the states' criterion-concentrations fall within the same range.

a. Dissolved Oxygen

One parameter for which the states have a number of criteria with concentrations different from the criterion-concentration issued by US EPA is dissolved oxygen (DO). The primary reason for this is that US EPA has issued only one criterion for dissolved oxygen in fresh water, which was published in the 1970s. All the states have at least one DO criterion with a criterion-concentration equal to US EPA's (5.0 mg/L), but they also have additional criteria for this important parameter for different types of waters. Typically, a state's generic default dissolved oxygen criterion (applicable to all waters lacking type-specific, region-specific, or waterbody-specific criteria) will have a criterion-concentration of 5.0 mg/L, as do most dissolved oxygen criteria for warm water habitats in general. For waters containing trout, or cold water habitats in general, the DO WQC usually have a criterion-concentration of 6.0 mg/L or 7.0 mg/L; exceptions being Iowa's acute cold water aquatic life DO criterion, which has a concentration of 5.0 mg/L, and Tennessee's criterion for naturally producing trout streams, which has an acute criterion-concentration of 8.0 mg/L.

On the other end of the concentration range, Louisiana has a number of waterbody-specific dissolved oxygen WQC with criterion-concentrations ranging from 3.5 mg/L down to 2.0 mg/L.

Arkansas also has DO criteria with a concentration of 2.0 mg/L that apply, between mid-May and mid-September, to streams having watersheds of less than 10 square miles. Another noteworthy feature of Arkansas' dissolved oxygen criteria is that for streams within a given eco-region, the criterion-concentration increases with the size of a stream's watershed. For example, in the Arkansas Valley the criterion-concentration for the smallest streams is 2.0 mg/l, for streams with watersheds between 11 and 150 square miles it is 3.0 mg/L, and for streams with watersheds larger than 400 square miles it is 5.0 mg/L.

b. Pathogens

i. Shellfish Harvesting

Louisiana and Mississippi are the only two states that have chronic bacterial WQC applicable to shellfish waters, and their criterion-concentrations are identical to US EPA's (14 MPN/100 mL of fecal coliform bacteria). Louisiana also has a second fecal coliform WQC expressed as a maximum of 10% of all valid samples with bacterial densities greater than 43 MPN/100 mL.

ii. Drinking Water Supply

Only two states, Minnesota and Arkansas, have such criteria for total coliform bacteria, the bacterial indicator used in the US EPA Primary Drinking Water Standard. In fact, Minnesota's total coliform WQC for raw drinking water supply drawn from Class 1A surface waters is identical to US EPA's Primary Drinking Water Standard for finished drinking water. (The US EPA standard is incorporated into the state's WQS regulations by reference.) The incorporation is logical because Class 1A includes only those waters that are (or could be after clean-up) sufficiently clean that they can meet all Primary Drinking Water Standards without undergoing any treatment. By contrast, Class 1B, 1C, and 1D waters have ambient concentrations such that federal drinking water standards could be met after these waters have undergone different degrees of treatment, with 1B waters needing the least and 1D the most. (Minnesota does not provide numeric WQC for bacteria or any other contaminants for its Class 1B through 1D waters. In theory, such concentrations could be back-calculated using the federal drinking water standard and removal rates achieved by the treatment processes specified in the Minnesota WQS regulations for each contaminant. Such analysis is beyond the scope of this report.)

Arkansas has three criteria for total coliform bacteria in drinking water supplies: 1) a monthly average of 5000 organisms/100 mL, 2) no more than 20% of samples with more than 5000 organisms/100 mL, and 3) no more than 5% of samples with more than 20,000 organisms/100 mL. The third criterion bears the closest resemblance to the US EPA standard, which stipulates that total coliform bacteria should be detected in no more than 5% of finished drinking water samples

Illinois, Louisiana, and Mississippi have bacterial drinking water supply WQC, but they are expressed as a measure of fecal coliform bacteria, rather than total coliform. Illinois and Louisiana have acute (instantaneous) WQC with a criterion-concentration of 2000 organisms/100 mL. Mississippi has an acute criterion specifying that no more than 25% of samples collected between May 1 and October 31 shall have above 400 organisms/100 mL, and a second criterion specifying that no more than 25% of samples collected between November 1 and April 30 shall have levels greater than 4000 organisms/100 mL (i.e., ten times as high).

Iowa's chronic *E. coli* criteria, applicable to all waters entering a sinkhole and losing[24] stream segments, have the same criterion-concentration as US EPA's WQC for this water-contact recreation indicator bacteria: 126 organisms/100 mL. Iowa also has a "sample maximum" criterion of 235 organisms/100 mL. (This criterion is assumed to be directed at protecting consumers of drinking water drawn by wells from fairly shallow ground water.)

iii. Water-Contact Recreation

The other set of uses for which US EPA and states have bacterial WQC is activities that involve recreational contact with surface waters. All ten Mississippi River states have at least one criterion, for either fecal coliform or for *E. coli*, with a criterion-concentration equal to that of the corresponding US EPA criteria for these two indicator parameters applicable to such uses.[25] This is the case for all chronic criteria for bacteria for recreational uses and for the acute criteria for fecal coliform.[26] Such criteria are either employed as default values, which apply to recreation waters in general, or applied to primary (whole-body) contact recreation waters.

The major differences between state and US EPA bacterial criteria for recreation are in: 1) the states' secondary contact recreation WQC, and 2) the state-derived acute *E. coli* criteria for primary contact recreation. US EPA has neither of these forms of WQC. Instead, the Agency refers to its criteria for fecal coliform, *E. coli*, and enterococci as applying to "bathing waters," which strongly implies primary contact recreation, and has never published WQC for "secondary" contact recreation. In addition, the Agency has not actually issued acute WQC for *E. coli* or enterococci, but rather has "Single Sample Maximum" (SSM) values. There is considerable confusion surrounding the SSM, which many take to be bacterial densities that should never be surpassed, even for an instant. This reading of the US EPA criterion document and associated guidance leads one to consider the SSM values as acute criteria with a criterion-duration of an instant and a criterion-frequency of zero. In fact, the SSM values published by US EPA are components of an assessment methodology related to US EPA's chronic (30-day criterion-duration) WQC for these two indicators, and address only those situations in which just a single grab sample has been collected in a 30-day period. In essence, US EPA's SSM values were derived by constructing a bell-shaped distribution

[24] A losing stream is one in which water, at some points along its course, has some of the volume of water travel into the groundwater. A gaining stream is one in which water moves from groundwater into the stream.
[25] For state chronic WQC for fecal coliform bacteria, though the criterion-concentrations are identical to EPA's, there is some question as to whether the WQC are identical. The problem is that the state (Minnesota, Illinois, Missouri, Kentucky, Arkansas, Tennessee, and Mississippi) criteria are all expressed as geometric means, while US EPA's criterion is a logarithmic mean.
[26] One exception is Missouri's Class B chronic criterion-concentration for *E. coli* for "whole body contact recreation," which has a criterion-concentration of 548/100 mL; whereas US EPA's chronic criterion-concentration is 126/100 mL. The state's Class A whole body contact chronic criterion for *E. coli*, on the other hand, does have the same concentration as US EPA's.

centered on 126 organisms/mL (US EPA's criterion-concentration for its chronic WQC, stated as a 30-day geometric mean) with an assumed log standard deviation of 0.4, and marking the points on the concentration distribution curve above which only 25%, 18%, 10%, and 5% of the *E. coli* levels in the distribution fall. (US EPA refers to these as the upper 75%, 82%, 90% and 95% confidence levels.) For instance, the 75% SSM value applicable to US EPA's WQC for Enterococci in fresh water (30-day geometric mean of 33 colonies/100 mL) is 61 colonies/100 mL. This means that if, over some 30-day period, the only data available was a single grab sample with a concentration of 61 colonies/100 mL, there would be a 75% probability that the geometric mean concentration over those 30 days was equal to or greater than the criterion-concentration of 33 colonies/100 mL.

As for secondary contact criteria, Kentucky and Arkansas have acute criteria for fecal coliform with a criterion-concentration of 2000 organisms/100 mL. Missouri has a chronic criterion (7 calendar months) with a criterion-concentration of 1800 organisms/100 mL. Arkansas has a chronic (5 months) fecal coliform criterion for secondary contact with a concentration of 1000 organisms/100 mL. (US EPA's acute fecal coliform WQC for primary contact specifies no more than 10% of samples with more than 400 organisms/100 mL. Its chronic criterion-concentration is 200 organisms/100 mL.) Arkansas has a chronic (5 months) *E. coli* WQC for secondary contact with a concentration of 630 organisms/100 mL. Missouri has a chronic (7 months) WQC for this use with a concentration of 1134 organisms/100 mL. (US EPA's chronic [duration: 30 days] *E. coli* WQC, which applies to primary contact recreation, has a concentration of 126 organisms/100 mL.)

Despite the lack of an acute US EPA criterion for *E. coli*, five states (Minnesota, Iowa, Kentucky, Arkansas, and Tennessee) have adopted such criteria for primary contact recreation. Iowa, Arkansas, and Tennessee have criteria expressed as a "sample maximum," with Tennessee's criterion having with the highest criterion-concentration, 941 organisms/100 mL (applicable to all waters except lakes, reservoirs, State Scenic Rivers, and waters assigned Tier 3 antidegradation protection, for which the criterion-concentration is 487 organisms/100 mL). Arkansas has a criterion-concentration for lakes, rivers, Extraordinary Resource Waters, Ecologically Sensitive Waters, and Natural and Scenic Waterways of 298 organisms/100 mL, and a criterion-concentration for all rivers and streams not falling into one of the above special designations of 410 organisms/100 mL. Iowa has an acute *E. coli* WQC with a criterion-concentration of 235 organisms/100 mL, which applies to Primary Contact Recreation and Children's Recreational Use waters. Minnesota and Kentucky have acute *E. coli* criteria expressed as a percentage of samples that shall not surpass the criterion-concentration, with Kentucky's limit set at no more than 20% of samples above 240 organisms/100 mL and Minnesota's at no more than 10% above 1260 organisms/100 mL.

c. Nutrients

Comparison of criterion-concentrations for WQC related to nutrients and their effects are complicated by the fact that US EPA has issued different criteria for the same pollutant/parameter for each of 14 different major eco-regions nationwide, while those of the ten states with such criteria (MN, IL, TN)[27] have not adopted a similar mapping scheme. Illinois, for example, has a total phosphorous WQC with a criterion-concentration of 0.05 mg/L that applies to all lakes with a surface area of 20 acres or more, regardless of their location within the state. However, there are two US EPA eco-regions in Illinois: one has an US EPA total phosphorous WQC concentration for lakes/reservoirs of 0.01 mg/L, and the other a concentration of 0.062 mg/L. Illinois' criterion-concentration is in the upper end of the overlapping EPA range.

Comparison of Minnesota's eutrophication criteria (total phosphorous, chlorophyll a, and turbidity measured by the visibility depth of a Secchi disk) to those issued by EPA for the same water quality parameters is difficult because the state's criteria break Minnesota down into four different eco-regions while US EPA's ecosystem map only designates three. Although some of the eco-region names used by the state and by US EPA are similar,[28] none are exactly the same. Nevertheless, a comparison of the range of concentrations specified by Minnesota and by US EPA for lakes and reservoirs across all eco-regions and uses[29] within the state yields interesting results. Minnesota's range of criterion-concentrations specified for phosphorous for lakes and reservoirs in all use categories and all eco-regions is 12– 90 µg/L, which is somewhat broader than US EPA's specified range of 8–37 µg/L. The corresponding ranges for the state's and US EPA's chlorophyll a WQC are 3– 30 µg/L and 2.43– 8.59 µg/L, respectively. For turbidity, Minnesota's criterion-magnitudes range (0.7–6.0 meters) has greater variation than the comparable US EPA values (1.4–4.9 meters.) Tennessee has a chlorophyll a criterion applicable to just one waterbody (Pickwick Reservoir), which has a criterion-concentration of 18 µg/L, while US EPA's chlorophyll a WQC for lakes and reservoirs in the eco-region where Pickwick is located has a criterion-concentration of 4.93 µg/L. (Tennessee has also issued guidance threshold values for total phosphorous and nitrate plus nitrite for 15 different subecoregions in the state. Because these numbers have not been incorporated into the state's WQS regulations, they are not true WQC; hence, their concentrations have not been compared with US EPA's criterion-concentrations, in this report.)

2. Criterion-Concentration: Toxic Chemicals

No clear patterns emerge from cross-state comparison of the number and percentage of state WQC for toxic substances that have criterion-concentrations: 1) lower, 2) equal, or 3) higher

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[27] Wisconsin is working on a very detailed set of nutrient WQC, which will address not only lakes and reservoirs but also rivers and streams.

[28] Examples of similar ecosystem names employed by the state of Minnesota and U.S. EPA: 1) Western Corn Belt Plains (MN) versus Corn Belt/Northern Great Plains (US EPA), and 2) Northern Glaciated Plains (MN) versus both Mostly Glaciated Dairy Region (US EPA) and Nutrient Poor, Largely Glaciated Upper Midwest (US EPA).

[29] U.S. EPA does not distinguish between cold and warm water habitats in the WQC it has published for phosphorous, chlorophyll a or turbidity, in its set of "nutrient criteria." That is, within an eco-region, the WQC for a given pollutant is the same, regardless of the natural temperature regime from one waterbody to the next. Minnesota, on the other hand, has two cold water life categories applicable to lakes and reservoirs within its Class A: 1) designated trout lakes; and 2) designated trout lakes (except lakes harboring lake trout). It also has Class 2B and 2Bd waters, both of which provide habitat for cool and warm water species.

than the criterion-concentration of corresponding US EPA WQC. Still, some observations are worth noting.

With regard to aquatic life WQC for toxics, Tennessee (100%) and Iowa (80%) have the highest percentage of WQC (acute and chronic) with criterion-concentrations equal to those of corresponding US EPA WQC. Louisiana and Missouri have the highest percentage (34 and 32 percent, respectively) of aquatic life WQC with criterion-concentrations lover than the corresponding US EPA values. Also, 32 of Minnesota's acute aquatic life WQC have concentrations lower than US EPA's. Louisiana has the highest proportion (41%) of chronic aquatic life WQC that specify a criterion-concentration lower than the corresponding US EPA value. Wisconsin and Minnesota have the highest fractions (50% and 49% respectively) of aquatic life WQC with concentrations higher than US EPA's.

Turning to human health WQC, ninety-eight percent of Tennessee's WQC, and 96% of Iowa's WQC have criterion—concentrations equal to the corresponding US EPA values. With regard to state WQC that correspond to a significant degree to US EPA's "fish consumption" WQC (Human Health: Organisms (HHO)), Tennessee has the highest percentage of WQC (98%) with a criterion-concentration identical to the criterion-concentration of the corresponding (HHO) US EPA WQC, while Iowa's percentage is 95%. These two states (IA, TN) also have the highest fractions (98% and 97%, respectively, of their WQC corresponding to US EPA's "water and fish consumption" WQC (Human Health: Water and Organisms (HHWO)) with criterion-concentrations equal to US EPA's corresponding values. As for drinking water supply WQC, Tennessee, Missouri, and Iowa have over 90% of their criteria with criterion-concentrations equal to the threshold concentrations set forth in US EPA's somewhat corresponding Primary Drinking Water Standards.

As for human health criteria with criterion-concentrations below the concentrations specified in EPA water quality criteria and drinking water standards, Louisiana (81%) and Wisconsin (77%) stand out. These two states also have the highest percentage of "fish consumption" and "water and fish consumption" WQC with concentrations equal to the corresponding US EPA concentrations. (Neither of these states has any drinking water supply WQC.) Kentucky's (50%) is the highest among the ten states with concentrations lower than somewhat corresponding US EPA threshold values.

The state with by far the overall highest percentage of human health criteria with criterion-concentrations higher than the corresponding US EPA value is Arkansas, with 86%. The next highest is Missouri, with 50%. (It is worth noting is the fact that Arkansas' total number of human health WQC is just seven, so its absolute numbers are much smaller than its percentages.) Missouri (88%) and Mississippi (50%) have the largest percentages of WQC corresponding to US EPA's "Human Health: Organisms" with higher criterion-concentrations than the federal agency's values. Arkansas has the highest percentage (100%) of WQC corresponding to US EPA's Human Health: Water and Organisms (HHWO) with concentration's higher than US EPA's, while Mississippi has the second highest—seventy-five (75%). None of the states have a high percentage of their drinking water supply WQC having concentration's higher than those stipulated in US EPA's Primary Drinking Water Standards; in fact, the highest such percentage is twenty three (23)—Kentucky's count.

a. State Criterion-Concentrations That Are Lower Than US EPA'*s*

i) <u>Aquatic Life Criteria</u>

Acute Toxicity

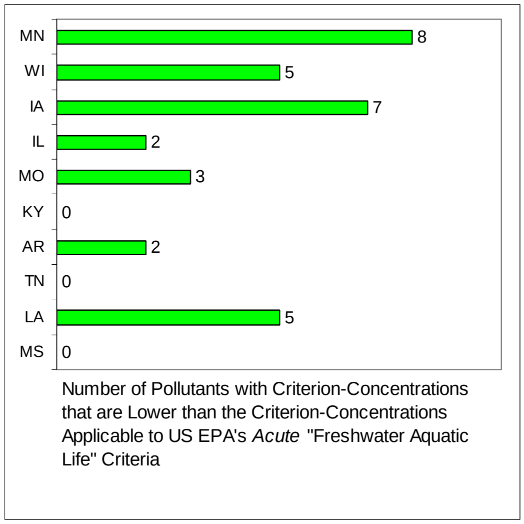

TABLE 8

Compared to the other Mississippi River states, Minnesota has the greatest number (8) of pollutants for which the state aquatic life WQC specify acute criterion-concentrations that are lower than the acute criterion-concentrations specified by corresponding US EPA "freshwater aquatic life" criteria. Kentucky, Tennessee, and Mississippi have no pollutants with state aquatic life WQC acute criterion-concentrations that are lower than those specified by US EPA's corresponding acute "freshwater aquatic life" criteria. These counts are in terms of pollutants. Some states have more than one designated use for aquatic life, and sometimes the criterion-concentrations differ from one aquatic life subcategory to another. For example, Iowa has acute WQC for 31 toxics, and it has six subcategories of aquatic life, which means it could have a total of 186 acute aquatic life WQC for toxics. The counts in this report reflect the situation with one of the six subsets of aquatic life designated uses. A similar approach was taken with other states, and with chronic aquatic life WQC, when appropriate.

Chronic Toxicity

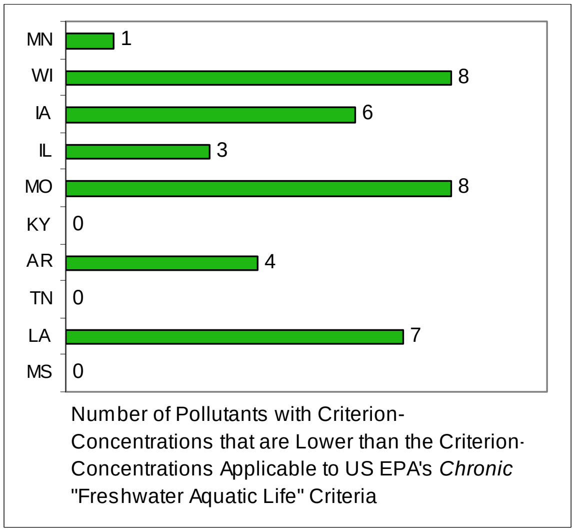

TABLE 9

Compared to the other Mississippi River states, Wisconsin and Missouri have the greatest number of pollutants (eight) for which the state aquatic life WQC specify chronic criterion-concentrations that are lower than the chronic criterion-concentrations specified by corresponding US EPA "freshwater aquatic life" criteria. Kentucky, Tennessee, and Mississippi have no pollutants with state aquatic life chronic criterion-concentrations that are lower than those specified by US EPA's corresponding chronic "freshwater aquatic life" criteria. Counts for the remaining state go from one (MN) to seven (LA).

ii) <u>Human Health Criteria</u>

Consumption of Fish and Other Aquatic Organisms

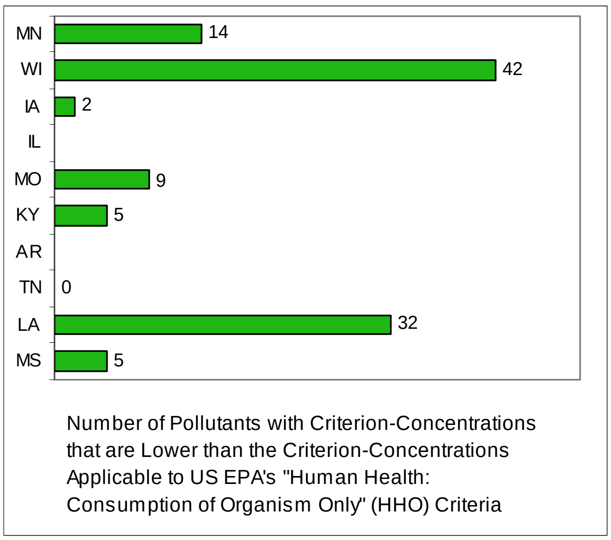

TABLE 10

Among those Mississippi River states that have adopted human health-related WQC comparable to US EPA's recommended "Human Health: Organisms" (HHO) criteria, Wisconsin[30] and Louisiana[31] have the greatest number of pollutants (42 and 32, respectively) for which the state human health-related WQC criterion-concentrations are lower than the criterion-concentrations specified in US EPA's corresponding (HHO)criteria. The count for the remainder of the states with this kind of WQC ranges from zero (TN) to fourteen (MN).[32]
Illinois and Arkansas do not have any WQC for toxics that correspond to US EPA's Human Health: Organisms (HHO) criteria.

Consumption of: Water plus Fish and Other Aquatic Organisms

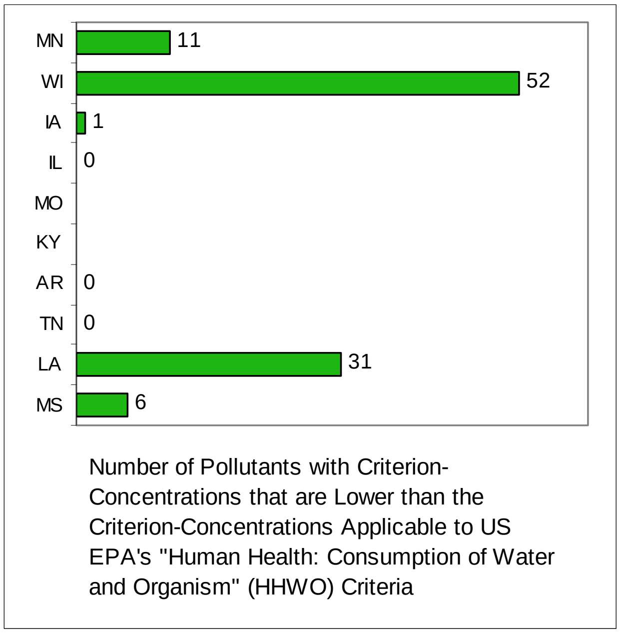

TABLE 11

Among those Mississippi River states that have adopted human health-related WQC comparable to US EPA's recommended "Human Health: Water and Organisms" (HHWO) criteria,

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[30]The WI count represents the state's total number of "Human Criteria: Non-Public Water Supply" criteria applicable to waters harboring warm water communities of aquatic life. Not presented in the above graph are the is the larger number (57) of "Non-Public Water Supply Criteria applicable to cold water aquatic communities with criterion-concentrations lower than that for the US EPA HHO WQC nor the lesser number of such WQC for limited aquatic life waters.

[31] For the purposes of this summary report, Louisiana's "Human Health Protection: Non-Drinking Water Supply" criteria were compared to the HHO criteria published by EPA. It should be noted that unlike the HHO criteria published by EPA, these state "Human Health Protection: Non-Drinking Water Supply" criteria do not apply solely to exposure of humans to toxic chemicals via consumption of aquatic organisms from a given waterbody; rather, these criteria are aimed at protecting humans who use a given waterbody not only for fish consumption but also for water-contact recreation. The Tennessee and Wisconsin WQC counted in this category also include water contact recreation-based exposure, along with fish consumption.

[32] The count for Minnesota represents its "Human Health-based aquatic life criteria" applicable to "cool and warm water fishery" waters. Minnesota has no such WQC applicable to "cold water fishery" waters.

Wisconsin (52) [33] and Louisiana (31)[34] are the states with the greatest number of pollutants with state human health-related criterion-concentrations that are lower than the criterion-concentrations specified in US EPA's corresponding HHWO criteria. The count for the remaining states with this type of WQC ranges from zero (IL, AR, TN) to eleven (MN). Neither Missouri nor Kentucky has adopted WQC for toxics that correspond to US EPA's Human Health: Water and Organisms criteria.

Drinking Water Supply

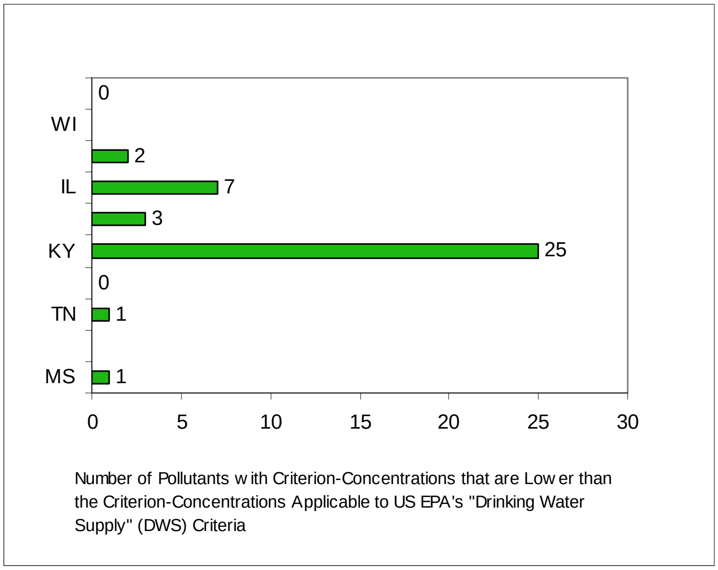


TABLE 12

Of the 8 states that appear to have at least one WQC that applies to drinking water supply use alone (i.e., not in combination with fish consumption and/or water contact recreation), Kentucky has, by far, the largest number (25) of such WQC with criterion-concentrations lower than concentration of the US EPA-established Primary Drinking Water Standard (a.k.a. Maximum Contaminant Level). Counts for other states having this kind of WQC ranges from zero (MN, MS) to seven (IL). Wisconsin and Louisiana have not adopted any drinking water supply criteria for toxic contaminants.

[33] This WI count (52) represents the state's total number of "Human Criteria: Public Water Supply" criteria applicable to waters harboring warm water communities of aquatic life. Not presented in the above graph is the larger number (60) of "Public Water Supply" criteria applicable to cold water aquatic communities with criterion-concentrations lower than that for the US EPA HHO WQC. Likewise, the MN count represents those of the state's Human Health-based aquatic life criteria" that apply to "cool and warm water fishery" waters. MN also has a set of such WQC applicable to "cold water fishery" waters.

[34] For the purposes of this summary report, Louisiana's "Human Health Protection: Drinking Water Supply" criteria were compared to the HHWO criteria published by EPA. It should be noted that unlike the HHWO criteria published by EPA, these state "Human Health Protection: Drinking Water Supply" criteria do not apply solely the combined human consumption of water and aquatic organisms; rather these criteria address the combination of drinking water supply and two other uses: a) "fish" consumption, and b) water contact recreation. The Tennessee and Wisconsin WQC included in these counts also address the effects of these three routs of exposure combined.

b. State Criterion-Concentrations That Are Equal to EPA's

i) Aquatic Life Criteria

Acute Toxicity

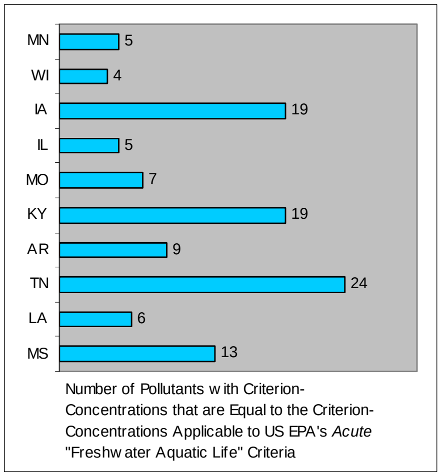


TABLE 13

Compared to the other Mississippi River states, Tennessee (24), Iowa (19), and Kentucky (19) are among those with the highest number of pollutants for which the state aquatic life WQC specify acute criterion-concentrations equal to the acute criterion-concentrations specified by US EPA's corresponding "freshwater aquatic life" criteria. Wisconsin has the lowest number of pollutants with state aquatic life acute criterion-concentrations equal to those specified by US EPA's corresponding acute "freshwater aquatic life" criteria. The counts for the rest of the states go from five (MN, IL) to thirteen (MS).

Chronic Toxicity

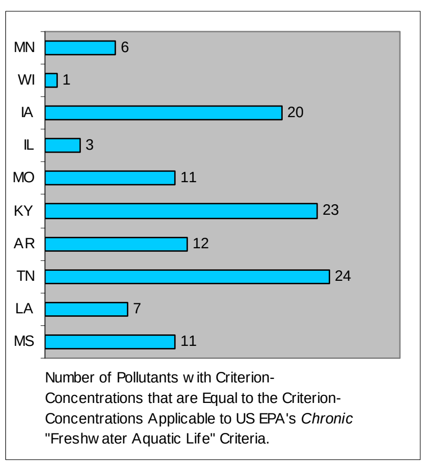


TABLE 14

Compared to the other Mississippi River states, Tennessee (24), Kentucky (23), and Iowa (20) have the highest number of pollutants for which the state aquatic life WQC specify chronic criterion-concentrations equal to the chronic criterion-concentrations specified by corresponding US EPA "freshwater aquatic life" criteria. The counts for the rest of the states range from one (WI) to twelve (AR).

ii) <u>Human Health Criteria</u>

Consumption of Fish and Other Aquatic Organisms

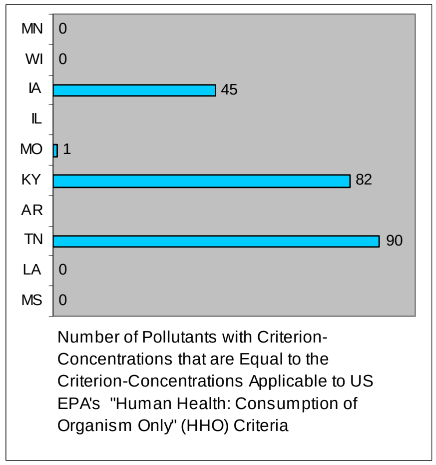
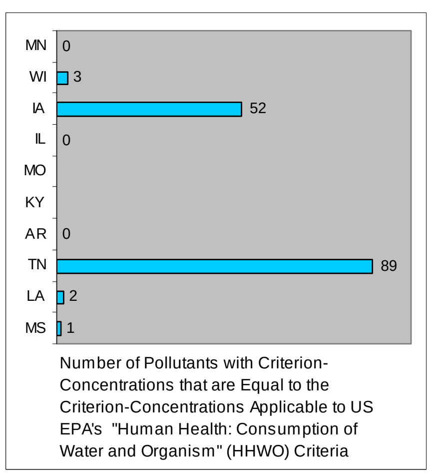


TABLE 15

Among those Mississippi River states that have adopted human health-related WQC comparable[35] to US EPA's recommended "Human Health: Organisms" (HHO) criteria, Tennessee and Kentucky have the greatest number (90 and 82, respectively) of pollutants for which the state human health-related WQC specify criterion-concentrations equal to the criterion-concentrations specified in US EPA's corresponding HHO criteria. Minnesota, Wisconsin, Louisiana, and Mississippi have no pollutants with state human health-related criterion-concentrations equal to those specified by US EPA's corresponding HHO criteria. Neither Illinois nor Arkansas has WQC corresponding to US EPA's HHO criteria.

Consumption of: aa) Water, plus bb) Fish and Other Aquatic Organisms



[35] Neither Minnesota nor Illinois have adopted any numeric WQC directly corresponding to EPA's HHO criteria.

TABLE 16

Among those Mississippi River states that have adopted human health-related WQC comparable[36] to US EPA's recommended "Human Health: Water and Organisms" (HHWO) criteria, Tennessee and Iowa have the greatest number of pollutants (89 and 52, respectively) for which the state human health-related WQC specify criterion-concentrations equal to the criterion-concentrations specified in US EPA's corresponding HHWO criteria. Minnesota, Illinois, and Arkansas have no pollutants with state human health-related criterion-concentrations equal to those specified by US EPA's corresponding HHWO criteria. Missouri and Kentucky have not adopted any WQC that correspond to US EPA's HHWO criteria.

Drinking Water Supply

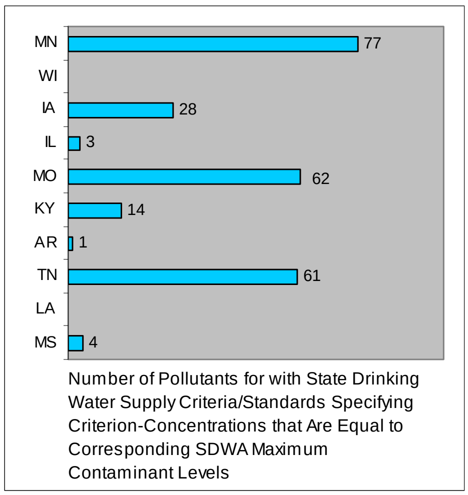


TABLE 17

Among those Mississippi River states that have adopted drinking water supply criteria corresponding[37] to the Primary Drinking Water Standards (a.k.a. Maximum Contaminant Levels (MCLs)) issued by US EPA under the Safe Drinking Water Act (SDWA), Minnesota, Missouri, and Tennessee have the most pollutants (77, 62, and 61, respectively) for which state drinking water supply criteria specify criterion-concentrations equal to the concentration of the US EPA SDWA standard for the same toxic contaminant.. Of the states with drinking water supply criteria, Mississippi (4), Illinois (3), and Arkansas (1) have the smallest number of criteria with

[36] Missouri has not adopted criteria that directly correspond to the HHWO criteria published by U.S. EPA.

[37] Wisconsin does not have WQC addressing solely exposure to toxics resulting from the source of one's drinking water supply, rather, its "Human Threshold Criteria: Public Water Supply" and "Human Cancer Criteria: Public Water Supply" criteria address the combination of drinking water supply use and consumption of sport-caught fish. Illinois' "Public and Food Processing Water Supply" criteria are based on acute conditions whereas SDWA criteria are based on chronic conditions. Louisiana has no WQC for toxic substances applicable solely to the Drinking Water Supply designated use; rather, the state's "Human Health Protection: Drinking Water Supply" criteria apply not only to drinking water supply use, but "also protect(s) for primary and secondary contact recreation and fish consumption." Mississippi has no WQC for toxic substances specifically applicable to their Public Water Supply use alone. Waters with the "Public Water Supply" use designation must comply with the state's "Water and Organisms" criteria.

concentrations lower than the concentration of the corresponding US EPA standard. Wisconsin and Louisiana have not adopted drinking water supply WQC for any toxic contaminants.

c. State Criterion-Concentrations That Are Higher Than US EPA's

i) Aquatic Life Criteria

Acute Toxicity

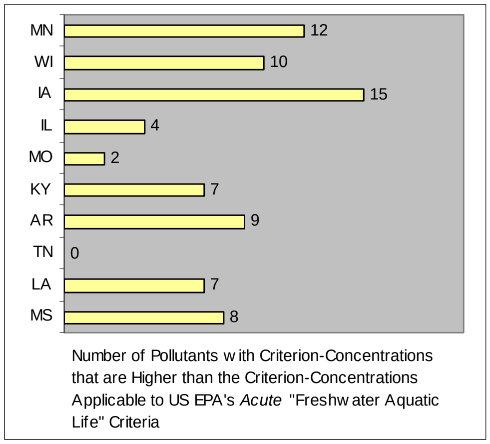


TABLE 18

Compared to the other Mississippi River states, Iowa (15) and Minnesota (12) have the greatest number of pollutants for which the state aquatic life WQC specify acute criterion-concentrations that are higher than the acute criterion-concentrations specified in US EPA's corresponding "freshwater aquatic life" criteria. There is no pollutant for which Tennessee has adopted an acute criterion-concentration that is higher than the corresponding US EPA criterion-concentration. Other state counts range from two (MO) to ten (WI).

Chronic Toxicity

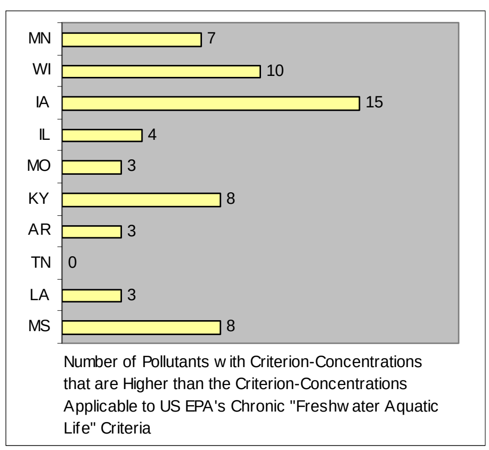


TABLE 19

Compared to the other Mississippi River states, Iowa has the greatest number of pollutants (15) for which the state aquatic life WQC specify chronic criterion-concentrations are higher than the chronic criterion-concentrations specified in US EPA's corresponding "freshwater aquatic life" criteria. There is no pollutant for which Tennessee has adopted a chronic criterion-concentration that is higher than the corresponding US EPA criterion-concentration. Counts for the remaining states range from three (MO, AR, and LA) to ten (WI).

ii) Human Health Criteria

Consumption of Fish and Other Aquatic Organisms

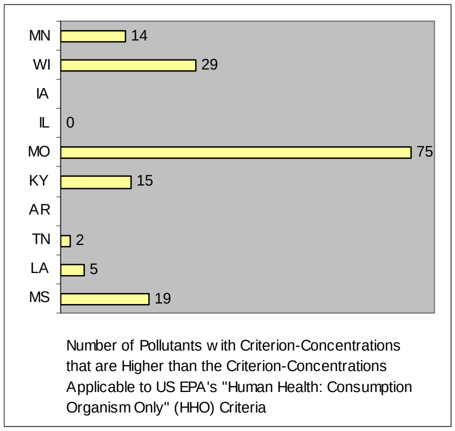


TABLE 17

Among those Mississippi River states that have adopted human health-related WQC comparable to US EPA's recommended "Human Health: Organisms" (HHO) criteria,[38] Missouri has, by a substantial degree, the greatest number (75) of pollutants with state human health-related WQC having criterion-concentrations that are higher than the criterion-concentrations specified in US EPA's corresponding (HHO) criteria. The state with the next highest number is Wisconsin, with 29.[39] The counts of the remaining states with this type of WQC range from Iowa's zero to Mississippi's nineteen (19). Illinois and Arkansas lack such WQC.

Consumption of: aa) Water, plus bb) Fish and Other Aquatic Organisms

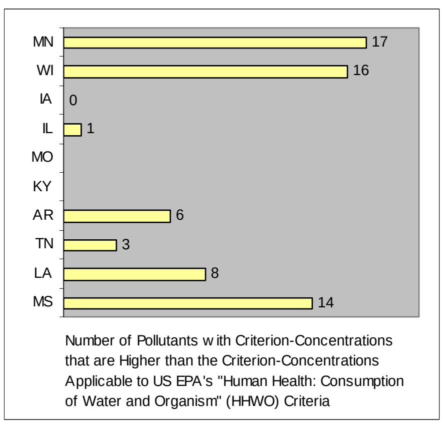


TABLE 18

[38] Minnesota's WQS regulations lack numeric WQC corresponding to U.S. EPA's HHO criteria. The state does have "Human health-based: aquatic life" WQC, but these apply to combined human consumption of aquatic organisms and drinking water.

[39] This WI count represents the state's total number of "Human Criteria: Non-Public Water Supply" criteria applicable to waters harboring warm water communities of aquatic life. Not presented in the above graph are the is the smaller number (14) of "Non-Public Water Supply Criteria applicable to cold water aquatic communities with criterion-concentrations lower than that for the US EPA HHO WQC nor the larger number (63) of such WQC for limited aquatic life waters.

Among those Mississippi River states that have adopted human health-related WQC comparable to US EPA's recommended "Human Health: Water and Organisms" (HHWO) criteria, Minnesota (17), Wisconsin (16),[40] and Mississippi (14) have the greatest number of pollutants with state human health-related criterion-concentrations that are higher than the criterion-concentrations specified in US EPA's corresponding (HHWO) criteria.[41] The remainder of the states have between zero (IA) and eight (LA) of this type of WQC with higher criterion-concentrations than US EPA's HHWO criteria. Missouri and Kentucky do not have any of this kind of WQC for toxic substances.

Drinking Water Supply

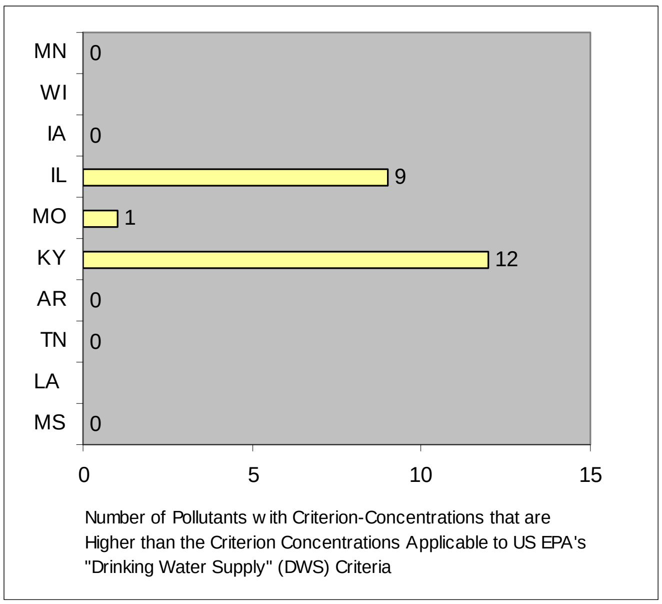


TABLE 22

Among those Mississippi River states that have adopted drinking water supply criteria somewhat corresponding[42] to the Primary Drinking Water Standards (a.k.a. MCLs) issued by US EPA

[40] Both WI and MN vary the criterion-concentration for this type of human health WQC depending on the type of waterbody from which the fish consumed were taken. This WI count represents the state's total number of "Human Criteria: Non-Public Water Supply" criteria applicable to waters harboring warm water communities of aquatic life. Not presented in the above graph are the is the smaller number (14) of "Non-Public Water Supply Criteria applicable to cold water aquatic communities with criterion-concentrations lower than that for the US EPA HHO WQC nor the larger number of such WQC for limited aquatic life waters. Likewise, the count for MN is that for that state's "Human Health=based aquatic life criteria" applicable to "cool and warm water fishery" waters. MN also has a set of such WQC applicable to "cold water fisheries."

[41] Wisconsin's "Non-Public Water Supply: Human Cancer" and/or "Non-Public Water Supply: Human Threshold" WQC specify three subsets of criterion-concentrations for three different types of waters—those supporting "cold water sport fish communities," "warm water communities," and "limited aquatic life." The criterion-concentrations specified by EPA's "Human Health: Organisms Only" are, for the purposes of this summary report, compared to the Wisconsin's "warm water communities" criterion-concentrations.

[42] Wisconsin does not have WQC addressing solely exposure to toxics resulting from the source of one's drinking water; rather, its "Human Threshold Criteria: Public Water Supply" and "Human Cancer Criteria: Public Water Supply" criteria address the combination of drinking water supply use and consumption of sport-caught fish.

under the Safe Drinking Water Act (SDWA), Kentucky (12) and Illinois (9) have the most pollutants for which state drinking water supply criteria specify criterion-concentrations higher than the concentration of the US EPA SDWA standard for the same toxic contaminant.. Of the states with drinking water supply criteria, Minnesota, Iowa, Missouri, Arkansas, Tennessee, and Mississippi have the smallest number of criteria (either zero or one) with concentrations higher than the concentration of the corresponding US EPA standard. Wisconsin and Louisiana have not adopted drinking water supply WQC for any toxic contaminants.

C. Articulation of Criterion-Duration

According to terminology employed in some EPA guidance documents, the criterion-duration component of a numeric WQC specifies the length of an "excursion"—a specified time period over which the water body 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 4 days, which results in their being expressed as 4-day average concentrations. The occurrence of one or more *excursion(s)* (e.g., in the case of cyanide, a 4-day period in which the in-stream concentration 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 (see next section-D) has an actual *exceedence* of a water quality criterion occurred.

As illustrated in Tables 23 and 24, none of the 10 Mississippi River states have clearly-specified durations for all of their water quality criteria. In fact, fewer than half of the states' WQC have clearly-specified criterion-durations.

Durations are clearly specified for a higher proportion of the criteria for key traditional parameters than the criteria for toxic chemicals. The pollutants with the highest rate of clearly-specified criterion-durations were ammonia and fecal coliform bacteria.[43] For traditionals, there are more chronic criteria with clearly-specified durations than acute criteria. For toxics, however, the reverse is true.

Chronic criteria for aquatic life uses, for both traditional and toxic pollutants/parameters, have the highest percentage of clearly-stated criterion-durations. These are most often expressed as average values over a certain number of hours (24 or 96) or days (one, four, or thirty). Several states have criteria for indicator pathogens applicable to water-based recreational uses that are specified as averages over a multi-month recreational season (e.g., May 1 to September 30).

Illinois' "Public and Food Processing Water Supply" criteria are based on acute conditions whereas SDWA criteria are based on chronic conditions. Louisiana has no WQC for toxic substances applicable solely to the Drinking Water Supply designated use; rather, the state's "Human Health Protection: Drinking Water Supply" criteria apply not only to drinking water supply use, but "also protect(s) for primary and secondary contact recreation and fish consumption."

[43] Most states have adopted the EPA format for ammonia criteria—a total of three : a) an hourly average, b) a 4 day average, c) a 30 day average. Likewise, most have adopted the duration of 30 days from EPA's chronic criterion for fecal coliform bacteria.

The most common examples of vaguely worded criteria are ones expressed as "concentration not to exceed ___," "maximum concentration of ___," or "minimum level of ___," with no reference to an average, mean, or other central tendency. Read literally, these seem to indicate a criterion-duration of a mere second and the criterion-frequency of zero. All of the states have at least a few criteria expressed in this manner, with several states having a majority of their criteria fitting this description.

By contrast, criteria expressed as concentrations not to be surpassed "at any time" or "never to exceed" are clear indications of a criterion-duration of only an instant and a frequency of zero. A number of Kentucky's acute aquatic life criteria for traditional pollutants are stated as an "instantaneous maximum." Arkansas' acute aquatic life criteria for toxic chemicals are expressed as "never to exceed" concentrations. Mississippi has special chloride, sulfate, and total dissolved solids criteria for the Mississippi River that are expressed as concentrations that the waters are "not to exceed . . . at any time," as well as clear instantaneous criteria for dissolved oxygen, barium, fluoride, and lead that are applicable to all waters. Missouri's temperature criteria for certain sections of the Mississippi River demonstrate another way of clearly stating that the applicable duration for a given use combination for a particular pollutant is an instant and that the frequency is zero: "At no time shall temperature . . . exceed the listed limits . . . ." Similarly, Illinois has specified that its dissolved oxygen criteria "shall not be less than __ at any time."

Another frequently encountered source of ambiguity regarding durations are chronic criteria expressed in terms of "daily," "monthly," and "yearly" averages, as opposed to "24-hour," "30-day," and "365-day" rolling averages. The term "daily average," for example, could mean either: 1) the average over any contiguous 24-hour period (i.e., rolling 24-hour average); or 2) the average over any period between 12:00 AM to 11:59 PM (i.e., calendar day average). Rolling averages would appear to be more consistent with the sciences of physiology and toxicology than purely sequential blocks of time based on the systems of dividing time devised by humans. That is, a group of fish will be affected in the same way by 30 contiguous days of exposure to a certain average concentration of a toxic compound, regardless of how those 30 days happens to fall within calendar months.

There are also several instances where a criterion is expressed as an average, mean, or median value, but the extent of time over which water quality values should be averaged is not specified. An example is Mississippi's fecal coliform criterion for shellfish harvesting, which states that "[t]he median fecal coliform MPN . . . shall not exceed 14 per 100 mL." Left unstated is the intended averaging period. For example, whether the median should be taken over an hour, 12 hours, 24 hours, 7 days, 30 days, the entire shellfish harvesting season, a year, or an even longer period. (By contrast, Mississippi's fecal coliform criterion for chronic recreational exposures is clearly stated as a mean value over 30 days.) Louisiana's sulfate WQC applicable to all waters seems to call for the averaging of all available data, going as far back as records exist. Slightly more precise is the Illinois chronic criterion for aquatic life, written as the "arithmetic average . . . over any period of at least 4 days," which leaves the criterion-duration open to be anything from 96 hours to the entire historical record. Somewhat further circumscribed is Tennessee's *E. coli* criterion for domestic water supply uses, articulated as the mean of at least five samples collected "over a period of no more than 30 consecutive days, with individual samples being collected at intervals of not less than 12 hours." This could translate into a duration of anywhere between 2.5 and 30 days (60 to 720 hours).[44] Illinois has a fecal coliform criterion expressed in almost exactly the same manner, except that it does not specify a minimum interval between sampling events. Arkansas has chronic criteria for total dissolved solids that specify "samples collected between 30 and 360 days." Also confusing is language referring to a "minimum value for at least 16 hours of every 24-hour period," which, among others, is used in Iowa's aquatic life criteria for dissolved oxygen. It is unclear whether this refers to the lowest instantaneous value encountered during any 16 hour period within any 24-hour period, or, as is more likely, to the lowest 16-hour rolling average during any rolling 24-hour period.

[44] The 2.5-day minimum duration was calculated by multiplying the minimum sampling interval, 12 hours (0.5 days), by the minimum number of samples, five, which yields 60 hours (2.5 days).

TABLE 23: Clarity of Criterion-Durations for Selected Traditionals

	Temp		DO		pH		P/Chl a		Cl^-		Cl^-		Path		Path	
	Aquatic Life										*DWS*				*Rec*	
	ac	cr	ac	cr	ac	cr	ac	cr	ac	cr	ac	cr	ac	cr	ac	cr
MN	?	#	--	#?	#?	--	--	#	#	#	--	#?	#?	--	#?	#
WI	#?	#	#	--	#?	--	--	--	#	#	#?	--	--	--	#?	--
IA	#?	--	--	#	#?	--	--	--	--	--	--	#?	--	--	#?	#
IL	#/#?	#	#	#	#?	--	#	--	#?	--	--	--	--	#	#?	#
MO	#?	--	#?	--	#?	--	--	--	#?	#	--	--	--	--	--	#
KY	#?	--	#	#	#?	--	--	--	#?	#?	#?	--	--	--	#?	#
AR	#?	#	#?	--	#?	--	--	--	#?	#	#?	--	--	--	--	#
TN	#?	--	#?	#	#?	--	--	(#)	--	--	--	--	--	?	#?	#
LA	#?	--	#?	--	#?	--	--	--	--	--	--	?	#?	--	#?	#
MS	#?	--	#	#	#?	--	--	--	#	--	#?	--	#?	#	#?	#

Legend

Temp. **=** temperature

DO = dissolved oxygen

P/Chlor a = phosphorous and/or chlorophyll a (Minnesota has both)

Path = pathogen indicator (total coliform, fecal coliform, *E. coli*, enterococci)

DWS = drinking water supply use

Rec = water-contact recreation uses

= Criterion-duration is clearly/precisely specified

#? = Somewhat clear specification of criterion-duration, but requires assumption(s) and/or background knowledge. For instance:

1) Criteria are stated as "concentration not to exceed" or "maximum concentration," rather than "concentration not to surpass at any time" or "instantaneous maximum, never to surpass."
2) Criteria are stated as "percentage of samples," where if "sample" means "grab sample," then the applicable duration is apparently an instant.

? = Criterion-duration is not mentioned or not clearly specified, e.g., open ended "average concentration" or "quasi-numeric" criterion, such as those articulated as "no change above natural background," or "no change in pH more than 1 unit"

#/#? = The durations for some of this type of criteria are clearly articulated, but others are less so.

-- = There is no criterion of this type for this pollutant/parameter.

(#) = Tennessee's chlor a WQC is listed in its WQS under recreation, not aquatic life.

TABLE 24: Clarity of Criterion-Durations for Toxic Pollutants

	Aquatic Life		*Human Health*					
			DWS		FC		DWS + FC	
	acute	chronic	acute	chronic	acute	chronic	acute	chronic
MN	#	#	?	--	--	--	--	#
WI	#?	#?	--	--	#?	--	#?	--
IA	?	?	?	?	#?	--	#?	--
IL	#	?	#?	--	#?	--	(#?)	(--)
MO	#?	#?	--	#	--	#	--	--
KY	?	?	#?	--	#?	--	--	--
AR	#	#	--	--	#?	--	(#?)	(--)
TN	#??	#??	?	?	?	?	?	?
LA	#??	#??	--	--	?*	?*	--	--
MS	#??	#??	--	--	?	?	?	?

Legend

DWS = drinking water supply
FC = human consumption of fish, shellfish or other aquatic organisms. Such WQC are sometimes called "Fish Consumption," "Human Health: Organisms (HHO),"or "Organisms Only." Some of the studied states refer to such WQC as "Non-Drinking Water Supply" criteria.
DWS + FC = human consumption of both drinking water and aquatic organisms originating in a particular water body. Such WQC are sometimes called "Consumption of Drinking Water and Aquatic Organisms," or "Human Health: Water and Organisms." Some of the studies states call such WQC simply "Drinking Water Supply" though they address not only exposure from drinking water but also fish consumption.
= the criterion-duration is clearly/precisely specified
#? = the criterion-duration is somewhat clearly specified but requires assumption(s) and/or background knowledge. For instance:

3) Criteria are stated as "concentration not to exceed" or "maximum concentration," rather than "concentration not to surpass at any time" or "instantaneous maximum, never to surpass."
4) Criteria are stated as "percentage of samples," where if "sample" means "grab sample," then duration apparently instantaneous

#?? = It is not apparent that state regulations say anything about duration; however, they do make specific reference to WQC issued by EPA as the basis for state regulations. Hence, it is reasonable to assume that the duration applicable to the relevant EPA acute and chronic WQC also apply to the state WQC in question.
? = Criterion-duration is not mentioned or not clearly specified, e.g., open ended "average concentration" or "quasi-numeric" criterion.
-- = No criterion of this type has been specified for this pollutant/parameter.
(#) or (--) = State just has "generic" human health WQC. It is assumed by the authors that such WQC apply to fish consumption, though it is less clear that they apply to drinking water plus fish consumption.
?* = It is not apparent that Louisiana has specified FC criteria, but it is clear that the state has adopted criteria for fish consumption plus water-contact recreation.

In a similar vein, Minnesota's dissolved oxygen criteria for various categories of aquatic life uses 7 mg/L as "a daily minimum." If this were worded as "a daily average minimum value," or a "minimum 24-hour average," it would clearly refer to the average concentration over a 24-hour period. But the Minnesota language per a "daily minimum" could also be taken to mean the minimum instantaneous concentration occurring during any 24-hour period. This interpretation, however, would raise the question of why the state WQS regulations did not simply describe it as an "instantaneous minimum, at any time." Likewise, Arkansas has a fecal coliform criterion for primary contact recreation expressed as "a monthly maximum" that shall not be exceeded. (By contrast, Illinois has a dissolved oxygen WQC stated as "4.0 mg/L as a daily minimum averaged over 7 days." Uncertainty about the meaning of "daily minimum" is eliminated by a subsequent provision of the regulations: "Daily minimum is the minimum dissolved oxygen concentration in 24 consecutive hours." Illinois also has dissolved oxygen criteria that refer to "a daily mean," which clearly means the *average* level over 24 hours.

Criteria expressed as a concentration not to be surpassed in more than a certain percentage of available water quality samples[45] are similarly unclear about the criterion-duration. The criterion-duration applicable to this type of WQC appears to be a second or an instant, because the regulations refer to a percentage of samples. Most ambient monitoring takes the form of "grab" sampling, which refers to collecting a series of single aliquots of water, by manual or mechanical means. It only takes a second to collect each of these individual measurements. Hence, the criterion-duration of concern is, for purposes of this study, assumed to be an instant/second.

In come cases, such as in Tennessee, Louisiana, and Mississippi, state WQS regulations are silent as to what criterion-durations apply to some or all of their WQC, but clearly indicate that EPA's section 304(a) criteria are the basis for them. In these instances, if one were familiar with EPA's criteria, one could assume that the criterion-durations for the corresponding EPA WQC also apply to the states'. For example, EPA's aquatic life criteria for toxics have one set with a one-hour duration (acute WQC, also called Criterion Maximum Concentration) and one with a 96-hour (four-day) duration (chronic WQC, also called Criterion Continuous Concentration).

Highlights of state-specific findings about the Mississippi River states' performance in terms of clearly specifying the durations applicable to their criteria for traditional and toxic pollutants are summarized in the following paragraphs, in order of the states' locations along the north-south axis of the river.

Minnesota has the highest fraction of clearly-specified criterion-durations of the ten states. The durations for approximately half of its criteria for key traditionals and three out of its four types of toxic criteria are clearly-specified.

[45] Eight of the states that use some variant on the "percentage of samples" approach for one or more of their WQC for bacteria. If one assumes that, here, "sample" refers to a single measurement (i.e., grab sample), and that all such "samples" have been collected in an unbiased manner, then it could be inferred that the language about a percentage of samples is intended reflect an implicit water quality criterion expressed as "the level of fecal coliform bacteria shall not surpass ____more than __% of the time." As written, these are technically not water quality criteria, in that they do not describe waterbody conditions consistent with supporting a designated use. Instead, this language describes a characteristic of a set of samples, which is actually to an assessment methodology.

Wisconsin has a higher proportion (50%) of clearly-specified durations for key traditionals than most of the other states. However, while the durations applicable to its aquatic life criteria for toxics had only minor ambiguity, those applicable to criteria addressing human health effects of toxics lack clearly-specified durations.

One-third of Iowa's criteria for traditional pollutants have clearly-specified durations. In contrast, there are no clearly-specified durations for Iowa's criteria for toxic pollutants.

Illinois has the highest proportion (60%) of criteria applicable to traditional pollutants with clearly-specified durations. For toxic pollutants, however, only the durations applicable to the state's acute aquatic life criteria are clearly-specified.

While just one-third of Missouri's criteria for traditional pollutants have clearly-specified durations, the picture for toxic pollutants is better. Missouri's human health criteria have clearly-specified durations, and the durations for its aquatic life criteria for toxics have only minor ambiguities.

The durations applicable to one-third of Kentucky's traditional criteria are clearly-specified. Conversely, none of the state's WQC for toxics have clearly-specified durations. The state's acute criteria for aquatic life are described as "the highest instream concentration . . . to which an organism can be exposed for a brief period of time without causing an unacceptable harmful effect," and the definition of chronic criteria merely refers to levels to which aquatic organisms can be "exposed indefinitely." The terms "brief period" and "indefinitely" are not defined in the State's WQS regulations.

While Arkansas has a lower proportion (38%) of clear durations for key traditional parameters than several of the other states, the durations applicable to all of Arkansas' criteria for toxics pertaining to aquatic life are clearly-specified. The durations applicable to Arkansas' human health criteria are unclear.

Only 43% of Tennessee's criteria for traditional pollutants have clearly-specified durations, and there is no Tennessee WQC for toxic pollutants with a clearly-specified duration.

Only 17% of Louisiana's criteria for traditional pollutants have clearly-specified durations. Moreover, there is considerable uncertainty as to what might be the applicable criterion-duration for all of the state's criteria for toxic pollutants.

Half of Mississippi's criteria for key traditionals have clearly-specified durations. On the other hand, none of the durations applicable to the state's toxics criteria are clearly-specified.

D. Articulation of Criterion-Frequency

In EPA water quality standard terminology, the criterion-frequency specifies the maximum rate at which excursions[46] can occur with the waterbody of concern still fully able to support the designated use to which the criterion applies. For example, EPA guidance specifies a criterion-frequency of once in three years for both its acute and chronic aquatic life WQC for toxic chemicals. This means that only if two or more excursions occur during any 3-year period has there actually been an exceedence of the WQC in question. For example, only if the 4-day average concentration of cyanide in a lake were higher than the US EPA's chronic criterion-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. Hence, the waterbody would be placed on the state's section 303(d) list or in another category of impaired waters pursuant to EPA's Integrated Listing Guidance.

Compared to their criterion-durations, the ten states had an even lower fraction of water quality criteria for which criterion-frequencies have been clearly specified. Most of the examined WQC contained nothing indicative of a criterion-frequency.

In fact, there is only one example of a category of criteria in which there are fairly clearly-specified frequencies. This group, which cuts across states, is comprised of criteria expressed in terms of a percentage of the timeat least if one assumes that the applicable duration for such criteria is an instant. That is, if the criterion indicates that the concentration of a pollutant should not surpass a certain concentration more than 10% of the time, then the criterion-frequency is 10%.

One of the very few examples of a clearly-stated criterion-frequency is Wisconsin's fish and aquatic life criterion for chlorides, which includes a criterion-frequency of once in three years.

In contrast to the criteria adopted by the ten Mississippi River states, EPA's criteria for the protection of aquatic life from the effects of toxic chemicals have a clearly stated recommendation of a frequency of excursions (conditions inconsistent with those described by the combination of the criterion-magnitude and criterion-duration) of once in three years. Mississippi, Louisiana, and Tennessee might have intended for their aquatic life criteria for toxics to include a frequency of once in three years, given that they say, or strongly imply, that they either adopted EPA's criteria or employed the methodology that EPA uses in setting its criteria. However, no mention is made in these states' WQS regulations with regard to this, or any other, frequency.

In the case of its WQC addressing human health effects of toxic pollutants, US EPA documents do not specify a frequency of excursions consistent with supporting relevant uses.

[46] In this report, and in some U.S. EPA guidance documents, "excursion" means a circumstance in which waterbody conditions (level of a pollutant, etc.) are worse than those described by the combination of the criterion-concentration and criterion-duration of a given WQC.

IV. DISCUSSION

A. “Missing” WQC: How Important?

A state has not adopted a water quality criterion for a designated use/water quality parameter combination. How much difference might that actually make in the real world? That is, if a particular pollutant were present, how serious a problem could it potentially pose to humans and/or aquatic life? And what reason is there to think that this particular pollutant might be present in one or more waterbody in the state?

These are reasonable questions, for which there are no clear-cut answers. To the extent possible, the following sections attempt to address them. First the inherent risk posed by pollutants is discussed, followed by an examination of what might be determined about the likelihood of a particular pollutant being present in a specific locale.

1. Relevance of a given pollutant/other water quality parameter to support of particular designated uses

The relative importance of a pollutant or other water quality parameter (e.g., dissolved oxygen, pH, and temperature) needs to be judged in the context of the designated uses being considered. For instance, levels of dissolved oxygen are critical indicators of the ability of a water body to support aquatic life, but low dissolved oxygen levels do not pose a health risk to humans who swim in or drink the water. Conversely, levels of bacteria indicative of the presence of fecal material from warm-blooded creatures are probably not particularly relevant to support of aquatic life (typically cold blooded species), although high levels may render a water body unsuitable for human recreation.

Table 25, based partly upon recent EPA guidance,[47] lists pollutant/water quality indicators with a high degree of utility with regard to four key designated uses.

TABLE 25

Aquatic Life	**Water-based Recreation**	**Drinking Water**	**Fish Consumption**
Biosurveys - fish	Pathogen indicators - Fecal coliform	Pathogens and/or indicators Nitrates	Mercury PCBs

[47] For example, dissolved oxygen, pH, temperature, and conductivity (a surrogate for total dissolved solids) are listed by US EPA in its July 2002 Consolidated Assessment and Listing Methodology guidance (CALM) as “core indicators for determining whether conditions support aquatic life, along with stream flow and the physical condition of the stream channel. (Stream hydrology and the conditions of the banks and bed of a waterbody are, in the eyes of the Clean Water Act, not “pollutants,” though their disruption by human activities is a form of pollution. Since pollutants are also a subset of pollution, alteration of stream flow and modification of the stream channel and removal of riparian vegetation are “non-pollutant” forms of pollution.).

- macro-invertebrates Dissolved Oxygen Temperature pH Turbidity Total dissolved solids Nutrients Heavy metals Endocrine disruptors	- *E. coli* - Enterococci Chlorophyll a (algae indicator) Nutrients	Nutrients Trace metals Water-soluble pesticides and other synthetic organic compounds Salinity Total Dissolved Solids Chlorophyll a (algae indicator)	Dioxin DDT Chlordane Other synthetic organic chemicals with high bioaccumulation[48] potential Pathogens (per shellfish)

Another measure of the relevance of pollutants and other parameters to a given water body use is whether or not US EPA has issued recommended water quality criteria pursuant to its responsibilities under Section 304(a) of the Clean Water Act. Appendix G contains a list of such pollutants for: 1) freshwater aquatic life, 2) saltwater aquatic life, 3) fish consumption, and 4) combined fish consumption and aquatic life. Also included in Appendix G is the set of contaminants for which EPA has issued primary drinking water standards (also known as "maximum contaminant levels" (MCLs)) under authority of the Safe Drinking Water Act.[49]

The nature of potential health effects on humans resulting from exposure to high levels of toxic chemicals in water is also relevant. Appendix B presents a list of chemicals that EPA has flagged as carcinogenic in agency's listing of Section 304(a) water quality criteria. Of course, inducing cancer is not the only means by which toxic chemicals can adversely affect humans. Mercury and cyanide are two chemicals that can cause serious health effects—even death—but are not carcinogens. High levels of nitrates in drinking water can lead to serious health effects on infants. In recent years, effects of chemicals on the human endocrine system have emerged as a concern.

Even if a state has adopted one or more water quality criteria for a given constituent relevant to a certain designated use, those criteria need to address appropriate exposure scenarios. For example, just a few minutes of exposure to insufficient levels of oxygen can prove fatal to many types of animal life; likewise momentary exposure to high levels of waterborne pathogens can lead to serious illness in humans. For such fast-acting water quality parameters, adequate protection for humans and aquatic life cannot be ensured without acute criteria—criteria that specify what parameter levels may cause harm over short-term exposure durations.[50] On the other hand, levels of carcinogens found in even the most polluted waters are only likely to cause

[48] Appendix C provides a list of constituents with high rates of bioaccumulation.

[49] Because there are federal drinking water quality standards that apply to finished (treated) drinking water delivered by all but the smallest of public drinking water systems, the lack of WQC applicable to surface waters that serve as a source of raw (untreated) water supply for such systems does not mean that consumers of the finished water provided by such systems are not being protected from harmful levels of contaminants. Rather, the most likely effect of lack of drinking water supply water quality criteria on customers of a public drinking water system is increased price of the finished water delivered by such systems. Price increases could result from the increased costs incurred by a drinking water utility in order to bring levels of contaminants in its raw water supply down to the levels specified by US EPA-issued primary drinking water standards for finished drinking water.

[50] For instance, EPA's WQC addressing acute exposure of aquatic organisms to toxic chemicals have a criterion-duration of one hour. With very high levels of certain parameters, the appropriate duration could be just an instant. In other cases, acute criteria have durations ranging up to two or three days.

cancer after fairly long periods of exposure—e.g., for a year or more. For most pollutants other than carcinogens, a combination of acute and chronic criteria is needed to ensure full protection of designated uses.

The mode of action of a pollutant and likely exposure scenarios are also relevant considerations with regard to the need for WQC applicable to intermittent and ephemeral waters. For instance, humans who might be swimming in such waters are highly unlikely to be exposed to carcinogenic pollutants for sufficient time to run an increased risk of having cancer at some time in the future. On the other hand, they could be exposed to waterborne pathogens for enough time to contract a disease. As for aquatic life that inhabit such waters (e.g., breeding amphibians), there could be a real risk of being exposed to harmful conditions (unnaturally low dissolved oxygen, unnaturally high temperatures, and problematic concentrations of toxic pollutants) for lengths of time adequate to result in illness or death. For example, US EPA has published WQC for nearly 3 dozen toxic chemicals, aimed at protecting aquatic life from adverse effects of acute (one hour's duration) exposure to such pollutants.

2. Occurrence of the pollutant in surface waters.

Unfortunately, far less is known about levels of pollutants in our nation' rivers, lakes, estuaries and other type of waterbodies than many members of the public assume. This results from the fact that federal agencies, states, and private sector entities have only a fraction of the resources needed to obtain a thorough picture of the condition of waterbodies across the country.

Of course, some pollutants are more widely used and discharged than others. Indeed, some of the pollutants for which EPA issued WQC back in the 1980s may no longer be in widespread use. In some cases their use may have even been banned (though not necessarily their manufacture nor incidental creation in industrial processes) may have been banned. For such pollutants it may not matter whether a state establishes criteria. On the other hand, many new potentially harmful chemicals have come into use in recent decades, for which US EPA has been able to issue WQC for only a small fraction.

Also, knowing that a given toxic substance is found in only a tiny portion of waters nationwide may not allay public concerns about the condition of individual waterbodies. Those using one of the handful of waters in the country that are contaminated by certain toxicant are unlikely to worry less about themselves and their loved ones as the result of knowing said pollutant occurs in very few other waters that have been monitored, across the nation. And, those who use one of the many waters that never have been monitored for that toxic substance still have reason to fear that their particular waterbody could be one of the small percentage in which the substance is present.

a. Discharge-related Data

One source of information about how commonly certain pollutants are discharged nationwide is the industry-specific "technology-based" regulatory packages EPA developed and refers to as effluent guidelines. Limitations on point source[51] discharges of a particular pollutant under this CWA-authorized program are a good indication that the contaminant is relatively common. (A list of pollutants covered by the Organic Chemicals, Plastics, and Synthetic Fibers effluent guidelines is provided in Appendix D.)[52]

There are, however, several limitations on the utility of EPA effluent guideline regulations as indicators of what might be found in waters in any particular area or the country in general. First, although some were published recently, most of these regulations were issued quite a few years ago—for example, the organic chemicals package came out 20 years ago. Obviously, over time some chemicals that were once commonly discharged may have been phased out, while entirely new chemicals may have emerged. Furthermore, these regulations often do not identify all the individual pollutants that may be present in the discharges of a certain kind of industry; instead, they may rely on discharge limits for some indicator parameter, such as total suspended solids (TSS), whose removal is thought to incidentally result in substantial removal of various categories of pollutants. Finally, these regulations only deal with discharges from industrial point sources (wastewater carried through pipes and other conveyances), hence there could be pollutants that are released into surface waters by: 1) municipal sewage treatment plants, 2) "wet weather" point sources (e.g., municipal separate storm sewer systems [MS4s]. and 3) nonpoint sources (e.g., runoff from row crop agriculture or air emissions) that are ultimately deposited in lakes, rivers, and other waters) that would not be covered.

Another EPA data source that may provide some indication of the likelihood that a particular pollutant or category of pollutants is present in at least some state waters is the Toxics Release Inventory (TRI). In 1986, Congress passed legislation requiring EPA and the states to collect data on releases and transfers of toxic chemicals from larger industrial facilities. As of 2006, nearly 23,000 facilities contributed information to the TRI.[53] EPA publishes a Public Data Release Report annually, summarizing data from the previous year. Tables showing releases of toxic chemicals are available, according to industrial categories, and by state, divided among different routes of disposal and release. One such route is "surface water discharges," and the following table (Table 26) lists, in rank order, the 25 pollutants for which the highest amounts of discharges to surface waters were reported by industrial facilities required to report under the TRI.

TABLE 26

The Twenty-Five (25) Pollutants With the Largest Reported Discharges to Surface Waters According to the Toxics Release Inventory (listed in order, beginning with highest number of pounds discharged)	
1. Nitrate compounds	14. Nickel compounds
2. Manganese compounds	15. Chlorine

[51] Under the CWA, point sources are those facilities that discharge through a pipe, ditch, or other kind of man-made conveyance, which includes trucks, trains, and some kinds of vessels. Concentrated animal feeding operations (CAFOs) are also point sources.

[52] For more information about this regulation, as well as effluent guidelines covering other industrial categories, see U.S. EPA, Effluent Limitation Guidelines, http://www.epa.gov/waterscience/guide (last visited Oct. 2, 2008).

[53] US EPA makes summary information from TRI available through its website, http://www.epa.gov/tri. Also available on the US EPA website is access to TRI Explorer, which can be used to conduct customized searches of the database.

3. Ammonia	16. Cobalt compounds
4. Methanol compounds	17. Dichloram
5. Sodium nitrate	18. Manganese
6. Barium compounds	19. Certain glycol ethers
7. Zinc compounds	20. Lead compounds
8. Ethylene glycol	21. Phenol
9. Vandanium compounds	22. Arsenic compounds
10. Copper compounds	23. Chromium compounds
11. Acetaldehyde	24. Cresol (mixed isomers)
12. Formaldehyde	25. 1,4 Dioxane
13. Formic Acid	

Included in the list are several metals, or compounds thereof, including barium, chromium, cobalt, copper, lead magnesium, manganese, nickel, vandanium, and zinc. The pollutants arsenic (compounds), chlorine, formaldehyde, and methanol are also reported. Ammonia ranks third in terms of total quantity reported as discharge to surface waters, while nitrate compounds have the distinction of topping the list.

The TRI has limitations. For instance, it only contains information about industrial operations, and only those that generate more than a certain amount of toxic waste per year. It lacks data about releases from municipal and commercial facilities, as well as agricultural operations and residential areas. Also, even for those facilities that do report to TRI, releases categorized as discharges to surface waters or to municipal sewage treatment plants do not necessarily provide a good indication of how much of a given pollutant ends up in rivers, lakes, estuaries, bays, and marine waters. For example, much of the mercury in waterbodies across the nation does not come from direct point source discharges; rather, for many waters the majority of mercury is deposited from the atmosphere, a large portion of which originated as air emissions from electrical power generating facilities that burn coal.

Another potential indicator of what toxic pollutants are possibly being discharged, in amounts that could impair one or more designated uses, is the list of 56 compounds for which the NPDES program in Illinois has established water quality-based effluent limits (WQBELs) for point source discharge permits (Appendix F). Presumably the state not only found each of these pollutants in the effluent of at least one point source, but also determined that the levels in the wastewater were high enough to potentially cause or contribute to the exceedence of the state's relevant WQC[54] in the receiving waterbody. Among the pollutants on this state list is formaldehyde, which is one of nine organic compounds among the 25 chemicals with the highest total discharges to surface waters nationwide, as reported in the Toxics Release Inventory (see Table 26). There are also several polycyclic aromatic hydrocarbons (PAHs), such as benzo-a-pyrene, as well as nearly two dozen carcinogens, including PAHs, chloroform, hexachlorobenzene, methylene chloride, pentachlorophenol and vinyl chloride. Though examination of lists of chemicals for which the other nine states covered in this report would

[54] Actually, Illinois does not have formally adopted WQC for any of these 56 compounds. Rather, they have published a list of "derived" WQC, some for aquatic life uses and some for human health, for these pollutants. According to the state document in which these WQC are listed, these "derived criteria" can be used by the state in setting water quality-based effluent limits (WQBELs) under the NPDES program. The 56 toxic compounds for which WQBELs have been established are a subset of a larger number of pollutants for which the state has issued "derived WQC."

likely provide useful information, the authors of this report are not aware of other states having compiled lists of toxic substances for which water quality-based NPDES effluent limits have been set.

Of course, the fact that a particular pollutant has been found at levels of concern in one or more industrial discharges in a given state does not mean it is present in all industrial effluents within that state, or that it is being discharged by all, or even a majority of dischargers in that state. Likewise, just because a chemical is present in some discharges in a particular state does not necessarily mean that it would be found in one or more industrial effluents in another state. Still, there is a reasonable possibility that industrial facilities similar to those in Illinois may be found in other states, and that these comparable operations discharge one or more of the same pollutants.

b. Waterbody-related Information

i) Section 303(d) Impaired Waters Lists

The state-developed and EPA-approved lists of polluted waters required by Section 303(d) of the CWA provide another potential indicator of pollutants likely to be found in numerous waterbodies. When states or EPA place a water body on this list because of exceedences of pollutant-specific WQC they specify the pollutant(s) triggering the listing. States will also sometimes name individual (or categories of) pollutants as likely causes of impairment even in the absence of ambient data for them. A common example of the latter is the naming of "nutrients," phosphorous, and/or nitrogen as a reason for impairment of aquatic life and/or recreational uses based solely on documentation of nuisance algal blooms.

A national compendium of pollutants named as causes for 303(d) listing can be found on EPA's TMDL/303(d) website.[55] The most frequently named causes are: 1) pathogens (usually coliform indicator bacteria), 2) mercury, 3) sediment (either suspended in the water column or settled on the waterbed), 4) metals other than mercury, and 5) nutrients (nitrogen and phosphorous). (See Appendix E for a rank-order list of stressors cited as a cause of impairment.)

The frequency at which nutrients are named as a cause for 303(d) listing of waters is somewhat surprising, given how few states across the country have adopted numeric WQC for these pollutants. The likely explanation is the ease of detection: algal blooms resulting from excessive nutrient loading can be observed with the naked eye, whereas effects of other types of pollution are often harder to discern. A similar situation exists per "sediment"—trained professionals, and often even well-informed lay persons, can easily and quickly spot evidence of excess levels of sediment in a given type of waterbody. Hence sediment is often listed as a cause of impairment even in situations where there are no applicable numeric WQC.

There are numerous examples of 303(d) listings based on exceedence of narrative WQC, as opposed to numeric criteria, among the ten Mississippi River states covered by this report. For example, although it has no numeric WQC for either phosphorous or nitrogen, and its

[55] *See* U.S. EPA, National Summary of Impaired Waters and TMDLs, http://www.epa.gov/owow/tmdl (See "National Summary of Impaired Waters and TMDLs.")

chlorophyll a WQC applies only to one reservoir, Tennessee has 118 waters on its 303(d) list for which “nutrients” is given as the cause of impairment. Likewise, Louisiana has 95 waters on its 303(d) list with “nutrients” listed as the cause of impairment, and Wisconsin, Kentucky, and Mississippi have over 100, despite none of the three states having numeric WQC for this parameter. Illinois alone has 673 waters so listed—and though some of the listings are due to exceedence of the state’s numeric phosphorous WQC, many are not. In Illinois the WQC applies only to lakes with a surface area greater than 20 acres, and only 288 of all the waters on the state’s 303(d) list are lakes, reservoirs or ponds, thus nearly 400 of the waters are apparently rivers or streams whose listing is based on non-numeric criteria.

A similar pattern occurs with regard to 303(d) listings for “sediments,” “sedimentation,” or “turbidity.” Tennessee, for example, has no numeric WQC for any of these parameters, yet it has listed 411 waters due to “sediments” and five due to “turbidity.” Illinois has cited “turbidity” as a cause of impairment for 306 of its 303(d) waters, with another 219 waters with “sediment” as their listing cause, yet it has no related numeric WQC. In the absence of a pertinent WQC Wisconsin has also listed 195 waters for “sediments.”

States are to be commended for having taken the initiative to list waters based solely on visually observed conditions presumed to be inconsistent with one or more of the state’s narrative WQC. Nevertheless, adoption of numeric WQC for phosphorous, nitrogen, chlorophyll a, as well as one or more parameters related to sediment would likely be beneficial in the long run. First, 303(d) listings of waters based on numeric WQC, as a general rule, are less likely to be questioned than those based on narrative WQC. Second, numeric WQC are more likely to reveal less extreme, and therefore less apparent, adverse impacts of these pollutants on surface waters.

In contrast to the often visible effects of nutrient or sediment overloading of waters, in most cases increases in the incidence of gastrointestinal illness among swimmers as a result of exposure to pollutants will not be detected without sophisticated epidemiological studies. Likewise, impacts on the health of persons who consume fish and other aquatic organisms with unsafe levels of mercury, PCBs, and other bioaccumulative pollutants are difficult to detect, in part because there can be a lag time of years between exposure and the onset of illness. Therefore, most waters included on 303(d) lists because of pathogens, metals, and/or synthetic organics are there not due to observance of actual effects, but because observed or projected levels of these pollutants, or indicators thereof, were higher than those specified by a numeric WQC.

Among the metals, mercury is by far the most commonly cited cause of impairment for waterbodies on the 303(d) lists published by the ten states. This is because the primary source of most surface water mercury contamination is deposition of atmospheric mercury originally discharged into the air by both manmade and natural sources. This widespread phenomenon affects surface waters on a much broader basis than discharges from point sources and land-based nonpoint sources. Other metals frequently mentioned as causes of impairment on 303(d) lists are copper, lead, selenium, zinc, iron, manganese, aluminum, cadmium, and arsenic.

Polychlorinated biphenyls (PCBs) are the most commonly reported category of synthetic organic compounds for 303(d)-listed waters, with over 2000 waters citing them. This is an example of a pollutant whose manufacture and use was banned years ago, yet many waters are still affected—in some cases by intentional discharges that ceased long ago (e.g., PCBs in the Hudson River), but also by ongoing accidental discharges from aging electrical transformers and other sources. (There is a highly industrialized stretch of the Delaware River where over 100 dischargers have PCB limits in their NPDES permits. This situation bears witness to the fact that PCBs are still being created as a byproduct of certain industrial processes.) Not as dominant but still prevalent are pesticides, which are mentioned in conjunction with over 1300 waters nationwide. Several hundred of these waters are affected by pesticides that are no longer registered for uses likely to cause surface water pollution, but that remain as "legacy pollutants" because they break down slowly—examples include dichloro-dephenyl-trichloroethane (DDT), aldrin, dieldrin, and chlordane. Some waters were listed because of known or suspected levels of pesticides that are still in widespread use, such as atrazine and diazinon.[56] Worth noting is the fact that no waters anywhere in the U.S. were placed on the 303(d) list due to high levels of glyphosate, the active ingredient in the widely-used herbicide Roundup. This could be due to the fact that US EPA has not issued CWA criteria for this compound, although it has developed a Primary Drinking Water Standard for Safe Drinking Water Act purposes. It could also be due to the compound having degraded before entering a waterbody, or shortly after it.

A weakness of 303(d) listings as an indicator of the frequency at which a given pollutant actually occurs in U.S. rivers, lakes, bays, estuaries, and marine waters is the fact that the vast majority of waters are not monitored regularly, and even those samples that are collected may not be analyzed for a particular substance. Therefore the fact that a certain pollutant has only been reported in a small number of waters nationwide does not necessarily mean it is not present in any given water or type of waterbody in an entire state, or that it has not reached levels that could cause harm to humans or aquatic life and wildlife. Consequently, simply because there are no state WQC exceedences on file for a pollutant does not necessarily indicate that no exceedences have occurred. If a state has not adopted a WQC for a given pollutant, the state might take the position that said pollutant cannot be the basis for 303(d) listing, for the simple reason that there is no WQC to be exceeded. Additionally, states are less likely to monitor ambient levels of pollutants for which they have no WQC, compared to those for which criteria have been adopted. Moreover, even if a state does check for a particular pollutant, it is likely to do so less frequently for pollutants that are more expensive to test, such as synthetic organic compounds, than "traditional" parameters such as dissolved oxygen, pH, and temperature. Finally, even if a state did test every sample it collected for a given chemical, there still would be a significant chance of missing incidents of actual contamination because limited resources mean they can only collect data on a fraction of all stream miles and lake acres, and only for a tiny percentage of the time.[57]

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[56] US EPA has not issued final WQC for atrazine, though it has issued draft aquatic life criteria. Final aquatic life criteria for diazinon were published in early 2006. Of the ten Mississippi River states, IA, MO, MN, and TN have already incorporated atrazine WQC into their WQS regulations, and IL has included the compound on a list of "derived" WQC that are used for guidance in implementing other CWA programs including NPDES permitting. None of the 10 states have official WQC for diazinon, although IL does have a "derived" value. IL, MO, IA and LA have listed a total of three dozen waters due to atrazine. None have given diazinon as the reason for listing any waters.

[57] In a recent compendium of state 305(b) and 303(d) biennial reports on the condition of their waters, US EPA found that states had assessed (not necessarily actually monitored) 19% of stream miles and 38% of lake acres. Only for bays and estuaries had a majority (87% of the total square mileage) been assessed. Also, even of the

ii) Studies of Pollutants in the Mississippi River

A final source of information on the presence of pollutants in the Mississippi River is reports conducted by governmental and nongovernmental entities on the river itself. For instance, in its 2007 report, *Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities*, the National Research Council of the National Academy of Science mentioned the results of several studies of pollutants in the Mississippi River. On page 43 the report summarizes:

> "[i]n addition to the water quality concerns of nutrients and sediments there are many other Mississippi river water quality problems. For example, toxic substances of concern in the Mississippi River include metals (primarily mercury, zinc, and lead), organometallic compounds (primarily methylmercury and tributyltin), and a long list of toxic organic chemicals. Important among the latter are the chlorinated aromatic compounds (including PCBs), chlorinated hydrocarbons (including DDT, its degradation products, and other pesticides), and polycyclic aromatic hydrocarbons."

The National Research Council cites papers included in U.S. Geological Service Circular 1133 (1995), edited by Robert H. Meade. A paper by D.A. Goolsby and W. E. Pierra titled *Pesticides in the Mississippi River* reports that "[t]he pesticides detected most frequently and in highest concentrations [included] . . . atrazine, alachlor, metolachlor and cyanazine . . . . Two herbicides, atrazine and metolachlor were detected in more than 95 percent of the samples." Another paper, *Polychlorinated Biphenyls and Other Synthetic Organic Contaminants Associated with Sediments and Fish in the Mississippi River*, by C.E. Rostad, et al., reported the presence of a number of pesticides and industrial chemicals, including heptachlor, heptachlor epoxide, hexachlorobenzene, lindane, methoxychlor, and pentachlorobenze, along with numerous types of PCBs.

3. Potential of WQC for One Designated Use to Provide Coverage for One or More Other Uses

In some cases, it could be reasonable to conclude that levels of a pollutant appropriate to one use would also be sufficient to support another use. For instance, often WQC for protection of aquatic life from effects of toxic chemicals will specify pollutant levels significantly lower than those needed to protect certain human uses, such as drinking water supply and fish consumption. This is logical because aquatic organisms are essentially continuously breathing the water in which they are immersed, whereas human exposure via drinking water, fish consumption and swimming is much less frequent. This is the case for eight of the pollutants for which EPA has issued both aquatic life and human health criteria.[58] For the aquatic life WQC, the criterion-

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fraction of waters that have been monitored at all, few have been checked frequently and at numerous locations. Very few of these assessed waters were monitored once a week or month. A frequency of once per quarter (every three months) is more common, particularly at "core monitoring stations," but it is not unusual for samples to be collected no more than once every year or two. Also, few of the samples collected during these efforts were analyzed for the full range, or even the majority, of pollutants for which there are US EPA and/or state WQC.

[58] Nickel, selenium, zinc, cyanide, endosulfan, (2 isomers), endrin, and lindane (gamma-BHC).

concentrations are lower and the criterion-durations are apparently shorter; the criterion-frequencies for both are very small. On the other hand, there are nine pollutants with human health criteria that specify lower levels of pollution than do the aquatic life criteria.[59] However, these human health WQC will not necessarily provide adequate protection to aquatic life. If the criterion-duration for the human health WQC is considerably longer than that for the aquatic life WQC having the shortest criterion-duration, attainment of the human health criterion would not necessarily protect aquatic life against short term spikes of high concentrations of the chemical. (Unfortunately, EPA documents regarding its human health WQC for toxics do not provide a clear, consistent message as to the criterion-duration; also, they make no mention of a criterion-frequency. Some text suggest a criterion-duration of an instant, but other US EPA-published text suggests a considerably longer period—as much as 70 years, which is the average human lifetime.) Also, a large majority of the toxic chemicals for which EPA has published human health criteria (fish consumption and/or drinking water supply) do not have EPA aquatic life criteria.

4. Possibility of Protection Being Provided By Standards or Measures Developed in Conjunction with Other Environmental/Public Health Programs

In certain circumstances it may be possible that standards or other threshold values developed pursuant to other environmental or public health programs could provide protection, though a WQC for a certain pollutant/use combination has not been adopted. Perhaps the best example is the relationship between the Primary Drinking Water Standards set by US EPA under the authority of the federal Safe Drinking Water Act and the drinking water supply criteria established by states pursuant to the Clean Water Act. The federal drinking water standards apply to the *finished* water supplied to homes, businesses, and other facilities by all but the smallest drinking water utilities in the country. ("Finished" drinking water is that which is delivered by a drinking water utility, through its distribution system, to its customers. With rare exceptions, if the utility drew its raw water supply from a surface water of some sort—lake, reservoir, river, etc.—then all its finished water will have undergone treatment to remove contaminants, and will be required to meet federal Primary Drinking Water Standards.)

By contrast, the water quality criteria that states set forth in their water quality standards for drinking water supply water apply to *raw* water -- the untreated water that a drinking water utility pulls out of a surface water, and eventually sends to its customers. Hence, even if a state has not established a drinking water supply criterion for a given pollutant, customers of drinking water utilities which draw their raw water from surface waters would still be protected, if there were a federal Safe Drinking Water Act standard for that contaminant. In addition, even if there were no state drinking water supply WQC nor an applicable finished drinking water standard for a given contaminant that happened to be present in a raw drinking water supply, it is possible

[59] Arsenic, mercury, chlordane, DDT, dieldrin, pentachlorophenol, heptachlor, heptachlor epoxide, and toxaphene. Most of these pollutants are highly bioaccumulative, which means the levels of pollutants in the water in which a fish swims would need to be very low, in order to keep the levels in animals at the upper end of the food chain at low enough levels so as not to pose a threat to human consumers of aquatic organisms.

that that the pollutant removal systems employed by most drinking water systems that rely on surface water bodies would incidentally lower the levels of the contaminant to safe levels.

It should be noted, however, that even if customers of a particular public water supply utility are adequately protected from adverse effects on their health resulting from contaminants in their drinking water by federal drinking water standards; the absence of state WQC applicable to the raw drinking water supply could impact people in other ways. If a drinking water utility has to invest in special drinking water treatment equipment in order to decrease levels of one or more contaminants in its raw drinking water to meet federal drinking water standards, the cost of that additional treatment will likely be passed on to the utility's customers.[60]

5. Need for Both Acute and Chronic WQC for a Given Pollutant/Use Pair

As a general rule, when a WQC for a given pollutant/parameter is needed with regard to a particular use, it would be best to have at least one acute criterion and one chronic criterion. The following text from the first paragraph of Appendix D to EPA's Technical *Support Document for Water Quality-based Toxics Control* explains the importance of having both acute and chronic WQC:

> "a simple format, such as specifying a concentration that must not be exceeded at any time or place, is not realistic. Furthermore, such a simple format does not take into account the fact that aquatic organisms can tolerate higher concentrations of pollutants for short periods of time than they can tolerate through a complete life cycle."

Although this EPA guidance appears in a document dealing with toxic chemicals and has posed the concept with regard to protecting aquatic organisms, these points also apply to "traditional" stressors and to all types of organisms, including humans.

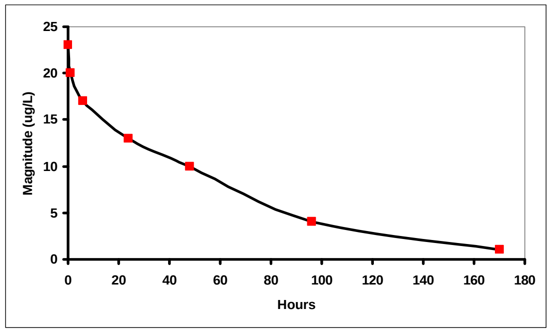
Ideally, criteria for a given use and pollutant/parameter would consist of a graph, with concentration plotted on the x-axis and duration of exposure on the y-axis. The line on the graph, representing a given biological response such as death of 5% of exposed individuals (LC_5), would slope from the upper left corner downward to the lower right corner, reflecting the well-known fact that short-term exposure to extremely stressful conditions can be equally harmful as long-term exposure to only moderately stressful conditions. As an example, Figure A (below) plots the LC_5 of an imaginary synthetic organic compound, with the magnitude of stress (in this case, concentration) plotted on the y-axis and the duration of exposure shown on the x-axis. At higher concentrations (above approximately 23 µg/L), 5% lethality would occur in a matter of minutes, or even less. At a medium concentration (e.g., 10 µg/L) it would take considerably longer exposure (around 50 hours) to cause 5% the test organisms to die. And at lower concentrations (e.g., 1 µg/L) it would take even longer (around 170 hours) to achieve the same outcome.

[60] For more detailed discussion of this effect, see *supra* Part III.B.1.d.

Figure A

Magnitude vs. Duration

LC 5 – Ethylmethyl Nastee



EPA acute WQC for aquatic life (aka CMC): 1 hr average

EPA chronic WQC for aquatic life (aka CCC): 96 hour average

Federal EPA and the states have not published WQC in this format simply because they lack sufficient data upon which to base such a graph. Instead, these agencies have typically compromised, publishing just one criterion for short term exposures and another for longer term.[61] For example, in the case of aquatic life WQC for toxic chemicals, US EPA has published acute WQC (1 hour exposure) and chronic WQC (96 hours).

One situation in which a given chronic aquatic life WQC might not be needed would be ephemeral streams, ponds and wetlands. For instance, whether or not a chronic WQC would be needed for a particular pollutant in order to protect aquatic organisms depends largely on two factors: 1) the maximum period during which living organisms are present, and 2) the criterion-duration for the chronic WQC. For example, if during a typical ten year period, the longest continuous period for which amphibians use an ephemeral pool for reproduction were 14 days, then application of a WQC with a criterion-duration of, say 30 days would likely not be essential to protecting those particular aquatic populations' long term survival. Rather, a chronic WQC with a duration of around 14 days would be needed along with at least one acute criterion.

Sometimes it is unnecessary to have both acute and chronic criteria. For example, there is usually just a chronic human health criterion and no acute criterion for carcinogens; because the levels of these chemicals found in surface waterbodies are so low that cancer can only result from years, or even decades, of exposure. On the other hand, one can imagine uses typically involving patterns of exposure for which having acute WQC would be more important than having chronic WQC—e.g., swimming at an ocean beach. Most people who live near the ocean spend at most a few hours per day actually in the water, and only during the summer recreation season; also, people who vacation at the beach typically only stay for a couple of weeks per year. In this, and similar situations, higher priority is assigned to setting acute water contact recreational criteria than chronic criteria, both because long-term exposure is far less common

[61] An exception is U.S. EPA's, and many states', aquatic life criteria for ammonia, which include values (concentrations) for three exposure durations: 1 hour, 4 days, and 30 days.

and because even momentary exposure to pathogens causing waterborne illness can result in infection and eventual illness.

6. Summary—Importance of Criteria for Specific Chemicals/Uses/Exposure Scenarios

It is generally difficult to prove that, for a given state or major interstate river basin, there is no need for one or more criteria for a given pollutant—at least with regard to those pollutants for which EPA has already developed recommended criteria for one or more waterbody uses. Any of these contaminants can be harmful to people and/or aquatic life under certain circumstances, and it is rarely possible to eliminate the chance that such circumstances might not arise somewhere within a large geographic region--if not now, then some time in the future. Even if, for some pollutant, levels were high enough to be of concern occur in only in a tiny percentage of waterbodies , or even if the conditions are detected as infrequently as once every few years, it still would be useful to have criteria in place in all waterbodies, just as a precaution. Otherwise, if a rare pollutant were found in a given waterbody, it would be hard to determine whether the measured levels of the pollutant pose a risk to those living things that might come in contact with it. Also, if the levels of the pollutant in the waterbody appeared to pose a significant risk, the ability of government authorities to move quickly to require that discharges of the contaminant to be reduced would likely be significantly impeded by absence of a formally adopted numeric WQC.

Of course, state water quality agencies, as well as EPA, rarely have the resources to carry out their duties without having to prioritize them. Just the public participation process that states undertake when establishing WQC takes time, of which government employees have limited amounts. Nevertheless, it would not seem to require much effort to incorporate into a state's WQS regulations—during the course of performing the CWA-required triennial review of the State's standards—criteria for all of those pollutant/use combinations for which EPA has already provided recommended WQC.

It is important to recognize the possibility that EPA's criteria are not a highly reliable indicator of the threat posed to particular waterbody uses by certain levels of specific pollutants, either for all waters in a state or even for a portion thereof. This is more likely the case with regard to aquatic life criteria, as compared to those for human health, because the natural conditions to which aquatic organisms have adapted over the course of their evolution can vary significantly from one type of waterbody to another, and even among the same types of waters in different eco-regions. Furthermore, the array of indigenous species of plants and animals varies from one waterbody to another, across the landscape.

By contrast, there is less of a need for site-specific water quality criteria for protection of human health. The key reason is that the species of concern (Homo sapiens) is the same, no matter where you are located. The most common reason for adjusting US EPA's recommended human health criteria is to account for unique regional or local patterns of consumption of aquatic organisms and/or drinking water, as well as water contact recreation. For example, some waterbodies have higher rates of subsistence fishing than the national average. Also, persons living in hot climates drink more water than the national average rate of consumption.

Developing site-specific criteria can be a time-consuming, and sometimes technically challenging, exercise. Recognizing these realities, EPA has been working to assist states in developing methodologies for assessing whether a waterbody can support an aquatic life use via use of biological surveys. Incorporation of key elements of these biosurvey methods into a state's WQS regulation provides an efficient way of screening waters with regard to aquatic life protection. However, if a biosurvey indicates that a waterbody is not fully supporting aquatic life uses, it is still necessary to identify the specific pollutants and/or other sources causing the imbalance. Numeric, parameter-specific WQC play a crucial role not only in identifying the causative factors leading to waters with impaired aquatic life, but also in establishing Total Maximum Daily Loads, water quality-based NPDES permits, and measurable targets for all types of waterbody restoration efforts.

Another limitation of biocriteria/biosurvey methods it that, though they are very useful in establishing whether or not aquatic life use is supported in a given waterbody, they have limited applicability to human health-related uses—fish consumption, drinking water supply, and water contact recreation. Given that humans do share many biochemical and cellular processes with all other forms of life, the fact that waterbody conditions are harmful to various types of aquatic life would be reason for concern that conditions might also pose a threat to human users of a waterbody. Nevertheless, this fact alone would not serve as a sound basis for concluding that the waterbody is in fact impaired for one or more human health-related uses. This is the case for a variety of reasons. First, stressors such as altered stream hydrology and channel modification that can have very serious adverse effects on aquatic life would not likely pose risk to human health. Similarly, microorganisms that are pathogenic to fish, shellfish, or other aquatic life would not necessarily be pathogenic to humans. (Conversely, human pathogens usually will not be infectious of aquatic species.) Of course, levels of a given pollutant that would be harmful to various kinds of aquatic life in a given waterbody might, or might not, be harmful to humans would use that waterbody, and visa versa.

Unfortunately, there currently are no methods applicable to human health that parallel biosurveys for aquatic life support. That is, there are no cost-effective techniques that, for human health, provide a direct measure of the integrated effects of numerous waterborne pollutants on humans over time. Hence, for the foreseeable future, the only means of assessing potential risk to humans from pollution of surface waters will remain pollutant-specific numeric water quality criteria, and associated waterbody monitoring.

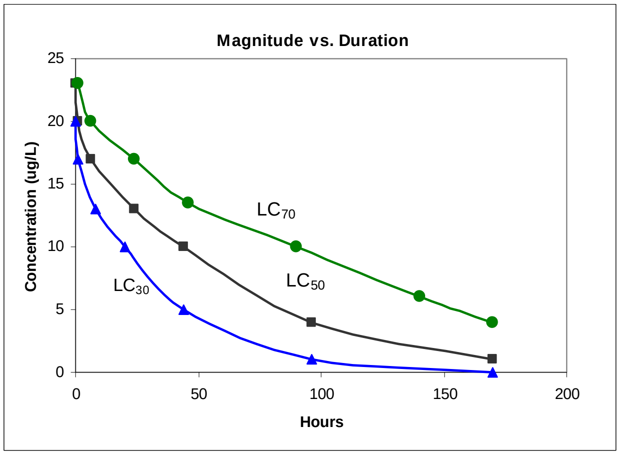
B. Unclear Duration and/or Frequency—Does It Matter?

Yes—very much!

First, as discussed in the next section of this report, in order to determine whether one WQC for a given pollutant and use affords the same, more, or less protection as another WQC for the same pollutant/use combination, one needs to know not only the criterion-concentration but also the criterion-duration and criterion-frequency for both WQC. This means that if any of the three components of either of the WQC is expressed in an ambiguous fashion, determination of the relative degree of protection provided by the two WQC becomes impossible. At best, all that can be done in such circumstances is to assume a specific value for each of the vaguely expressed criterion components, and then heavily qualify any tentative conclusions that might be drawn.

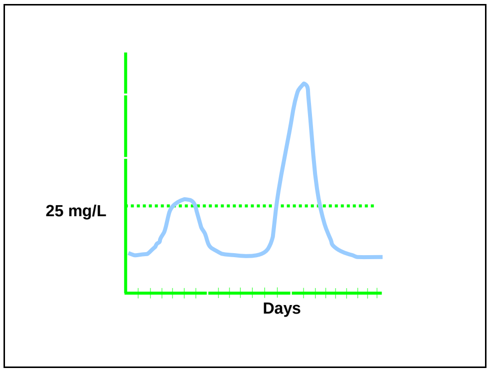
When determining what the effect of exposure would be on an organism, the importance of knowing more than just the pollutant concentration is illustrated by Figure B, below. For example, suppose someone inquired as to whether Figure B indicates that exposure to a concentration of 10µg/L would have lethal effects on more than half of the exposed organisms. Obviously, the question cannot be answered without knowing the length of time over which the organisms would be exposed to that concentration. For instance, plot LC_{50} indicates that exposure to 10µg/L for around 50 hours would kill half the exposed organisms, while plot LC_{30} indicates that a 25-hour exposure to 10µg/L would be lethal to just 30% of organisms (LC_{30}). Plot LC_{70} indicates that exposure to 10µg/L for about 100 hours would result in 70% lethality.

Figure B



Clearly-expressed criterion-duration and criterion-frequency are also crucial to implementation of clean water programs. Figure C illustrates this point. The y-axis represents concentration of a (unnamed) pollutant, while the x-axis measures time, marked off in days. The curved solid line represents data from a 21-day continuous monitoring event (a highly unusual circumstance, particularly with regard to toxic substances, but useful to imagine for discussion purposes), and the dotted straight line represents a criterion-concentration of 25 mg/L, but no criterion-duration or criterion-frequency is specified.

Figure C



Given this information, what can one say about whether a water quality criterion has been exceeded? The answer is, “Nothing-- with any degree of confidence.” If the criterion-frequency is zero and the criterion-duration is one hour or less, then there were clearly multiple instances of exceedences; likewise with a duration of three to five days, and frequency of zero. However, if the relevant WQC had a duration of six to nine days, this data would not appear to indicate any exceedences. Consequently, changing the criterion-duration and/or the criterion-frequency can change whether, based upon a given set of ambient monitoring data, a water body belongs on the 303(d) list of waters – those failing to meet one or more WQC, just as could changing the criterion-concentration.

The same conundrum would present itself to those trying to develop a TMDL or write water quality-based NPDES permit limits (WQBELs) consistent with meeting WQS. Here, the curved line in the graph would represent not the results of continuous monitoring, but the output of a computer model of instream pollutant concentrations under a certain waterbody-wide loading situation total maximum daily load (TMDL) or single source discharge scenario (WQBEL). Without being told the criterion-duration or the criterion-frequency, it would be impossible to say whether or not a given scenario generated by the model was consistent with WQC attainment.

The difficulties posed in the hypothetical continuous monitoring scenario illustrated by the graph above would also be encountered when attempting to determine WQS attainment status for a waterbody based on non-continuous monitoring data, a far more common situation. For instance, assume that over some 30-day period, four instantaneous “grab” samples had been collected, analyzed for levels of a certain pollutant, and found to meet applicable quality assurance/quality control specifications. Also assume that one of those four samples had a concentration higher than a relevant criterion-concentration. The answer to the question “Has the WQC applicable to this pollutant been exceeded?” would differ depending on the criterion-duration and criterion-frequency. If the duration were “instantaneous” and the frequency “zero,” the WQC would have unquestionably been exceeded. But if the duration was 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 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 the samples were collected. (Assuming the criterion-frequency is zero.) In addition, if the criterion-frequency were “two or more times per year,” then based on the above evidence one might not conclude that there was any exceedence of the WQC in question. (Actually, depending on how much data had been collected, there could be a very good chance that more than one excursion had occurred, even if only one had been observed. This is because it would be contrary to the laws of probability to conclude that no additional excursions (30-day periods with average bacterial concentrations above the criterion-concentration) had occurred during any 12-month period encompassing the 30 days in which the four grab samples had been collected, if these four individual samples were the only ones gathered during a given 12-month period. The reason for this conclusion is that, given that there are 336 thirty (30)-day periods in any 12-month period, the odds of having randomly chosen to collect samples during the only 30-day period in which an excursion happened to occur are very low--several times lower than randomly selecting a card from a well-shuffled deck of 52, and having that card turn out to be one named in advance.)

Another possible way in which different assumptions about the criterion-duration for a WQC can result in different outcomes is manifested by the difficulty of achieving the pollutant loadings specified in a TMDL or a NPDES permit. For example, it would seem that meeting a TMDL wasteload allocation or a 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.

Last, but not least, the need for clear statements of duration and frequency, along with specified concentrations, makes biological sense. Common experience informs us that the extent of harm resulting from exposure to some stressor depends not only on the intensity of the stressor (e.g., acidity of a liquid) but also the amount of time of exposure to said intensity (e.g., duration of immersion of a fish in water with a certain pH). The conceptual experiment presented in the following text box is intended to illustrate the importance of knowledge not only of stressor intensity (heat of a flame, in this case) but also the time of exposure to the stressor.

"**Hands-On" Demonstration of Importance of Duration and Frequency**

A real-world illustration of the importance of specifying both a duration and a frequency in a description of acceptable exposure scenarios is provided by a simple experiment involving a candle and the palm of one's hand.

Phase 1: A) Light a candle. B) Hold your hand palm down about two feet above the flame. Lower your hand to a point at which you can feel the heat emanating from the flame, but it is not painful to hold your hand indefinitely at that spot. C) Then lower your hand to a point at which you can leave it for no more than 5 seconds before it starts to really hurt. D) Remember approximately how many inches above the flame this second position was.

Congratulations, you have now identified a threshold for a given biological response—serious pain, which can be expressed as: 1) a location ("x" inches above the heat source), and 2) a span of time (5 seconds). With a thermometer, you can convert the location function into a temperature, by putting the thermometer at the point in space where you could hold you had for 5 seconds, maximum. That temperature constitutes the magnitude of the "stressor" of concern—heat. The duration is five seconds.

Phase 2: A) Ask someone who did not see you do the experiment on yourself and does not really know the nature of the experiment if they would be willing test your estimate of a particular threshold exposure pattern associated with unacceptable pain. B) Show them the lit candle. Now they know the nature of the stressor to which they will be exposed. C) Tell the person how high above the flame you held your hand when it started to hurt—3 inches, for example. D) Tell him/her that you were able to hold your hand at that location "for a short while." (Do not say "5 seconds," or give any hint of what "short time" means to you.) E) Ask him/her if s/he would be willing to do what you just told them you had done. F) Record their response.

The "smart" answer is "No." Why? Because *you* did not clearly define the conditions to which their hand would be exposed. You gave them a good idea of the intensity (magnitude) of the stress, but your description of the duration of exposure to that magnitude was quite vague. Not knowing that by "for a short while" you meant five seconds, they might have thought it meant one or two seconds, or perhaps, 50 seconds or even perhaps five minutes. Also, you offered no information about the frequency of exposure events. Hence, even if you told the person the distance from the flame and the period of time (2 seconds), how are they to know you were not, for instance, asking them to hold their hand 3 inches above the tip of the flame for 2 seconds, take it away for 10 seconds, move it back over for another 2 seconds, and so on indefinitely? That exposure pattern could eventually prove painful. On the other hand, the scenario you envisioned could have been 5 seconds over the flame and two *minutes* off, which could probably be repeated dozens of times without significant pain.

Alternatively, keeping one's hand 3 inches above the flame for 15 seconds (rather than just 5 seconds) would cause a considerable increase in the level of pain (same magnitude, longer duration, than the original experiment.) Likewise, a significant increase in pain would result from holding your hand two inches (rather than 3 inches) above the flame for 5 seconds (increased magnitude, same duration).

C. Comparative Level of Protection

Contrary to common belief, the relative degree of protection[62] a particular state WQC provides to designated uses, compared to the corresponding (same pollutant/use pair) criterion from another entity (US EPA or state), cannot be determined simply by comparing their respective criterion-concentrations. In order to compare the relative level of protection provided by two WQC, the criterion-duration and criterion-frequency for the two criteria must also be examined. Easiest to understand are situations in which the two WQC under consideration have an identical criterion-duration and the same criterion-frequency. Here, that WQC with the lower criterion-concentration will indeed provide a greater level of protection to the relevant designated use(s).[63] Other patterns regarding concentration, duration, and frequency of two WQC under consideration also make it fairly easy to determine which would be the most protective. For instance, if two WQC for the same pollutant/use pair had identical criterion-concentrations and criterion-durations, the criterion with the lower criterion-frequency (specifying a lower rate of occurrence of "excursions"[64] as consistent with support of the designated use) would provide a higher level of protection. That is, if a state aquatic life criterion for a toxic pollutant specifies a criterion-frequency of once in five years and a concentration and duration equal to the corresponding US EPA criterion, then the state WQC would provide more protection than an US EPA WQC specifying a criterion-frequency of once in three years.

Likewise, a state WQC with identical criterion-concentrations and criterion-frequencies to a comparable US EPA criterion, but with a shorter criterion-duration, would provide a higher level of protection for the designated use to which it applies. For example, a WQC with a criterion-duration of an instant would afford greater protection than one with a criterion-duration of an hour—if both WQC have the same criterion-concentration and criterion- frequency. And, of course, a WQC with a lower criterion-concentration, shorter criterion-duration, and lower criterion-frequency would be more protective of applicable designated uses. This, and all other possible combinations of relative (higher/lower, shorter-longer) criterion-concentration, criterion-duration and criterion-frequency in which the WQC of one entity (A) would provide a greater degree of protection that a comparable criterion from a second entity (B) are listed in the following table.

[62] In this report, "level of protection" is not intended to be synonymous with "stringency." Here "protection" is an indicator of risk to aquatic life or humans, while "stringency" means more difficult to achieve, in terms of technical achievability and economic feasibility. Of course, often "more protective" standards are "more stringent," but this is not always the case. Sometimes, for instance, a criterion that is more protective than another might not be more difficult to achieve, because the steps needed to achieve a certain level of a pollutant might be exactly the same as would be needed to achieve a considerably lower pollutant level. That is, currently available pollutant removal methods might "overshoot" the higher pollutant level. Also, in some circumstances, it might be more difficult and/or expensive, to, say, keep the 1 hour average concentration from ever going above 50 $\mu g/L$ at any time than it would be to keep, say, the 7 day average below 15.

[63] In the case of the water quality parameter dissolved oxygen, greater protection would be associated with higher concentrations. With pH, either too low or too high a reading can present problems.

[64] As used in this report, and in some US 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

TABLE 27
SITUATIONS IN WHICH “ENITY A” WQC CLEARLY MORE PROTECTIVE THAN EQUIVALENT “ENTITY B” WQC

	Concentration	**Duration**	**Frequency**
Entity A WQC vs. Entity B WQC	**lower**	**shorter**	**lower**
“	equal	**shorter**	**lower**
“	**lower**	equal	**lower**
“	**lower**	**shorter**	equal
“	**lower**	equal	equal
“	equal	equal	**lower**
“	equal	**shorter**	equal

On the other hand, a WQC with a higher criterion-concentration, longer criterion-duration, and a higher criterion-frequency than those of another WQC would definitely provide less protection than the WQC to which it is being compared. Similarly, of two criteria with identical criterion-concentrations, the WQC with a longer duration and higher frequency would provide less protection to the use to which it applies. These two, and all other possible combinations of criterion-concentration, criterion-duration, and criterion-frequency that result in “Entity A” having a *less* protective WQC then “Entity B” are listed in Table 28, immediately below.

TABLE 28
SITUATIONS IN WHICH “ENTITY A” WQC CLEARLY LESS PROTECTIVE THAN EQUIVALENT “ENTITY B” WQC

	Concentration	**Duration**	**Frequency**
Entity A WQC vs. Entity B WQC	**higher**	**longer**	**higher**
“	equal	**longer**	**higher**
“	**higher**	equal	**higher**
“	**higher**	**longer**	equal
“	**higher**	equal	equal
“	equal	equal	**higher**
“	equal	**longer**	equal

Finally, the following table (number 29) illustrates situations in which the pattern of differences in the concentration, duration, and frequency of one criterion versus another makes it impossible to surmise the relative degree of protection two WQC provide by simply looking at these three criterion elements.

TABLE 29
SITUATIONS IN WHICH COMPARATIVE LEVEL OF PROTECTION CANNOT BE DETERMINED BY SIMPLY LOOKING AT THE TWO CRITERIA

	Concentration	**Duration**	**Frequency**
Entity A WQC vs. Entity B WQC	**lower**	**shorter**	**higher**
"	equal	**shorter**	**higher**
"	**lower**	equal	**higher**
"	**lower**	**longer**	equal
"	**higher**	equal	**lower**
"	**higher**	**shorter**	equal
"	equal	**longer**	**lower**

In these cases, differences in one WQC component are offset by differences in another component. For example, for two chronic aquatic life WQC applicable to a given toxic chemical, suppose that the US EPA WQC had a criterion-concentration of 40 µg/L and the state WQC a concentration of 30 µg/L, while the US EPA WQC had a criterion-duration of four days and the state WQC a duration of seven days, and both had a criterion-frequency of once in three years. That is:

	Concentration	Duration	Frequency
EPA	40 µg/L	4 days	1 in 3 years
State	30 µg/L	7 days	1 in 3 years

Typically, there would not be enough information on the patterns of toxicity of a pollutant under different combinations of concentration and duration to determine whether tendency toward greater protection provided by the lower criterion-concentration of the state WQC would be offset by tendency toward less protection of its longer criterion-duration. In such instances, a series of toxicity tests on different aquatic species involving a concentration of 30 µg/L and a duration of seven days would be needed to ascertain whether the state WQC provides a greater, equal, or lower degree of protection to aquatic ecosystems than the WQC issued by US EPA.

Likewise, if a WQC has two out of the three components (concentration, duration, and frequency) "going in the same direction" (i.e., toward more protective or toward less protective) as the same components in a second WQC, and the third component is going in the opposite direction, it is not safe to assume that the first WQC is more or less protective than the second based on the direction of the third component. For example, as in the previous paragraph, assume there is a US EPA WQC with a concentration of 30 µg/L, duration of four days, and frequency of once in three years, but this time the state WQC has a concentration of 30 µg/L, duration of seven days, and a frequency of once in five (5) years. That is:

	Concentration	Duration	Frequency
EPA	40 µg/L	4 days	1 in 3 years
State	30 µg/L	7 days	1 in 5 years

Here, both the state's criterion-concentration and criterion-frequency differ from the comparable values in US EPA's WQC in a way that makes the state's WQC more protective, but the state's criterion-duration differs in a way that makes it less protective. Without doing a set of studies spanning several years,[65] it would be impossible to determine which WQC provides a greater level of protection to aquatic life.

Challenging as it sometimes can be to ascertain the relative degree of protection provided by two WQC, getting a reasonably reliable estimate of the absolute level of protection supplied by a given WQC can be even more demanding, in terms of the amount of information needed. It is well known, for example, that the levels of a given parameter consistent with full support of indigenous aquatic life can vary significantly from one aquatic ecosystem to another. This is due to several factors, including site-specific natural variation in: 1) waterbody chemistry affecting bioavailability of some pollutants, and 2) the particular set of resident aquatic species found in a given waterbody or category of waters. Consequently, although a state aquatic life WQC with a higher criterion-concentration than a corresponding US EPA WQC would provide less relative protection than the US EPA criterion (assuming that the two criteria had identical criterion-durations and criterion-frequencies), it is possible that, in a given waterbody, depending on the water's chemical and biological composition, the state WQC may be sufficient to provide the same exact level of protection for which the US EPA criterion was designed. If this were the case, then attainment of the US EPA criterion in that waterbody would actually provide more protection than US EPA had intended.[66] Performance of waterbody-specific toxicity studies would be required to establish what actual degree of protection the state WQC would provide to the community of aquatic organisms living there.

Likewise, only examination of waterbody-specific factors could provide a reliable estimate of the actual (as opposed to relative) level of protection that two WQC for a given toxic pollutant/use combination provide to humans engaged in health-related uses (fish consumption, recreation, and drinking water supply). The key factors that can affect the actual level of protection that a WQC provides are related to site-specific patterns of human use.

For instance, in the case of "fish consumption" use(s), it is quite possible that in a given locality or region the actual rate of human consumption of aquatic organisms varies from that assumed in the methodology US EPA used to develop its recommended CWA Section 304(a) criteria for toxic chemicals. Hence, if a significant portion of the persons using a given waterbody (or set of waterbodies) engages in subsistence fishing, i.e., obtaining a substantial portion of their normal diet by catching and consuming fish, shellfish, and/or other aquatic organisms—then their rate of consumption will be higher than the national average rate of 17.5 grams/day that US EPA used to calculate its HHO and HHWO criteria. In fact, studies of patterns of subsistence fishing reveal that consumption rates of ten times the 17.5 grams/day EPA rate are not unusual within

[65] Experiments lasting years would be needed because both WQC have criterion-frequency expressed as an event occurring no more than once in a certain number of years.

[66] US EPA's aquatic life WQC for toxics are designed to keep the rate of mortality for the 95th percentile species (going from least sensitive to most sensitive) representative of indigenous aquatic life from being higher than 50%. That is, if there were 100 species present in a waterbody, there would be only five species that were more sensitive to the toxic pollutant of concern. Hence only the "top 5%" of species would be expected to experience lethality rates above 50%, while the remaining 94% of the species would likely have lethality rates of less than 50%.

some populations of people. If higher rates of fish consumption are occurring in a given waterbody, then adoption of the HHO and/or HHWO criteria issued by US EPA as the "fish consumption" or "water and fish consumption" WQC for that waterbody will result in a lower level of protection for subsistence fisherpersons than the criteria were intended to provide. So if, for a given carcinogenic and bioaccumulative[67] toxic substance in a particular waterbody, a state adopts the EPA HHO criterion (which was designed to keep cancer rates at or below 10^{-6}, or one incremental case of cancer per 1,000,000 people) if there were a population of persons engaged in subsistence fishing on that waterbody, they would likely[68] run an incremental cancer risk of more than one in a million.

To counteract the effect of higher waterbody-specific rates of fish consumption than the rate assumed in EPA's human health WQC for toxics, the state criterion-concentration for bioaccumulative pollutants in waterbodies used for subsistence fishing need to be set lower than EPA's (provided the state's criterion-duration and criterion-frequency for this type of WQC are identical to EPA's, whatever they might be). And, of course, this would only be the case if the state's goal in developing its human health criteria for toxics is to provide the same level of risk to humans as that aimed for by EPA. This is likely the scenario for Louisiana, where rates of subsistence fishing are considerably higher than the national average. Most of Louisiana's human health criteria related to consumption of locally harvested fish, shellfish, and other aquatic life have lower criterion-concentrations than the corresponding EPA criteria. Although some of the ten states acknowledge, in their WQS regulations, the potential need for watershed-specific, or site-specific adjustments to WQC related to human consumption of aquatic organisms to account for subsistence fishing, there is no evidence in their WQS regulations that such alterations have been made for any individual waters or subcategories of waters within the state.

Minnesota and Wisconsin do adjust the criterion-concentration of their fish consumption-related WQC for persistent bioaccumulative toxic pollutants from waterbody type to waterbody type, but not to reflect differences in rates of human consumption of aquatic organisms. In Wisconsin, for example, which of three sub-sets of such criteria applies to a given type of waterbody depends on what types of fish would naturally inhabit said waterbodies, such as "cold water sport fish communities," "warm water communities," or "limited aquatic life." [69] The fact that criterion-concentrations for Wisconsin's fish consumption—related WQC for cold water communities tend to be lower than those for warm water communities has to do with the tendency for a higher degree of bioaccumulation up food chains in which cold water fish are top predators, as compared to that in fish inhabiting warm waters. This, in turn, is due to the state's use of different average percent lipid values for cold water fish (0.044) verses warm water fish (0.013). Minnesota also takes percent lipid in the tissues of game fish found in different sets of waterbodies into account in its WQC related to human intake of fish and aquatic organisms.

[67] For toxic substances, including but not limited to carcinogens, the risk of human ingestion via the fish consumption route is only significant for those pollutants that bioaccumulate/biomagnify to a substantial degree.
[68] This statement is qualified by "likely" because it is at least theoretically possible that other risk factors, such as lower rates of water consumption than the 2.0 liters/day national average used by U.S. EPA in calculating its national HHWO criteria, could offset the effects of higher-than-average rates of fish consumption.
[69] The state's "warm water communities" criteria applicable to consumption of fish by humans further address three subcategories: a) Warm Water Sport Fish, b) Warm Water Forage, and c) Limited Forage. The criterion-concentration for a given toxic pollutant is always the same for these three sub-subcategories.

Percent lipid levels are relevant because persistent bioaccumulative pollutants tend to accumulate to higher levels in tissues with higher lipid content.

Another factor that can affect the degree of protection provided by human health WQC applicable to certain sub-populations, in specific settings, is the rate of water consumption. In calculating its WQC for combined consumption of drinking water and aquatic organisms (HHWO), US EPA uses a default water consumption rate of 2.0 liters/day. (US EPA employs the same assumption in developing primary drinking water standards under the Safe Drinking Water Act, and some states have directly or indirectly adopted it when establishing drinking water supply WQC.) The 2.0 liters/day rate represents a national average for all adults across the United States.[70] However, some groups of people are likely to consume more than the national average, for example, those who work outdoors and/or engage in heavy labor, who exercise regularly, and who live in hot/dry climates are likely to consume more than the local, state, or national average quantity. (Of course, there are also subpopulations that consume less per day than the nationwide average, e.g., more sedentary persons and/or those living in colder-than-average climates.)

Given these differences in water consumption rates, it is likely that, in some cases, state drinking water supply WQC that explicitly or implicitly employ EPA's 2.0 L/day water consumption rate will provide a greater, or lesser, degree of protection than that targeted by the comparable EPA criteria. For example, when rates of water consumption are lower than 2.0 liters/day, the state WQC based on 2.0 liters/day would provide a higher level of protection (lower rate of illness per unit population) than that intended by the EPA's Section 304(a) Human Health: Water and Organisms (HHWO) criteria, as well perhaps as the primary drinking water standards established be US EPA, in accordance with the Safe Drinking Water Act. In these instances, drinking water supply WQC would need to have higher criterion-concentrations to offset the effect of lower consumption rates, if the objective was to equalize the level of protection provided by the state WQC and the US EPA HHWO WQC. For example, if a US EPA HHWO criterion for a given substance had a criterion-concentration of 30 μg/L, then the state "consumption of drinking water and aquatic organisms" WQC could have a criterion-concentration somewhat higher than 30 μg/L, and still provide the same level of protection as the US EPA WQC—assuming that the state and US EPA WQC have the same criterion-duration and criterion-frequency. Conversely, where rates of water intake are higher than 2.0 liters/day, a lower criterion-concentration would be needed to equalize the level of protection of the state and US EPA WQC.

Of course, as mentioned previously in this report, it is impossible to determine the relative degree of protection provided by one WQC versus another if either of the two criteria lacks a clearly-stated criterion-concentration, criterion-duration, or criterion-frequency. Since the values for any of these three components of numeric WQC could theoretically range from zero to infinity, if a state's WQS regulations make no mention of a criterion-duration (or averaging period) or criterion-frequency—as is often the case with state WQC examined in this study, then any tentative conclusions about the relative, or absolute, level of protection provided by such WQC would be mere speculation.

[70] Given the effects of global climate change, this national average water consumption rate may need to be re-examined in the not too distant future. Warmer temperatures are likely to increase typical rates of water consumption.

In a number of instances, states have included language in their WQS regulations that strongly implies a criterion-duration of an instant and a criterion-frequency of zero, although the intent is not entirely clear. In some cases, assumptions about criterion-duration and criterion-frequency could only be based on features of a state's regulations and guidance other than the WQC themselves, such as: 1) stream design flows (e.g., the lowest seven-day average flow likely to occur an average of once in 10 years (7Q10)) used for setting water quality-based NPDES permits and/or establishing TMDLs; or 2) assessment methodologies employed in interpreting available ambient monitoring data for purposes of developing a state's Section 303(d) impaired waters list, Section 305(b) statewide water quality reports, or Integrated 303(d)/305(b) reports. There are still other cases in which nothing a state has published provides any hint as to what the criterion-duration and/or criterion-frequency is supposed to be for a given or set of WQC.

Regardless of what language in a state's regulations and/or guidance related to establishing and implementing water quality criteria could be used to infer a precise criterion-duration and/or criterion-frequency, in the absence of a clearly-stated criterion-duration and criterion-frequency appearing in a state's WQS regulations, nothing can be said with a high degree of confidence about the relative, and/or absolute, level of protection provided by a given state numeric WQC.

Of course, the same is true for US EPA water quality criteria—if US EPA guidance documents do not provide exact statements of a concentration, duration, and frequency, then the relative level of protection offered by an Agency WQC versus a corresponding state or other entity WQC cannot be established. Although US EPA guidance is quite clear about the criterion-duration and criterion-frequency applicable to its aquatic life WQC for toxics, a number of the Agency's aquatic life WQC for traditional pollutants lack a clearly-specified criterion-duration and/or criterion-frequency. Furthermore, considerable ambiguity still exists with regard to the criterion-duration and criterion-frequency applicable to US EPA's human health WQC for toxic pollutants. For both the HHO and HHWO criteria published by US EPA, either a criterion-duration of: 1) an instant, 2) 365 days, or 3) as much as 70 years is implied, depending on which particular passages of EPA publications one examines. EPA's WQC publications are also silent as to a criterion-frequency for its human health criterion, which could be taken to imply an intended frequency of zero.

As for state WQC applicable to public drinking water supply uses, even if a state's WQC for this surface waters use category has very precise criterion-concentrations, criterion-durations, and criterion-frequencies, it is still difficult to render any judgment as to whether greater protection is provided to users of public water supply systems by these state drinking water supply WQC, or by EPA's federal SDWA drinking water standards. This is so for two key reasons. First, the SDWA standards apply to finished water (raw source water already treated to remove contaminants), whereas state drinking water supply criteria apply to raw (untreated) source water. Hence, if a state drinking water supply WQC and a federal primary drinking water standard were exactly identical—with the same concentration, duration, and frequency—they still would not necessarily provide the same level of protection to those who consume drinking water from SDWA-governed public water utilities. In fact, it is probable that the state drinking water supply WQC would provide a higher level of protection than the SDWA standard would alone—given that most drinking water utilities that draw their raw source water from surface water (as opposed to ground water) pass it through treatment processes aimed at removing a variety of contaminants, before sending the resulting finished drinking water through their distribution system to homes, businesses, and other facilities. Suppose, for instance, that the set of treatment techniques employed by a given drinking water system removed around 50% of a given contaminant. This would mean that, if the raw water drawn into the system's water treatment works had levels of a given contaminant equal to that specified by the federal standards for finished (after treatment) drinking water, the actual finished water that the drinking water utility provided to its customers would have only half the level of contaminant specified by the US EPA drinking water standard for that contaminant. Only if the treatment employed by a given public water supply utility happened to increase levels of a contaminant above that entering the treatment works might a drinking water supply WQC, applied by itself without the "backup" provided by federal drinking water standards, result in less protection to those who consume the utility's finished drinking water. (Disinfection byproducts such as chlorite and various trihalomethanes are examples of contaminants whose levels are often increased by typical drinking water treatment processes.)

Given the potential effect of drinking water treatment on raw water supply versus finished drinking water, only those armed with contaminant-specific information about the efficacy of various combinations of treatment methods could produce a reliable estimate of the relative degree of protection provided by a federal safe drinking water standard versus a state drinking water supply criteria. Unfortunately, such data on contaminant-specific removal rates of various drinking water treatment techniques—working in isolation or in combination—often either does not exist or is not readily available.

In summary, with regard to the level of protection provided by the WQC adopted by the ten states examined in this report in comparison to corresponding WQC issued by US EPA, there are no over-arching patterns. That is, it is not the case all of the hundreds of state criteria are more, less, or equally protective than the equivalent WQC published by the federal agency; nor is this true with regard to any one of the ten states. On average, certain groups of WQC for certain states do tend to be more protective than US EPA's, but there are also groups of criteria that are almost all identical to US EPA's, and then there are groups for some states with a majority that are less protective. Furthermore, such judgments cannot be rendered with any degree of confidence for many of the pairs of state and US EPA WQC because of the lack of clearly articulated criterion-durations and/or criterion-frequencies.

Consequently, the results of such comparisons are best revealed through reading of the Overview Reports for each of the ten states, which were prepared for this ELI project. These can be found along with this report on the Environmental Law Institute's website, at www.elistore.org.

Appendix A

Water Quality Standards (WQS) in the Clean Water Act Context

When it passed the modern version of the Clean Water Act (CWA) in 1972, Congress created an overall framework based on sequential application of two very different strategic approaches. The first is the "technology-based" approach (TBA). The second was a modified version of the approach that had been attempted up to that point—the "water quality-based" approach (WQBA). The idea was that, first, the technology-based approach would be used to achieve major across-the-board reductions in discharges of pollutants from industrial and municipal "point sources"—those whose wastewater is discharged through a pipe, tunnel, ditch, or other type of manmade conveyance.

The water quality-based approach serves as the back-up for the technology-based approach, and only comes into play in situations where the reductions resulting from implementing the TBA did not achieve the goals set out in the CWA, as articulated by individual states on a waterbody-by-waterbody basis. These state-set (subject to EPA review) waterbody-specific water quality objectives are called water quality standards (WQS). If the limits imposed by the TBA reduced discharges of pollutants to a degree sufficient to achieve WQS in a given water body, then the WQBA components of the CWA remain on "standby." On the other hand, if WQS are not achieved after full implementation of technology-based controls, then the water quality-based approach is activated, and everything that happens under this fallback strategy would be driven by and aimed specifically at the objective of meeting WQS.

Technology-Based Approach: Overview

Under the technology-based approach (TBA), limits are set on amounts of pollutants that can be released by any member of each of about 50 major categories of point sources. Most of these categories consist of types of industrial facilities – pulp mills, petroleum refineries, metal finishers, pharmaceuticals manufacturers, etc. Also included are discharges from three different components of municipal wastewater systems – sewage treatment plants (STPs), separate stormwater sewage systems (MS4s), and combined sewer overflows (CSOs). And, though most types of agricultural activities are not regulated by the CWA, concentrated animal feeding operations (CAFOs) are considered point sources and regulated under this system.

Category-wide performance requirements are established under the TBA – maximum discharge rates (e.g., pounds per day) of specific pollutants or groups of pollutants. The limits applicable within each category are set based on cost-effectiveness analyses performed by EPA, which is charged by the CWA to determine what levels of discharge can be achieved by the best available treatment economically achievable (BATEA, or just BAT) that can be employed by facilities in that category. EPA spells out these technology-based limits in regulations called "effluent guidelines." These requirements are later converted into discharger-specific permit requirements under the National Pollutant Discharge Elimination System program (NPDES), which is managed by state-level agencies in all but a limited number of states and/or categories of dischargers.

Perhaps the major benefit of the technology-based approach, at least from a program administration standpoint, is that, once EPA has set final effluent guidelines for a given category of discharger, it is relatively simple to set permit limits for individual facilities within that category. All operations within a given category will be required to achieve the same degree of effluent quality. But the TBA has one key drawback—technology-based limits are set without regard to the ultimate effect on water quality in the streams, lakes, bays, estuaries, and other surface waters that receive these discharges. This concept can be illustrated by the following diagram:

source of pollutant(s) → pollutant(s) → (water body)

Under the TBA, regulators start by identifying a type of facility that is thought to be a significant discharger of pollutants into surface waters. Then technologically feasible and economically affordable limits on discharges from all facilities of this type are established. All of this can be done without collecting any ambient water quality data, or even performing any computer modeling of expected levels of pollutants in given water bodies.

On a given water body, the degree of improvement in water quality is that which results from the collective imposition of technology-based limits on all points sources discharging to that water body, plus any efforts that have been made to reduce pollutant loadings from nonpoint sources. This may turn out to be too little, too much, or just the right amount of control needed to reach the desired condition of the water body. This is why "water body" appears in parenthesis in the diagram above – impacts on receiving waters are, in effect, an afterthought of the TBA.

Water Quality-Based Approach: Overview

In contrast to the technology-based approach (TBA), the water quality-based approach is entirely focused on achieving a specific set of environmental objectives – those spelled out in state water quality standards (WQS). This concept can be illustrated by the highly simplified diagram below:

water body → pollutant(s) → source(s) of pollutants

The first step in this process is determining, as much as possible, the current condition of a specific water body. Through collection of samples of water, biota, fish tissue, and bottom sediments – along perhaps with some sort of "modeling" of the water body – officials derive an estimate of levels of pollutants, over space and time, within the water body, along with other indicators of the water body's status.

The next step is to compare the best estimates of individual aspects of the current condition of the water body with the desired conditions specified in water quality standards (in the water quality criteria component of WQS, in particular.) If it turns out that all features of the water body that have been examined are as good as, or even better than, WQS, then that is the end of the water quality-based process for that particular water body. The technology-based requirements would remain in place.

But, if any of the characteristics of the water body appear to be in worse shape than that specified by some component of applicable WQS, then the remainder of the water quality-based approach must be implemented. Step one is announcing to the public that there is a problem, by putting the water on the so-called "303(d) list" (or the "impaired waters list").[71] Waters on this list are ones not fully attaining WQS, and require further action, including developing, for each pollutant causing the non-attainment, a "pollutant budget" – a total maximum daily load (TMDL).

TMDLs not only identify an overall loading capacity for a given pollutant in a certain water body, they also divide this cap on the loading rate among all the known, and possible future, sources of that pollutant. The portion of the total loading rate assigned to one or more point sources is called the "wasteload allocation" (WLA), whereas the part assigned to nonpoint sources is termed the "load allocation" (LA).[72] Because EPA interprets the CWA as only requiring TMDLs for water bodies not meeting WQS, the TMDL cap will, of necessity, specify a lower rate of loading of the pollutant in question than the current loading rate. Hence, each TMDL is, in essence, a pollutant-specific "diet" for a given water body.

The next step in the regulatory water quality-based process under the CWA is translation of the wasteload allocations into water quality-based effluent limits (WQBELs) in the NPDES permits that govern discharges from point sources into the waterbody to which the TMDL applies. WQBELs, like all NPDES provisions, are enforceable requirements, and those failing to comply can be subject to fines and even, in rare cases, time in prison.

Load allocations (LAs) developed in TMDLs are not, under federal law, converted into regulatory requirements for nonpoint sources – all true nonpoint sources[73] are exempt from any federal controls under the CWA. However, LAs can serve a very important purpose – providing benchmarks against which the performance of various voluntary nonpoint source management measures employed by farmers and other landowners can be compared. And, ultimately, whether or not WQS are attained provide an indicator of whether nonpoint sources management efforts in the watershed of a given waterbody have succeeded.[74]

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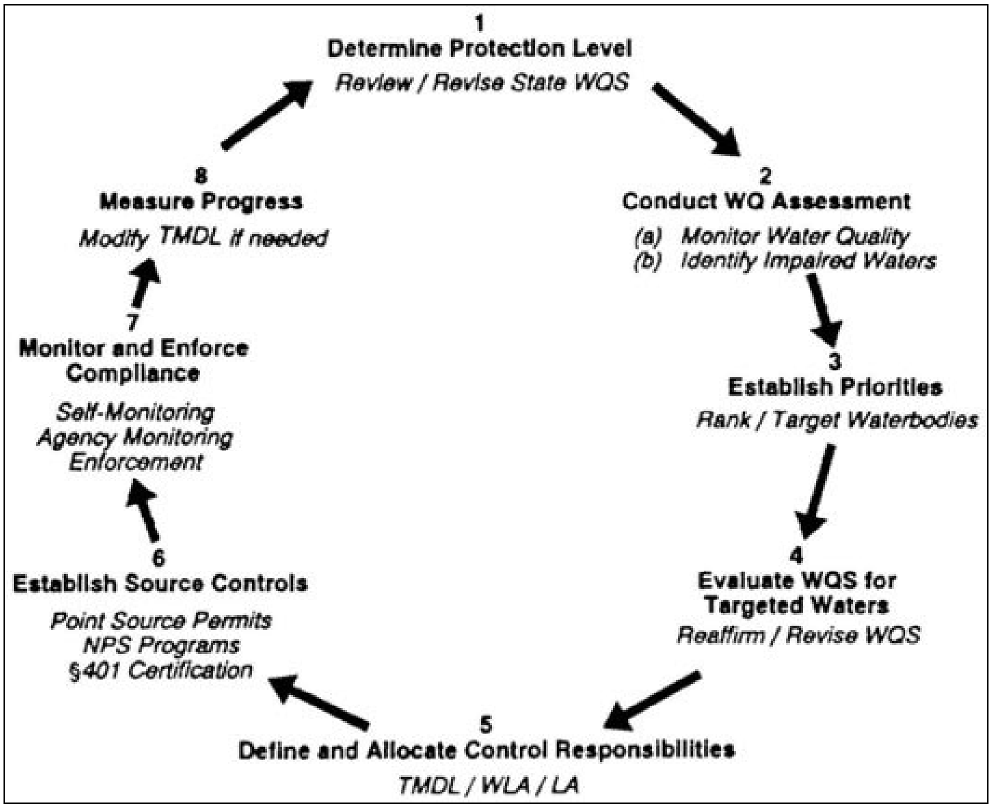
[71] Actually, according to EPA's interpretation of section 303(d) of the CWA, not all waters failing to achieve WQS must be placed on the 303(d) list. Once all necessary TMDLs are completed for a water body, for example, that water can be taken off the 303(d) list [Category 5 of EPA's Integrated CWA Report] and put in another grouping of impaired waters [Category 4a, in the EPA system.] Also included in Category 4 are: 1) waters without all needed TMDLs, but where existing programs have resulted in water quality improving at a rate that should result in attainment of WQS within a few years; or 2) waters impaired only by non-pollutant forms of pollution, such as altered streamflow and channelization. Given this new EPA approach to categorizing waters, the 303(d) list and a list of all impaired waters are not necessarily synonymous.

[72] Some confusion has been generated by use of the term "load allocation" in this manner. It is important to remember that, as used by EPA, "load allocation" refers to that portion of the overall acceptable loading capacity of a water body for a certain pollutant, and not the total overall loading rate, which EPA calls the "loading cap" or "TMDL cap."

[73] Sometimes, precipitation-dependent point sources, such as municipal storm sewers, construction site runoff, and concentrated animal feeding operations (CAFOs), are mistakenly called nonpoint sources.

[74] The key conceptual and policy difference between the technology-based approach and the water quality-based approach is how they answer the question, "How much pollutant reduction is enough?" With the TBA, the answer is, whatever amount is deemed achievable through application of treatment and management measures that can be afforded by the majority of operators in a given category. With the WQBA, the answer is whatever reductions it takes to meet WQS. Until quite recently, federal, state, and local government nonpoint source programs typically

Thus, water quality standards are the forcing mechanism for the entire water quality-based process under the Clean Water Act. WQS not only trigger application of the WQBA, they also drive the various regulatory and non-regulatory programs. Increasingly, WQS are the ultimate benchmark against which clean water programs are measured. The following diagram illustrates the driving role of WQS in the CWA's water quality-based approach.



Source: The *Water Quality Standards Handbook: Second Edition.* Available at: http://www.epa.gov/waterscience/standards/handbook/chapter07.htmL

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followed the technology-based approach. EPA is now promoting achievement of WQS as the ultimate benchmark by which nonpoint source efforts are measured.

APPENDIX B

Pollutants that EPA Has Flagged As Carcinogenic in Its Table of Current National Recommended Water Quality Criteria *(under Section 304(a) of the CWA)*

Acrylonitrile
Aldrin
Arsenic
Benzene
Benzidine
Benzo(a)Anthracene
Benzo(b)Flouranthene
Benzo(k)Flouranthene
Benzo(a)Pyrene
alpha-BHC
beta-BHC
Bis(2-Chloroethyl) Ether
Bis(2-Ethylhexyl) Phthalate
Bromoform
Carbon Tetrachloride
Chlordane
Chlorodibromomethane
Chloroform
Chrysene
4,4' DDT
4,4'-DDD
4,4'-DDE
Dibenzo(a,h)Anthracene
3,3'-Dichlorobenzidine
Dichlorobromomethane
1,2-Dichloroethane
1,2-Dichloropropane
1,3-Dichloropropene
Dieldrin
2,4-Dinitrotoluene
Dioxin (2,3,7,8 TCDD)
1,2-Dipheylhydrazine
Heptachlor
Heptachlor Epoxide
Hexachlorobenzene
Hexachlorobutadiene
Hexachloroethane
Ideno(1,2,3-cd)Pyrene
Isophorone
Methylene Chloride
N-Nitrosodibutylamine
Nitrosodiethylame
N-Nitrosodiphenylamine
N-Nitrosodimethylamine
N-Nidrosodi-n-Propylamine
N-Nitrosopyrrolidine
Pentachlorophenol
Polychlorinated Biphenyls
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toxaphene
1,1,2-Trichloroethane
Trichloroethylene
2,4,6-Trichlorophenol
Vinyl Chloride

APPENDIX C

Pollutants Identified As Bioaccumulative By the Great Lakes Initiative, the Toxic Release Inventory, and/or the EPA Persistent Bioaccumulative and Toxic (PBT) Chemical Program

	GLI	TRI	PBT
Aldrin		x	x
Benzo(a)Anthracene		x	x
Benzo(b)Flouranthene	x-p	x	
Benzo(j)Flouranthene		x	
Benzo(k)Flouranthene	x-p	x	x-p
Benzo(a)Pyrene		x	x
Benzo(g, h, i) perylene	x-p	x	
alpha-BHC	x		
beta-BHC	x		
delta-BHC	x		
Gamma-BHC (Lindane)	x		
4-bromophenyl phenyl ether	x		
Chlordane	x	x	x
4-chlorophenyl phenyl ether	x		
4,4' DDT	x		x
4,4'-DDD	x		x
4,4'-DDE	x		x
Dibenzo(a,h) Anthracene	x-p	x	
Di-n-Butyl Phthalate	x		
Dieldrin	x		x
Dioxin (2,3,7,8 TCDD)	x	x	x
Endrin	x		
Heptachlor	x	x	
Heptachlor Epoxide	x		
Hexachlorobenzene	x	x	x
Hexachlorobutadiene	x		
Hexachlorocyclo-hexane (technical)	x		
Ideno(1,2,3-cd)Pyrene	x	x	
Isorin		x	
Lead		x	
Methoxychlor	x	x	
Mercury	x	x	x
Mirex	x		x
Octachlorostyrene	x	x	x
Pendimethalin		x	
Pentachlorobenzene	x	x	
Phenol	x-p		
Photomirex	x		
Polychlorinated Biphenyls	x	x	x
Tetrabromo bis-phenol A		x	
1,2,3,4 Tetrachlorobenzene	x		
1,2,4,5 Tetrachlorobenzene	x		
Toluene (methylbenzene)	x-p		
Toxaphene	x	x	x
Trifluralin		x	

<u>Legend</u>

GLI – listed as a persistent bioaccumulative pollutant of concern under the Great Lakes Initiative
TRI – treated as a PBT in EPA's Toxic Release Inventory
PBT – included in EPA's Persistent Bioaccumulative and Toxic Chemical Program
x-p – considered a potential bioaccumulative pollutant of concern

APPENDIX D

Pollutants Regulated by EPA Organic Chemicals, Plastics, and Synthetic Fibers Effluent Guidelines	
Acenaphthene	2,4-Dinitrophenol
Acenaphthylene	2,4-Dinitrotoluene
Acrylonitrile	2,6-Dinitrotoluene
Anthracene	Ethylbenzene
Benzene	Fluoranthene
Benzo(a)anthracene	Fluorene
3,4-Benzofluoranthene	Hexachlorobenzene
Benzo(k)fluoranthene	Hexachlorobutadiene
Benzo(a)pyrene	Hexachloroethane
Bis(2-ethylhexyl) phthalate	Methyl Chloride
Carbon Tetrachloride	Methylene Chloride
Chlorobenzene	Naphthalene
Chloroethane	Nitrobenzene
Chloroform	2-Nitrophenol
2-Chlorophenol	4-Nitrophenol
Chrysene	Phenanthrene
Di-n-butyl phthalate	Phenol
1,2-Dichlorobenzene	Pyrene
1,3-Dichlorobenzene	Tetrachloroethylene
1,4-Dichlorobenzene	Toluene
1,1-Dichloroethane	Total Chromium
1,2-Dichloroethane	Total Copper
1,1-Dichloroethylene	Total Cyanide
1,2-trans-Dichloroethylene	Total Lead
2,4-Dichlorophenol	Total Nickel
1,2-Dichloropropane	Total Zinc2
1,3-Dichloropropylene	1,2,4-Trichlorobenzene
Diethyl phthalate	1,1,1-Trichloroethane
2,4-Dimethylphenol	1,1,2-Trichloroethane
Dimethyl phthalate	Trichloroethylene
4,6-Dinitro-o-cresol	Vinyl Chloride

APPENDIX E

Most Frequently Reported Causes of Impairment on State 303(d) Lists Nationwide *(starting with stressor listed most often)*
Pathogens **Mercury** **Sediment** (includes “siltation,” “sediment/siltation,” “sediment,” “suspended sediment,” “fine sediment”) **Metals** (other than Mercury) **Nutrients** (nitrogen, phosphorous, eutrophication, trophic state index, and related terms) **pH** **Temperature** (the pollutant is actually “heat,” temperature is an indicator of amount of heat) **Habitat Alterations** **Turbidity** (includes waters listed for “total suspended solids,” “clarity,” “transparency” and related terms) **Polychlorinated Biphenyls (PCBs)** **Pesticides** (most frequently named individual pesticide is atrazine, followed by DDT and chlordane) **Salinity/Total Dissolved Solids/Chlorides/Sulfates** **Flow Alteration(s)** **Ammonia** **Toxic Organics** (most frequent: PAHs, followed by chrysene, 2 phthalate esters, tetrachloroethylene) **Total Toxics** (based on bioassays of overall toxicity, no individual chemicals named) **Dioxins** **Toxic Inorganics** (most frequent: boron, cyanide, fluoride, hydrogen sulfide, perchlorate) **Chlorine** **Nuisance Exotic Species** **Trash** **Radiation** (most frequent: barium, gross alpha, radium 226, cesium, uranium, radium 228)

APPENDIX F

Pollutants for Which Illinois Has Established Water Quality-Based Effluent Limits (WQBELs), Using Its "Derived" Water Quality Criteria

- Acenaphthene
- Acenaphthylene
- Acetone
- Acetonitrile
- Acrylonitrile
- Anthracene
- Benzo (a) anthracene
- Benzo (a) pyrene
- Benzo (b) fluoranthene
- Benzo (k) fluoranthene
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- Chrysene
- Dibenz[a,h]anthracene
- 1,2-dichlorobenzene
- 1,3-dichlorobenzene
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,1-dichloroethylene
- 1,2-dichloroethylene
- 2,4-dichlorophenol
- 1,2-dichloropropane
- 1,3-dichloropropylene
- Ethyl mercaptan
- Fluoranthene
- Fluorene
- Formaldehyde
- Hexachlorobenzene
- Hexachloobutadiene
- Hexachloroethane
- n-hexane
- Hydrazine
- Indeno [1,2,3-cd] pyrene
- Methyl-tert-butyl ether
- 2-methyl-4,6-dinitrophenol
- Methylene chloride
- Methyl ethyl ketone
- 4-methyl-2-pentanone
- 4-methylphenol
- 2-methylphenol
- 2-methyl-1-propanol
- Naphthalene
- 4-nitroaniline
- Nitrobenzene
- Pentachlorophenol
- Phenanthrene
- Propylene
- Pyrene
- Tetrachloroethylene
- Tetrahydrofuran
- 1,2,4-trichlorobenzene
- 1,1,1-trichloroethane
- 1,1,2-trichloroethane
- Trichloroethylene
- Vinyl chloride

APPENDIX G

Toxic Pollutants for Which EPA Has Published Recommended Water Quality Criteria under Section 304(a) of the Clean Water Act to Protect Aquatic Life

Freshwater Aquatic Life Protection		**Salt Water Aquatic Life Protection**	
Acute	*Chronic*	*Acute*	*Chronic*
4,4'-DDT	4,4'-DDT	4,4'-DDT	4,4'-DDT
Aldrin	alpha-Endosulfan	Aldrin	alpha-Endosulfan
alpha-Endosulfan	Aluminum	alpha-Endosulfan	Arsenic
Aluminum	Arsenic	Arsenic	beta-Endosulfan
Arsenic	beta-Endosulfan	beta-Endosulfan	Cadmium
beta-Endosulfan	Cadmium	Cadmium	Chlordane
Cadmium	Chlordane	Chlordane	Chlorine
Chlordane	Chlorine	Chlorine	Chlorpyrifos
Chlorine	Chlorpyrifos	Chlorpyrifos	Chromium (VI)
Chlorpyrifos	Chromium (III)	Chromium (VI)	Copper
Chromium (III)	Chromium (VI)	Copper	Cyanide
Chromium (VI)	Copper	Cyanide	Demeton
Copper	Cyanide	Diazinon	Diazinon
Cyanide	Demeton	Dieldrin	Dieldrin
Diazinon	Diazinon	Endrin	Di-n-Butyl Phthalate
Dieldrin	Dieldrin	gamma-BHC	Endrin
Endrin	Endrin	Heptachlor	Guthion
gamma-BHC	Guthion	Heptachlor Epoxide	Heptachlor
Heptachlor	Heptachlor	Lead	Heptachlor Epoxide
Heptachlor Epoxide	Heptachlor Epoxide	Mercury	Lead
Lead	Iron	Nickel	Malathion
Mercury	Lead	Nonylphenol	Manganese
Nickel	Malathion	Pentachlorophenol	Mercury
Nonylphenol	Mercury	Selenium	Methoxychlor
Parathion	Methoxychlor	Silver	Mirex
Pentachlorophenol	Mirex	Toxaphene	Nickel
Selenium	Nickel	Tributyltin	Nonylphenol
Silver	Nonylphenol	Zinc	PCBs
Toxaphene	Parathion		Pentachlorophenol
Tributyltin	PCBs		Selenium
Zinc	Pentachlorophenol		Toxaphene
	Selenium		Tributyltin
	Toxaphene		Zinc
	Tributyltin		
	Zinc		

APPENDIX H

Toxic Pollutants for Which EPA Has Published Recommended Water Quality Criteria under Section 304(a) of the Clean Water Act to Protect Human Health

Human Health Protection	
Consumption of Organisms Only (HHO)	*Consumption of Water & Organisms (HHWO)*
1,1,2,2-Tetrachloroethane	1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane	1,1,2-Trichloroethane
1,1-Dichloroethylene	1,1-Dichloroethylene
1,2,4-Trichlorobenzene	1,2,4-Trichlorobenzene
1,2-Dichlorobenzene	1,2-Dichlorobenzene
1,2-Dichloroethane	1,2-Dichloroethane
1,2-Dichloropropane	1,2-Dichloropropane
1,2-Diphenylhydrazine	1,2-Diphenylhydrazine
1,2-Trans-Dichloroethylene	1,2-Trans-Dichloroethylene
1,3-Dichlorobenzene	1,3-Dichlorobenzene
1,3-Dichloropropene	1,3-Dichloropropene
1,4-Dichlorobenzene	1,4-Dichlorobenzene
2,3,7,8-TCDD (Dioxin)	2,3,7,8-TCDD (Dioxin)
2,4,6-Trichlorophenol	2,4,6-Trichlorophenol
2,4-Dichlorophenol	2,4-Dichlorophenol
2,4-Dimethylphenol	2,4-Dimethylphenol
2,4-Dinitrophenol	2,4-Dinitrophenol
2,4-Dinitrotoluene	2,4-Dinitrotoluene
2-Chloronaphthalene	2,4,5,-TP
2-Chlorophenol	2,4-D
2-Methyl-4,6-Dinitrophenol	2-Chloronaphthalene
3,3'-Dichlorobenzidine	2-Chlorophenol
4,4'-DDD	2-Methyl-4,6-Dinitrophenol
4,4'-DDE	3,3'-Dichlorobenzidine
4,4'-DDT	4,4'-DDD
Acenaphthene	4,4'-DDE
Acrolein	4,4'-DDT
Acrylonitrile	Acenaphthene
Aldrin	Acrolein
alpha-BHC	Acrylonitrile
alpha-Endosulfan	Aldrin
Anthracene	alpha-BHC
Antimony	alpha-Endosulfan
Arsenic	Anthracene
Benzene	Antimony
Benzidine	Arsenic
Benzo(a)Anthracene	Asbestos
Benzo(a)Pyrene	Barium
Benzo(b)Fluoranthene	Benzene
Benzo(k)Fluoranthene	Benzidine
beta-BHC	Benzo(a)Anthracene
beta-Endosulfan	Benzo(a)Pyrene
Bis(2-Chloroethyl) Ether	Benzo(b)Fluoranthene
Bis(2-Chloroisopropyl) Ether	Benzo(k)Fluoranthene
Bis(2-Ethylhexyl)Phthalate	beta-BHC
Bromoform	beta-Endosulfan
Butylbenzyl Phthalate	Bis(2-Chloroethyl) Ether
Carbon Tetrachloride	Bis(2-Chloroisopropyl) Ether
Chlordane	Bis(2-Ethylhexyl) Phthalate

APPENDIX H (cont.)

Toxic Pollutants for Which EPA Has Published Recommended Water Quality Criteria under Section 304(a) of the Clean Water Act to Protect Human Health

Human Health Protection	
Consumption of Organisms Only (HHO)	*Consumption of Water & Organisms (HHWO)*
1,1,2,2-Tetrachloroethane	1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane	1,1,2-Trichloroethane
1,1-Dichloroethylene	1,1-Dichloroethylene
1,2,4-Trichlorobenzene	1,2,4-Trichlorobenzene
1,2-Dichlorobenzene	1,2-Dichlorobenzene
1,2-Dichloroethane	1,2-Dichloroethane
1,2-Dichloropropane	1,2-Dichloropropane
1,2-Diphenylhydrazine	1,2-Diphenylhydrazine
1,2-Trans-Dichloroethylene	1,2-Trans-Dichloroethylene
1,3-Dichlorobenzene	1,3-Dichlorobenzene
1,3-Dichloropropene	1,3-Dichloropropene
1,4-Dichlorobenzene	1,4-Dichlorobenzene
2,3,7,8-TCDD (Dioxin)	2,3,7,8-TCDD (Dioxin)
2,4,6-Trichlorophenol	2,4,6-Trichlorophenol
2,4-Dichlorophenol	2,4-Dichlorophenol
2,4-Dimethylphenol	2,4-Dimethylphenol
2,4-Dinitrophenol	2,4-Dinitrophenol
2,4-Dinitrotoluene	2,4-Dinitrotoluene
2-Chloronaphthalene	2,4,5,-TP
2-Chlorophenol	2,4-D
2-Methyl-4,6-Dinitrophenol	2-Chloronaphthalene
3,3'-Dichlorobenzidine	2-Chlorophenol
4,4'-DDD	2-Methyl-4,6-Dinitrophenol
4,4'-DDE	3,3'-Dichlorobenzidine
4,4'-DDT	4,4'-DDD
Acenaphthene	4,4'-DDE
Acrolein	4,4'-DDT
Acrylonitrile	Acenaphthene
Aldrin	Acrolein
alpha-BHC	Acrylonitrile
alpha-Endosulfan	Aldrin
Anthracene	alpha-BHC
Antimony	alpha-Endosulfan
Arsenic	Anthracene
Benzene	Antimony
Benzidine	Arsenic
Benzo(a)Anthracene	Asbestos
Benzo(a)Pyrene	Barium
Benzo(b)Fluoranthene	Benzene
Benzo(k)Fluoranthene	Benzidine
beta-BHC	Benzo(a)Anthracene
beta-Endosulfan	Benzo(a)Pyrene
Bis(2-Chloroethyl) Ether	Benzo(b)Fluoranthene

APPENDIX H (cont.)

Toxic Pollutants for Which EPA Has Published Recommended Water Quality Criteria under Section 304(a) of the Clean Water Act to Protect Human Health

Human Health Protection	
Consumption of Organisms Only (HHO)	*Consumption of Water & Organisms (HHWO)*
Bis(2-Chloroisopropyl) Ether Bis(2-Ethylhexyl)Phthalate Bromoform Butylbenzyl Phthalate Carbon Tetrachloride Chlordane	Benzo(k)Fluoranthene beta-BHC beta-Endosulfan Bis(2-Chloroethyl) Ether Bis(2-Chloroisopropyl) Ether Bis(2-Ethylhexyl) Phthalate Nitrosopyrrolidine, N N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Pentachlorobenzene Pentachlorophenol Phenol 1,2,4,5-Tetrachlorobenzene Tetrachloroethylene Thallium Toluene Toxaphene Trichloroethylene 2,4,5-Trichlorophenol Vinyl Chloride Zinc

APPENDIX H (cont.)

Pollutants for Which EPA Has Promulgated Primary Drinking Water Quality Standards Under the Safe Drinking Water Act (also known as Maximum Contaminant Levels)

1,1,1-Trichloroethane
1,1,2-Trichloroethane
1,1-Dichloroethylene
1,2,4-Trichlorobenzene
1,2-Dibromo-3-chloropropane
1,2-Dichloroethane
1,2-Dichloropropane
cis-1,2-Dichloroethylene
2,4,5-TP (Silvex)
2,4-D
Alachlor
Alpha particles
Antimony
Arsenic
Asbestos
Atrazine
Barium
Benzene
Benzo(a)pyrene (PAHs)
Beryllium
Beta particles & photon emitters
Bromate
Cadmium
Carbofuran
Carbon tetrachloride
Chloramines
Chlordane
Chlorine
Chlorine dioxide
Chlorite
Chlorobenzene
Chromium (total)
Cyanide (as free cyanide)
Dalapon
Di(2-ethylhexyl) adipate
Di(2-ethylhexyl) phthalate
Dichloromethane
Dinoseb
Dioxin (2,3,7,8-TCDD)
Diquat
Endothall
Endrin
Ethylbenzene
Ethylene dibromide
Fluoride
Glyphosate
Haloacetic acids (HAA5)
Heptachlor
Heptachlor epoxide
Hexachlorobenzene
Hexachlorocyclopentadiene
Lead
Lindane
Mercury
Methoxychlor
Nitrates
Nitrite
1,2-Dichlorobenzene
Oxamyl (Vydate)
PCBs
1,4-Dichlorobenzene
Pentachlorophenol
Picloram
Radium 226 and Radium 228 (combined)
Selenium
Simazine
Styrene
Tetrachloroethylene
Thallium
Toluene
Total Trihalomethanes
Toxaphene
1,2-Dichloroethylene (trans)
Trichloroethylene
Uranium
Vinyl chloride
Xylenes (total)

APPENDIX H (cont.)

"Traditional" Pollutants[i]/Other Water Quality Parameters for Which EPA Has Issued CWA Criteria and/or SDWA Standards

	Aquatic Life				Human Health								IWS[ii]	AWS[iii]
	Fresh[iv]		Salt[v]		DWS[vi]		DW[vii]		FC[viii]		1°C[ix]			
	Acu[x]	*Chr*[xi]	*Acu*	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*		
Alkalinity/Buffering Capacity *(see Calcium Carbonate [$CaCO_3$] below)*														
Ammonia	**x**	**x**												
Barium								**x**-*p*[xii]						
Boron/Borates														**x**
Calcium Carbonate ($CaCO_3$)	**x**												**x**	
Chloride	**x**	**x**						**x**-*s*[xiii]						
Chlorides plus Sulfates					**x**[xiv]									
Chlorophyll a		**x**[xv]												
Color		**x**[xvi]						**x**-*s*						
Foaming Agents								**x**-*s*						
(total dissolved) Gases	**x**													
Hardness (*see Calcium Carbonate [$CaCO_3$] above*)														
Hydrogen Sulfide	**x**			**x**										
Nitrate-N								**x**-*p*						
Nitrite-N								**x**-*p*						
Nitrogen (Total-TKN and nitrite/nitrate)		**x**[xvii]												
Odor								**x**-*s*						
(Dissolved) Oxygen	**x**													
Pathogens (indicators thereof)														
Total coliform bacteria								**x**-*p*[xviii]						
Fecal coliform bacteria										**x**[xix]	**x**[xx]	**x**		
Enterococci											**--**[xxi]	**x**[xxii]		
E. coli											**--**	**x**		
pH	**x**[xxiii]							**x**-*s*						
Phosphorous		**x**[xxiv]												

	Aquatic Life				Human Health								IWS[ii]	AWS[iii]
	Fresh[iv]		Salt[v]		DWS[vi]		DW[vii]		FC[viii]		1°C[ix]			
	Acu	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*	*Acu*	*Chr*		
Salinity and Dissolved Solids														
(see "chlorides plus sulfates" above)														
(total dissolved) Solids								**x**-*s*						
(suspended, settleable) Solids		**x**[xxv]												
Sulfate								**x**-*s*						
Sulfates plus Chlorides														
(see "Chlorides and Sulfates)														
Temperature	**x**		**x**											
Turbidity														
depth of the compensation point for photosynthesis														
(see "suspended, settleable solids")														
depth of Secchi disk visibility		**x**[xxvi]												
Nephelometric Turbidy Units (NTUs)		**x**												

[i] The term "Traditional pollutant" has been used by US 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. US 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, US 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, phosphorus, and turbidity. For purposes of this study, the definition of "traditional pollutant" is expanded to also include traditional pollutants, plus all non-toxic "non-priority" pollutants and one toxic "non-priority" pollutant – ammonia.

[ii] IWS = Industrial Water Supply

[iii] AWS = Agricultural Water Supply

[iv] Fresh = Freshwater

[v] Salt = Saltwater (coastal and marine)

[vi] DWS = Drinking Water Supply criteria, issued by US EPA, pursuant to the CWA. Drinking Water Supply criteria apply to "source water"—the "raw" water that a public water supply system takes from a surface water (river, lake, etc). Typically, such water undergoes treatment to remove contaminants before it is sent by a drinking water utility to its customers. US EPA has issued such WQC only for a couple of "traditional" pollutants/parameters; it has published none pertaining to toxic chemicals. Like all WQC issued by US EPA, these are guidance, for the states to use in setting their own DWS criteria.

[vii] DW = Drinking Water Standards, promulgated by US EPA, under authority of the federal Safe Drinking Water Act (SDWA). Such standards apply to "finished" drinking water—that water sent into the distribution lines of a public water system (PWS). EPA drinking water standards are legally enforceable requirements. EPA issues two types of Drinking Water Standards: 1) Primary, and 2) Secondary. Unlike EPA water quality criteria, Primary DW standards are legally enforceable. These standards address risks to human health resulting from drinking contaminated water. Primary DW standards are also called "Maximum Contaminant Levels" (MCLs), but despite their title, these are not concentrations that should never be surpassed, even for an instant. Rather, attainment of MCLs is determined by taking the average of at least four grab (instantaneous) samples of finished drinking water, with a least one sample taken during each of four consecutive 3-month periods. Hence, the duration of DW standards is, in essence, 12 months. Secondary drinking water standards address cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. As opposed to Primary standards, Secondary standards published by EPA are not regulatory requirements; rather, they are, like EPA water quality criteria, merely guidance. For purposes of this report, it is assumed that the duration applicable to secondary DW standards is the same as applicable to primary standards—12 months, taken as the "rolling average" of four consecutive calendar months.

[viii] FC = Fish Consumption. Human consumption of fish, shellfish, and other aquatic life taken from a waterbody designated for such use.

[ix] $1^{o}C$ = Primary Contact Recreation, which includes swimming, snorkeling, water skiing, surfing, wind surfing, whitewater rafting and other forms of recreation in which contact with, and immersion in, a waterbody is common.

[x] Acu = Acute criterion. Applies to exposure to pollutants of a short term, typically an hour or less, though sometimes several hours.

[xi] Chr = Chronic criterion. Applies to exposure to pollutants of a longer term, typically at least a day, and often weeks, months, or even years.

[xii] X-p = Primary Drinking Water Standard, promulgated by EPA under the Safe Drinking Water Act. Aimed at protecting human consumers of drinking water provided by public water supply systems.

[xiii] X-*s* = Secondary Drinking Water Standard, issued by EPA under the Safe Drinking Water Act. Unlike Primary Drinking Water Standards, Secondary Standards are not federally enforceable requirements; they are simply guidance values. Their purpose is to address the appearance, smell, and taste of drinking water.

[xiv] This drinking water supply water quality criterion was published by US EPA in 1976. It is not human-health-based; rather, like Secondary Drinking Water Standards published by EPA, this WQC addresses human "welfare" [taste of finished drinking water; as well as increased costs to drinking water utilities associated with: 1) dealing with increased corrosion of pipes in its distribution system, and 2) additional treatment to remove chlorides and sulfates.]

[xv] EPA's ecoregio-specific/waterbody type-specific WQC for chlorophyll a is one of the Agency's package of "nutrient criteria," along with criteria for total nitrogen, total phosphorous, and turbidity. These nutrient WQC are listed under aquatic life, but the algal blooms resulting from excess nutrients also can impact drinking water supply/drinking water and water-based recreation. More information about EPA's nutrient criteria program can be found at: http://www.epa.gov/waterscience/criteria/nutrient/

[xvi] The EPA WQC for color applicable to aquatic life uses states, "Increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonably established norm." This language implies that it is the "seasonal" average depth of the compensation point that is relevant, rather than the depth of this point at any one instant. Nevertheless, the language is not 100% clear. Also, the meaning of "seasonal" is not entirely clear, but is assumed to refer to that period of time, in a given locale, when temperatures and light levels would foster growth of algae.

[xvii] EPA's eco-region-specific/waterbody type-specific WQC for total nitrogen are included in the Agency's package of "nutrient criteria," along with total phosphorous, chlorophyll a and turbidity. These nutrient WQC are listed under aquatic life, but the algal blooms resulting from excess nutrients also can impact drinking water supply/drinking water and water-based recreation. More information about EPA's nutrient criteria program can be found at: http://www.epa.gov/waterscience/criteria/nutrient/

[xviii] The EPA-promulgated Primary Drinking Water Standard specifies that no more than 5% of samples of finished drinking water shall have detectable levels of total coliform bacteria. Standards and criteria expressed in terms of a level not to be surpassed in more than a certain percent of either: 1) samples or 2) time can be difficult to place in an acute versus chronic dichotomy. In both cases, the duration of each exposure event (a consecutive period of time during which levels in the water of concern are above the level specified) could range anywhere from an instant to weeks, months, or even years. This depends on both the pattern of fluctuation of levels of the pollutant of concern in the water being sampled, as well as the timing of sample collection. For example, if finished drinking water from a certain drinking water utility were monitored continuously for detectable levels of total coliform bacteria over an entire year and detectable levels of total coliform bacteria were found 5% of the time, coliform levels in the drinking water would have been above detection for a total of just over 18 days (5% of 365 days). Those 18 days could occur in one contiguous block of time—a pattern consistent with chronic exposure. But the period totaling 18 days could have been broken up into eighteen one-day periods, scattered across the year—more of an acute pattern. The Primary Drinking Water Standard for total coliform bacteria has been listed in this table as "acute," based on the fact that drinking water is not typically subject to continuous monitoring; rather a series of instantaneous grab samples are taken.

[xix] EPA's criterion for fecal coliform levels in shellfish harvesting waters is stated as a median value of a certain measure of levels of this category of bacteria; however, the EPA criteria document does not specify the period of time over which the median value should apply—an hour, 6 hours, a day, one month, several months, a year, several years, and so on. This criterion is listed as chronic because most of the possible interpretations of the relevant EPA language are consistent with chronic durations.

[xx] In 1976, EPA issued water quality criteria for fecal coliform bacteria in waters used and/or designated for primary contact recreation. One of the values published by the Agency states: "…nor shall more than 10% of the total samples taken over a 30 day period exceed 400 per 100 mL." Like the Agency's Primary Drinking Water Standard for total coliform bacteria, this threshold value could be consistent with both acute and chronic exposure patterns. However, since EPA has issued what is clearly a chronic criterion (duration: 30 days) for fecal coliform for primary contact recreation, the "percentage criterion" is listed here as "acute." (Also, as with finished drinking water, waterbodies designated for water contact recreation are usually monitored via a series of individual instantaneous "grab: samples.) Also worthy of note is the fact that, as written, this is technically not a water quality criterion, in that it does not describe waterbody conditions consistent with supporting a designated use. Instead, this language describes a characteristic of a set of samples, which is more akin to an assessment methodology. If one assumes that, here, "sample" refers to a single measurement (i.e., grab sample), and that all such "samples" have been collected in an unbiased manner, then it could be inferred that the language about a percentage of samples is intended to reflect an implicit water quality criterion expressed as "the level of fecal coliform bacteria shall not surpass 400 per 100 mL more than 10% of the time, during any month."

[xxi] EPA has published "single sample maximum" values in the criteria documents for both Enterococci and *E. coli*. The title of these values has led some to believe they constituted acute WQC—concentrations not to be surpassed at any time, for even an instant. To the contrary, these values do not reflect the results of studies of the effect of momentary recreational exposure to waters with various levels of indicator bacteria such as *E. coli*. They are, rather, statistically-derived values representing the lowest concentration that would need to be found in a situation in which only one grab sample had been collected over a 30 day period, indicative of a certain probability (e.g., 75%, 90%) that the 30-day geometric mean of the ambient E.coli concentration was equal to the chronic criterion-concentration (126/100 mL). In recent guidance, EPA has suggested that if more than one grab sample is available per 30 days, the geometric mean of those two or more samples be calculated, and compared to the chronic criterion-concentration.

[xxii] EPA has published two chronic Enterococci WQC – one for fresh waters and one for coastal/marine waters.

[xxiii] EPA has published two acute aquatic life WQC for pH – one for fresh waters and one for coastal/marine waters.

[xxiv] EPA's eco-region specific/waterbody type-specific WQC for total phosphorous are included in the Agency's package of "nutrient criteria," along with total nitrogen, chlorophyll a and turbidity. These nutrient WQC are listed under aquatic life, but the algal blooms resulting from excess nutrients also can impact drinking water

supply/drinking water and water-based recreation. More information about EPA's nutrient criteria program can be found at: http://www.epa.gov/waterscience/criteria/nutrient/.

[xxv] EPA's WQC, published in 1976, reads "Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than ten percent, from the seasonably established norm for aquatic life." The reference to seasonal norm indicates this is a chronic WQC, with a duration of several months, varying from area to area, depending on the length of time when weather, and water temperatures, are warm.

[xxvi] EPA's eco-region specific/waterbody type-specific WQC for turbidity are included in the Agency's package of "nutrient criteria," along with total phosphorous, total nitrogen, and chlorophyll a. Criteria for lakes and reservoirs are expressed as the maximum depth at which a Secchi disk remains visible. Those for rivers and streams are stated in NTUs. These nutrient WQC are listed under aquatic life, but the algal blooms resulting from excess nutrients also can impact drinking water supply/drinking water and water-based recreation. More information about EPA's nutrient criteria program can be found at: http://www.epa.gov/waterscience/criteria/nutrient/

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