WATER QUALITY STANDARDS
POSITION PAPER

ASSESSMENT OF CURRENT WATER QUALITY CRITERIA for DISSOLVED OXYGEN

MARCH 2, 2021
WATER QUALITY CRITERIA for DISSOLVED OXYGEN

ISSUE

Why must Kansas revise ambient water quality criteria for dissolved oxygen?

It is the mission of the Kansas Department of Health and Environment (KDHE) to protect the health and environment of all Kansans by promoting responsible choices. One facet of this mission is the setting of water quality standards based on the best science available. As part of setting water quality standards, submittal of the revisions must be submitted to the U.S. Environmental Protection Agency (EPA) for review and approval to be applicable under the Clean Water Act. Following a revision to the dissolved oxygen criteria submitted to EPA as part of the March 27, 2015 Kansas Water Quality Standards, EPA returned an Action Letter dated 7/18/2017 with Section II items F, G and H addressing this revision.

CURRENT NUMERIC CRITERIA

- Tables of Numeric Criteria
  - Table 1g. Temperature, Dissolved Oxygen, And pH Numeric Aquatic Life Criteria

<table>
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<tr>
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<sup>a</sup> - (1) The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. (2) Dissolved oxygen concentrations can be lower than 5.0 mg/L when caused by documented natural conditions specified in the "Kansas Implementation Procedures: Surface Water Quality Standards". (3) For lakes or reservoirs experiencing thermal stratification, the dissolved oxygen criterion is only applicable to the top layer or epilimnion of the waterbody.

<sup>b</sup> - pH range outside the zone of initial dilution.

<sup>c</sup> - (1) Beyond the zone of initial dilution a discharge shall not elevate the temperature of a receiving surface water above this temperature, except as provided in paragraph 28-16-28e(c)(2)(C)(ii). (2) Additional requirements in paragraph 28-16-28e(c)(2)(C)(i).
BACKGROUND

What is dissolved oxygen?

Dissolved oxygen is naturally occurring in water through means of photosynthetic life present in the water and from equilibrium with the atmosphere. Additionally, forced mixing from high winds or cascading streams, such as rapids, results in a surface exchange of oxygen between the water and air. Just as we, humans, need oxygen in the air to survive and thrive, aquatic organisms rely upon its presence in water and it is termed dissolved oxygen.

How does dissolved oxygen affect aquatic life?

Dissolved oxygen is most simply defined as the amount of oxygen that is present in water. Just as all terrestrial animals require oxygen in the air, all aquatic animals need dissolved oxygen in the water.

The term for low oxygen, in the air and water, is hypoxia. Hypoxia can greatly impair aquatic organisms, and, if oxygen is depleted enough, result in morbidity of aquatic life.

Summary of current dissolved oxygen criteria to protect aquatic life:

Kansas’ current dissolved oxygen criteria are presented numerically at Table 1g and narratively at 28-16-28e(b). Following adoption by the state of a water quality standard, part of the process for meeting the needs of the Clean Water Act for approval and legal effectiveness of new water quality standards requires submittal to, review by, and approval from the EPA. In the previous triennial review package sent to the EPA, termed the 2015 triennial review, a revision to the dissolved oxygen criteria in Table 1g was included. Specifically, this change was made to add footnotes a(2) and a(3) speaking to natural conditions observed in Kansas’ surface waters.

EPA reviewed and responded to this revision to Kansas’ surface water quality standards in the 7/18/2017 Action Letter (under Section II’s Items F, G, and H referenced in the following sections) and in it declared these additions items “on which EPA is taking no action”, which equates to resulting in neither an approval nor disapproval. Thus in relation to the Clean Water Act, the dissolved oxygen criteria of 5.0 mg/L for all aquatic life tiers are considered applicable from Table 1g but only for footnote a(1) which had been approved by EPA many years prior.

EPA 7/18/2017 Action Letter Section II Item F:

F. Kansas Surface Water Quality Standards Tables of Numeric Criteria (January 21, 2015): Table 1g. Temperature, Dissolved Oxygen, and pH Numeric Aquatic Life Criteria; New Footnote a(2) addressing Dissolved Oxygen – Natural Conditions.

The dissolved oxygen (DO) criteria used by Kansas is 5.0 mg/L for Special, Expected and Restricted Aquatic Life Uses. The KDHE added a new footnote, a(2), addressing implementation of the dissolved oxygen (DO) criteria as follows:

(2) Dissolved oxygen concentrations can be lower than 5.0 mg/L when caused by documented natural conditions specified in the “Kansas Implementation Procedures: Surface Water Quality Standards.”
The section of this provision referenced in the “Kansas Implementation Procedures: Surface Water Quality Standards” is a new provision in this rule referenced document and is addressed below in Section H.

EPA 7/18/2017 Action Letter Section II Item G:

G. Kansas Surface Water Quality Standards Tables of Numeric Criteria (January 21, 2015): Table 1g. Temperature, Dissolved Oxygen, and pH Numeric Aquatic Life Criteria. Footnote (a)3 addressing Dissolved Oxygen in lakes or reservoirs.

The KDHE added a new footnote, (a)3, addressing implementation of the dissolved oxygen (DO) criteria as follows:

(3) For lakes or reservoirs experiencing thermal stratification, the dissolved oxygen criterion is only applicable to the top layer or epilimnion of the waterbody.

Supporting documentation is needed from the KDHE to be able to determine whether this approach is scientifically defensible and protective per requirements at 40 CFR § 131.11. Supporting documentation must include an explanation as to how the top layer or epilimnion, the metalimnion, and the hypolimnion will be defined. Of particular concern with this approach is that the DO criteria is excluded from protecting the metalimnion during stratification; this zone is of particular importance during hot summer months as refugia for aquatic life. The criteria must be sufficient to protect designated uses and consistent with EPA’s regulations at 40 CFR §§ 131.6(c) and 131.11(b)(1)(ii).

EPA 7/18/2017 Action Letter Section II Item H:


The following new provision and explanatory statements were added to the Kansas Implementation Procedures:

C. Naturally Occurring Conditions for Low Dissolved Oxygen (DO) Criterion in Streams Applicable regulation: Kansas Surface Water Quality Standards: Tables of Numeric Criteria 1g

Some conditions that occur naturally can cause low dissolved oxygen levels in streams. Typically, the incidence of low dissolved oxygen occurs in the summer when water temperatures are high (reducing the ability of water to retain dissolved oxygen) and stream flows are low (reducing the ability of the stream to re-aerate itself or flush or dilute any oxygen-demanding substances present in the water). At times, the introduction of natural organic materials such as during periods of leaf fall can cause low dissolved oxygen levels in some segments of streams. Additionally, ground water reaching the surface through springs and seeps may have low dissolved oxygen. Digressions from the dissolved oxygen criterion under the above conditions should be excluded for the purposes of Section 303(d) of the Federal Clean Water Act.

Natural conditions contributing to the local digression of low dissolved oxygen should be documented during the field site visit. Factors including flow conditions, ambient air and water temperatures, presence of allochthonous organic matter from wildlife or riparian vegetation, dystrophic inputs to the stream from wetland areas and extended days of cloud cover should be noted at the time of sampling. Additionally, observations
and samplings of the resident aquatic life community, including fish, mussels, macroinvertebrates and other shellfish should be made at the time of deficient oxygen to ascertain possible stress on the biota or lack thereof. These ancillary data and information will be used in the Section 303(d) listing and assessment process to determine whether the incident of low dissolved oxygen can be discounted.

The EPA provided comments (11/19/2004) on this provision during the public notice of the new and revised KS WQS. Specifically, EPA stated the following:

“Supporting documentation will be needed to demonstrate that a given approach is scientifically defensible and protective per the requirements of 40 C.F.R. § 131.11 if the EPA determines if this is a change in WQS. The criteria must be sufficient to protect designated uses and consistent with the EPA’s regulations at 40 C.F.R. §§ 131.6(c) and 131.11(b)(1)(ii). Supporting documentation consistent with the expectations of naturally occurring conditions articulated in this provisions will also be needed to substantiate that the low dissolved oxygen conditions are indeed due to naturally-occurring, non-anthropogenic contributions.”

The KDHE responded (2/18/2015) with the following:

“KDHE understands it will be necessary to provide any applicable supporting documentation to EPA on a case-by-case basis for waterbodies where the new criteria will be implemented.”

EPA’s regulations at 40 CFR § 131.11 require states to adopt water quality criteria that protects the designated use and is based on a sound scientific rationale. In addition, EPA’s regulations allow states to establish numeric criteria based on 304(a) Guidance modified to reflect site specific conditions. EPA’s 1986 DO criteria recommendations, published pursuant to section 304(a) of the CWA, state that alternative criteria may be appropriate “where natural conditions alone” create the DO concentrations. It goes on to say that “absolutely no anthropogenic dissolved oxygen depression in the potentially lethal area below the 1-day minima should be allowed unless special care is taken to ascertain the tolerance of resident species to low dissolved oxygen.”

Also in KDHE’s response to the EPA’s comments was a statement made in regards to Application of criteria for designated uses of surface waters (page 5):

“Most Kansas impairments are, in fact, anthropogenic because of land and water activities, regardless if the substance is natural or synthetic.”

The EPA expects the KDHE to submit methods used and analyses conducted to develop site-specific DO criteria, on a site-specific basis, that demonstrate support of the aquatic life use designation per 40 CFR § 131.6; this demonstration includes naturally-occurring low DO. The EPA must approve any new site-specific DO criteria in order for the criteria to be effective and implementable for CWA purposes in Kansas.

What improvements can and need to be made to the dissolved oxygen criteria to address EPA’s comments?

The revision to the dissolved oxygen criteria for the additional two footnotes follows years of samples from Kansas surface waters indicating natural conditions occur in surface waters resulting in hypoxia. Footnote a(2) speaks to generally applying the implementation procedures for handling natural excursions below the criteria and was addressed in Section II Items F and H in EPA’s 7/18/2017 Action Letter. By contrast, footnote a(3) directly states a natural condition of lakes and reservoirs, thermal stratification, can
result in varying dissolved oxygen concentrations and was addressed in Section II Item G of EPA’s 7/18/2017 Action Letter.

As EPA’s 7/18/2017 Action Letter Section II Item G in regards to footnote a(3) of Table 1g requests supporting documentation to demonstrate scientific defensibility, a review and summary of the underlying science is presented here. Addressing the specific natural condition presented in footnote a(3), lakes and reservoirs of great enough depth often experience and persist in thermal stratification. The thermal stratification is a result of warming and cooling of the water body. Sunlight decreases in intensity the deeper in a water column, and turbidity, or other light limiting factors, contributing to this decrease in sunlight at depth results in the water being heated less at greater depths. Thus, the water becomes naturally warmer near the surface and remains cooler at the bottom.

This thermal stratification in lakes and reservoirs, as a result of decreasing sunlight penetration with increasing depth, is important in relation to dissolved oxygen. The temperature of water changes how dense it is, and cooler water is denser than warmer water. Denser objects sink and less dense, or lighter, objects subsequently float. This density difference results in stratification and effectively separates the water into distinct layers that do no mix with one another. These layers, from top to bottom, are termed the epilimnion, metalimnion, and hypolimnion. This stratification is typically observed seasonally in Kansas, with mixing from top to bottom occurring in the spring and fall (Figure 1).

**Figure 1.** Seasonal stratification by temperature in lakes and reservoirs.

As a result of the water separating into distinct layers by temperature, dissolved oxygen also becomes stratified by each thermally distinct layer. As demonstrated in KDHE’s Dissolved Oxygen White Paper from 2011 (Appendix White Paper), Clinton Lake exhibits the thermal stratification accompanied by a decrease in dissolved oxygen with increasing depth. This observed lack of dissolved oxygen deeper in the water is a result of the same decreasing sunlight penetration with increasing depth that creates the thermal stratification and is further compounded by the lack of mixing between these different densities of water layers where more oxygenated waters near the surface do not interact with and reach the bottom layers despite continued biological oxygen consumption (Appendix White Paper paragraph 2, page 2).

As thermal stratification is a natural process observed in some Kansas lakes, during some seasons, the addition of footnote a(3) was intended to clarify that application of the DO criteria of 5.0 mg/L was to protect aquatic life in the zone they inhabit, the epilimnion. However, EPA’s comment under their decision of no action taken stated “supporting documentation is needed from the KDHE to be able to determine whether this approach is scientifically defensible and protective per requirements at 40 CFR § 131.11,” and EPA further outlined specifically to define the top layer or epilimnion, the metalimnion, and the hypolimnion. Finally, EPA expressed particular concern that the dissolved oxygen criteria would not
protect the metalimnion during stratification as it is a zone of refugia for aquatic life during hot summer months.

In a similar effect to thermal stratification in lakes, the tropholytic zone of lakes can also result in natural conditions depleting oxygen content in water. The tropholytic zone, also known as the benthic zone or profundal zone, is where light is more scarce and oxygen produced via photosynthesis is consumed more rapidly by respiration than it can be produced. The tropholytic zone is also more commonly referred to as the bottom of the lake. This area is defined, and pictured, as the sediment interface with the bottom water, and it is also a zone of great chemical influence with the lake’s waters; in particular, it has been shown to heavily consume oxygen present\textsuperscript{4,5,6,7}. Oxygen depletion is elevated in this area due to organic matter that sinks to the bottom and decomposes, an oxygen consuming process, and from various chemical reactions occurring naturally in the sediment. Thus, the tropholytic zone of lakes and reservoirs is naturally depleted of oxygen regardless of season, and historically has not been appropriately represented in Kansas’ Surface Water Quality Standards.

This Position Paper addresses EPA’s comment for supporting documentation from KDHE to determine scientific defensibility and protection as required at 40 CFR § 131.11. As EPA stated and alluded to, defining terms that aren’t general knowledge is appropriate in rule language and adding definitions for the epilimnion, metalimnion, and hypolimnion is appropriate when used in the rule text elsewhere. Protecting the metalimnion during stratification for refugia of aquatic life during hot summer months is a request that solicited further scientific review that has shown its consideration was not taken as fully into account as necessary with the previous attempted revision. Specifically, its limitation to the protection of aquatic life in the epilimnion solely, when other species may be present in and require the metalimnion, would not be in agreement with the Clean Water Act’s Section 101 (a)(2) goal of “water quality which provides for the protection and propagation of fish, shellfish, and wildlife.” Thus, further scientific review was conducted and a proposed change related to this footnote’s intent, in addition to a summary of the review’s findings, is presented in this document.

**U.S. Environmental Protection Agency (EPA) Recommended Dissolved Oxygen Criteria**

Under Section 304(a) of the Clean Water Act, the EPA is required to develop and publish criteria for water quality accurately reflecting the latest scientific knowledge. The most recent criteria for dissolved oxygen are presented by the EPA in the 1986 Gold Book (Table 1)\textsuperscript{8}. The values presented are in table form and have been replicated here. Currently, the surface water quality standards for Kansas apply the early life stages warmwater criteria of 5.0 mg/L to all surface waters with aquatic life uses in the state.

**Table 1.** The USEPA’s 1986 Gold Book\textsuperscript{8} values for dissolved oxygen.

<table>
<thead>
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<tbody>
<tr>
<td></td>
<td>Early Life Stages</td>
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</tr>
<tr>
<td>30 Day Mean</td>
<td>NA</td>
<td>6.5</td>
</tr>
<tr>
<td>7 Day Mean</td>
<td>9.5 (6.5)</td>
<td>NA</td>
</tr>
<tr>
<td>7 Day Mean Minimum</td>
<td>NA</td>
<td>5.0</td>
</tr>
<tr>
<td>1 Day Minimum</td>
<td>8.0 (5.0)</td>
<td>4.0</td>
</tr>
</tbody>
</table>

In addition to these numeric criteria for adoption on a statewide basis, the Clean Water Act allows for the adoption of site specific criteria. Upon communication with the EPA, attention was directed to the 2015 EPA document “A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim
Figure 2. Process for identifying and documenting a natural condition for temperature, DO, and pH as outlined in EPA’s 2015 Interim Document for defining natural conditions for site-specific criteria development."
This framework\textsuperscript{9} is considered by KDHE to be a valid methodology for developing scientifically
defensible site-specific criteria. Additionally, KDHE intends to adopt this 2015 guidance for site specific
criteria derivation into the “Kansas Implementation Procedures: Surface Water Quality Standards”.

**Scientific review and rationale for improvements to Table 1g footnote a(3)**

EPA’s 7/18/2017 Action Letter Section II Item G states concern with exclusion of dissolved oxygen
criteria for the metalimnion as the zone “is of particular importance during hot summer months as refugia
for aquatic life” and “criteria must be sufficient to protect designated uses and consistent with EPA’s
regulations at 40 CFR § 131.6(c) and 131.11(b)(1)(ii).” To clarify which aquatic species EPA was
referring to, a request for that information was sent with the desire for supporting documentation. An
article by Quist et al. (2002)\textsuperscript{10} for walleye in a Great Plains reservoir was subsequently provided.
Exploring walleye as a species in Kansas lakes has led to further study of the Gold Book criteria (Table 1)
in addition to finding and reviewing articles on walleye habitats and spawning patterns in addition to their
presence in Kansas reservoirs.

**Table 1.** The USEPA’s 1986 Gold Book\textsuperscript{8} values for dissolved oxygen.

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</tr>
<tr>
<td>Minimum</td>
<td>5.0</td>
<td>3.0</td>
</tr>
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</table>

Walleye were a species introduced to Kansas lakes and reservoirs through stocking in the 1960’s and
1970’s (Quist et al. 2002\textsuperscript{10}); since then, they have been able to reproduce on their own in addition to
walleye larvae annually stocked to supplement due to natural losses from this artificial habitat and being a
game fish. The designated “Aquatic life support use” has been applied to all Kansas lakes and reservoirs
on the surface water register and have been defined as “the use of classified surface waters other than
classified stream segments for the maintenance of the ecological integrity of lakes, wetlands, and ponds,
including the sustained growth and propagation of native aquatic life; naturalized, important, recreational
aquatic life; and indigenous or migratory semiaquatic or terrestrial wildlife directly or indirectly
dependent on classified surface waters other than classified stream segments for survival.”\textsuperscript{11} Since Walleye
were an introduced species, they are considered a species for the aquatic life support use protection as
they are naturalized (additions are to equal fishing recreational reductions\textsuperscript{10}) and considered one of
Kansas’ game fish species meeting the “important” and “recreational aquatic life” terminology used.

In various states’ water quality standards and put forth by the EPA in the 1986 Gold Book\textsuperscript{8} (Table 1),
criteria for dissolved oxygen are initially split between warmwater and coldwater species and further
subdivided into ‘early’ or ‘other’ life stages to protect. The 5.0 mg/L used in Table 1g is a reflection of
the dissolved oxygen criteria for warmwater species of early life stages. However, fish that would seek
thermal refuge in the metalimnion, would assumedly belong to the coldwater species early life stages
indicated. To determine applicability of protection for the early life stages for coldwater fish, walleye
spawning habits were examined. Natural reproduction of walleye involve moving into rivers or
windswept shallows (1 to 6 feet deep) when water temperature is only a few degrees above freezing and
peak spawning occurs from 42 to 50 degrees Fahrenheit\textsuperscript{11}. As thermal stratification is seasonally
constrained to warmer months of the year that are warmer than these early life stage conditions, nor is
thermal stratification typically occurring at a depth of 2 meters or less, consideration for early life stages is not applicable to DO criteria for the metalimnion.

Further examination of walleye was conducted to determine if this species seeking thermal refuge should reasonably be assumed to be a coldwater species. The EPA’s 1986 Gold Book states “criteria for coldwater fish are intended to apply to…waters containing coldwater or coolwater fish deemed by the user to be closer to salmonids in sensitivity than to most warmwater species.” Articles were reviewed that have examined walleye habitats in non-native reservoirs and lakes to determine preferred habitat of this species. The preferred area inhabited by walleye in a stratified lake varied based on trophic state of the waterbody and the species were demonstrated to preferentially select temperature over oxygen availability for physiological reasons, but dissolved oxygen and temperature are both significant factors in determining their preferred habitat. This was demonstrated through walleye seeking cooler water at the cost of dissolved oxygen levels at or below 3 mg/L for extended periods and are even capable of tolerating dissolved oxygen as low as 1 mg/L for short periods. However, concentrations of dissolved oxygen less than 1 mg/L proved to be lethal to the species for short periods. While the walleye preferentially select temperature favorable to their preferred habitat, it was shown that the 3 mg/L concentration of dissolved oxygen is adequate for their survival in these warmer months. This 3 mg/L concentration matches the warmwater criteria for other life stages in EPA’s 1986 Gold Book (Table 1), and it is indicative of walleye as being a coolwater species closer to warmwater species in sensitivity than to salmonids with coldwater criteria.

However, another portion of walleye habitat had to be selected besides physical environment of the metalimnion as protective of the species. Specifically, the 1986 Gold Book states the limit for Other Life Stages of Coldwater species “has been established at 4 mg/L because a significant proportion of the insect species common to salmonid habitats are less tolerant of acute exposure to low dissolved oxygen than are salmonids” and that “the acute lethal limit for salmonids is at or below 3 mg/L.” This is assumed to equate that protection of walleye food sources needs to be considered for warmwater or coldwater criteria applicability as well. The 2002 Quist et al. article states Gizzard shad are “generally the most important prey item throughout the year” for walleye in Great Plains reservoirs. Gizzard shad are considered a warmwater species and thus considered protected with the warmwater criteria applied to the epilimnion. Since the desired food source of this coolwater species in Kansas lakes and reservoirs is adequately protected, the 4 mg/L coldwater species criteria (Table 1) is not applicable to walleye in these water bodies.

Following review of walleye and applicable criteria in EPA’s 1986 Gold Book and available scientific literature, the EPA’s warmwater criteria for other life stages at 3.0 mg/L (Table 1) is considered protective of walleye during thermal stratification. The temperature refuge EPA stated is further supported in the scientific literature, and the same literature considers 3.0 mg/L for dissolved oxygen content of waters to be protective of this species for extended periods. Thus, protection of walleye in the metalimnion during thermal stratification is considered scientifically defensible at 3.0 mg/L dissolved oxygen content.

Following further review with EPA and discussion of other coolwater species to protect in the state, the criteria of 3.0 mg/L was to be considered a floor where no excursions were to be permitted without impairment listing on the 303(d) list in addition to the need for continuous monitoring as opposed to Kansas’ current regular sampling with instantaneous monitoring. Thus, 4.0 mg/L was an agreed upon cushion to protect species following current sampling constraints in assessment capabilities.

How could revision of the dissolved oxygen criteria affect Kansas?
KDHE’s monitoring protocols currently monitor for dissolved oxygen in streams and in lakes and reservoirs. There is no expected impact to monitoring from revising the standards to address EPA’s comments satisfactorily. However, additional assessment will be required with the measured values to determine the depth ranges of the thermally stratified layers to apply criteria assessments against.

Under the current dissolved oxygen criteria of 5.0 mg/L for Kansas waters, water bodies experience natural conditions depleting the dissolved oxygen content. Revising the standards to account for seasonal, natural occurrences of dissolved oxygen excursions would better refine this over-assessment of impaired waters. Following listing of water bodies as impaired, further assessments consuming time and resources are allocated to the water body for drafting and implementing a Total Maximum Daily Load for the watershed to determine sources of the impairment and load allocations to point and nonpoint sources to eliminate the impairment. Listing a waterbody as impaired for dissolved oxygen when a naturally occurring process produces this aberration results in greater cost to regulated entities in the waterbody’s watershed and a greater cost to KDHE for regulating a water body for a naturally occurring phenomenon. Thus, revising the dissolved oxygen criteria to reduce the over-protection of water bodies results in less cost to the regulated community, less burden to KDHE for implementation of the rule, and results in a more accurate assessment and evaluation of the water body in question.

**ACTIONS**

Under section 304(a)(1) of the Clean Water Act, the EPA is required to publish and periodically update ambient water quality criteria. Water quality criteria for dissolved oxygen were last updated for protecting aquatic life in the 1986 Gold Book5; Kansas previously adopted from the 1986 Gold Book8 the warmwater early life stages dissolved oxygen criterion of 5.0 mg/L1.

In 2011, KDHE released the White Paper for Allowances for Low Dissolved Oxygen Levels for Aquatic Life Use3 (Appendix). Other states’ approaches were explored and discussed from Region VII primarily and included a few other surrounding or relatively similar states. Several options were presented for exceptions to the current water quality standard:

1. Lower the dissolved oxygen criterion to 4 mg/L as an instantaneous minimum
2. Assess dissolved oxygen similarly as a chronic impairment (binomial; 10%)
3. Explicitly state allowances for dissolved oxygen lower than 5 mg/L when caused by documented natural conditions
4. Explicitly exclude applying dissolved oxygen criteria to the lowest portions of a lake (i.e. the hypolimnion)

In 2015, KDHE submitted to EPA for review Table 1g with two additional footnotes that adapted the language from approaches 3 and 4 from the White Paper for Allowances of Low Dissolved Oxygen3 (Appendix) to exclude dissolved oxygen excursions caused by documented natural conditions and exclude dissolved oxygen outright from protecting the lowest portions of a lake.

EPA’s review resulted in no action taken and it was specified what information and alterations to the proposed criteria were desired. Specifically, scientific background supporting the rationale of the new criteria, defining the stratified layers of the lake to be protected, protecting thermal refugia of the
metalimnion, and the use of site-specific criteria for site-specific conditions were all areas of further elaboration and alteration requested.

**SUMMARY**

The aquatic life ambient water quality criterion for dissolved oxygen is currently established at 5.0 mg/L for all Kansas surface waters. Upon further refinement of this criteria to apply to naturally occurring conditions, including thermal stratification in lakes and reservoirs and organic matter decomposition in streams (Referenced in the Implementation procedures) under Table 1g footnotes a(2) and a(3), EPA responded that further scientific background supporting the change be provided, definitions of new technical terms introduced, protection for aquatic life using more than surface waters in lakes are considered, and site-specific criteria be developed for site-specific conditions occurring.

**Concerns:**

Site-specific criteria for low dissolved oxygen due to natural inputs such as groundwater deprived of oxygen or leaf litter decomposing in the water are site-specific conditions that are expected to vary between sites. In contrast, site-specific criteria for a naturally occurring, seasonally changing, and potentially daily changing, dissolved oxygen stratification in lakes and reservoirs is an immense and burdensome undertaking. However, refining the dissolved oxygen criteria and providing supporting scientific rationale for changes to protect the upper layers of lakes and reservoirs is likely to address many of the issues site-specific criteria would be otherwise burdensome to account for, let alone represent in an assessment or regulatory manner.

**OPTIONS**

Use of site-specific criteria for establishing natural excursions from the current dissolved oxygen criteria has been suggested both in the Water Quality Standards Implementation Procedures and by the EPA. Following the 2015 “A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document”, EPA lays out what is expected with this approach.

For streams experiencing natural dissolved oxygen consumption from excessive vegetative litter decomposing in the streambed (leaves in fall), or other natural causes of hypoxia, site-specific criteria may be appropriate when used on an as-needed basis due to the site-specific requirements of terrestrial vegetative biota to incur this condition. Site-specific criteria are accompanied by location and temporal constraints for dissolved oxygen, but this contrasts with both the naturally occurring thermal stratification in lakes and reservoirs and the oxygen consumption of sediment. Lakes and reservoirs incur seasonal turnover of the stratification that is not aligned with calendar dates but a variety of weather conditions such as wind, sunlight, and rainfall. Thus, revising criteria applicable to stratified lakes and sediment oxygen demand is the more appropriate approach for establishing criteria to reflect and protect for these natural phenomena.
To regulatorily present this improved precision in criteria, Table 1g would then be altered to now include two tables and the original EPA approved footnotes before the 2015 triennial review with an inclusion for accounting of the sediment interface’s oxygen depletion:

**Proposed Table 1g.** Proposed updates to the table currently representing the numeric standards for protecting dissolved oxygen content of Kansas’ surface waters.

**Non-Thermally Stratified Surface Waters**

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<td>Restricted</td>
<td>5.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.5-8.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32°C&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**Thermally Stratified Lakes or Reservoirs**

<table>
<thead>
<tr>
<th>Aquatic Life Use</th>
<th>Dissolved Oxygen (DO)</th>
<th>pH</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Special Epilimnion</td>
<td>5.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.5-8.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Special Metalimnion</td>
<td>4.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.5-8.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32°C&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Expected Epilimnion</td>
<td>5.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.5-8.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Expected Metalimnion</td>
<td>5.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.0 mg/L&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.5-8.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- **a** – (1) The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution. (2) Dissolved oxygen concentrations may be lower than criteria in the bottom measurement from a measured profile reaching full depth in lakes or reservoirs. (3) For thermally stratified lakes and reservoirs, narrative criteria specified in K.A.R 28-16-28b through 28-16-28h still apply to all depths. (4) Thermally stratified refers to lakes or reservoirs naturally experiencing a change in the temperature at different depths where warmer, less dense waters are at the surface and colder, more dense waters are at the bottom. Specifically, the epilimnion is the warmer, less dense, upper layer of water, and the metalimnion is the zone of transition from the epilimnion at the surface and colder, more dense, bottom water.

- **b** – pH range outside the zone of initial dilution.

- **c** – (1) Beyond the zone of initial dilution a discharge shall not elevate the temperature of a receiving surface water above this temperature, except as provided in paragraph 28-16-28e(d)(2)(C)(ii). (2) Additional requirements in paragraph 28-16-28e(d)(2)(C)(i).

The new technical terms “epilimnion” and “metalimnion” would now be used in the water quality standards numeric criteria table 1g. Thus, it is appropriate to define the terms. As the term “hypolimnion” is not used in the suggested rule language, it is prudent to not include a definition for this layer of thermal stratification following guidelines for writing regulatory language. Following discussion and review with the editor for the WQS regulations, addition of the definitions to the table was deemed appropriate.

As presented, these revisions to Table 1g would result in more precise protection of lakes and reservoirs in Kansas with the dissolved oxygen criteria from its current overprotection of the hypolimnion, metalimnion, and bottom sediment interface as present. These revisions do not address attempts in the previous revision to allow addressing other naturally occurring excursions from the dissolved oxygen criteria of 5.0 mg/L, such as organic matter decomposition from litterfall in autumn or groundwater inputs to streams. As these naturally occurring conditions can be more readily defined temporally and spatially via observation and analysis, it is recommended site-specific criteria for dissolved oxygen be developed following EPA’s 2015 Interim Document and referenced in the “Kansas Implementation Procedures: Surface Water Quality Standards.”
These revisions to Table 1g and to the Implementation Procedures are anticipated to fully address EPA’s 7/18/2017 Action Letter Section II Items F, G, and H.

Alternative Approaches to Address EPA’s 7/18/2017 Action Letter:

The dissolved oxygen criteria presented as Table 1g with just footnote a(1) have been approved by EPA previously. It is considered possible to remove the additional footnotes a(2) and a(3) and retain the 5.0 mg/L for all applicable surface waters in Kansas due to this previous approval by EPA and its current standing as Clean Water Act effective. This option would be considered the least burdensome to change from a regulatory perspective due to its lack of change from current implementation.

A hybridized approach to retaining 5.0 mg/L for all layers of a lake or reservoir and setting criteria for the stratified layers would be to refine footnote a(3). Footnote a(3) for Table 1g can be revised to state “For lakes or reservoirs experiencing thermal stratification, the dissolved oxygen criterion is only applicable to the epilimnion and metalimnion of the waterbody.” EPA’s comment from the previous submission does not draw conflict with excluding the hypolimnion, and its removal through this exclusion would reduce much of the overprotection presented in the current criteria for dissolved oxygen. The definitions of the epilimnion and metalimnion would be added to the list of definitions at 28-16-28b as demonstrated with the first option of multiple tables for Table 1g.

With each of these solutions, footnote a(2) from Table 1g would be removed. However, there are other natural conditions that occur in surface waters of Kansas resulting in dissolved oxygen criteria excursions. One condition common to all lakes and reservoirs is sediment oxygen consumption, and this individual consideration should still be considered for addition to the criteria. Other natural occurrences more unique to each water body and location may be better refined in the future by development of site-specific criteria following the 2015 EPA document “A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document” and should be considered for adoption in the Kansas Implementation Procedures: Surface Water Quality Standards.

Impact Considerations:

The current dissolved oxygen criteria of 5.0 mg/L for all surface waters does not account for natural conditions such as lakes and reservoirs experiencing thermal stratification. Establishing criteria to protect the aquatic life in lakes and reservoirs undergoing stratification would likely result in fewer occurrences of impairment assessments due to natural conditions than what the currently approved criteria designate. Thus, further refinement of the criteria is likely to ease the regulatory burden for the state with 303(d) listing of impaired waters and subsequent development of a TMDL to address this impairment.

An increase in expected burden is estimated for assessment of dissolved oxygen measurements in thermally stratified lakes and reservoirs. Calculations for a water column with temperature and dissolved oxygen measurements will need to be made to demarcate the depth ranges of the epilimnion, metalimnion, and hypolimnion. It is considered within KDHE’s capacity to make this assessment following the criteria revision.

Lake chemistry site assessment:

The KDHE dataset for sampling conducted includes 343 unique lake locations for temperature and 219 unique lake locations for dissolved oxygen. The dataset used extends from May of 1989 to September of
2018 and includes depths from 0 m to 24 m. For evaluating stratification, depth had to be analyzed with these parameters, and for samples recorded at greater than 3 meters in depth there were 127 lake sites with 2,664 temperature measurements and 127 lake sites with 2,661 dissolved oxygen samples. Example figures\textsuperscript{15} of these data are provided and analyzed for comparison to the scientific concepts and regulatory approaches considered.
Jetmore Lake was sampled for temperature and dissolved oxygen on July 20th, 1999 and June 13th, 2016. By visual comparison of the data, the 1999 sampling demonstrates that the lake is isothermal and would be compared to the current criteria of 5.0 mg/L for all waters; by contrast, the 2016 sampling demonstrates the lake has thermally stratified and would be compared to the proposed stratified lakes criteria. Following the current dissolved oxygen criteria, the lake would be attaining in 1999 but impaired in 2016. However, using the proposed criteria revision of 3 mg/L in the metalimnion for stratified lakes would likely move this lake to be assessed as attaining the dissolved oxygen criteria. The isothermal conditions in 1999 reinforce the expansion of the criteria to account for this instead of deriving site-specific criteria due to a lack of pre-definability for stratification by a temporal (season) or spatial (depth) number as this may have been caused by strong winds physically mixing the waters from top to bottom. Thermal stratification is dynamic in relation to its duration and frequency.
Milford lake is included for review of a lake with known harmful algal blooms (HAB). It has received warning designations from the HAB program in 2011 and each of 2014–7. As can be seen, Milford thermally stratifies during each of the years sampled; however, dissolved oxygen data demonstrate several characteristics of a lake with a HAB. This includes the extremely high oxygen content at the surface in 2009 (~13 mg/L) and complete oxygen depletion at the bottom (~0 mg/L). This is likely a result of the excessive photosynthesizer growth (algae) at the surface producing oxygen and then decomposition of its resultant excess organic matter at the bottom of the lake depleting the oxygen. Comparing the criteria revision to Milford is also pertinent as it is a lake that has a TMDL on it (http://www.kdheks.gov/tmdl/2013/Milford_TMDL.pdf) for eutrophication and dissolved oxygen. As is demonstrated, the lake would still be considered impaired due to depleted dissolved oxygen in the metalimnion as seen in multiple years and even depletion observed in the epilimnion in 2000.
REFERENCES


Appendix: White Paper
WATER QUALITY STANDARDS
WHITE PAPER

ALLOWANCES FOR LOW DISSOLVED
OXYGEN LEVELS FOR AQUATIC LIFE USE

JANUARY 10, 2011
ALLOWANCES FOR LOW DISSOLVED OXYGEN LEVELS FOR AQUATIC LIFE USE

ISSUE

Should Kansas explicitly define conditions where low dissolved oxygen is acceptable?

It is the mission of the Kansas Department of Health and Environment (KDHE) to protect the health and environment of all Kansans by promoting responsible choices. One facet of this mission is the setting of water quality standards based on the best science available.

CURRENT CRITERIA

Currently, the Kansas Water Quality Standards (KSWQS) define the water quality criterion (5 mg/l) for dissolved oxygen in Table 1g of the KANSAS SURFACE WATER QUALITY STANDARDS: Tables of Numeric Criteria. K.A.R. 28-16-28e (d) states: The numeric criteria for the designated uses of classified surface waters shall be the numeric criteria specified in the department’s “Kansas surface water quality standards: tables of numeric criteria,” dated December 6, 2004, which is hereby adopted by reference. Table 1g includes the following condition for dissolved oxygen: The concentration of dissolved oxygen in surface waters shall not be lowered by the influence of artificial sources of pollution.

BACKGROUND

Dissolved oxygen is critical to maintaining a robust aquatic life community in Kansas waters. Dissolved oxygen (DO) is the concentration of oxygen dissolved in water and is necessary for the support of oxygen-demanding aquatic organisms such as fish, crawfish, snails; etc. For the warm water streams and lakes of the state, a universal criterion of 5 mg/l of dissolved oxygen has been applied for decades. To date, there have been no exceptions to this value nor site-specific criteria derived for any Kansas stream, lake or wetland. The listing methodology for developing the 303(d) list of impaired waters assesses dissolved oxygen as an acute impairment. Therefore, the frequency of dissolved oxygen levels falling below 5 mg/l on any Kansas water cannot be more than once every three years. A number of streams have been identified as impaired by low dissolved oxygen. Typically, the incidence of low dissolved oxygen occurs in the summer when water temperatures are high (reducing the ability of water to retain dissolved oxygen) and streamflows are low (reducing the
ability of the stream to re-aerate itself or flush or dilute any oxygen-demanding substances present in the water). At times, the introduction of organic material is natural, such as during periods of leaf fall. Additionally, ground water reaching the surface through springs and seeps may not have 5 mg/l of dissolved oxygen.

Lakes have also been listed for deficient dissolved oxygen, oftentimes in conjunction with eutrophication impairments. However, lakes with moderate levels of nutrient or algal content have sufficient levels of dissolved oxygen, but see dissolved oxygen diminish at their lower depths. This condition occurs particularly during times when the lake or reservoir thermally stratifies with warmer water lying above cooler, denser water. In Kansas lakes with moderate to high turbidity, light penetration into the water column is limited and organic material tends to accumulate in the lower depths (hypolimnion). Thus aerated water is thermally blocked from the hypolimnion and primary productivity to create dissolved oxygen is minimal at depth. Conversely, decomposition of organic matter and respiration by the aquatic life present near the lake bottoms consume what dissolved oxygen exists.

As an example, depth profiles for Clinton Lake are presented for 1991, 2006 and 2009. The lake showed stratification in 1991 and 2006, marked by the rapid decrease in temperature with depth. At the same time, the dissolved oxygen levels in the lower portions of the lake fell below 5 mg/l. In 2009, the lake was thoroughly mixed with uniform temperature throughout its profile. Dissolved oxygen levels in 2009 remained above the water quality standard.

The existing water quality standards expect dissolved oxygen to not be lowered by artificial sources of pollution. Secondary treatment by permitted wastewater facilities removes Biochemical Oxygen Demand (BOD) sufficiently so that the stream (or lake) receiving the wastewater does not see its dissolved oxygen levels sag below 5 mg/l. Kansas streams typically see a diel\(^1\) pattern for dissolved oxygen.

\(^1\) Diel – a chronological 24-hour day
oxygen, with the highest levels during daytime oxygen production by plant photosynthesis and the lowest concentrations seen during dark periods of respiration and decomposition. However, the language of the water quality standards implies that natural causation of low dissolved oxygen may occur and would be acceptable. Nonetheless, no allowance for naturally diminished dissolved oxygen has been made through the impaired waters [303(d)] listing process. Dissolved oxygen below 5 mg/l at a frequency more often than once every three years is cause for listing, with no regard to cause.

OTHER STATES’ APPROACH

Within Region VII, Iowa maintains a criterion of 5 mg/l for warm water aquatic life, but does restrict its application in lakes to their upper layer. Missouri is similar to Kansas stating water contaminants will not cause dissolved oxygen to fall below standards, but with no explicit allowances for natural conditions. Missouri does use a binomial approach in listing waters for dissolved oxygen and that analysis may discount some infrequent, naturally occurring episodes of low dissolved oxygen. Nebraska does not identify exceptions to its criteria, but applies a 1-day minimum of 5 mg/l and a 7-day average of 6 mg/l during the early life stage period of April through September. Nebraska also has criteria of 3, 4 and 5.5 mg/l during October thru March as 1, 7 and 30 day averages. Thus, while not having a provision accounting for natural causes of low dissolved oxygen, the use of averages allow for such causes to be discounted.

For the other two surrounding states, Oklahoma has a criterion of 5 mg/l for warm water aquatic communities, but decreases that to 4 mg/l during June 16 to October 15. Impairment is cited if more than 10% of the samples are below the criterion or if more than 2 samples are below 2 mg/l. For lakes, impairment is claimed if more than 50% of the lake water column has a dissolved oxygen concentration less than 2 mg/l or if 10% of the surface samples are below the 5/4 mg/l criteria.

In Colorado, stream dissolved oxygen is deemed impaired if the 15th percentile falls below the applicable criterion of 6 mg/l (7 mg/l during spawning season). Furthermore, Colorado states: Where dissolved oxygen levels are less than these levels occur naturally, a discharge shall not cause a further reduction in dissolved oxygen in receiving water. So there is a more overt recognition of naturally deficient conditions. For lakes, Colorado asserts: The dissolved oxygen criteria is intended to apply to the epilimnion and metalimnion strata of lakes and reservoirs. Dissolved oxygen in the hypolimnion may, due to the natural condition, be less than the table criterion. No reduction in dissolved oxygen levels due to controllable sources is allowed.

Elsewhere, Tennessee claims within their listing methodology: If the source of the low DO is a natural condition such as ground water, spring, or wetland, then the low DO is considered a natural condition and not pollution. North Carolina applies a daily average of 5 mg/l for non-trout waters, with a minimum instantaneous value of 4 mg/l and notes: swamp waters, lake coves or backwaters and lake bottom waters may have lower values if caused by natural conditions. Ohio and Pennsylvania have criteria for warm water fisheries of a 5 mg/l average and 4 mg/l minimum and applies its criteria only to the epilimnion (upper) layer of lakes. Minnesota applies a daily minimum of 5 mg/l to its cool and warm water fisheries and splits the year into two seasons; May through September and October through April. The assessment for dissolved oxygen requires no more than ten percent of the measurements taken in either period violate the standard. Furthermore, measurements must be taken before 9:00 am to
be representative of minimal conditions. Finally, dissolved oxygen in wetlands is expected to be maintained at background concentrations, indicating that wetlands have a propensity for low dissolved oxygen.

**OPTIONS**

There are a number of options that Kansas could adopt as an exception to the current water quality standard pertaining to dissolved oxygen. These options may be considered individually or as a combination to address situations in lakes and/or streams where dissolved oxygen levels fall below 5 mg/l.

1. Lower the dissolved oxygen criterion to 4 mg/l as an instantaneous minimum.
2. Assess dissolved oxygen similarly as a chronic impairment (binomial; 10%)
3. Explicitly state allowances for dissolved oxygen lower than 5 mg/l when caused by documented natural conditions.
4. Explicitly exclude applying dissolved oxygen criteria to the lowest portions of a lake (i.e. the hypolimnion)

**Impact Considerations:** Continuation of the status quo could allow some waters to remain perpetually listed as impaired when the cause of dissolved oxygen (DO) depression is the result of naturally occurring conditions. The consequence of listing waters as impaired include the implication that certain waters are polluted, thus lessening its value and potential uses that could be made of that water. Providing an allowance for naturally occurring conditions would allow waters to be assessed as unimpaired based on their natural state. Such a provision would direct state and federal resources toward true impairment issues, increasing the efficacy of water quality restoration efforts.

**REFERENCES**


