RATIONALE:
Nevada's Recreational Risk Thresholds for Cyanobacteria

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Recreational Risk Thresholds

Recreational risk thresholds serve as the basis for the application of recreational advisories, response actions, and allocation of resources. The World Health Organization (WHO) developed a hierarchy of the relative probability of acute health effects to account for the possible exposures through recreational activities (contact, ingestion, and inhalation) during recreational exposure to cyanobacteria (WHO, 2003). Using the WHO's framework, Nevada has developed risk threshold values from several sources described below and applied them to a hierarchy of recreational risk (**Table 1**). Risk levels are categorized into three levels: low, moderate, and high. Each level of risk corresponds to measurable parameters of cyanobacteria or cyanotoxin abundance and indicates the need for particular actions.

Recreational Risk	Possible Health Implications	Possible Actions
Low probability of adverse health effects	Short-term adverse health outcomes, e.g., skin irritations, gastrointestinal illness	-Post on-site risk advisory signs. -Inform relevant authorities. -Post online recreational advisory.
Moderate probability of adverse health effects	Potential for long-term illness with some cyanobacterial species health outcomes, e.g., skin irritations, gastrointestinal illness	-Post on-site risk advisory signs. -Inform relevant authorities. -Post online recreational advisory. -Issue social media release -Consider restricting access
High probability of adverse health effects	Potential for acute poisoning Potential for long-term illness with cyanobacterial species Short-term adverse activities health outcomes, e.g., skin irritations, gastrointestinal illness	Post on-site risk advisory signs. -Inform relevant authorities. -Post online recreational advisory. -Issue social media release -Contact local media -Consider restricting access

Table 1. Nevada's Hierarchy of Risk for Cyanobacteria

Nevada has derived threshold values for three cyanotoxins: microcystin, cylindrospermopsin, and anatoxin-a. Microcystin and Cylindrospermopsin have been subject to extensive research and have established methodologies for analysis. Risk threshold values for microcystin and cylindropspermopsin are based on a combination of guidance from the US Environmental Protection Agency (EPA) and the WHO. Although Anatoxin-a has been the subject of a smaller body of research, the neurotoxicological effects are of such concern that, to adequately protect the health of the public, recreational risk thresholds have been developed based on toxicological studies conducted in California and Oregon. Below are descriptions of the studies and methodologies on which Nevada's risk thresholds are based.

EPA

EPA issued guidance documentation specifying recreational risk thresholds for the issuance of recreational advisories in 2019. The documentation included recreational risk values for microcystin and cylindrospermopsin (EPA, 2019) (**Table 2)**. EPA's study design for microcystin and cylindrospermopsin provide the health effects basis for development of oral toxicity values that are used as the measure of effect for oral exposure through incidental ingestion while recreating. The results are based on short-term and subchronic studies and therefore are an estimate (with uncertainties spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a short-term exposure period.

Table 2. EPA Swimming Advisory Recommendations for Microcystins and Cylindrospermopsin, 2019

Microcystins Magnitude (µg/L)	Cylindrospermopsin Magnitude (µg/L)	Exceedance Threshold
8	15	Not to be exceeded

The EPA selected incidental ingestion during primary contact activities (such as swimming) in derivation of the swimming advisory values because data suggest that incidental ingestion can be considered the highest potential exposure pathway for cyanotoxins while recreating. EPA cited studies of incidental ingestion during recreation indicate that the odds of ingesting a teaspoon or more of water are significantly higher among swimmers than among those who just immersed their head in a swimming pool or those who participated in the other, more limited contact activities on surface waters. Therefore, the EPA determined that using a swimmer scenario for exposure as the basis for the criteria is protective of these other aquatic activities.

WHO

The WHO issued guidance documentation for recreational risk thresholds for cyanobacteria cell concentration and microcystin concentration in 2003 (**Table 3**). For protection from health outcomes not due to cyanotoxin toxicity, but rather to the irritative or allergenic effects of other cyanobacterial compounds, the WHO issued a guideline level of 20,000 cyanobacterial cells/ml (corresponding to 10mg chlorophyll-a/litre under conditions of cyanobacterial dominance), derived from the prospective epidemiological study by Pilotto et al. (1997) (WHO, 2003). Whereas the health outcomes reported in this study were related to cyanobacterial density and duration of exposure, they affected less than 30% of the individuals exposed. At this cyanobacterial density, 2–4mg microcystin/litre may be expected if microcystin-producing cyanobacteria are dominant, with 10mg/litre being possible with highly toxic blooms. Thus, health outcomes due to microcystin are unlikely.

Relative Probability of Acute Health Effects	Cyanobacteria (cells/mL)	Chlorophyll *a* (µg/L)	Estimated Microcystin Levels (µg/L)
Low	< 20,000	< 10	< 10
Moderate	20,000–100,000	10–50	10–20
High	>100,000–10,000,000	50–5,000	20–2,000
Very High	> 10,000,000	> 5,000	> 2,000

Table 3. WHO Recreational Action Levels for Cyanobacteria, Chlorophyll *a,* and Microcystin, 2003

The WHO microcystin recreational thresholds for high risk are based on calculations of incidental ingestion by a child recreating in dense cyanobacteria scum. Calculations suggest that a child playing in *Microcystis* scum for a protracted period and ingesting a significant volume could receive a lethal dose, although no reports indicate that this has occurred (WHO, 2003). Based on evidence that a lethal oral dose of microcystin-LR (the most toxic compound of the microcystin family of toxins) in mice is 5000–11,600mg/kg body weight and sensitivity between individuals may vary approximately 10-fold, the ingestion of 5–50 mg of microcystin could be expected to cause acute liver injury in a 10-kg child. Concentrations of up to 24 mg/liter microcystin from scum material have been published. Based on this data, the WHO recommended values for high to very-high risk exposure to microcystin represents a conservative approach to protecting vulnerable populations. Uncertainty factors were accounted for during extrapolation from mouse to human, differing sensitivities within humans, and for an incomplete toxicological database.

California Office of Environmental Health Hazard Assessment

The California Office of Environmental Health Hazard Assessment (OEHHA) conducted toxicological studies to guide the state's development of recreational risk values for cylindropspermopsin (**Table 4**). OEHHA's recommended upper level of risk for cylindrospermpsin is based on a benchmark dose (BMDL) study in mice conducted by Humpage and Falconer (2003) (OEHHA, 2016). The endpoint was increased kidney weight, indicating mild impaired kidney function. The exposure scenario is a child swimming in recreational waters for 2 hours per day (30.25 kg child ingesting 0.05 L water per hour, or 0.1 L per day). OEHHA's high risk threshold value is health-based and conservative.

Basis of Trigger	Trigger (µg/L)	Study
Risk Management: *Precautionary Approach*	1	--
OEHHA's Action Level	4	Humpage and Falconer (2003)
Modified OEHHA Action Level	17	Humpage and Falconer (2003)

Table 4. OEHHA Action Levels for Cylindrospermopsin, 2016

OEHHA also conducted toxicological studies to guide the state's development of recreational risk values for anatoxin-a (**Table 5**). OEHHA's recommended threshold for low risk is based on Oregon's recreational risk guidelines by Farrer et al. (2015) (OEHHA, 2016). The study looked at short term oral exposure in mice done by Fawell et al. (1999b). The mice were examined for a wide range of toxicological endpoints both during and at the end of the study. There was no statistically

significant difference between the control group and any of the dosed groups for any of these endpoints. However, there were two unexplained deaths in the study -- one each in the mid- and high-dose groups. Anatoxin-a was not suspected in these deaths, but it was not possible to rule it out. Therefore, OEHHA set the lowest dose, as the No-Observed Adverse Effect level. The exposure scenario was a child swimming in recreational waters for 2 hours per day (20 kg child ingesting 0.05 L water per hour, or 0.1 L per day).

Basis of Trigger	Trigger (µg/L)	Study
Risk Management: *Precautionary Approach*	Detect	--
Risk Management: *OEHHA's Guideline*	20	Fawell et al., 1999b
OEHHA's Action Level	90	Fawell et al., 1999b

Table 5. OEHHA Action Levels for Anatoxin-a, 2016

OEHHA's recommended anatoxin-a threshold for high risk was also based on the short-term oral study in mice by Fawell et al., (1999b) (**Table 5**). As described above, there was no statistically significant difference between the control group and any of the dosed groups for a wide array of endpoints. OEHHA did not consider the two unexplained mortalities described above to be treatment related. The mice in this study were exposed daily through oral gavage, which is a somewhat stressful technique that can lead to unintended mortalities. OEHHA identified the highest dose as the highest risk level. The exposure scenario included a child swimming in recreational waters for 5 hours per day (30.25 kg child ingesting 0.05 L water per hour, or 0.25 L per day). OEHHA also considered exposures through inhalation and skin contact.

Nevada Recreational Risk Thresholds for Cyanobacteria

Based on the above toxicological studies, and with the intent of developing a hierarchy of risk based on recreational contact with varying concentrations of cyanobacteria and their toxins, **Table 6** describes Nevada's recreational risk thresholds for cyanobacteria. The thresholds align with the hierarchy of risk described in **Table 1**. Overall risk level will be dictated by the highest risk associated with any single analyte.

Table 6. Nevada Recreational Risk Thresholds for CyanobacteriaAnalyte	Low Risk	Moderate Risk	High Risk
Microcystin (µg/L)	>4 and ≤8	>8 and ≤2,000	>2,000
Cylindrospermopsin (µg/L)	>8 and ≤15	>15 and ≤17	>17
Anatoxin-a (µg/L)	>Reporting Limit and ≤20	>20 and ≤90	>90
Cyanobacteria (cells/mL)	20,000	NA	NA

Microcystin Recreational Risk Thresholds

Based upon EPA studies (2019), a threshold value of 8 µg/L for microcystin will serve as Nevada's threshold for moderate probability of adverse health effects from recreational exposure. Concentrations above the detection limit but below this threshold value still have the potential to have a relatively low recreational risk on human health and may be appropriate to recommend caution with recreational contact. Concentrations detected above this threshold value will be considered as a moderate recreational risk and appropriate actions to protect public health will be recommended.

Based upon WHO studies (2003), a threshold value of 2,000 µg/L for microcystins will serve as Nevada's threshold for high probability of acute health effects from recreational exposure. Microcystin concentrations detected above this threshold value will be considered as a high recreational risk, and the highest level of precautions will be recommended to protect human health.

Cylindrospermopsin Recreational Risk Thresholds

Based upon EPA studies (2019), a threshold value of 15 µg/L for cylindrospermopsin will serve as Nevada's threshold for moderate probability of adverse health effects from recreational exposure. Concentrations above the detection limit but below this threshold value still have the potential to

have a relatively low recreational risk on human health and may be appropriate to recommend caution with recreational contact. Concentrations detected above this threshold value will be considered as a moderate recreational risk and appropriate actions to protect public health will be recommended.

Based upon OEHHA studies (2016), a threshold value of 17 µg/L for cylindropsermopsin will serve as Nevada's threshold for high probability of acute health effects from recreational exposure. Microcystin concentrations detected above this threshold value will be considered as a high recreational risk, and the highest level of precautions will be recommended to protect human health.

Anatoxin-a Recreational Risk Thresholds

Based upon OEHHA studies (2016), a threshold value of 20 µg/L for anatoxin-a will serve as Nevada's threshold for moderate probability of adverse health effects from recreational exposure. Concentrations above the detection limit but below this threshold value still have the potential to have a relatively low recreational risk on human health and may be appropriate to recommend caution with recreational contact. Concentrations detected above this threshold value will be considered as a moderate recreational risk and appropriate actions to protect public health will be recommended.

Based upon OEHHA studies (2016), a threshold value of 90 µg/L for anatoxin-a will serve as Nevada's threshold for high probability of acute health effects from recreational exposure. Microcystin concentrations detected above this threshold value will be considered as a high recreational risk, and the highest level of precautions will be recommended to protect human health.

Cyanobacteria Concentration Recreational Risk Thresholds

A threshold value for cyanobacteria concentrations of 20,000 cells/mL will act as Nevada's low recreational risk threshold for cyanobacteria concentration in a waterbody. This value is based on the WHO's risk thresholds (**Table 4**).

Sources

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