Developing a Risk-Based Monitoring Plan for Contaminants of Emerging Concern in Drinking Water Sources

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HOW TO USE THIS GUIDANCE DOCUMENT

This guidance document is intended to be used as a starting point. All water quality monitoring plans are unique and determined by specific factors like location, objectives, budgets, etc. These resources should be applied and modified as appropriate.

INTRODUCTION

Contaminants of emerging concern (CECs) are a subset of unregulated chemicals that are not commonly monitored in the environment and are suspected to negatively impact human and/or environmental health. In some cases, CECs may have been released into the environment for an extended period of time but have only recently become detectable with advanced technologies (e.g. legacy pesticides). In other cases, the creation of new chemicals or changes in existing chemical use lead to new CECs being released and detected in the environment (e.g. pharmaceuticals, artificial sweeteners). Many CECs are associated with everyday human activity and are continuously entering water sources due to their widespread use.

The effects of CECs on human and environmental health are a topic of ongoing research. In many cases, there is sufficient research to create a health guideline for a CEC, but not enough to create a regulatory threshold. Conventional drinking water treatment is not adequately equipped to remove all CECs before distribution to the public. As a result, there is some concern about chronic exposure to trace amounts of CECs through drinking water.

The uncertainty surrounding the health impacts of CECs has led to substantial uncertainty surrounding the regulatory future of CECs. This poses a particular challenge for drinking water utilities who must comply with water quality regulations while proactively protecting public health. All of the uncertainty around CECs has made it difficult for drinking water utilities to incorporate CECs into monitoring programs and long-term planning initiatives.

Testing for trace amounts of CECs present in drinking water is expensive. Monitoring for CECs without specific targets or objectives is therefore not cost effective for drinking water utilities, nor does it provide enough information to guide decision-making. This document outlines a methodology for designing a risk-based monitoring plan for CECs. It was developed by a team of graduate student researchers as part of a client-based master's thesis project at the Bren School of Environmental Science and Management, University of California, Santa Barbara[1].

[1] The client-based master's thesis project can be accessed at the following website: https://denverwater.wixsite.com/sharedsource

OVERVIEW

These guidelines are designed to help drinking water utilities develop an adaptable, long-term strategy for addressing the risk posed by CECs. The sections that follow will outline three steps:

Step 1: Monitor for CECs to determine baseline conditions.
Step 2: Determine the risk of individual or classes of CECs.
Step 3: Design a long-term monitoring plan.

This guidance document will provide a methodology and recommendations for utilities while they are designing a CEC monitoring program in Step 1 and Step 3. These steps will answer the following questions:

1. Which CECs should be monitored?
2. Where should monitoring take place?
3. How often should monitoring occur?

STEP 1: MONITOR FOR CECs TO DETERMINE BASELINE CONDITIONS

Collecting baseline data is important because it serves as the basis for informed decision-making and long-term data collection. This step will help drinking water utilities answer the following questions:

- Which CECs, if any, are present in source water and drinking water?
- What are the sources of CECs?
- Are there trends in CEC presence and concentrations that could inform a future monitoring strategy?

To answer these questions and assess the risk posed by CECs (Step 2), data collected during the baseline monitoring program should:

- Measure concentrations of individual CECs (presence/absence testing is not sufficient to assess risk).
- Span an appropriate time period (minimum of three years of quarterly samples recommended).
- Account for all sources of water to a drinking water treatment plant.

If a utility has already collected CEC data that meets all three of these criteria, they can move on to Step 2 and Step 3. If a utility has no previous CEC data or existing data does not meet these

criteria, or it is unclear whether they do, the following section outlines how to design a baseline monitoring program.

How to Design an Effective Baseline Monitoring Program

A wide range of CECs should be tested for in a baseline monitoring program. This can increase the price of testing, so the number of sites at which CECs are monitored for may need to be limited. To identify potential trends, quarterly testing for three years is recommended.

What CECs Should be Monitored?

Different classes of CECs are associated with different sources and land use types. This information can be used to identify a smaller, targeted set of CECs to include in the baseline monitoring program. The purpose of targeted monitoring is to determine which CECs are present in the source water watershed and to avoid the expense of monitoring for CECs that are unlikely to be present.

> **Example:** If agriculture is absent in a utility's source water watershed, it is less likely that associated agricultural pesticides and herbicides will be present. If agriculture is present, there may be specific pesticides associated with the crop types in the area.

Land use types and concentrated human activity (e.g. cities, heavily recreated areas) should be identified within the source water watershed. Table 1 is an example of a simple way to identify the classes of CECs associated with land use and human activity in the utility's source water watershed. Depending on the size and hydrology of the source water watershed, it may be appropriate to have separate CEC test lists for different land use types (i.e. rural vs. urban).

Table 1. Common CEC classes associated with different land use types.
This table is not comprehensive list of potential CEC classes. A utility should conduct its own research into CEC classes based on the specific land use types and regulatory concerns in their source water watershed.

Land Use Types/Potential Sources	CEC Classes
Agriculture	Pesticides Insecticides Herbicides Estrogenic Hormones
Livestock	Veterinary Antibiotics Pharmaceuticals
Industry	Perfluorinated Compounds Volatile Organic Compounds Solvents
Wastewater Treatment Plants	Estrogenic Hormones Pharmaceuticals Disinfection By-Products Chemicals in Personal Care Products Perfluorinated Compounds
Recreation	Chemicals in Personal Care Products Perfluorinated Compounds
Urban Storm Water	Chemicals in Personal Care Products Pesticides Herbicides Perfluorinated Compounds Flame Retardants

If a utility's source water watershed has numerous and/or mixed land use types, this approach may not be the most effective. Instead, the utility could do presence/absence CEC screening to determine the classes of CECs present. This presence/absence screening should be done quarterly for one year to ensure that any seasonal variation in the types of CECs present are captured. Once complete, the utility can create a custom list of CECs to monitor quantitatively during the baseline program. The custom list would include all CECs detected during the presence/absence screening.

Note: Water quality testing services tend to test for a wide range of CECs in a single analytical method. The CEC classes likely to be present in the collection system should be represented on the test list. As working relationships become established with laboratories, it may be cost effective to develop a custom test list.

Where Should Monitoring Take Place?

The number of sites in a baseline monitoring program should be limited to minimize the cost of sampling, considering that utilities strive to provide safe and affordable drinking water to the public. At minimum, a utility should monitor at the following locations in a baseline program:

- Raw water at the drinking water treatment plant.
- All sources of water to a drinking water treatment plant.

Example: If the drinking water treatment plant treats water from two separate rivers and a groundwater well, the baseline monitoring program should include a minimum of four sites:

The raw water of the drinking water treatment plant
A site that represents all water coming from river 1
A site that represents all water coming from river 2 (without the influence of river 1)
The groundwater well

If there are insufficient funds available to monitor all minimum sites, then the priority should be to monitor the intake of drinking water treatment plants. If there are sufficient funds, a utility can increase the number of sampling sites to test hypotheses about CEC sources. Mapping land use and places where human activity is concentrated is one way to gain a better understanding of the spatial relationships between potential sources. Monitoring sites can then be selected to isolate potential sources of interest.

How Often Should Monitoring Occur?

CECs should be monitored at least once per quarter for one to three years in a baseline monitoring program. Three years of baseline monitoring is recommended because this frequency will give utilities a solid foundation of information to identify possible trends, inform CEC risk assessment, and build a long-term monitoring plan.

STEP 2: DETERMINE THE RISK OF INDIVIDUAL CECs

For the purpose of this methodology, the risk a CEC poses to a drinking water utility was defined as the potential for CEC concentrations to exceed a health guideline, which could be a future regulatory standard. Risk is quantified by calculating the Risk Ratio. Once risk is quantified, it is classified as High, Medium, Low or Very Low. The risk classification is then used to make management decisions and design a long-term CEC monitoring plan.

Calculate the Risk Ratio

The Risk Ratio is calculated by dividing the observed concentration of a CEC in source water by an existing health guideline.

$$\text{Risk Ratio} = \frac{\text{Observed Concentration}}{\text{Health Guideline}}$$

Observed Concentration

The baseline monitoring program will be the source of observed CEC concentrations. The value used should be the concentration observed at the location at which risk is being determined. There are several options of observed concentrations (the mean, the median, the maximum or the minimum) that can be used to assess risk. It is recommended to use the maximum detected value because it provides an estimate of the upper bound of risk posed by a given CEC. However, the utility should decide which observed concentration to use.

Example: To determine the risk posed by a CEC from a specific source, the concentration at the sampling location that represents that source should be used. If the risk from a specific source is not necessary, the overall risk posed by CECs can be calculated using the concentration at the drinking water treatment plant.

Health Guidelines

A health guideline is a science-based human and/or ecological threshold developed by state or federal water agencies. This threshold is not currently enforced but may be used to inform future enforceable regulations. It can act as a placeholder for determining how close the observed concentration is to exceeding a future regulation.

Health guidelines are provided by a variety of agencies with a range of values therefore, selecting the proper guideline to use in the Risk Ratio calculation is an important step. One approach is to select the most stringent health guidelines available. It cannot be guaranteed that future regulations will be as stringent as these guidelines, but this approach represents the upper bound of the risk posed.

Where to Find Health Guidelines

The California Office of Environmental Health Hazard Assessment and the Minnesota Department of Health are examples of agencies that have defined health guidelines for a range of CECs. An internet search can be done to identify if health guidelines exist for the CECs detected in a utility's source water watershed.

Note: There are different types of health guidelines available for CECs. It is important to be clear about the type of health guideline selected for the Risk Ratio calculation. For example, if a health guideline for recycled water is used the Risk Ratio may be lower than if a groundwater health guideline is used. This is because recycled water guidelines may assume that recycled water is being added to a large body of water and there may be significant dilution before water is treated at drinking water plants.

Risk Classification

Once the Risk Ratio is calculated, the following step is to classify the risk. Risk classification is used to signal how to design and adapt the long-term monitoring plan based on the likelihood of exceeding a future regulation. Each utility should have an internal conversation on risk preferences to determine appropriate interventions for each classification. The following risk classifications (Table 2) provides an example of how a utility may define the different ranges of risk.

Table 2. Risk Ratio Classification Guidelines.

Risk Classification	Risk Ratio
Very Low	<0.001
Low	0.002 - 0.01
Medium	0.02 - 0.49
High	>0.5

If a utility creates its own ranges for risk classification, the range should span several orders of magnitude. One possible approach to creating risk classification guidelines is to select a risk ratio threshold that would trigger a management intervention when exceeded. This threshold could be a situation where the observed concentration reaches a certain risk classification, for example any CEC that poses a "medium risk" requires intervention.

What if There is No Health Guideline Available?

The Risk Ratio cannot be calculated without a health guideline. Developing health guidelines is an expensive process and has not been done for every CEC. If there is no health guideline available for a CEC that was detected a utility should continue monitoring the contaminant and keep an eye open for any changes in health guidelines for the contaminant. In some cases, a utility may be able to use data and information from other CEC's to make an educated guess about the risk level of a CEC without a health guideline. Two such cases are described below.

1. Use the health guideline of another similar CEC (in the same chemical class with similar chemical properties) as a proxy.

> **Example:** PFOS and PFOA have known health guidelines. Other chemicals in this family such as PFHpA and PFHxA do not. Since these CECs also have similar chemical properties, the health guideline for PFOS/PFOA could be used to calculate the Risk Ratio. If substitution is used, it is critical to explicitly note that no health guideline currently exists for the CEC in question.

2. Assign a risk classification based on the risk classification of other chemicals in the same chemical class.

> **Example:** Ten pharmaceuticals were detected in source water, but health guidelines are only available for six. The Risk Ratio should be calculated for the six pharmaceuticals that have health guidelines and be assigned a risk classification. If they are all classified as very low risk, then a utility could assume that the four pharmaceuticals without health guidelines are also very low risk.

STEP 3: DESIGN A LONG-TERM MONITORING PLAN

The final step is to use the baseline monitoring data and the risk assessment to design a long-term monitoring plan for CECs. The specifics of the long-term monitoring plan will largely be determined by the results of the risk assessment, available monitoring budget, and objectives of the utility. The following section will discuss how baseline monitoring data and risk assessment can guide a utility in answering three basic questions:

1. Which CECs should be monitored?
2. Where should monitoring take place?
3. How often should monitoring occur?

What Should Be Monitored?

All CECs that were detected in baseline monitoring should also be monitored in the long-term plan.

Where and How Should Monitoring Take Place?

The number of sites at which CECs are monitored should be largely determined by the risk classification and available monitoring budget. Risk classification is used to signal the level of urgency, which will determine where and how often a CEC should be monitored.

CECs that were classified as low or very low risk do not need to be monitored as extensively. It may be appropriate to only test for these CECs at the drinking water treatment plant every two or three years. CECs classified as high risk should be given more attention. It is recommended that high risk CECs be monitored quarterly every year. Additional sites may be added to gain a better understanding of sources depending on budget. If a utility determines that a high-risk CEC poses an immediate threat, it may be appropriate to complete an additional study that requires more intensive sampling.

Adapting the Long-Term Monitoring Plan

Given the fast pace at which science and technology relevant to CECs are evolving, a risk assessment should be completed every five years to incorporate updated health guidelines or regulatory information. The long-term CEC monitoring plan should also be re-evaluated every five years. During re-evaluation, a utility should consider factors that could influence the concentrations and types of CECs present in source water (e.g. land use change, extreme event affecting water supply). Two key factors that may change are the types of CECs present in the source water watershed and their observed concentrations.

Types of Contaminants

When changes occur in a source water watershed, it is possible that new types of CECs will be detected. This can be expected when there are significant land use changes or major shifts in the area human activity is occurring. For example, the conversion of previously undeveloped land into urban/suburban areas may introduce new types of CECs to that area.

Contaminant Concentrations

The concentration of CECs can also vary with land use changes and environmental conditions. Drought is one example. During drought there will likely be lower streamflow. However, CECs may still be released in the same quantities, resulting in higher relative concentrations. With less

water available to dilute the CECs, something that previously posed a low risk may change risk classifications depending on the severity of the drought.

CONCLUSION

Overall this approach provides drinking water utilities with a clear, flexible, and strategic way to incorporate contaminants of emerging concern (CECs) into water quality monitoring plans. This guidance document has outlined a risk-based methodology for utilities to use when designing a monitoring plan for CECs. Generally, the three steps are:

Step 1: Monitor for CECs to determine baseline conditions.
Step 2: Determine the risk of individual or classes of CECs.
Step 3: Design a long-term monitoring plan.

ADDITIONAL RESOURCES

1. Managing Contaminants of Emerging Concern in California: Developing Processes for Prioritizing, Monitoring, and Determining Thresholds of Concern: Produced by California Ocean Science Trust, National Water Research Institute, San Francisco Estuary Institute, Southern California Coastal Water Research Project, and Urban Water Research Center of the University of California, Irvine.
2. Minnesota: Comparison of State Water Guidance and Federal Drinking Water Standards. https://www.health.state.mn.us/communities/environment/risk/guidance/waterguidance.html
3. California Public Health Goals. https://oehha.ca.gov/water/public-health-goals-phgs