An Approach for Applying EPA's 2012 Recreational Water Quality Criteria Recommendation to Non-primary Contact Exposure Scenarios

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Notices

This document has undergone contractor-led external peer review as well as a review process within the U.S. Environmental Protection Agency (EPA). This document has undergone final review and been approved for publication by the Standards and Health Protection Division and Health and Ecological Division in the Office of Science and Technology.

Disclaimer:

This EPA document proposes an approach for adjusting EPA's existing §304(a) Recreational Water Quality Criteria recommendation for primary contact recreation that provides a similar risk of GI illness in non-primary contact exposure scenarios. This document does not change or substitute for any law, regulation, or any other legally binding requirement and is not legally enforceable. This document is not a regulation and does not impose legally binding requirements

on EPA, states, tribes, or the regulated community, and might not apply to a particular situation based upon the circumstances. EPA may change this document in the future.

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Abstract

EPA's 2012 Recreational Water Quality Criteria (RWQC) document describes primary contact recreation as "activities where immersion and ingestion are likely and there is a high degree of bodily contact with the water, such as swimming, bathing, surfing, water skiing, tubing, skin diving, water play by children, or similar water-contact activities." However, some states and authorized tribes adopt uses other than primary contact recreation. These other types of recreational uses have historically been dubbed secondary contact, limited water contact, limited body contact, partial body contact, incidental contact, or limited contact recreation (henceforth all referred to as non-primary contact recreation). Non-primary contact recreation is often associated with less ambient water contact and where immersion and ingestion of ambient water is less likely than primary contact recreation. Consequently, some states and tribes assign less stringent water quality values for non-primary contact recreation on the basis that less contact with pathogens in water compensates for a higher concentration of those pathogens resulting in the same overall risk of illness. However, there is limited information on how to determine water quality that would protect the public while engaging in non-primary contact recreation.

EPA proposes a method for applying non-primary contact exposure scenarios to the geometric mean and statistical threshold value in EPA's 2012 RWQC for primary contact recreation. This method characterizes exposure during different types of water recreation using quantitative data on the amount of incidental ingestion of ambient water. EPA derives an equation implementing this method as:

$$C_{non-primary}^{FIB} = C_{primary}^{FIB} \times \frac{I_{primary}}{I_{non-primary}}$$

where:

$C_{primary}^{FIB}$ = the concentration of fecal indicator bacteria (FIB) associated with a particular risk of illness during primary contact recreation.

$C_{non-primary}^{FIB}$ = the concentration of FIB in the same ambient water associated with the same risk of illness during non-primary contact recreation.

$I_{primary}$ = the amount of ambient water incidentally ingested during primary contact recreation as described in EPA's 2012 RWQC.

$I_{non-primary}$ = the amount of ambient water incidentally ingested during a specific non-primary contact recreational activity.

When the value of $C_{primary}^{FIB}$ equals a primary contact criterion magnitude specified in EPA's 2012 RWQC, the value $C_{non-primary}^{FIB}$ represents a comparable non-primary contact magnitude with the same risk of illness. This method is an approach for adjusting EPA's existing §304(a) RWQC recommendation for primary contact recreation to provide a similar risk of GI illness in non-primary contact exposure scenarios. This method is not itself an EPA criterion recommendation pursuant to §304(a) of the Clean Water Act.

1. Introduction

Between 2000 and 2014 there were at least 140 untreated recreational water–associated outbreaks that caused at least 4,958 illnesses and two deaths (Graciaa et al., 2018). EPA's 2012 recreational water quality criteria (RWQC) recommendation (USEPA, 2012b) provides specific levels of protection from gastrointestinal illness associated with "primary contact" recreation. EPA's 2012 RWQC document describes primary contact recreation as "activities where immersion and ingestion are likely and there is a high degree of bodily contact with the water, such as swimming, bathing, surfing, water skiing, tubing, skin diving, water play by children, or similar water-contact activities." For some waters where primary contact activities do not occur, occurs seasonally, or where the water quality does not support primary contact recreation, some states and authorized tribes adopt other types of recreational uses. These other types of recreational uses have historically been dubbed secondary contact, limited water contact, limited body contact, partial body contact, incidental contact, or limited contact recreation (henceforth all referred to as non-primary contact recreation).

Non-primary contact recreation can also result in gastrointestinal illness (Dorevitch et al., 2012). However, non-primary contact recreation is presumed to be associated with less ambient water contact and where immersion and ingestion of ambient water is less likely compared to primary contact recreation. Consequently, water quality standards for non-primary contact recreation are often less stringent than EPA's recommendation for primary contact recreation based on the presumption that less contact with ambient water compensates for a higher pathogen concentration in recreational waters resulting in the same risk of illness. Some states have developed values for protection of non-primary contact recreation by multiplying EPA's RWQC recommendations for primary contact recreation by a factor of five and occasionally as high as ten. However, there is a limited or outdated scientific basis for developing or evaluating water quality standards for non-primary contact recreational uses. The multiplier value of five was derived from RWQC recommendations in a 1968 National Technical Advisory Committee report (Federal Water Pollution Control Administration, 1968) that EPA later assessed as insufficient (USEPA, 1986).

Although the scientific justification for previous multiplier values was limited, using a multiplier to adjust primary contact recreation values to address risk in non-primary contact exposure scenarios may be a reasonable approach. Illness risk associated with recreational exposure to ambient water is related to both the degree of exposure to water during recreation and the concentration of pathogens in that water (USEPA, 2012a). EPA's 2012 RWQC identifies gastrointestinal (GI) illness as the most appropriate health endpoint through the exposure route of oral ingestion. Individuals engaging in activities with greater water contact (i.e., greater exposure through oral ingestion) have a higher risk of GI illness compared to individuals engaging in activities with less water contact (i.e., less exposure through oral ingestion) (Russo et al., 2020; Wade et al., 2008; Wade et al., 2006; Wade, Pai, Eisenberg, & Colford, 2003; Wade et al., 2010). A recent systematic review and meta-analysis (Russo et al., 2020) evaluated risk of illness associated with three different categories of recreational activities corresponding to different types of water contact – swimming, minimal contact (e.g., fishing, boating, and canoeing or kayaking in calm waters), and sports-related contact (e.g., snorkeling, surfing, and canoeing or kayaking in turbulent waters). The study by Russo et al. (2020) suggests minimal contact activities with a lower level of exposure to ambient water are associated with a lower risk of GI

illness compared to swimming, whereas sports-related activities with the same or higher level of exposure to ambient water are associated with the same or higher risk of GI illness compared to swimming. Thus, both water quality and the level of exposure determines illness risk associated with recreation in ambient water.

Given a concentration of pathogens in ambient water, the main difference between risk of GI illness associated with primary contact recreation and risk of GI illness associated with non-primary contact recreation is the level of exposure through oral ingestion. EPA's current RWQC recommendation (USEPA, 2012b) applies to a level of exposure characterized as primary contact recreation. One way to achieve a similar level of public health protection for non-primary contact recreation is to apply alternative exposure scenarios to the values EPA recommends in its 2012 RWQC for primary contact recreation that results in the same level of pathogen ingestion during non-primary contact recreation. This white paper proposes a method for adjusting EPA's RWQC recommendation for primary contact recreation to provide a similar risk of GI illness in non-primary contact exposure scenarios. This proposed method is not itself a criteria recommendation as provided under §304(a) of the Clean Water Act.

2. Application of the methodology from EPA's 2012 RWQC to non-primary contact recreation scenarios

EPA proposes a method for applying non-primary contact exposure scenarios to the methodology used in EPA's 2012 RWQC for primary contact recreation. The proposed method uses quantitative data on the amount of incidental ingestion of ambient water during different types of recreational activities as the measure of exposure.

2.1. Approach

When developing its 2012 RWQC, EPA identified the hazard of concern as pathogenic microorganisms in fecally-contaminated surface waters. Pathogens often co-occur with bacterial indicators of fecal contamination. Therefore, EPA relied on fecal indicator bacteria (FIB) to serve as pathogen indicators. A pathogen indicator, as defined in §502(23) of the CWA, as amended by the BEACH Act, is defined as: "a substance that indicates the potential for human infectious disease." EPA has a long history of using FIB for protecting people who use recreational waters and has long set water quality criteria for the protection of primary contact recreation based on the relationship between FIB density and the occurrence of human illness. Using a series of epidemiological studies EPA conducted in association with the development of its 1986 Ambient Water Quality Criteria for Recreation Waters (Cabelli, 1983; Dufour, 1984; USEPA, 1986) and National Epidemiological and Environmental Assessment of Recreational Water (NEEAR) studies (USEPA, 2009; Wade et al., 2008; Wade et al., 2006; Wade et al., 2010), EPA found gastrointestinal (GI) illnesses had the strongest association with FIB concentration and concluded that criteria based on protecting the public from GI illness will prevent most types of recreational waterborne illnesses (USEPA, 2012b). Those epidemiological studies used primary contact and no-contact exposure groups to evaluate illness rates associated with different levels of FIB in recreational waters. The epidemiological studies allowed EPA to develop a dose-response assessment (i.e., evaluation of illness risk at different water quality levels) among participants who engaged in primary contact recreation. EPA developed criteria values as levels of FIB corresponding to specified illness rates.

In this paper, EPA proposes an approach for determining the water quality necessary to protect non-primary contact recreational uses. The approach is based on applying adjustment factors to EPA's 2012 RWQC for primary contact recreation. EPA's 2012 RWQC focused on water quality associated with risk of GI illness during primary contact recreation. However, differences in risk of GI illness between primary and non-primary contact recreation can be characterized as due to differences in exposure to pathogens in water through oral ingestion. The approach proposed here assumes the same stressors EPA used to develop it's 2012 RWQC for primary contact recreation (pathogenic microorganisms in fecally-contaminated surface waters) but derives adjustment factors representing differences in levels of water contact during primary and non-primary contact recreation. The adjustment factors are derived from data on incidental ingestion during primary and non-primary contact recreation. Application of the adjustment factors to the values in EPA's 2012 RWQC for primary contact recreation results in water quality values with a similar risk of GI illness during non-primary contact recreation.

As mentioned above, EPA does not consider the approach described in this paper or any values resulting from the approach as criteria recommendations pursuant to §304(a) of the Clean Water Act. Instead, EPA considers the approach described in this paper an implementation tool to help states and authorized tribes make risk management decisions when considering recreational designated uses other than primary contact recreation and to help determine the levels of FIB necessary to protect those designated uses. Any water quality values resulting from the application of the approach described in this paper are not applicable for Clean Water Act purposes until a state or authorized tribe adopts them into their state or tribal water quality standards and EPA approves them. EPA expects states and authorized tribes to rely on their EPA-approved RWQC for primary contact recreation when both primary and non-primary contact recreation co-occur or are co-designated consistent with EPA regulations at 40 CFR §131.11(a) regarding protection of the most sensitive designated use.

2.2. Assumptions

EPA assumes the hazard of concern, indicators of fecal contamination, enumeration methods, human health endpoints, scope of analysis, and the pathogen dose-response relationship EPA used to develop its 2012 RWQC for primary contact recreation are applicable to both primary contact and non-primary contact recreation. EPA assumes the pathogens causing GI illness associated with primary contact recreation are the same pathogens causing GI illness associated with non-primary contact recreation. EPA also assumes the same FIB EPA used to develop its 2012 RWQC for primary contact recreation applies to non-primary contact recreation scenarios.

Although the dose-response relationships of most pathogens are sigmoidal in shape with an inflection point above which there is a steep increase in risk of infection and illness with increasing dose, the relationship between dose and illness risk is roughly linear in the low-dose range below the inflection point that includes the illness risk targets of EPA's 2012 RWQC (32 – 36 illnesses/1000 recreators). Thus, EPA assumes that the dose-response relationships of the pathogens responsible for excess GI illness associated with non-primary contact recreation is also linear in the dose range expected to occur in non-primary contact recreational waters.

EPA conducted epidemiological studies that were the basis of its 2012 RWQC at highly used beaches at a variety of geographic locations that included participants with a broad

demographic profile. EPA assumes the same health outcomes, host-pathogen profile, FIB-pathogen relationships, and FIB-risk relationships apply to both primary contact and non-primary contact recreators.

2.3. Exposure assessment

EPA proposes applying an adjustment factor to EPA's 2012 RWQC to characterize alternative exposure scenarios associated with non-primary contact recreation. A critical component of this approach is an assessment of the exposure associated with different recreational activities. EPA describes primary contact recreation as "activities where immersion and ingestion are likely and there is a high degree of bodily contact with the water, such as swimming, bathing, surfing, water skiing, tubing, skin diving, water play by children, or similar water-contact activities." However, water recreation encompasses a greater diversity of activities including but not limited to snorkeling, windsurfing, bodysurfing, rafting, canoeing, kayaking, rowing, standup paddle-boarding, boating, fishing, caving, and sailboarding. Furthermore, the weather and water conditions during recreation may have a substantial effect on the magnitude and/or probability of exposure. For example, rafting, canoeing, or kayaking in relatively calm conditions are likely to result in a lower exposure compared to those same activities during high water flows or in turbulent conditions.

Microbial exposure assessment estimates or measures the route, duration, magnitude, and frequency of exposure to a microbial hazard, along with the number and characteristics of the person or population exposed (USEPA, 2012a). Understanding the exposure profile of recreators in ambient water during primary and non-primary contact recreation provides the basis for adjusting the exposure assessment element underlying the studies and methodology in EPA's 2012 RWQC.

2.3.1. Route

The epidemiological studies that form the basis of EPA's 2012 RWQC for primary contact recreation evaluated a variety of adverse health endpoints including GI illnesses, upper respiratory illnesses, rash, eye ailments, earache, and skin infections. Because the primary route of exposure to microorganisms causing GI illness is oral ingestion, EPA assumes incidental oral ingestion of ambient water as the route of exposure to water-borne pathogens associated with both primary and non-primary contact water recreation.

2.3.2. Duration

Duration of exposure describes the length of time a person is exposed to a microbial hazard. The epidemiological studies that form the basis of EPA's 2012 RWQC for primary contact recreation estimated illness risk associated with the cumulative exposure to ambient water that typically occurs during a one-day beach visit. EPA assumes that a one-day visit to a surface water location is a reasonable characterization of the duration of exposure for both primary contact and non-primary contact recreation.

2.3.3. Magnitude

Exposure magnitude describes the amount (dose) of a microbial hazard. In the context of water-based recreation, exposure magnitude can be characterized as jointly the amount of water that recreators incidentally ingest and the density of pathogenic microorganisms in the ingested water.

Although recreators generally seek to avoid swallowing ambient water while recreating, instances of incidental ingestion during recreation can occur. The cumulative amount of water that recreators incidentally ingest during one day of water-based recreation is primarily determined by two factors. One factor is the amount of water recreators swallow with each instance, and the other factor is the number of times such instances occur.

The number of times recreators swallow ambient water during one day of recreation can vary with different recreational activities. The probability of incidental water ingestion is highest when recreators immerse their head below the surface of the water, and different recreational activities are associated with different probabilities of head immersion. For example, Wade et al. (2006) found in their epidemiological study of primary contact recreation that 30% (1734/5716) of beachgoers reported immersing their head below the surface of the water whereas Dorevitch et al. (2011) found in their study of incidental water ingestion during non-primary contact recreation that only 5.4% (41/766) of surface water canoers and 3.4% (27/801) of surface water kayakers reported capsizing (and thus immersing their head below the surface of the water).

The amount of water swallowed with each instance may also vary with different recreational activities. For example, the amount of swallowed water in each instance is likely higher with head immersion compared to splashing or hand-to-mouth contact. The amount of swallowed water in each instance may also depend on the level of physical exertion or the unique characteristics of the activity (e.g., water skiing where relatively large amounts of water may be forced into the mouth during impact with the water's surface).

Several studies of incidental water ingestion associated with different types of water-based recreational activities have been published (DeFlorio-Barker et al., 2018; Dorevitch et al., 2011; Dufour, Behymer, Cantu, Magnuson, & Wymer, 2017; Dufour, Evans, Behymer, & Cantu, 2006; Schets, Schijven, & de Roda Husman, 2011; Suppes, Abrell, Dufour, & Reynolds, 2014). EPA developed exposure values for primary contact recreation in a recent recreational water quality criteria for cyanotoxins (USEPA, 2019a) based on results of Dufour et al. (2017). EPA's Exposure Factors Handbook summarizes many (but not all) of these studies and provides tables of ingestion estimates for a variety of different types of recreational activities (USEPA, 2019b). These studies reported the amount of incidental ingestion either as a rate of ingestion per unit time or as a total amount over a particular time period. EPA assumes that the magnitude of exposure is characterized as jointly the cumulative amount of ambient water incidentally ingested during the exposure duration (one day of recreation) and the density of pathogenic microorganisms in the water ingested.

Children exhibit behaviors that increase their exposure to environmental contaminants, including increased head and body immersion in recreational waters (USEPA, 2009; Wade et al., 2008; Wade et al., 2006) and hand-to-mouth contact (Xue et al., 2007). Children also stay in the water longer than adults (Wade et al., 2008; Wade et al., 2006) and ingest more water (DeFlorio-Barker et al., 2018; Suppes et al., 2014). Although EPA exposure values for primary contact recreation in a recent recreational water quality criteria for cyanotoxins were based on exposure

to children (USEPA, 2019a), EPA's 2012 RWQC recommendations are based on exposure to the general population including children. Therefore, the approach proposed in this paper assumes exposure to the general population including children.

2.3.4. Frequency

Frequency of exposure describes how often a person is exposed to a microbial hazard. As discussed in section 2.3.3, the probability of incidental water ingestion is highest when recreators immerse their head below the surface of the water. A variety of conditions and circumstances can affect the frequency of such events. However, the epidemiological studies underlying EPA's 2012 RWQC for primary contact recreation evaluated illness rates associated with the cumulative total of all exposure events during one day of primary contact recreation in a typical beach environment. Because primary contact and non-primary contact recreation are likely to occur in ambient surface waters with similar physical characteristics, EPA assumes the frequency of individual exposure events is determined by the particular recreational activity of the recreator. Thus, the frequency of exposure is incorporated into the characterization of exposure magnitude and the exposure dose constitutes the total number of organisms in the set of individual exposures that occur during one day of recreation.

2.4. Developing adjustment factors for non-primary contact exposure scenarios

The "dose" associated with illness risk is the number of pathogenic microorganisms incidentally ingested during recreation. As discussed in section 2.3, the number of pathogenic microorganisms incidentally ingested during recreation is determined by both the density of pathogenic microorganisms in the water and the amount of water incidentally ingested. The FIB density recommended in EPA's 2012 RWQC associated with a particular illness rate assumes an ingestion amount typically expected while engaging in primary contact recreation over the course of a single day. Ingestion amount associated with non-primary contact recreation can be used to estimate an alternative FIB concentration that results in the same "dose" of pathogenic microorganisms that results in the same illness rate as provided by EPA's 2012 RWQC for primary contact recreation.

The relationship between microorganism concentration, ingestion amount, and illness risk can be represented mathematically. Assuming illness risk during recreation is the result of the number of pathogenic microorganisms incidentally ingested, then:

$$D_{primary} = C^{org}_{primary} \times I_{primary} \qquad \text{(Equation 1)}$$

and

$$D_{non-primary} = C^{org}_{non-primary} \times I_{non-primary} \qquad \text{(Equation 2)}$$

where:

$D_{primary}$ = the number of pathogenic microorganisms ("dose") incidentally ingested during primary contact recreation,

$D_{non-primary}$ = the number of pathogenic microorganisms ("dose") incidentally ingested during non-primary contact recreation,

$C^{org}_{primary}$ = the concentration of pathogenic microorganisms in ambient water during primary contact recreation,

$C^{org}_{non-primary}$ = the concentration of pathogenic microorganisms in ambient water during non-primary contact recreation,

$I_{primary}$ = the amount of ambient water incidentally ingested during primary contact recreation as described in EPA's 2012 RWQC.

$I_{non-primary}$ = the amount of ambient water incidentally ingested during a specific non-primary contact recreational activity.

Because illness risk is determined by the number of pathogenic microorganisms incidentally ingested during recreation and EPA is interested in identifying a concentration of pathogenic microorganisms that results in the same illness risk under both primary contact and non-primary contact exposure scenarios, EPA sets the number of microorganisms ingested to be the same in both scenarios such that:

$$D_{primary} = D_{non-primary}$$

Thus, EPA can combine Equation 1 and Equation 2 to yield:

$$C^{org}_{non-primary} \times I_{non-primary} = C^{org}_{primary} \times I_{primary} \quad \text{(Equation 3)}$$

Equation 3 represents two exposure scenarios (non-primary contact recreation on the left and primary contact recreation on the right) where the combination of water quality and incidental ingestion amount for each scenario result in the same illness risk. Because EPA seeks to identify water quality during non-primary contact recreation that results in the same illness risk as water quality during primary contact recreation, EPA rearranges Equation 3 to yield:

$$C^{org}_{non-primary} = C^{org}_{primary} \times \frac{I_{primary}}{I_{non-primary}} \quad \text{(Equation 4)}$$

Equation 4 specifies the concentration of pathogenic microorganisms in water during non-primary contact recreation associated with the same illness risk as primary contact recreation by multiplying the concentration of pathogenic microorganisms in water associated with the illness rate specified in EPA's 2012 RWQC with the ratio of primary contact ingestion amount to non-primary contact ingestion amount. However, EPA's 2012 RWQC for primary contact recreation does not specify a concentration of pathogenic microorganisms in water, but rather a concentration of FIB. Applying the assumptions described in Section 2.2 that increasing GI illness associated with increasing FIB densities in human-impacted waters is due to increasing concentrations of pathogens that cause GI illness and the dose-response relationship for pathogens that cause GI illness in recreational waters is linear in the dose range expected to occur in waters used for recreation, EPA can represent the concentration of pathogenic microorganisms in water as directly proportional to the concentration of FIB. Such

proportionality can be represented as a simple linear equation in two variables with a y-intercept of 0 and a slope of k such that:

$$C_{primary}^{org} = k_{primary} \times C_{primary}^{FIB}$$

and

$$C_{non-primary}^{org} = k_{non-primary} \times C_{non-primary}^{FIB}$$

where:

$C_{primary}^{org}$ = the concentration of pathogenic microorganisms in ambient water during primary contact recreation,

$C_{non-primary}^{org}$ = the concentration of pathogenic microorganisms in ambient water during non-primary contact recreation,

$C_{primary}^{FIB}$ = the concentration of FIB in ambient water during primary contact recreation,

$C_{non-primary}^{FIB}$ = the concentration of FIB in ambient water during non-primary contact recreation,

$k_{primary}$ = the slope of the linear relationship between the concentration of pathogens and the concentration of FIB in primary contact recreational waters,

$k_{non-primary}$ = the slope of the linear relationship between the concentration of pathogens and the concentration of FIB in non-primary contact recreational waters.

Applying the assumption described in Section 2.2 that the relationship between the concentration of pathogenic microorganisms and the concentration of FIB in recreational waters are the same for primary contact and non-primary contact recreation, $k_{primary}$ and $k_{non-primary}$ are equal. Thus, EPA can represent the constant of proportionality under primary contact and non-primary contact exposure scenarios as a single constant *k* such that:

$$C_{primary}^{org} = k \times C_{primary}^{FIB}$$

and

$$C_{non-primary}^{org} = k \times C_{non-primary}^{FIB}$$

Replacing $C_{primary}^{org}$ with $k \times C_{primary}^{FIB}$ and replacing $C_{non-primary}^{org}$with $k \times C_{non-primary}^{FIB}$ in Equation 4 yields:

$$k \times C^{FIB}_{non-primary} = k \times C^{FIB}_{primary} \times \frac{I_{primary}}{I_{non-primary}} \quad \text{(Equation 5)}$$

Because the proportionality constant *k* is on both sides of Equation 5, they cancel yielding:

$$C^{FIB}_{non-primary} = C^{FIB}_{primary} \times \frac{I_{primary}}{I_{non-primary}} \quad \text{(Equation 6)}$$

Equation 6 shows that the concentration of FIB representing illness risk associated with non-primary contact recreation equals the concentration of FIB representing the same illness risk associated with primary contact recreation multiplied by the ratio of primary contact ingestion amount to non-primary contact ingestion amount. When $C^{FIB}_{primary}$ equals a criterion value provided in EPA's RWQC recommendations for primary contact recreation, $C^{FIB}_{non-primary}$ equals an adjusted value for non-primary contact recreation with the same illness risk. Note that $I_{primary}$ is the amount of incidental ingestion of ambient water associated with primary contact recreation, and $I_{non\text{-}primary}$ is the amount of incidental ingestion of ambient water associated with the non-primary contact recreational activities that are the focus of the analysis. Also note Equation 6 is like multiplying a value for primary contact recreation with a multiplier as has been common past state practice, except here the multiplier is derived from quantitative data representing exposure during specific non-primary contact recreational activities. Furthermore, $I_{primary}$ and $I_{non\text{-}primary}$ can be specified in any appropriate unit of measure because they effectively cancel (provided the units of measure for both values are the same). Section 3 discusses considerations when choosing ingestion amount estimates for Equation 6.

3. Incidental water ingestion during different recreational activities

Applying the methodology from EPA's 2012 RWQC to non-primary contact recreation using Equation 6 depends on quantitative data on the amount of incidental water ingestion associated with recreation. The value $I_{primary}$ represents the amount of incidental ingestion associated with primary contact recreation as defined in EPA's 2012 RWQC, and the value $I_{non\text{-}primary}$ represents the amount of incidental ingestion associated the targeted non-primary contact recreation. Several published studies provide ingestion amount estimates for a variety of different recreational activities (DeFlorio-Barker et al., 2018; Dorevitch et al., 2011; Dufour et al., 2006; Schets et al., 2011; Schijven & de Roda Husman, 2006; Stone, Harding, Hope, & Slaughter-Mason, 2008; Suppes et al., 2014; USEPA, 2019a). These studies provide incidental ingestion estimates for the following activities:

- Boating,
- Canoeing in calm water (i.e., no capsizing),
- Canoeing in turbulent water (i.e., with capsizing),
- Exercise swimming,
- Fishing,
- Kayaking in calm water (i.e., no capsizing),
- Kayaking in turbulent water (i.e., with capsizing),
- Leisure swimming,
- Occupational diving,
- Rowing in calm water (i.e., no capsizing),

- Rowing in turbulent water (i.e., with capsizing),
- Sports diving with full face mask,
- Sports diving with ordinary face mask,
- Surfing,
- Swimming,
- Wading/splashing,
- Walking.

EPA's Exposure Factors Handbook (USEPA, 2019b) summarizes many of these studies and compiles quantitative estimates of incidental ingestion provided by those studies in a collection of tables.

The approach described in this white paper relies on accurately establishing the ratio of incidental ingestion of ambient water associated with primary contact to the incidental ingestion of ambient water associated with non-primary contact recreation. Thus, selecting an appropriate matched pair of quantitative measurements for both primary and non-primary contact recreation is essential. Because the epidemiological studies forming the basis of EPA's 2012 RWQC describe exposure as swimming or wading, it is reasonable to use an incidental ingestion estimate associated with swimming or wading as an appropriate value for $I_{primary}$. EPA's Exposure Factors Handbook lists a range of estimates of incidental ingestion associated with primary contact recreation. EPA has also derived peer-reviewed ingestion rate estimates associated with primary contact recreation acceptable for developing recreational water quality criteria (USEPA, 2019a). However, EPA has not derived analogous ingestion rate estimates for non-primary contact recreation with the same scientific rigor. At the time of this writing, ingestion rate estimates for non-primary contact recreation are limited, with only one study (Dorevitch et al., 2011) providing estimates of incidental ingestion associated with typical non-primary contact recreational activities. Additional data on incidental ingestion of ambient water during non-primary contact recreational activities may become available as interest in implementing the approach proposed in this paper increases.

The approach described in this white paper depends on accurately establishing the ratio of primary contact to non-primary contact incidental ingestion of ambient water. Thus, the selection of values for $I_{primary}$ and $I_{non\text{-}primary}$ should consider potential biases present in both estimates. A variety of factors could potentially bias estimates of incidental ingestion associated with recreation. Some sources of bias may be random (that is, inherently unpredictable such as fluctuations in the readings of a measurement apparatus), whereas other sources of bias may be systematic (that is, always affecting the results in a predictable direction). Sources of potential bias include:

- Gender (e.g., female versus male),
- Age (e.g., children versus adults),
- Salinity (fresh waters versus marine waters),
- Study venue (surface waters versus pools),
- Measurement technique (cyanuric acid in urine versus categorical self-reported ingestion amount such as drop, teaspoon, mouthful, shot glass, etc.),
- Definition of recreational activity (e.g., wading, bathing, playing, swimming, etc.),

- Recreational activity specifications (e.g., any contact with water versus requiring head-immersion),
- Statistic reported (e.g., arithmetic mean, geometric mean, median, 95th percentile, etc.),
- Unit of measurement (e.g., ml/hour, ml/day, or ml/event),
- Other study-specific uncontrolled confounding variables (either known, forgotten, or unknown).

Because Equation 6 calculates an adjustment factor as the ratio of $I_{primary}$ to $I_{non\text{-}primary}$, one approach for choosing appropriate values for $I_{primary}$ and $I_{non\text{-}primary}$ is to choose a pair of values with the same biases so that the biases cancel. In addition, units of measure for $I_{primary}$ and $I_{non\text{-}primary}$ should be the same, should be appropriate for describing incidental ingestion of ambient water during recreation, and should be consistent with the distribution of the underlying data.

The value of $I_{primary}$ represents the primary contact exposure scenario in the epidemiological studies that was the basis of EPA's 2012 RWQC, and the value of $I_{non\text{-}primary}$ represents the non-primary contact exposure scenario of interest. Because the primary contact exposure scenario in EPA's epidemiological studies was a combination of children and adults engaging in primary contact recreation, $I_{primary}$ should be a value that reflects overall incidental ingestion of both children and adults engaging in primary contact recreation.

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