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

Kentucky

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Overview

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The findings presented in this document are based only on what was found in final state WQS regulations as of December 31, 2008. Hence, though the existence of proposed changes to state water quality standards may be acknowledged, typically in footnotes, the contents of such potential modifications are not reflected in the various analyses contained in the report. Likewise, associated guidance documents, policy memoranda, and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards program or how WQS are applied in other water quality programs.

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

ELI Project No. 063101

Table of Contents

List of Acronyms

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

A. Introduction

This document is one of a number of state-specific reports resulting from an Environmental Law Institute (ELI) analysis of the numeric water quality criteria[1] (WQC) component of the water quality standards (WQS) of the ten states that border directly on the Mississippi River. In this report ELI compares the state numeric water quality criteria to recommended criteria and related standards[2] issued by the U.S. Environmental Protection Agency (EPA). The findings presented in the documents produced for this report are based on the most recent version of the state's WQS regulations as of December 31, 2008. Hence, only water quality criteria contained in final state regulations were examined. Associated guidance documents, policy memoranda and other state publications related to the state's WQS are not reflected in this report. As such, one limitation of this report is that it does not fully describe a given state's water quality standards or how standards are applied in other water quality programs.

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

B. Summary of Findings

The water quality criteria specified in Kentucky's water quality standards (WQS) regulations[3] present a mixed picture when compared to the criteria published by EPA, in terms of 1) pollutant and use combinations[4] covered, 2) the degree to which all key elements of criteria are clearly articulated, and 3) level of protection likely afforded to applicable designated uses. Kentucky has adopted numeric water quality criteria for a significant array of pollutant/use combinations. There are, however, a number of instances in which the state has not established criteria for pollutant/use combinations for which EPA has issued[5] WQC under the authority of Section 304(a) of the CWA.

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

[2] The *recommended EPA criteria* are water quality criteria (WQC) issued by that agency under authority of the federal Clean Water Act. The *related standards* are regulatory requirements applicable to finished (post treatment) drinking water that is delivered to homes and businesses by a public drinking water system, promulgated by EPA under authority of the Safe Drinking Water Act.

[3] 401 Ky. Admin Regs. 5:031 (2003)

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

[5] Throughout this report, the criteria recommended by EPA will be referred to as the EPA's "issued" or "published" criteria, interchangeably. Unlike Primary Drinking Water Standards promulgated according to the federal Safe Drinking Water Act, EPA WQC are not regulatory requirements; rather, they are guidance. Hence, while use of

For example, the state is missing[6] aquatic life criteria for a number of traditional pollutants[7] for which EPA has issued such WQC, including the nutrients nitrogen and phosphorous and the related "response indicator" chlorophyll a - a direct indicator of levels of algae. Kentucky also lacks numeric criteria aimed at reflecting levels of sediments in the water column and/or bottom of the waterbody.

Kentucky has adopted criteria for a large number of toxic pollutants[8] to protect aquatic life. Indeed, with only four pollutants lacking aquatic life criteria, the state has adopted water quality criteria (WQC) for 90% of the pollutants for which EPA has published freshwater aquatic life criteria.

The state has also adopted criteria for a large number of toxic pollutants to address risks associated with human consumption of fish. Lacking "Human Health: Fish Consumption" criteria for only four pollutants, the state has adopted "Human Health: Fish Consumption" criteria for 96% of the pollutants for which EPA has published corresponding criteria.

Kentucky has adopted "Human Health: Domestic Water Supply Source" criteria for a large number of pollutants – about half of which have somewhat corresponding maximum contaminant level (MCL) values that EPA has issued pursuant to the Safe Drinking Water Act (SDWA).[9] Those in the other half are contaminants for which EPA has not issued any SDWA standards.

One feature of the state's WQS regulations that is not directly consistent with EPA's 304(d) list of WQC is its lack of a set of human health criteria intended to address the combined consumption of water as well as fish and other aquatic organisms. EPA has issued such criteria for 113 toxic chemicals, which it calls "Human Health: Water and Organisms (HHWO) criteria.

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terms like "promulgated" and "established" is appropriate with reference to EPA's drinking water standards, they are not used in conjunction with EPA's Section 304(a) WQC.

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

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

[8] In this report, "toxic pollutant" includes not only EPA's "priority toxic pollutants" but also: a) all those toxics that EPA called, for CWA purposes, "non-priority pollutant," and, b) as well as all toxic chemicals not falling in either of these categories (the one exception being ammonia; see footnote 7 above).

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

For those traditional pollutants for which both Kentucky and EPA have criteria for a given pollutant/use combination, the state's criteria have criterion-concentrations[10] identical, or very close, to the corresponding WQC issued by EPA and by most of the other nine states covered in this Environmental Law Institute study.

The criterion-concentrations in all of the state's aquatic life WQC for toxic chemicals are either equal to or only slightly higher than the criterion-concentrations in corresponding EPA's freshwater aquatic life criteria. The criterion-concentrations in most of Kentucky's "Human Health: Fish Consumption" criteria are equal to the criterion-concentrations in the corresponding EPA criteria. The criterion-concentrations in about half of Kentucky's "Human Health: Domestic Water Supply Source" criteria for toxics are lower than the contaminant concentrations specified by EPA's SDWA standards, while there is a roughly even split between those criterion-concentrations that are higher than EPA's Safe Drinking Water Act values and those that are equal to EPA's drinking water standards.

Most of the state's criteria for traditional pollutants, regardless of the designated use to which a criterion applies, lack clearly articulated criterion-durations and/or criterion-frequencies. Furthermore, none of Kentucky's criteria for toxic pollutants, for either aquatic life or human health, have clearly stated criterion-durations or criterion-frequencies.

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

Unfortunately, the relevance of the tables in Appendix C to Kentucky's WQC is significantly limited by the previously mentioned fact that none of the state's criteria have both a clearly specified criterion-duration and criterion-frequency. Further complicating comparison of the level of protection afforded to applicable designated uses by a state WQC is the fact that most of EPA's criteria for traditional pollutants lack a clearly articulated criterion-duration and

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

criterion-frequency. This means that, for the numerous Kentucky WQC having the same criterion-concentration as that in corresponding EPA WQC, one cannot say with 100% confidence what the relative degree of protection of the two actually is. That is, though at first it might seem that those Kentucky and EPA criteria having the same criterion-concentration would provide equal levels of protection, in most cases, a considerable degree of uncertainty would be associated with such a determination. The reason, of course, is that any such effort would require making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually settled upon, by the state and/or EPA. Clearly, the outcome of attempts to compare the protection provided by a state versus an EPA would, therefore, be greatly affected by whatever assumptions were made. Assumption of some short-term duration (e.g., one hour), rather than a longer term (e.g., 30 days), would tend to make a criterion more protective. Likewise, assumption of a lower frequency (e.g., once in five years), rather than a higher frequency (e.g., once in two years) would have the same effect and would be more protective than if the alternative were used.

Kentucky's dissolved oxygen WQC for Cold Water Aquatic Life has a criterion-concentration of 5.0 mg/L, as does the only WQC for this parameter issued by EPA. But while Kentucky's WQS regulations clearly specify this as an "instantaneous minimum" concentration, EPA's WQC makes no reference to a criterion-duration. And, neither the state nor the federal agency mentions a criterion-frequency. In this report, when no mention is made of a criterion-duration, duration of an instant is assumed; likewise, when a WQC is silent regarding a criterion-frequency, then a default of a zero frequency of excursions[11] is employed. Under these assumptions, the state and EPA WQC would indeed provide identical protection of aquatic life, because the criterion-concentrations (5.0 mg/L), criterion-durations (instant), and criterion-frequency (zero), are the same for both criteria. But, if one assumed that the criterion-duration for the EPA WQC for the traditional parameter dissolved oxygen should be the same as that of all that agency's acute aquatic life WQC for toxic substances (one hour), then the state's WQC would be the more protective, since the concentrations remain 5.0 mg/L and the frequencies remain zero, while the state WQC has a shorter duration (an instant) than that of the EPA criterion (one hour).

A different set of situations can be illustrated by comparing Kentucky's and EPA's chronic aquatic life WQC for chloride. Here, the state has a higher criterion-concentration than does the corresponding EPA WQC; state criterion-concentration of 600 mg/L versus EPA criterion-concentration of 250 mg/L. Both the state and EPA WQC lack reference to a criterion-duration or criterion-frequency, in which case this report assumes duration of an instant and a frequency of zero. Based on these assumptions, the Kentucky criterion is less protective that it's EPA companion. If, however, as was done in the previous paragraph, EPA's WQC was assumed to have a criterion-duration of an hour, a more complex situation is produced. Now, we have a higher state criterion-concentration, shorter state criterion-duration (an instant versus an hour), and identical criterion-frequencies (zero). Answering the question, "Does the state's shorter criterion-duration, which would make the state's WQC more protective, offset the less-protective effect of the state's criterion-concentration?" requires more information than that provided by the two WQC alone. A literature search, and perhaps also performance of new lab or field studies, would be needed to determine which combination of concentration and duration (600 mg/L instantaneous verses 250 mg/l average for one hour) would provide the most protection

[11] As used in this report, and in some EPA guidance documents, an "excursion" is any period equal in length to the criterion-duration of a WQC when the average waterbody concentration is higher than the criterion-concentration.

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

The only two water quality parameters for which Kentucky has aquatic life WQC with criterion-concentrations that differ among categories of waters are dissolved oxygen and temperature. As for dissolved oxygen, there are, in essence, distinct WQC for each of 3 categories of waters, plus specific WQC for the mainstem of the Ohio River. The WQC for temperature an assigned to two large categories of waters: war water aquatic habitat and cold water aquatic habitat. Also, for both dissolved oxygen and temperature, different WQC can apply at different times of the year. There is no geographic variation in the criterion-concentration for a given type of (acute and/or chronic) aquatic life WQC for a given toxic pollutant, among waters of the state.

Turning from aquatic life to human health, safe levels of pollutants tend to vary less from waterbody to waterbody. The most obvious reason is that, unlike aquatic life WQC, human health criteria address impacts on just one species, regardless of the location of the waterbody to which the WQC apply. The most common reason for need for variation in human health criteria from one locale to another is differences in patterns of human use. For example, regarding drinking water use, 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. And, 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, or wetland). Hence, Kentucky has one fecal coliform criterion for Whole Body Contact Recreation (criterion-concentration of 200 colonies/100 ml) and another for Secondary Contact Recreation (criterion-concentration of 2000 colonies/100 ml). On the other hand, there is no evidence of the state having established site-specific WQC for any toxic chemicals, even persistent, highly-bioaccumulative ones, to account for differences in human fish consumption patterns from one part of the state to another, or on any particular waterbodies.

Returning briefly to the effects of un-addressed or imprecisely articulated criterion-durations and criterion-frequencies, in addition to making comparison of levels of protection afforded relevant uses difficult, if not impossible, such ambiguities can pose challenges to the implementation of CWA programs driven by WQS, 303(d) and 305(b) reporting on the condition of a state's waters, total maximum daily loads (TMDLs), and water-quality based effluent limits in NPDES permits. For instance, if a TMDL were being developed because of exceedances of one of Kentucky's Human Health: Fish Consumption WQC, the absence of a clearly articulated criterion-duration for this category of WQC would create a quandary. What should the time-

interval for the maximum loading set forth in the TMDL be? If one assumes, as has been done in this report, a default criterion-duration of an instant in such circumstances, then it would seem logical to express the TMDL as a maximum load over a very short interval, even just a second. On the other hand, if the criterion-duration for the state's Human Health: Fish Consumption WQC was twelve months (the averaging period used in determining compliance with SDWA standards), then setting a maximum twelve-month total load would seem appropriate.[12]

C. "Traditional" Pollutants/Parameters[13]

1) *Coverage*

a) Aquatic Life / "Warm Water Aquatic Habitat" and "Cold Water Aquatic Habitat"[14]

Kentucky lacks an acute and/or chronic WQC for a substantial fraction of the traditional pollutants for which EPA has published criteria, with most of the "missing"[15] criteria being chronic. The only missing acute criterion is for calcium carbonate. Among the several missing chronic criteria are a number corresponding to published EPA criteria related to hyper-eutrophication due to excess loadings of nutrients chlorophyll a, total phosphorous, total nitrogen, and turbidity. Kentucky has not adopted criteria comparable to either EPA's "semi-chronic" (four-day average) or chronic (30 days) criteria for ammonia, though it has acute criteria corresponding to EPA's.

The state has neither numeric nor "quasi-numeric"[16] criteria for total dissolved gases, while EPA has a quasi-numeric. See discussion of "quasi-numeric" criteria in Subsection C(3)(a)iii.

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

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

[14] Throughout this document, generic names (e.g., "aquatic life," and "human health: drinking water supply," and "human health: water contact recreation") are used in reference to certain categories of uses. When a state uses different wording to refer to one of the generic uses, the name the state employs is listed in quotation marks, following the generic use.

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

[16] For purposes of this report, "quasi-numeric criteria' is used to describe those criteria that are expressed in terms of a change from background (natural/historic and/or upstream of a pollutant source) conditions. For example, *temperature shall be increased no more than 1 degree C above background.*

However, Kentucky does have some "extra"[17] criteria; the state has acute aquatic life criteria for temperature in streams, and an acute-chronic "quasi-numeric" criterion for temperature. (EPA has only narrative criteria for temperature). The state also has acute and chronic criteria for dissolved oxygen, while EPA has only acute criteria (Appendix A, Table 1).

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

EPA has issued chronic WQC for fecal coliform bacteria applicable to consumption of shellfish, while Kentucky has not.[18]

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

Kentucky has criteria applicable to drinking water supply use for five of the eight traditional contaminants/ water quality parameters for which EPA has published "secondary" (pertaining to taste, odor, and appearance of finished drinking water, rather than health risk) standards under the Safe Drinking Water Act. Kentucky has no criteria for total coliform bacteria, odor or pH.

Also, in the case of the five contaminants for which the state has specified DWS criteria, those criteria appear to be applicable to acute conditions, while EPA's SDWA standards[19] are treated as chronic criteria (Appendix A, Table 2).

Kentucky also lacks WQC for the nutrients phosphorous and nitrogen, excess levels of which can lead to unnatural blooms of aquatic algae. High levels of algae in the raw water supply used by a public drinking water system can result in unpleasant taste and odor in finished drinking water, unless special care is taken in the drinking water treatment process. Such extra treatment efforts can, in turn, lead to increased costs to a drinking water utility and its customers.

d) Human Health: Water-contact Recreation / "Primary" and "Secondary Contact Recreation"

Kentucky has adopted criteria corresponding to EPA criteria not only for the indicator fecal coliform bacteria, but also for *E. coli* with regard to water-based recreation. Also, Kentucky has established two different criteria – Primary Contact Recreation and Secondary Contact Recreation – for fecal coliform.

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[17] For the purposes of this review, "extra pollutants" are those pollutants, for a given designated use, for which the state has formally officially adopted WQC while EPA has not published recommended WQC of the type specified.

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

[19] Unlike the water quality criteria that it issues for CWA purposes, the drinking water standards EPA promulgates, via formal rulemaking, under authority of the Safe Drinking Water Act are regulatory requirements, not just recommendations. EPA lacks actual drinking water supply criteria for traditional pollutants – specification of the levels of contaminants in surface waters being used as a raw water supply by public drinking water systems. The only EPA standards with regard to ensuring safe levels of contaminants in drinking water apply to "finished" water – that which results from raw water being passed through a treatment system aimed at removing contaminants to the degree practicable

Like EPA, Kentucky has only a chronic water-contact recreation criterion for *E. coli*, which applies to Primary Contact. It lacks chronic criteria for Enterococci corresponding to EPA's.

Kentucky has criteria for pH applicable to recreational use, whereas EPA has not (Appendix A, Table 3).

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

e) Agricultural Water Supply

EPA has issued agricultural water supply criteria for boron/borates, while Kentucky has not. Agricultural water supply is not among the uses for which a waterbody can be designated under the state's WQS regulations.

f) Industrial Water Supply

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

2) *Criterion-Concentration*[20]

a) Aquatic Life / "Warm Water Aquatic Habitat" and "Cold Water Aquatic Habitat"

The state's aquatic life criteria for traditional pollutants and water quality parameters have identical or very similar criterion-concentration to comparable criteria issued by EPA and to those of neighboring states covered by this study.

EPA has adopted ecoregion- and waterbody type-specific WQC (the four parameters covered by the Agency's "nutrient criteria") applicable to the two ecoregions present in Kentucky, Ecoregion IX (Southeastern Temperate Forested Plains and Hills) and Ecoregion XI (Central and Eastern Forested Uplands); however, Kentucky has not. Hence, comparison of state criterion-concentrations to EPA's is not feasible.

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

Not Applicable. State has no "human health: fish consumption" criteria that are applicable to "traditional" pollutants.

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

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

Kentucky's DWS criterion-concentrations for chlorides, foaming agents and sulfate are the same as the concentrations in EPA's secondary drinking water standards for these pollutants. Kentucky's WQC for total dissolved solids (TDS) has a concentration of 750 mg/L while EPA's corresponding value is 500 mg/L. Comparison of Kentucky's and EPA's standards for color is confounded by the fact that Kentucky's criteria is expressed as "Pt/Co units," while EPA's is stated as "color units." It is unclear whether these are the same or different units – the value for KY is 75 and for EPA is fifteen.

As explained in the "Discussion: Traditional Parameters" section of this report, for several reasons, comparison of the concentration in a state drinking water supply criterion with the concentration in a EPA drinking water standard is not a reliable indicator of the relative degree of protection provided to drinking water consumers.

d) Water-based Recreation / "Primary" and "Secondary Contact Recreation"

The state's Primary Contact Recreation criteria for fecal coliform bacteria, which apply during the recreation season (May 1 to October 31), have the same criterion-concentration (400 organisms/100 ml for acute; 200 organisms/100 ml for chronic) as EPA's. There is no EPA criterion comparable to Kentucky's Secondary Contact Recreation criterion for fecal coliform of 2000 colonies/100 ml, though a number of states use this same criterion-concentration.

Kentucky has an acute criterion for *E. coli* with a criterion-concentration of 240 colonies/100 ml and a chronic criterion with a concentration of 130 colonies/100 mL. EPA has no acute criterion for *E. coli*; its chronic criterion has a concentration of 126 colonies/100 ml.

e) Agricultural Water Supply

Not Applicable. Kentucky has no WQC for "traditionals" specifically applicable to this use, nor is agricultural water supply a distinct use in the state's WQS regulations.

f) Industrial Water Supply

Not Applicable. Kentucky has no WQC for "traditionals" specifically applicable to this use, nor is agricultural water supply a distinct use in the state's WQS regulations.

3) *Articulation of Criterion-Duration*[21]

[21] According to terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an *"excursion"*—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as four day average concentrations. The occurrence of one or more *excursion* (e.g., a four-day period in which the instream

Most of Kentucky's WQC for traditional pollutants/parameters have some ambiguity associated with the criterion-duration

a) Aquatic Life / "Warm Water Aquatic Habitat" and "Cold Water Aquatic Habitat"

Acute criteria

Some of the state's acute aquatic life criteria are clearly stated as having a duration of just a moment/second/instant. For example, the right-most column in the table in 401 KAR5:031. Section 4.(b)(2) is labeled "instantaneous maximum."[22] Likewise, several of the state's dissolved oxygen criteria are expressed as "instantaneous minimum shall not be less than." The Kentucky acute ammonia criterion expresses an instantaneous duration in a slightly different manner: "The concentration of the unionized form shall not be greater than 0.05 mg/L at any time instream after mixing."

On the other hand, Kentucky has a number of criteria that appear to have a duration of an instant, though this is not as clear as in the previous examples. For example, several pH criteria are stated in this fashion: "shall not be less than 6.0 nor more-than 9.0." Some of Kentucky's criteria, for temperature are expressed in the following manner, "Temperature shall not exceed" In all these cases, there is no indication that the cited values are anything other than levels not to be surpassed for even a second/instant; hence, a default criterion-duration of "instantaneous" is employed in this report.

Chronic criteria

Kentucky's "general use" chronic aquatic life criteria for dissolved oxygen states "shall be maintained at a minimum concentration of 5.0 mg/l daily average." It is not clear whether the "day" in this case refers to a calendar day – any period between 12:00 AM to 11:59 PM – or to any contiguous 24-hour period.

"Acute/chronic" criteria

One of Kentucky's criteria for cold water aquatic habitat is stated, "Water temperatures shall not be increased through human activities above natural seasonal temperatures." There also is a pH criterion expressed as follows, "shall not fluctuate more than 1.0 pH unit over a period of twenty-four (24) hours." These are examples of what this study calls "quasi-numeric" criteria, ones expressed in terms of a certain change from background conditions. Unlike the case of typical numeric WQC, determination of whether such criteria have been exceeded requires knowledge of not only current but also past water quality but also past (or current concentration above and below a discharge or point of loading of pollutants to a waterbody). Also, the wording of such criteria provides no indication as to what duration(s) of time the "no change" standard is intended to apply. It would presumably apply to the overall natural background pattern of

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concentration, for example, of cyanide was higher than the criterion-concentration of 5.2 µg/L) would not necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedance of a water quality criterion occurred

[22]The values in this table are not criteria per se, but rather guidance values to be used in setting site-specific WQS.

temperature, over time and space. Hence, attention would need to be paid not only to the instantaneous minimum temperature levels, but also average temperatures over various periods of time (minutes, hours, days, etc.).

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

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

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

Kentucky presents all its criteria for DWS, for all types of pollutants, in Table 1 of Section 6 of 401 KAR 5:031. Nothing in the table or accompanying footnotes specifies a criterion-duration for the values listed under the heading "Human Health: DWS." However, 401 KAR 5:031, Section 5, titled "Domestic water supply" stipulates, "Maximum allowable in-stream concentrations for specific substances, to be applicable at the point of withdrawal for domestic water supply from surface waster sources, are specified in Table 1 of Section 6 and shall not be exceeded."

Although this language does not use language such as "instantaneous maximum," or "concentration not to be exceeded at any time" or any other clear statement of a criterion-duration of a second or less, it is deemed a valid basis for employing a default criterion-duration of "instantaneous" for use with the listed DWS criterion-concentrations.

d) Human Health: Water-Contact Recreation / "Primary" and "Secondary Contact Recreation"

One of Kentucky's criteria for fecal coliform bacteria is stated as "nor shall more than 20% of all samples collected in any 30 day exceed." The state has a criterion for *E. coli* stated in exactly the same fashion. The criterion-duration for these WQC would appear to be a second or instant. This is because of the reference to a percentage of samples. Most ambient monitoring for bacteria takes the form of "grab" sampling (collecting a series of single aliquots of water, by manual or mechanical means). It takes only a second to reach into the water and grab each of these individual measurements; hence, the assumption that the duration of concern is an instant/second.

Both EPA's and Kentucky's WQC have chronic criteria for fecal coliform and for *E. coli* pertaining to recreational use with a clearly stated criterion-duration of 30 days (e.g., "shall not exceed colonies per 100 mL as a geometric mean of samples taken during a thirty-day period").

e) Agricultural Water Supply

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

f) Industrial Water Supply

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

4) *Articulation of Criterion-Frequency*[23]

Kentucky has a criterion for ammonia that does contain a clearly stated criterion-frequency of zero: "The concentration of the unionized form shall not be greater than 0.05 mg/L at any time instream after mixing." It also has bacterial WQC with implicit criterion-frequencies of 20%.

However, the vast majority of Kentucky's WQC for traditional pollutants/parameters lacks a clearly stated criterion-frequency, in which case a default frequency of zero is indicated.

A criterion-frequency of once in ten years for the majority of Kentucky's WQC could possibly be inferred from text in 401 KAR 5:031, Section 3, which sets forth "Stream flows for water quality-based permits." For instance, subsection (3)(a), subsection (3)(b), and subsection 3(e) of the state's WQS regulations specify use of a low-flow $7Q_{10}$ parameter "if deriving KPDES permit limitations to protect surface waters for the listed uses: aquatic life . . . water-based recreation . . . and aesthetics." The low-flow $7Q_{10}$ parameter is the lowest seven-day average stream flow that occurs, on average, once in ten years. If water quality based effluent limits (WQBELs) are established in NPDES permits according to these instructions, then ambient WQC for a given pollutant should be met at all times when flows are at or above the low-flow $7Q_{10}$ – an event which should, by definition, happen at a long-term average rate of once-in-ten years. This would hold only if the only anthropogenic sources of a given pollutant to waterbody in question were classified as point sources, under the definition set forth in the federal CWA and attendant EPA regulations.

There is, however, no such reference to design flows (be it a $7Q_{10}$, or some other stream flow) regarding application of WQC for purposes of implementing other aspects of the water quality-based process set forth in the CWA, such as 303(d) list development and establishing total maximum daily loads (TMDLs). Nor is there any over-arching statement about WQC applying at all times except when stream flows are below a certain level. Hence, a default to a frequency of zero seems more consistent with the text of the Kentucky WQS regulations than does a frequency of once-in-ten years.

5) *Discussion: Traditional Parameters*[24]

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

[24] For purposes of this ELI report, "traditional pollutant/parameter" refers to a number of pollutants and water quality parameters that were recognized as significant contributors to and indicators of degradation of the condition of surface water well before passage of the Clean Water Act in 1972. As used in this study, "traditional pollutant" includes those pollutants/parameters referred to as "conventional" in the CWA and EPA regulations and guidance,

With regard to traditional pollutants, Kentucky has adopted numeric WQC for a relatively small portion of the pollutant/use combinations for which EPA has issued WQC or related standards, particularly with regard to aquatic life uses. EPA has issued such values for some two dozen of the traditional pollutants examined in this part of this report. For some of these parameters EPA has issued criteria for more than one use.

Most significant as to coverage for "traditionals, etc." pollutants is the absence of numeric criteria for nutrients (P or N) and the related parameter chlorophyll a. The algal blooms resulting from excess loadings of nutrients can no only result in harm to aquatic life, but also interfere with drinking water supply and water-based recreational uses. Likewise, Kentucky lacks numeric criteria for turbidity/suspended solids/suspended sediments.

Despite lacking numeric criteria relevant to nutrients and the resulting eutrophication, the state has included on its 303(d) list of impaired waters 118 units/segments for which "nutrients" are given as a cause of impairment, seven for "phosphorous, and fourteen for "algal growth." Also, Kentucky has identified "sediment" as the reason that 313 waters needed to be placed on its 303(d) list. This indicates that the state has been quite amenable to using one or more of its narrative WQC as the basis for 303(d) listings; nevertheless adoption of numeric criteria for total phosphorous, total nitrogen, chlorophyll a, suspended sediments and embedded sediments could still result in listing a substantial number of additional waters per Section 303(d) of the CWA. Nutrients and sediment/sedimentation/turbidity are among the five most frequently mentioned causes of impairment for waters on state 303(d) lists nationwide, along with pathogens, mercury, and metals other than mercury.[25]

There are three parameters – total coliform bacteria, odor, and pH – for which EPA has issued standards under the Safe Drinking Water Act but Kentucky has no Domestic Water Supply criteria. However, given that 1) EPA has not issued actual water quality criteria for public water supply use; 2) EPA's drinking water standards for all traditionals except pathogens apply to aesthetics of drinking water (appearance, taste, and odor) rather than health; and 3) all public water supplies serving more than 25 connections are covered by Safe Drinking Water Act regulations regarding finished (at the tap) drinking water, the lack of drinking water supply criteria for such pollutants and parameters probably has little relevance to human health. On the other hand, high levels of contaminants in raw water supplies can increase the cost of meeting federal drinking water standards.

A large majority of Kentucky's WQC for traditionals have criterion-concentrations identical, or very close to, those published by EPA and those adopted by the other nine states covered by this study. For example, pertaining to domestic water supply use, Kentucky's criterion-concentration for chlorides, foaming agents, and sulfates are the same as EPA's. The Kentucky criterion-concentration for TDS is 1.5 times that of EPA's corresponding value.

A significant portion of Kentucky's criterion-durations in the criteria for "traditionals, etc" are not clearly stated. Most of these are stated in such a manner as to imply a criterion-

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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."

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

duration of an instant, but don't make this entirely clear. This is the case for a number of acute aquatic life criteria and all of the criteria applicable to domestic water supply and water contact recreation. Most of EPA's WQC for traditionals suffer from this same lack of specificity. By contrast, there are several aquatic life criteria that are clearly labeled as "instantaneous maximum" concentrations, while a number of dissolved oxygen WQC are expressed as "instantaneous minimum" values.

Most of the state's WQC for traditionals lack a well articulated criterion-frequency. For example, those WQC stated in terms of "instantaneous" values would seem to have a frequency of zero, although this would have been clearer if they were stated as instantaneous values "never to be surpassed." On the other hand, some of Kentucky's bacterial WQC related to water contact recreation have strongly implied criterion-frequencies (e.g., 20% of the time).[26]

Turning to the matter of level of protection, in cases where both the state and EPA have a well articulated criterion-duration and criterion-frequency, one can draw reliable conclusions about the degree of protection associated with one criterion verses another. Unfortunately, there is not one traditional pollutant or water quality parameter for which both Kentucky and the federal EPA have a corresponding WQC that clearly specifies the criterion-concentration, criterion-magnitude, and criterion-frequency. Perhaps the closest examples are certain pathogen WQC. For instance, Kentucky has this WQC for fecal coliform bacteria applicable to waters designated Primary Contact Recreation: "No more than 20 percent of the samples . . . shall exceed a fecal coliform density of 400/100 mL." The corresponding EPA criterion reads, "nor shall more than 10% of the samples . . . exceed 400/100 mL." Because the concentrations are identical, as well as the apparent duration (instant), but Kentucky's WQC accepts a frequency of excursions[27] twice as high as the EPA WQC, the state's WQC provides a lower level of protection to swimmers.

But, in the more common situation, where neither the state nor the corresponding EPA WQC has a well specified criterion-duration and criterion-frequency, any attempt to determine the absolute level of protection afforded to the applicable designated use(s) is an exercise with an inherently high degree of uncertainty. Obviously, any attempt to perform such comparisons with insufficiently precise WQC would require making assumptions that may or may not turn out to be consistent with the duration and/or frequency intended, or eventually decided upon, by the state. In turn, the results of attempts to compare the protection provided by a state vs. an EPA would, of course, be greatly affected by whatever assumptions were made. Assumption of some fairly long-term duration (for instance, 90 days), rather than a short-term (e.g., one hour), would tend to make a criterion less protective. Likewise, assumption of a higher frequency (for

[26] Actually, the language in the Kentucky WQS regulations refers to a percentage of samples having bacterial having a bacterial density higher than a specified amount. For purposes of this report, this is assumed to imply that the state believes water contact uses will be protected if the concentration of the indicator bacteria (fecal coliform, *E. coli*) goes above the criterion-concentration no more than a specified percentage of the time. Technically, WQC expressed as a percentage of samples are not a water quality criteria because they describe the characteristics of a set of samples taken from a waterbody, rather than the desired condition of the waterbody itself. A true WQC would state something along the line of: "The density of E.coli in surface waters shall be higher than 240 colonies/100 ml. no more than 20% of the time." What is presented as a WQC appears to be more like a waterbody assessment methodology—a proscribed means of interpreting data collected from a waterbody in order to infer the true (but never completely knowable, with current technology) condition of the waterbody over time and space.

[27] As used in this report, and in some EPA guidance documents, an "excursion" is any period equal in length to the criterion-duration of a WQC when the average waterbody concentration is higher than the criterion-concentration.

example, once in six months), rather than a lower frequency (e.g., once in five years) would have the same effect – more protective than if the alternative were the case.

For example, if a state and EPA criteria have identical durations and frequencies (most likely duration of instantaneous and frequency of zero, in the case of aquatic life WQC for traditional parameters), then comparison of state and EPA criterion-concentrations would provide a relatively good indicator of comparative levels of protection provided. If such assumptions were indeed reliable, then given the fact that most of Kentucky's WQC for traditionals applicable to aquatic life have criterion- concentrations identical to, or very close to, those in corresponding EPA WQC, then the state's WQC should provide essentially the same protection as would EPA's.

If, on the other hand, a state WQC had a shorter criterion-duration and a lower acceptable frequency of excursions, then any criterion with a criterion-concentration equal to or lower than that of the EPA WQC would definitely provide a higher level of protection to the relevant use(s). There are no such examples in Kentucky's WQC for traditionals. A related situation is one where the WQC being compared have identical criterion-concentrations and criterion-frequencies, but different criterion-durations. For example, both Kentucky's Domestic Water Supply criteria and EPA's standards for finished drinking water (established under authority of the federal Safe Drinking Water Act) are expressed in a manner that implies an acceptable frequency of excursions of zero. And, the criterion-concentrations of Kentucky's domestic water supply WQC are identical to the concentrations in EPA's (finished) drinking water standards. On the other hand, the state's WQC for domestic water supply are worded so as to imply a duration of just an instant, whereas compliance with federal drinking water standards under the Safe Drinking Water Act is measured in a way that, de facto, establishes a duration of an entire year (four consecutive calendar quarters). If the interpretations the durations and frequencies of state and EPA criteria and standards related to drinking water employed in this report are correct, then the much shorter duration of the state WQC compared to the EPA standard would appear to make the state's criterion considerably more protective than EPA's.

Comparison of a state's water quality criteria to EPA's drinking water standards is further confounded by the fact that water quality criteria apply to the raw, untreated water from a river or lake that is used as a raw water supply for a public drinking water system, while EPA's standards apply to drinking water at the tap, which usually has undergone some form of treatment to remove contaminants. Hence, a drinking water supply WQC with a concentration higher than that specified in a drinking water standard could actually provide equal, or even greater, protection to consumers of finished drinking water, if the drinking water treatment process succeeded in removing a significant percentage of the contaminant found in the raw drinking water supply. Along the same lines, in cases like Kentucky, where the state's WQC for (raw) water supply appears to be more protective than the federal standards for finished drinking water (concentration and frequency for the state and EPA drinking are identical and/or the state's duration is shorter), then the extra protection resulting from attainment of the state's WQC in the raw water supply would, for most contaminants, be enhanced by the reductions in contaminant levels resulting from traditional drinking water treatment systems.

As for a state WQC with a 1) higher criterion-concentration, 2) shorter criterion-duration, and 3) lower criterion-frequency, it would be hard to determine, without performing additional laboratory studies, whether the state WQC was more or less protective than the EPA criterion. That is, to what degree would the less-protective effect of the higher concentration be offset by the more protective effects of a shorter duration and lower frequency? Appendix C contains three

tables showing different combinations of relative criterion-concentrations, criterion-durations and criterion-frequencies, in terms of what can, or cannot, be said about the relative degree of protection.

Also, with regard to aquatic life WQC, there could be state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still provide aquatic life protection equal to that for which the EPA WQC were designed.[28] Of course, if the criterion-duration and criterion-frequency for a state and corresponding EPA criteria are the same (for instance, a duration of 24 hours and a frequency of zero) and the state's criterion-concentration for a pollutant[29] were higher than EPA's, then the state's criterion would indeed provide less protection to aquatic organisms in the waterbody or set of waterbodies than would EPA's, in relative terms. However, due to site-specific or watershed-specific conditions, the state's WQC could provide not only the same absolute level of protection as that for which the EPA WQC were designed, while use of the recommended EPA WQC in such waters would actually provide *greater* protection than that which EPA intended.

The only two water quality parameters for which Kentucky has aquatic life WQC with criterion-concentrations that differ among categories of waters are dissolved oxygen and temperature. As for dissolved oxygen, there are, in essence, distinct WQC for each of three categories of waters: 1) cold water aquatic habitats in general, 2) lakes and reservoirs that support trout, and 3) warm water aquatic habitat. There also is a specific WQC for the mainstem of the Ohio River. The WQC for temperature assigned to two large categories of waters: 1) warm water aquatic habitat, and 2) cold water aquatic habitat. (Also, for both dissolved oxygen and temperature, different WQC can apply at different times of the year.)

For example, Kentucky has a dissolved oxygen WQC for warm water aquatic habitat with a criterion-concentration of 4.0, a duration of an instant. EPA has issued only one dissolved oxygen WQC for inland fresh waters, with a criterion-concentration of 5.0. Unlike the corresponding state WQC, federal EPA's doesn't clearly specify a criterion-duration; hence a duration of an instant is assumed. Neither WQC mentions a criterion-frequency, so a frequency of zero is assumed. With these assumptions, we have state and EPA WQC with identical durations and identical frequencies, while the state has a lower dissolved oxygen criterion-concentration. Clearly, if the EPA WQC, with its criterion-concentration of 5.0, were applied to any given waterbody, it would likely provide greater protection than the WQC with a criterion-concentration of 4.0 mg/L. If indeed the natural level of dissolved oxygen goes down to, but never below, 4.0 mg/L, then the aquatic organisms in that environment would evolve to gain the ability to live and reproduce in such conditions. Hence, application of a criterion for dissolved oxygen of "instantaneous concentration shall at no time go below 5.0 mg/L" would likely provide not only greater protection than the state WQC with the lower dissolved oxygen concentration. But also an even higher level of protection than that for which EPA designed its WQC. The effect of the state's lower criterion-concentration of dissolved oxygen would be to bring the level of protection back down to that intended by EPA.

Turning to human health, site-specific factors generally play less of a role with regard to safe levels of pollutants than they can with aquatic life. One reason is that human health criteria

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

[29] In the case of dissolved oxygen, WQC with higher criterion-concentrations provide a higher (rather than lower) degree of protection, all other factors being equal.

address impacts on just one species, regardless of the location of the waterbody to which the WQC apply, while differences in the assemblage of species of animals and plants native to one waterbody to another is quite common. What often does change from one place to another is the pattern of human use. For example, persons in hotter climates tend to consume more water, on average, than those in cooler areas; in which case, the criterion-concentration would need to be lower in the warmer region, to offset the effect of the greater volume consumed, in order to keep the mass of the pollutant consumed per unit time the same. 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 locale to locale and/or within subpopulations of humans in a given place. Likewise, 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, or wetland). Hence, Kentucky has one fecal coliform criteria for Whole Body Contact Recreation (criterion-concentration of 200 colonies/100 mL) and another for Secondary Contact Recreation (criterion-concentration of 2000 colonies/100 mL). The lower criterion-concentration of the WQC applicable to waters designated for swimming and other forms of Whole Body Contact Recreation compensates for the fact that those using these waters in this way are exposed to pollutants for a considerably longer time than those who engage in Secondary Contact Recreation.

Returning to problems associated with imprecisely stated criterion-durations and criterion-frequencies, these can render considerably more challenging the implementation of CWA programs that are driven largely by WQC (Section 303(d) and 305(b) assessment and reporting, TMDLs, and water quality-based NPDES permitting programs). Clearly, it would be difficult for someone implementing one of these "downstream" CWA programs to deal with a WQC having a criterion-concentration reading, "not too high" or "levels no greater than approximately 40 µg/L - 60 µg/L."

Though perhaps less immediately obvious, imprecisely stated criterion-durations and criterion-frequencies can pose similar challenges to those presented by missing or vaguely stated criterion-magnitudes. For example, if over some 30-day period, four grab samples had been collected, analyzed for levels of a certain pollutant, passed through the state's quality assurance/quality control protocol, and one of those samples had a concentration higher than a relevant criterion-concentration, the answer to the question "Was this pollutant exceeded this WQC?" would differ depending on the criterion-duration and criterion-frequency. If the duration were instantaneous and the frequency zero, the WQC would have been exceeded, without question. But, if the duration were 30 days and the frequency remained at zero, the mere fact that one out of four instantaneous measurements surpassed the criterion concentration would not prove that an exceedance 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 exceedance of WQC in the water from which said samples were collected. And, if the criterion-frequency were "two or more times per year," then one might not conclude that WQC exceedance had occurred based on the above evidence.[30]

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

D. Toxic Chemicals[31]

1) *Coverage*

a) Aquatic Life / "Warm Water Aquatic Habitat" and "Cold Water Aquatic Habitat"

Acute Toxicity

The state has established acute aquatic life WQC for 28 toxic substances. Out of the 31 toxic pollutants for which EPA has issued[32] acute criteria for freshwater aquatic life, Kentucky has not adopted corresponding criteria for four pollutants: aluminum, diazinon, tributyltin, and nonylphenol. On the other hand, the state has adopted an acute aquatic life criterion for iron while EPA has not.

Chronic Toxicity

Out of the 35 toxic pollutants for which EPA has issued chronic criteria for freshwater aquatic life, Kentucky has not adopted corresponding for four pollutants: aluminum, diazinon, tributyltin, and nonylphenol. On the other hand, the state has adopted a chronic aquatic life criterion for phthalate esters while EPA has not.

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

The state has adopted Human Health: Fish Consumption WQC for a total of 103 toxic substances. Kentucky has not adopted Human Health: Fish Consumption criteria for only four out of the total 106 pollutants for which the EPA has issued corresponding HHO criteria: arsenic, di-n-butyl phthalate, manganese, and methylmercury. On the other hand, the state has adopted a "human health: fish consumption" criterion for mercury[33] while EPA has not.

c) "Human Health: Consumption of Water and Organisms"

Kentucky has not adopted human health criteria that are directly comparable to Human Health: Consumption of Water and Organisms (HHWO) criteria adopted by EPA.

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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).

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

[32] Throughout this report, the criteria recommended by EPA are referred to as the EPA's "issued" or "published" criteria, interchangeably.

[33] While EPA does not have a criterion for "mercury" as does Kentucky, it has issued a "Human Health: Organisms Only" WQC for methyl mercury. For purposes of this report, these are counted as different pollutants. Because of this, "methyl mercury" is included in the list of pollutants for which Kentucky does not have HHO criteria, while mercury is on the list of "extra" criteria.

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

Kentucky has adopted Human Health: Domestic Water Supply criteria for 119 pollutants. Absent language in the state's WQS regulations indicating clearly that this set of criteria is intended to protect for any other water use besides domestic water consumption, it is assumed, for the purposes of this review, that Kentucky's Human Health: Domestic Water Supply criteria are somewhat comparable[34] to the primary or secondary drinking water quality criteria that EPA has issued pursuant to the Safe Drinking Water Act (SDWA).

Of the 119 pollutants for which Kentucky has adopted Human Health: Domestic Water Supply criteria, there are 68 pollutants for which EPA has not issued primary or secondary drinking water quality criteria (Appendix B, Table 4). On the other hand, there are 30 pollutants for which EPA has issued MCL values and for which Kentucky has not adopted any "human health: domestic water supply" criterion (Appendix B, Table 3).

e) Human Health: Water-contact Recreation / "Primary" and "Secondary Contact Recreation"

Not Applicable. Kentucky has not adopted any primary or secondary contact recreation WQC for toxic pollutants; neither has EPA.

f) Agricultural Water Supply

Not Applicable. Kentucky has not adopted any "agricultural water supply" WQC for toxic pollutants; neither has EPA.

g) Industrial Water Supply

Not Applicable. Kentucky has not adopted any "industrial water supply" WQC for toxic pollutants; neither has EPA.

2) *Criterion-Concentrations,[35] Compared to EPA's*

a) Aquatic Life / "Warm Water Aquatic Habitat" and "Cold Water Aquatic Habitat"

Acute Toxicity

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

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

Of the 28 toxic pollutants for which Kentucky has adopted acute freshwater aquatic life WQC, 26 pollutants have WQC that correspond to EPA's recommended WQC.[36] Within this subset, nineteen pollutants have acute freshwater aquatic life WQC for which the criterion-concentrations are the same as the corresponding EPA values; and seven pollutants have WQC for which the criterion-concentrations are higher than the corresponding EPA values (Appendix B, Table 2).

Chronic Toxicity

Of the 32 toxic pollutants for which Kentucky has adopted acute freshwater aquatic life WQC, 31 pollutants have WQC that correspond to EPA's recommended WQC.[37] Within this subset, the chronic freshwater aquatic life criteria for 23 pollutants have the same criterion-concentrations as the corresponding EPA values; and eight pollutants have WQC for which the criterion-concentrations are higher than the corresponding EPA values (Appendix B, Table 2).

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

Of the 103 pollutants for which Kentucky has adopted Human Health: Fish Consumption criteria, 102 pollutants have WQC that correspond to the EPA's Human Health: Fish Consumption criteria.[38] Within this subset, the Human Health: Fish Consumption criteria for 82 pollutants have the same criterion-concentrations as the corresponding EPA values; five pollutants have WQC for which the criterion-concentrations are lower than the corresponding EPA values (Appendix B, Table 2); and fifteen pollutants have WQC for which the criterion-concentrations are higher than the corresponding EPA values (Appendix B, Table 2).

c) "Human Health: Consumption Water and Organisms"

Not Applicable. Kentucky has not adopted human health criteria that are directly comparable to "Human Health: Consumption of Water and Organisms" (HHWO) criteria adopted by EPA.

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

Of the 119 toxic pollutants for which Kentucky has adopted Human Health: Domestic Water Supply Source criteria, there are 51 pollutants[39] for which there are somewhat corresponding[40]

[36] The other two pollutants are iron and selenium. For iron, a EPA acute aquatic life criterion has not been issued. For selenium, the EPA criterion is expressed in the form of an equation and because the Agency is in the process of developing a more stringent criterion for selenium, direct quantitative comparison of EPA's selenium WQC to Kentucky's selenium WQC was not undertaken in this review.
[37] Kentucky has adopted a chronic aquatic life criterion for phthalate esters while EPA has not issued such criteria.
[38] Kentucky has adopted a "human health: fish consumption" criterion for phthalate esters while EPA has not.
[39] The other 68 contaminants are those for which EPA has not issued MCL values.
[40] The term "somewhat corresponding" has been used because water quality criteria and drinking water standards apply to different endpoints. WQC apply to surface waters within the jurisdiction of the Clean Water Act (CWA). Some of these waters are, or might be, used as a source of "raw" water by public and private drinking water systems.

maximum contaminant level (MCL) National Primary Drinking Water Quality Standards that EPA has issued pursuant to the Safe Drinking Water Act (SDWA). Within this subset, the criterion-concentrations in Kentucky's Human Health: Domestic Water Supply criteria for 25 pollutants are lower than, for twelve pollutants are higher than, and for fourteen pollutants are equal to EPA's MCL values.[41]

e) Human Health: Water-contact Recreation / "Primary" and "Secondary Contact Recreation"

Not Applicable. Kentucky has not adopted any water-based recreation criteria covering toxic pollutants.

f) Agricultural Water Supply

Not Applicable. Kentucky has not adopted any criteria covering toxic pollutants pertaining to "agricultural water supply" as a designated use; neither has EPA.

g) Industrial Water Supply

Not Applicable. Kentucky has not adopted any criteria covering toxic pollutants pertaining to "industrial water supply" as a designated use; neither has EPA.

3) *Articulation of Criterion-Durations*[42]

Hence, when a waterbody in Kentucky is designated Domestic Water Supply then a certain set of WQC apply to said river or lake, per the CWA. There also is another set of standards that apply to the "finished" water that results from raw water from a river or lake being run through treatment processes aimed at removing contaminants. These are called Drinking Water Standards, and are established as national regulations under authority of the SDWA. They are often referred to as "maximum contaminant levels" (MCLs). Another difference between Domestic Water Supply water quality criteria and EPA's SDWA standards pertaining to waterborne pathogens is that the former are expressed in terms of fecal coliform bacteria, while the latter employ the more encompassing grouping total coliform bacteria as the indicator parameter.

[41] Though Kentucky's Human Health: Domestic Water Supply WQC also do not correspond directly to EPA's human health criteria for consumption of water and fish combined (Human Health: Water and Organisms (HHWO)), it is interesting to note that the criterion-concentration in the majority of Kentucky's "Human Health: Domestic Water Supply" criteria are the same as the criterion-concentrations in EPA's HHWO criteria. Indeed, of the pollutants for which both a Kentucky "Human Health: Domestic Water Supply" criterion and a EPA "human health: water and organisms" criterion exist, 77% have criteria for which the criterion-concentrations adopted by Kentucky are equal to the criterion-concentration published by EPA. The pollutants for which one would expect EPA HHWO WQC to have lower criterion-concentrations lower than the state's Domestic Water Supply WQC are persistent bioaccumulative pollutants, because the incremental intake of such pollutants due to consumption of fish would be quite substantial. Hence, in order to compensate for the effects of this pathway, in addition to drinking water, the concentration of the pollutant in the ambient water would need to be lower, in order to provide the intended level of protection.

[42] According terminology employed in some EPA guidance, the criterion-duration portion of a numeric WQC specifies the length of an "excursion"—the time period over which waterbody concentration of a pollutant is higher (or in the case of dissolved oxygen, lower) than the criterion-magnitude. For instance, EPA's chronic aquatic life WQC for toxic chemicals have a criterion-duration of four days, which results in their being expressed as 4 day average concentrations. The occurrence of one or more *excursion* (e.g., a four day period in which the instream concentration, for example, of cyanide was higher than the criterion-concentration of 5.2 µg/L) would not

None of Kentucky's WQC for toxic chemicals has a clearly stated criterion-duration.

a) Aquatic Life / "Warm Water Aquatic Habitat" and "Cold Water Aquatic Habitat"

Neither the acute or chronic criteria for protecting aquatic life against adverse effects from toxic chemicals are clearly stated. Section 4(1)(j)(5) of KY's WQS regulations states, "Allowable instream concentrations for specific pollutants for the protection of warm water aquatic habitat are listed in Table 1 of Section 6 of this Administrative Regulation. These concentrations are based on protecting aquatic life from acute and chronic toxicity and shall not be exceeded." This language would seem to indicate that neither the acute nor chronic criterion-concentrations should be surpassed for even a moment, at any time. This reading would, however, not be consistent with biology/toxicology, not to mention the plain-English meaning of "acute" and "chronic." That is, the criterion-duration for an acute criterion for a given pollutant/use combination should always cover a shorter span of time than would the chronic criterion. The definitions of "acute" and "chronic" criteria provided in Kentucky's WQS regulations reflect this basic reality:

> "Acute criteria mean the highest instream concentration of a toxic substance to which an organism can be exposed for a brief period of time without causing an unacceptable harmful effect." 401 KAR 5:002 Section 1 (4)
>
> "Chronic criteria mean the highest instream concentration of a toxic substance to which an organism can be exposed indefinitely without causing an unacceptable harmful effect." 401 KAR 5:002 Section 1 (48)

Unfortunately, the terms "brief period" and "indefinitely" provide little in the way of a precise delineation of a criterion-duration.

Acute criteria

Based on the "not to exceed" language in 401 KAR 5:031, Section 4(1)(j)(5), the criterion-duration for Kentucky's acute aquatic life criteria for toxic substances is taken to be an instant for the purposes of this study.

Chronic criteria

As noted above, the only direct indication of a duration of time in which the criterion-concentrations for chronic effects on aquatic life would apply is the broad term "indefinitely." One reading of "indefinite" would render the criterion-duration to be the long-term average concentration of a pollutant in a given waterbody. This, in turn, would make the criterion-concentration differ from water to water, depending on the length of time over which data happened to have been collected. Such de-facto variation in the criterion-duration for a given WQC from one location to another does not seem consistent with basic physiology/toxicology.

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necessarily represent failure to meet WQC. Only when the rate at which excursions occur is higher than that specified by the criterion-frequency has an actual exceedance of a water quality criterion occurred.

Another possibility would be to infer that the criterion-duration for the chronic aquatic life WQC was supposed to be 96 hours, based on the following excerpt from Sec.4(1)(j)1:

> "The allowable instream concentration of toxics substances . . . which are noncumulative or non persistent with a half-life of less than 96 hours, shall not exceed:
>
> a. One-tenth (O.1) of the ninety-six hour median lethal concentration (LC_{50}) if representative indigenous or indicator aquatic organisms;" or
>
> b. A chronic toxicity unit of 1.00 utilizing the 25 percent inhibition concentration, or LC_{25}." [43]

Though this language is expressed in terms of lethal concentrations (LC) and toxicity units – as opposed to a pollutant concentration – the mention of chronic toxicity, as well as the repeated reference to 96 hours, could be taken to infer that the criterion-duration for chronic aquatic life criteria for toxic substances is intended to be 96 hours. 96 hours also happens to the criterion-duration for EPA's chronic aquatic life criteria for toxics.

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

Kentucky presents all of its criteria for Human Health: Fish Consumption for toxics and other types of pollutants in Table 1 of Section 6 of 401 KAR 5:031. Nothing in the table or accompanying footnotes specifies a criterion-duration for the values listed under the heading "Human Health: Fish." Absent any reference to a time period of greater than a second, or fraction thereof, this study employs a default criterion-concentration of "instantaneous maximum.

c) "Human Health: Consumption Water and Organisms"

Not Applicable. It does not appear that Kentucky has adopted human health criteria that are directly comparable to "Human Health: Consumption of Water and Organisms" (HHWO) criteria adopted by EPA.

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

Kentucky presents all its criteria for DWS, for all types of pollutants – including toxics – in Table 1, appearing in Section 6 of 401 KAR 5:031. Nothing in the table or accompanying footnotes specifies a criterion-duration for the values listed under the heading "Human Health: DWS." However, 401 KAR 5:031, Section 5, titled "Domestic water supply" stipulates, "Maximum allowable in-stream concentrations for specific substances, to be applicable at the point of withdrawal for domestic water supply from surface waster sources are specified in Table 1 of Section 6 shall not be exceeded." Although this language does not use "instantaneous maximum," "concentration not to be exceeded at any time" or any other clear statement of a criterion-duration of a second or less, it is deemed a valid basis for employing a default criterion-duration of "instantaneous" for use with the listed DWS criterion-concentrations.

[43] Virtually identical language appears in Sec. 4(1)(j)2.b, regarding bioaccumulative or persistent chemicals, except one-one hundredth (0.01) of the 96 hour LC50 is specified as the acceptable level.

e) Human Health: Water-contact Recreation / "Primary" and "Secondary Contact Recreation"

Not Applicable. Kentucky has not adopted any water-based recreation criteria covering toxic pollutants.

f) Agricultural Water Supply

Not Applicable. Kentucky has not adopted any criteria covering toxic pollutants pertaining to "agricultural water supply" as a designated use; neither has EPA.

g) Industrial Water Supply

Not Applicable. Kentucky has not adopted any criteria covering toxic pollutants pertaining to "industrial water supply" as a designated use; neither has EPA.

4) *Articulation of Criterion-Frequency*[44]

None of Kentucky's numeric WQC for toxic chemicals have a clearly stated criterion-frequency. In the absence of such specificity in the state's WQS regulations, this study employs a default criterion-frequency of zero.

A criterion-frequency of once in ten years for both acute and chronic aquatic life criteria for toxics could be possibly be inferred from text in 401 KAR 5:031, Section 3, which sets forth "Stream flows for water quality-based permits." For instance, subsection (3)(a) of the Kentucky WQS regulations specifies use of a low-flow $7Q_{10}$ parameter "if deriving KPDES permit limitations to protect surface waters for the listed uses: aquatic life." The low-flow $7Q_{10}$ parameter is the lowest seven day average streamflow that occurs, on average, once in ten years. If water quality-based effluent limits (WQBELs) are established in NPDES permits according to these instructions, then ambient WQC for a given pollutant should be met at all times when flows are at or above the low-flow $7Q_{10}$ – an event which should, by definition, happen at a long-term average rate of once-in-ten years. This would hold only if the only anthropogenic sources of a given pollutant to waterbody in question were classified as point sources, under the definition set forth in the federal CWA and attendant EPA regulations.

401 KAR 5:031, Section 3 (3) also provides instructions for NPDES permit writers pertaining to application of human health water quality criteria in setting WQBELs. According to subsection (3)(c)(2), the low-flow $7Q_{10}$ should be employed when setting permit limits based on Domestic Water Supply criteria for "non-cancer-linked substances." Using the logic set forth in the previous paragraph, a criterion-frequency of once-in-ten years could be inferred from this language.

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

401 KAR 5:031, Section 3 (3)(c)(1) and Section 3(3)(d) call for using the "harmonic mean" stream flow for setting WQBELs in NPDES permits based on 1) DWS criteria for "cancer-linked substances" and, 2) "Human health protection from fish consumption," respectively. This text still leaves unanswered the question, "Harmonic mean flow over what length of time?" In the context of implementation of the Clean Water Act across the country, "harmonic mean flow" most often applies to a period of a year or longer. This interpretation suffers from being essentially open-ended, and would result in the criterion-duration for a given WQC varying from waterbody to waterbody, depending on the length of time over which streamflow data has been collected on a given waterbody/assessment unit. Such de-facto variation for a given WQC would, unfortunately, seem inconsistent with basic physiology/toxicology.

Furthermore, though there is such language regarding stream design flows to be utilized in the NPDES program, there is, no such reference to design flows regarding application of WQC for purposes of implementing other aspects of the water quality-based process set forth in the CWA, such as 303(d) list development and establishing total maximum daily loads (TMDLs). Nor is there any over-arching statement about WQC applying at all times except when stream flows are below a certain level.

Hence, for the purposes of this report, a default to a frequency of zero seems more consistent with the actual text of the Kentucky WQS regulations.

5) ***Discussion: Criteria for Toxic Chemicals***

Kentucky has adopted water quality criteria for a substantial number of toxic pollutants to protect aquatic life in warm water habitats. Indeed, Kentucky's WQS regulations have specified criteria for 90% of the pollutants for which EPA has published aquatic life criteria, lacking equivalents to EPA's aquatic life criteria for only four pollutants (aluminum, diazinon, tributyltin, and nonylphenol).

With regards to human health criteria, Kentucky has adopted criteria for a large number of toxic pollutants to address risks associated with human consumption of fish and to protect drinking water from domestic water sources. Lacking Human Health: Fish Consumption criteria for only four pollutants (arsenic, di-n-butyl phthalate, manganese, and methylmercury[45]), the state has adopted Human Health: Fish Consumption criteria for 96% of the pollutants for which EPA has published corresponding criteria. Kentucky has also adopted Human Health: Domestic Water Supply criteria for a large number of pollutants; 119 to be exact. However, only 42% of these pollutants have maximum contaminant level (MCL) values that EPA has issued pursuant to the Safe Drinking Water Act (SDWA). And while having adopted "human health: domestic water supply source" criteria for 68 "extra" pollutants, there are 30 pollutants for which the state lacks Human Health: Domestic Water Supply Source criteria. Of these 30 pollutants without Human Health: Domestic Water Supply Source criteria, many of which are widely used herbicides (e.g., endothall, diquat, dalapon, simazine, alachlor, etc.).

The criterion-concentrations in all of Kentucky's aquatic life criteria are either equal to or only slightly higher than the criterion-concentrations in the corresponding EPA criteria. The criterion-concentrations in most of Kentucky's Human Health: Fish Consumption criteria are

[45] EPA's criterion for mercury is expressed as methylmercury levels in fish tissue. Kentucky's criterion is for mercury in the water column. This difference has been noted in this report by crediting the state with an extra "mercury" WQC and a missing "methyl mercury" WQC.

equal to the criterion-concentrations in the corresponding EPA criteria (Human Health: Organisms(HHO)). There are fifteen criteria with criterion-concentrations that are higher than the corresponding EPA values and five criteria with criterion-concentrations that are higher than the corresponding EPA values. Of the 119 pollutants for which Kentucky has adopted "Human Health: Domestic Water Supply Source" criteria, there are 51 pollutants[46] for which there are somewhat corresponding[47] maximum contaminant level (MCL) values in National Primary and Secondary Drinking Water Quality Standards that EPA has issued pursuant to the Safe Drinking Water Act (SDWA). Within this subset, the criterion-concentrations in Kentucky's Human Health: Domestic Water Supply criteria for 25 pollutants are lower than, for twelve pollutants are higher than, and for fourteen pollutants are equal to EPA's MCL values.

As for specification of a criterion-duration, none Kentucky's WQC for toxic chemicals articulate a duration. In the case of aquatic life criteria, for purposes of this report, a criterion-duration of an instant is assumed for acute criteria and a criterion-duration of four days (96 hours) is assumed for chronic WQC. As for both the Kentucky Human Health: Fish Consumption and the human health Domestic Water Supply criteria, a default to a criterion-duration of an instant is assumed.

Likewise, articulation of a criterion-frequency is missing for all of Kentucky's WQC, for both aquatic life and human health protection. Consequently, a criterion-frequency of zero is assumed for all Kentucky WQC for toxics.

Given that none of Kentucky's numeric aquatic life WQC for toxic chemicals have clearly stated criterion-durations or clearly stated criterion-frequencies, directly comparing the state's criterion-concentrations to those of EPA's is not a reliable means of determining the relative protectiveness of their water quality criteria. However, if one assumes, for discussion purposes, that the criterion-durations and criterion-frequencies for Kentucky's aquatic life WQC are the same as those for EPA's aquatic life criteria (acute criterion-duration of one hour, once in three years; chronic duration of 96 hours, once in three years), then it would be reasonable to conclude that those seven Kentucky acute aquatic life criteria having higher criterion-concentrations than EPA's are less protective than EPA's,[48] while those nineteen criteria having criterion-concentrations that are identical to EPA's are as protective as EPA's criteria. Likewise, those eight Kentucky chronic aquatic life WQC with criterion-concentrations higher than those of the federal EPA's chronic aquatic life WQC for the same pollutant would provide less

[46] The other 68 contaminants are those for which EPA has not issued MCL values.

[47] The term "somewhat corresponding" has been used because water quality criteria and drinking water standards apply to different endpoints. WQC apply to surface waters within the jurisdiction of the Clean Water Act (CWA). Some of these waters are, or might be, used as a source of raw water by public and private drinking water systems. Hence, when a waterbody in Kentucky is designated Domestic Water Supply then a certain set of WQC apply to said river or lake, per the CWA. There also is another set of standards that apply to the "finished" water that results from raw water from a river or lake being run through treatment processes aimed at removing contaminants. These are called Drinking Water Standards, and are established as national regulations under authority of the SDWA. They are often referred to as "maximum contaminant levels" (MCLs). Another difference between Domestic Water Supply water quality criteria and EPA's SDWA standards pertaining to waterborne pathogens is that the former are expressed in terms of fecal coliform bacteria, while the latter employ the more encompassing grouping total coliform bacteria as the indicator parameter.

[48] However, there could be state-specific, watershed-specific, or even waterbody-specific reasons that a state criterion can have a criterion-concentration higher that for the corresponding EPA criterion and still be equally protective of aquatic life. Possible reasons include differences in waterbody chemistry and in species present in a given type of aquatic ecosystems, compared to what were used in the studies on which EPA's criteria were based.

protection than those of EPA, while an equal level of protection would be provided by the 23 Kentucky chronic WQC with criterion-concentration's equal to EPA's.

However, as noted previously, Kentucky's WQS regulations make no mention of a criterion-frequency for its aquatic life WQC. Hence, the assumption most likely to be consistent with the language (or lack thereof) in the state's regulations would be a criterion-frequency of zero, rather than the somewhat higher frequency of once in three years that applies to EPA's aquatic life WQC for toxics. Likewise, though the state does articulate a four day (96 hour) duration for its chronic aquatic life WQC, the language of its regulation strongly implies a criterion-duration of only an instant – a significantly lower unit of time than the one hour duration specified in EPA's acute aquatic life WQC.

The effect of assuming a criterion-frequency of zero for the state's acute and chronic WQC is a tendency for the state's WQC for a given toxic pollutant to be more protective than the corresponding (acute and/or chronic) EPA WQC, because the state's WQC accepts a lower frequency of excursions[49] (none) than do the WQC of the federal EPA (one in three years). Likewise, assumption of a criterion-duration of an instant for the Kentucky acute aquatic life WQC inclines the state's acute aquatic life WQC toward greater protection, because it's WQC apply to a shorter time of exposure (a second or less) than the corresponding EPA WQC (one hour, i.e., 3600 seconds).

Based on the assumptions in the previous paragraph, all of the state's nineteen acute aquatic life WQC with criterion-concentrations identical to those of the corresponding EPA WQC would afford a higher level of protection to aquatic animals and plants than would the federal agency's WQC (same concentration, state duration shorter, state frequency lower). And even though Kentucky's chronic WQC for aquatic life have the same criterion-duration (four days/96 hours), these state WQC with criterion-concentrations identical to EPA's would provide a higher level of protection than the corresponding EPA WQC (same concentration, same duration, but the state frequency is lower).

More difficult to determine would be the relative protectiveness of those Kentucky aquatic life WQC with criterion-concentrations higher than those in the corresponding EPA criteria, seven acute and eight chronic. In theory, the considerably shorter criterion-duration and lower criterion-frequency of a given state acute aquatic life WQC for toxics could offset the somewhat higher criterion-concentration, making the state criterion the more protective. Careful analysis of available, and perhaps newly generated, toxicity data would be needed to determine whether this was the case, or whether the two WQC were equally protective, or even that the EPA WQC was more protective. The same would be true with regard to Kentucky's chronic aquatic life criteria for toxics: with the criterion-durations identical (four days/ 96 hours), would the less protective effect of the state's higher criterion-concentration be offset by its lower criterion-frequency?

There could also be state-specific, watershed-specific, or even waterbody-specific reasons that a state aquatic life criterion can have a criterion-concentration higher or lower than that for the corresponding EPA criterion and still be equally protective of aquatic life.[50] Kentucky has not, however, developed any such WQC for toxics; the same criterion-

[49] As used in this report, and in some EPA guidance documents, an "excursion" is any period equal in length to the criterion-duration of a WQC when the average waterbody concentration is higher than the criterion-concentration.

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

concentration for a given pollutant/designated use combination applies throughout the state, except for the criteria for certain heavy metals, which, like the EPA WQC for these pollutants, vary according to the hardness of the water in a given waterbody.

Turning to the protection of human health from adverse effects of toxics chemical provided by Kentucky's WQC in comparison to corresponding EPA WQC, such comparison cannot be made with a high degree of confidence because both the state and EPA have not clearly specified a criterion-duration or criterion-frequency for these sets of WQC. Nonetheless, likewise, if one assumes, for discussion purposes, that the criterion-durations and criterion-frequencies for Kentucky's Human Health: Fish Consumption criteria are the same as those of EPA's, whatever they might be, then it would be reasonable to conclude that those fifteen Kentucky Human Health: Fish Consumption criteria having criterion-concentrations higher than EPA's are less protective than EPA's, those fifteen WQC having criterion-concentrations lower than EPA's are more protective than EPA's, and those 80 criteria having criterion-concentrations that are equivalent to EPA's are as protective as EPA's. This would then suggest that most of Kentucky's Human Health: Fish Consumption criteria are as protective as EPA's, while some are less protective and a few are more protective.

Another point regarding the degree of protection provided by the state's Fish Consumption criteria is that EPA's human health criteria dealing with fish consumption (HHO and HHWO) assume a per-person daily intake of 17.5 grams of fish and other aquatic organisms. This estimate is based on national data, and represents the average rate of fish consumption. However, there are subpopulations that consume locally-caught fish at considerably higher rates. Native Americans, immigrants from Southeast Asia, and low income persons of all ethnic racial backgrounds are widely-recognized examples. For such subsistence fisherpersons, the EPA estimates that the fish consumption rate can be as high as ten times the 17.5 g/day national average. Since, for virtually all the toxics for which Kentucky has established Human Health: Fish Consumption, it's criterion-concentration is identical to that of corresponding EPA criteria (Human Health: Organism), if there are any waterbodies in Kentucky used by subsistence fishers, those people will face a higher risk of illness than that upon which EPA's human health criteria are based. In order to compensate for this situation, the criterion-concentrations for the Human Health: Fish Consumption criteria need to be set at lower levels than that which has been set by EPA.

As for the relative degree of protection provided to consumers of drinking water by Kentucky's Human Health: Domestic Water Supply water quality criteria and EPA's Primary Drinking Water Standards, simple comparison of the concentration stipulated by each of these threshold values is not a reliable methodology, for several reasons.[51] First, Kentucky's human health-related criteria for toxic chemicals lack specification of a criterion-duration or criterion-frequency. If one assumes that the criterion-durations and criterion-frequencies for Kentucky's Human Health: Domestic Water Supply Source criteria are the same as those in EPA's SDWA criteria, this would suggest that most of the state's Human Health: Domestic Water Supply Source criteria are either more protective than, or as protective as, EPA's corresponding SDWA criteria. Furthermore, even those state WQC with criterion-concentrations higher than the value

[51] The criterion-concentrations in about half of Kentucky's "human health: domestic water supply source" criteria are lower than EPA's MCL values for the same constituent; the criterion-concentrations in one-fourth of those criteria are higher than EPA's MCL values; and the criterion-concentrations in one-fourth of those same criteria are equal to EPA's MCL values.

set forth in the corresponding MCL are likely, in most cases, to provide equal or greater levels of protection as EPA's drinking water standards because typically the concentration of a given pollutant in the raw water supply will have been significantly lowered by drinking water treatment process before it is delivered as "finished water" by the drinking water distribution system.

Hence, for those 82 pollutants with a Kentucky Domestic Water Supply WQC with a concentration equal to that specified in the EPA drinking water standard for that pollutant could actually provide greater protection to consumers of finished drinking water. (This assumes that the same durations and frequencies apply to the state criteria and the federal standard.) For instance, if the drinking water treatment process to which the raw water is subjected removes 50% of a certain pollutant, then the level of the pollutant in the raw water could be two-times the concentration specified by the SDWA standard, and still meet that standard in the finished drinking water. For example, both the Kentucky Domestic Water Supply criteria and EPA's Drinking Water Standard for vinyl chloride are both 2.0 μg/L, so if a public water supply utility was using a river or lake with water meeting the state's water quality criterion for its raw drinking water supply, then finished drinking water supply with a concentration equal to half that of the drinking water standard (1.0 μg/L) should emerge from the treatment process. And, if the drinking water treatment system could remove more than 50% of the vinyl chloride, say 80%, then finished drinking water with a level of this contaminant of 0.16 μg/L.

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

Finally, we return briefly to the effects of the fact none of Kentucky's WQC for toxic chemicals has a clearly stated criterion-duration or a clearly stated criterion-frequency. Lack of clearly stated criterion-durations and criterion-frequencies can result in lack of consistency in the application of Clean Water Act programs that are driven by water quality criteria. For instance, if one assumes that the criterion-duration for the human health criterion is an instant and the frequency is zero, then any waterbody from which just one valid (meets QA/QC requirements/guidelines) grab sample, out of several such samples, with a concentration of a pollutant higher than the criterion-concentration should be included in the state's Section 303(d) list. On the other hand, if the criterion-duration for human health criteria were 365 days, then exceedance of WQC would not be indicated by having just one sample out of several collected over any 365-day period with a concentration above the criterion-concentration. In this latter case, the appropriate determinant of criterion exceedance would be having a set of samples collected over some 365-day periods with an average concentration higher than the criterion-concentration.

Appendix A

Missing and Extra Criteria for Traditional Pollutants: Kentucky

Table 1 - Aquatic Life

i) MISSING[52] POLLUTANTS

	ACUTE	CHRONIC
warm water/cold water[53]	calcium carbonate[54]	ammonia (4d, 30d) chlorophyll a (total dissolved) gases[55] nitrogen (total) phosphorous (total) turbidity (NTU) turbidity (Secchi)

ii) EXTRA[56] POLLUTANTS

	ACUTE	CHRONIC
warm/cold water streams	temperature	(dissolved) oxygen temperature[57]

[52] For the purposes of this review, "missing" means those pollutants for which EPA has issued WQC while the state has neither adopted nor officially proposed corresponding criteria.
[53] EPA's criteria do not distinguish between warm and cold water habitat.
[54] KY lacks actual numeric criteria; however it does have two "quasi-numeric" criteria.
[55] EPA's criteria are quasi-numeric, while KY has no criteria.
[56] For the purposes of this review, "extra pollutants" are those pollutants for which the state has established WQC while EPA has not.
[57] This "quasi-numeric criterion is neither clearly an acute nor a chronic criterion, as its criterion-duration is unspecified. For counting purposes, it has been listed just once, under "chronic," because the state has numeric acute criteria for temperature.

Table 2 - Drinking Water Supply[58]

i) MISSING POLLUTANTS

ACUTE	CHRONIC
total coliforms[59]	chlorides color foaming agents odor pH (dissolved) solids sulfate

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
chlorides color (dissolved) solids foaming agents nitrates + nitrites[60] sulfate	---

Table 3 - Water-Based Recreation

i) MISSING POLLUTANTS

ACUTE	CHRONIC
---	Enterococci

ii) EXTRA POLLUTANTS

ACUTE	CHRONIC
pH	pH

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

[59] EPA's SDWA standard for total coliform bacteria could be considered either an acute or chronic criterion—as it is stated, in effect as "no more than 5% of samples of finished drinking water shall have detectable levels of total coliform bacteria. For counting purposes in this report, the state is shown as lacking just an acute criteria for total coliform

[60] Applies only to main stem of the Ohio River

Appendix B

Table 1

	Aquatic Life Protection		Human Health Protection: Fish Consumption
	Acute	*Chronic*	
Pollutants with a state criterion-concentration **lower** than EPA's	---	---	1,1-Dichloroethylene 2,3,7,8-TCDD (Dioxin) Anthracene Dimethyl Phthalate gamma-BHC

Table 2

	Aquatic Life Protection		Human Health Protection: Fish Consumption
	Acute	*Chronic*	
Pollutants with a state criterion-concentration **higher** than EPA's	Cadmium Chromium III Copper Lead Mercury Silver Zinc	Cadmium Chromium (III) Copper Endrin Lead Mercury Nickel Zinc	Chlorobenzene Cyanide Dibenzo(a,h)Anthracene Endrin Ethylbenzene Hexachlorocyclopentadiene Ideno(1,2,3-cd)Pyrene 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Trans-Dichloroethylene 1,3-Dichloropropene 1,4-Dichlorobenzene Thallium Toluene Vinyl Chloride

Table 3

	Human Health	
	Drinking Water Supply Source[61]	*Non Drinking Water Supply Source*[62]
MISSING POLLUTANTS – pollutants for which the state has not formally proposed – nor officially adopted – WQC, whereas EPA has published recommended WQC of the type specified.	Arsenic Di-n-Butyl Phthalate Manganese Methylmercury	1,2-Dibromo-3-chloropropane Alachlor Alpha particles Atrazine Beta particles & photon emitters Bromate Carbofuran Chloramines Chlorine Chlorine dioxide Chlorite cis-1,2-Dichloroethylene Dalapon Di(2-ethylhexyl) adipate Dichloromethane Dinoseb Diquat Endothall Ethylene dibromide Glyphosate Haloacetic acids (HAA5) Iron Oxamyl (Vydate) Nitrite Picloram Radium 226 and Radium 228 (combined) Simazine Styrene Total Trihalomethanes Xylenes (total)

[61] Pollutants for which criteria were adopted for this designated use by the state are compared to the list of pollutants for which the EPA has issued human health criteria for consumption of aquatic organisms only (HHO).

[62] Pollutants for which criteria were adopted for this designated use by the state are compared to the list of pollutants for which the EPA has issued primary and/or secondary drinking water quality criteria (MCL values) pursuant to the Safe Drinking Water Act.

Table 4

EXTRA POLLUTANTS – pollutants for which the state has formally proposed or officially adopted WQC while EPA has not published recommended WQC of the type specified.	Human Health	
	Drinking Water Supply Source[63]	*Non Drinking Water Supply Source*[64]
		1,1,2,2-Tetrachloroethane 1,2-Diphenylhydrazine 1,3-Dichlorobenzene 1,3-Dichloropropene 2,4,6-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2-Chloronaphthalene 2-Chlorophenol 2-Methyl-4,6-Dinitrophenol (4,6-Dinitro-o-cresol) 3,3'-Dichlorobenzidine 4,4'-DDD 4,4'-DDE 4,4'-DDT Acenaphthene Acrolein Acrylonitrile Aldrin alpha-BHC alpha-Endosulfan Anthracene Benzidine Benzo(a)Anthracene Benzo(b)Fluoranthene Benzo(k)Fluoranthene beta-BHC beta-Endosulfan Bis(2-Chloroethyl)Ether Bis(2-Chloroisopropyl)Ether Bromoform Butylbenzyl Phthalate Chlorodibromomethane Chloroform Chrysene Dibenzo(a,h)Anthracene Dichlorobromomethane Dieldrin Diethyl Phthalate Dimethyl Phthalate Di-n-Butyl Phthalate

(Table 4 continues on the next page.)

[63] Id at 10
[64] Id at 11

Table 4 (cont.)

	Human Health	
	Drinking Water Supply Source[65]	*Non Drinking Water Supply Source*[66]
EXTRA POLLUTANTS – pollutants for which the state has formally proposed or officially adopted WQC while EPA has not published recommended WQC of the type specified.		Dinitrophenols Endosulfan Sulfate Endrin Aldehyde Ether, Bis(Chloromethyl) Fluoranthene Fluorene Hexachlorocyclo-hexane-Technical Hexachloroethane Ideno(1,2,3-cd)Pyrene Isophorone Methyl Bromide Methylene Chloride Nickel Nitrobenzene Nitrosamines Nitrosodibutylamine,N Nitrosodiethylamine,N Nitrosopyrrolidine,N N-Nitrosodimethylamine N-Nitrosodi-n-Propylamine N-Nitrosodiphenylamine Pentachlorobenzene Phenol Pyrene Tetrachlorobenzene,1,2,4,5- Trichlorophenol,2,4,5-

[65] Id at 10
[66] Id at 11

Appendix C

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

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

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

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

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

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

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

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Environmental Law Institute

2000 L Street, N.W., Suite 620

Washington, D.C. 20036

Telephone: (202) 939-3868

Fax: (202) 939-3868

www.eli.org

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