

STAFF REPORT

MONITORING FOR CONSTITUENTS OF EMERGING CONCERN IN CALIFORNIA'S AQUATIC ECOSYSTEMS

This staff report summarizes recommendations for monitoring Constituents of Emerging Concern (CECs) in aquatic ecosystems. These recommendations are from the report [Monitoring Strategies for Chemicals of Emerging Concern \(CECs\) in California's Aquatic Ecosystems](#) (Panel Report) written by the CEC Ecosystems Panel (Panel), dated April 2012.

Background

The State Water Resources Control Board (State Water Board), in collaboration with the David and Lucile Packard Foundation, provided funding to support a science advisory Panel. This Panel was charged with reviewing existing scientific literature on CECs in aquatic ecosystems; determining the state of current scientific knowledge regarding the risks that CECs in freshwater and marine water pose to human health and aquatic ecosystems; and providing recommendations on improving the understanding of CECs for the protection of public health and the environment. The Panel was initially convened in October 2009, through funding from the David and Lucile Packard Foundation, to provide information and recommendations on CECs¹ in marine water ecosystems. In June 2011, the State Water Board provided additional funding to expand the scope to include freshwater ecosystems. The Panel collaborated with stakeholders, who provided their perspectives of the water quality issues and additional information, during the development of the Panel Report. The Panel recommended a risk-based screening framework to identify CECs for monitoring and an adaptive phased monitoring approach to assess the presence of CECs and their potential risk to the environment.

Risk-Based Screening Framework

Using a risk-based screening framework, the Panel selected sixteen initial CECs to monitor in water (wastewater treatment plant (WWTP) effluent and receiving water), sediment, and tissue. The first step in the risk-based screening framework was to identify a universe of CECs. This universe was created from several sources including the United States Environmental Protection Agency Candidate Contaminant List. The Panel screened this list of CECs based on availability of toxicological information, analytical methods, and occurrence data from earlier monitoring.

The Panel then compared concentrations of CECs measured in the environment, called measured environmental concentrations or MECs in the Panel Report, to monitoring trigger levels (MTLs). In general, an MTL is a level above which there may be an adverse effect on aquatic organisms. The Panel applied appropriate safety factors to develop these MTLs:

- a) when a CEC mode of action (MOA) was not available;
- b) when a potential endocrine MOA was not incorporated into either the predicted no-effect concentration (PNEC) or No Observable-Effect Concentration (NOEC);
- c) to derive antibiotic resistance MTLs from antibiotic resistance NOECs;
- d) to adjust freshwater MTLs for use in saltwater;

¹ CECs may include a wide variety of substances including pharmaceuticals, flame retardants, newly registered contemporary use pesticides, industrial and agricultural products, fragrance, hormones, antibiotics and nanoparticles.

- e) to adjust for chronic exposure when only acute NOECs were available;
- f) to develop chronic thresholds from acute thresholds; and
- g) to account for dilution in the three exposure scenarios (an effluent dominated inland waterway, a coastal embayment (estuary), or an ocean discharge with municipal wastewater treatment plant effluent).

The number of safety factors applied to each MTL varied. Some incorporated a single safety factor, while others incorporated multiple safety factors.

The Panel also compared the MTLs to predicted environmental concentrations (PECs), which the Panel estimated for CECs in water, sediment, and tissue based on information on the CEC's properties, type of use, amount of use, and discharge patterns.

Those CECs that had MECs or PECs greater than their MTLs were selected to be on the initial list of CECs to be monitored.

Adaptive Phased Monitoring Approach

The Panel recommended implementing an adaptive phased monitoring approach to monitor the CECs identified through the risk-based screening framework. Briefly, the approach consists of four phases: (1) identification of relevant CECs, (2) development and implementation of a pilot monitoring program to assess the occurrence and effects of CECs, (3) revision of the CEC monitoring list based on the data collected, and (4) if needed, the development of action mechanisms to control the amount of a CEC in the ecosystem.

Phase 1 – Development of Initial List of CECs

The Panel recommended monitoring the CECs on its initial list. This initial monitoring list is presented in Tables 1, 2 and 3 for each exposure scenario. The Panel recommended that this list be reviewed and updated as new information becomes available to either add or remove CECs from the list.

Table 1. Scenario 1 - Inland Waterways – Municipal WWTP effluent dominated receiving waters and/or freshwater streams receiving storm water runoff.

CECs recommended for initial monitoring (Phase 2) in water, sediment, and tissue.

M = include in monitoring program

Compound	Effluent Dominated Waterway - Receiving Water ^a	WWTP Effluent ^b	Freshwater Stream - Storm Water (Receiving Water and Sediment) ^c	Tissue
Bis(2-ethylhexyl phthalate)				
Bisphenol A	M	M	M	
Bifenthrin	M	M	M	
Butylbenzyl phthalate				
Permethrin	M	M	M	
Chlorpyrifos	M	M	M	
Estrone	M	M	M	
Ibuprofen	M	M	M	
17-beta estradiol	M	M	M	
Galaxolide (HHCB)	M	M	M	
Diclofenac	M	M	M	
p-Nonylphenol				
Polybromated Diphenyl Ether (PBDE) 47		M	M	M
Polybromated Diphenyl Ether (PBDE) 99		M	M	M
Perflourooctane Sulfonate (PFOS)		M	M	M
Triclosan	M	M	M	

a. Samples would be collected upstream and downstream of the discharge point during dry and wet weather in a stream with a WWTP.

b. Samples would be taken from the effluent outfall of the WWTP.

c. Samples would be taken during dry and wet weather in two large freshwater streams and in the Sacramento-San Joaquin Delta. Direct sampling of storm water is not included in Phase 2 of the initial monitoring.

Table 2. Scenario 2 – Coastal Embayments or Estuaries:

CECs recommended for initial monitoring (Phase 2) in water, sediment, and tissue.

M = include in monitoring program

Compound	Receiving Water	WWTP Effluent	Sediment	Tissue
Bis(2-ethylhexyl phthalate)				
Bisphenol A	M	M		
Bifenthrin	M	M	M	
Butylbenzyl phthalate				
Permethrin	M	M	M	
Chlorpyrifos	M	M		
Estrone	M	M		
Ibuprofen				
17-beta estradiol	M	M		
Galaxolide (HHCB)	M	M		
Diclofenac				
p-Nonylphenol				
Polybromated Diphenyl Ether (PBDE) 47 and 99		M	M	M
Polybromated Diphenyl Ether (PBDE) 99		M	M	M
Perflourooctane Sulfonate (PFOS)		M	M	M
Triclosan				

Table 3. Scenario 3 – Ocean Discharge of Municipal WWTP effluent:

CECs recommended for initial monitoring (Phase 2) in water, sediment, and tissue.

M = include in monitoring program

Compound	WWTP Effluent ^a	Sediment ^b	Tissue ^b
Bis(2-ethylhexyl phthalate)	M	M	
Bisphenol A			
Bifenthrin			
Butylbenzyl phthalate	M	M	
Permethrin			
Chlorpyrifos			
Estrone			
Ibuprofen			
17-beta estradiol			
Galaxolide (HHCB)			
Diclofenac			
p-Nonylphenol	M	M	
Polybromated Diphenyl Ether (PBDE) 47	M	M	M
Polybromated Diphenyl Ether (PBDE) 99	M	M	M
Perflouroctane Sulfonate (PFOS)	M	M ^b	M
Triclosan	NA	NA	

a. Water samples would be collected from two WWTPs after final treatment as effluent leaves the plant.

b. tissue and sediment would be collected near the WWTP outfalls.

Phase 2 - Implement Monitoring of Initial List of CECs

This phase implements the monitoring of CECs selected in Phase 1. The purpose of Phase 2 is to:

- a) begin verifying the occurrence of targeted CECs in water (effluent and receiving water), sediment, and tissue samples;
- b) begin compiling a data set that characterizes the occurrence of CECs in water (effluent and receiving water), sediment, and tissue samples;
- c) begin evaluating potential methods and surrogate measures including analytical methods that identify compounds that are not routinely monitored; and
- d) begin developing a conceptual model to help with the assessment of the monitoring data in Phase 3.

The Panel strongly recommended the development and use of environmental fate models to summarize data on CECs including production and usage, loading and loss rates, and water, sediment and tissue transfer rates. The purpose of these models is to synthesize the available information to identify CECs that do or do not warrant future monitoring.

The Panel recommended using the knowledge and monitoring abilities of existing monitoring programs to assist in characterizing the presence of CECs in aquatic systems. It also recommended the development of detailed monitoring plans that align with the monitoring strategy presented in Table 4. The monitoring plans would:

- a) Clearly identify monitoring sites and sampling frequencies;
- b) Specify that monitoring should be conducted as part of selected special studies coordinated through the appropriate monitoring efforts; and
- c) Be developed in coordination with the appropriate regional monitoring programs to ensure use of consistent sampling and analysis methods, quality assurance and quality control, and data reporting.

Table 4 also lists some special studies to be done during the three year monitoring period. These concern bioanalytical screening assays, toxicity testing, antibiotic resistance, and passive sampling devices. Further explanation is provided in the Table 4 footnotes.

In addition to detailed monitoring plans, the Panel recommended developing a detailed Quality Assurance Project Plan (QAPP). The QAPP would include data validation and verification methods that address and ensure the accuracy and precision of the data. Such measures include matrix spikes, control and field blanks, and sample duplicates.

Furthermore, the Panel recommended that they, or a similar panel, review the monitoring plans prior to implementation. The Panel proposes that the phases be done over a five year period that includes development and review by the Panel during the first year, followed by monitoring in the second through fourth years, and independent review of the results by the Panel in the fifth year.

Table 4. Guidance for Developing Targeted/Pilot CEC Monitoring Workplans

M = include in monitoring program

Monitoring Design	Scenario 1		Scenario 2	Scenario 3	Cost Estimate
Phase 2 Validation Studies					\$2.1M
Parameter List	See Table 1		See Table 2	See Table 3	
Water type/source	Effluent Dominated Waterway/ WWTP ^d	Freshwater/ Storm Water Discharge - Receiving Water Station Only ^c	Embayment-estuary/ WWTP ^b	Ocean/ WWTP ^a	
Spatial coverage – Receiving Water	One dimensional gradient (up to six sites for each location)	One dimensional gradient (up to six sites for each location)	Two dimensional gradient (up to six sites in estuary)	Two dimensional gradient (up to six sites for each location)	
Number of WWTP and/or Freshwater Locations	Two WWTPs and Receiving Water (one in Northern California and one in Southern California)	Two large freshwater streams and the Delta	Five WWTPs in one estuary/ embayment	Two WWTPs and corresponding receiving waters	
Frequency	Wet and dry season over three years	Wet and dry season over three years	Semi-annual over three years	Semi-annual over three years	
Background	M	M	M	M	
Receiving, and/or Effluent Water (nonfiltered)	M	M	M		
Sediment (top 5 cm)	M	M	M	M	
Tissue ^e	M	M	M	M	
Phase 2 – Special Studies					\$1.0 M
Bio-analytical Screening Assays ^f	Pilot evaluation and validation studies	Pilot evaluation and validation studies	Pilot evaluation and validation studies	Pilot evaluation and validation studies	
Toxicity ^g	Pilot screening study at WWTP		Pilot screening study at one WWTP	Pilot screening study at one WWTP	
Antibiotic Resistance ^h	Pilot investigation at one WWTP		Pilot investigation at one WWTP		
Passive Sampling Devices (PDSs) ⁱ	Pilot investigation at one WWTP			Pilot investigation at one WWTP	
Development of Monitoring Plans and QAPP					\$300,000
Development of Phase 2 CEC Source and Fate Model					\$300,000
Phase 3 - Panel Re-visit (data analysis and interpretation of Phase 2 results)					\$90,000
Total Cost					\$3.8 M^j

a – Daily discharge >100 mgd; potentially conduct pilot investigation in southern California (coordinate with Bight program).

b – Daily discharge <100 mgd; potentially conduct pilot investigation in San Francisco Bay (coordinate with the Regional Monitoring Program).

c -- Potentially conduct pilot investigation for one stream in the San Francisco Bay Area (coordinate with BASMAA – RMC); one stream in Southern California (coordinate with the Stormwater Monitoring Coalition), and the

- Sacramento-San Joaquin Delta (coordinate with Regional Monitoring Program and the appropriate Delta organization(s)).
- d – Potentially conduct pilot investigation in Southern California (coordinate with the Stormwater Monitoring Coalition).
 - e - Identify appropriate species and tissues (e.g., bivalve and fish tissue for PBDEs; bird eggs for PFOS) in conjunction with local, regional and Statewide monitoring programs (e.g., SWAMP Bioaccumulation Workgroup; Bight, RMP and National Mussel Watch Programs).
 - f – Conduct evaluation and validation of bio-analytical screening methods that combine bioassays and subsequent non-targeted analyses to identify bioactive substances using a TIE process. Non-targeted analysis identifies constituents that are not routinely monitored.
 - g – 21 day fathead minnow recrudescence assay for freshwater matrices Implement periodic reproduction assessments using appropriate fish and invertebrate species. Coordinate efforts with NPDES WET and bioassessment monitoring. This assay should be used for research purposes only at the present time.
 - h - Conduct a pilot investigation using a bioassay that can be used to screen for antibiotic resistance. Wastewater may select for bacteria that are the most resistant to antibiotics. Moreover, there is uncertainty associated with the current risk screening levels for antibiotic resistance (mixture effects) in bacteria and antibiotics (chemical exposure and genetic effects). This pilot will begin the process of determining hazard characteristics of antibiotic resistance in indicator bacteria by establishing baseline conditions for effluents and sediment at outfalls.
 - i – Conduct a pilot investigation using passive sampling device (PSDs) that provide adequate capacity to concentrate the CECs in Table 1. PSDs are a sampling mechanism that captures the lipophilic (fat soluble portion) of a constituent). - These devices should have demonstrated acceptable performance in laboratory or field validation studies, and published guidance on translation of results.
 - J – Cost estimate provided by the Southern California Coastal Water Research Project.

Phase 3 – Assess/Update Monitoring and Response Plans

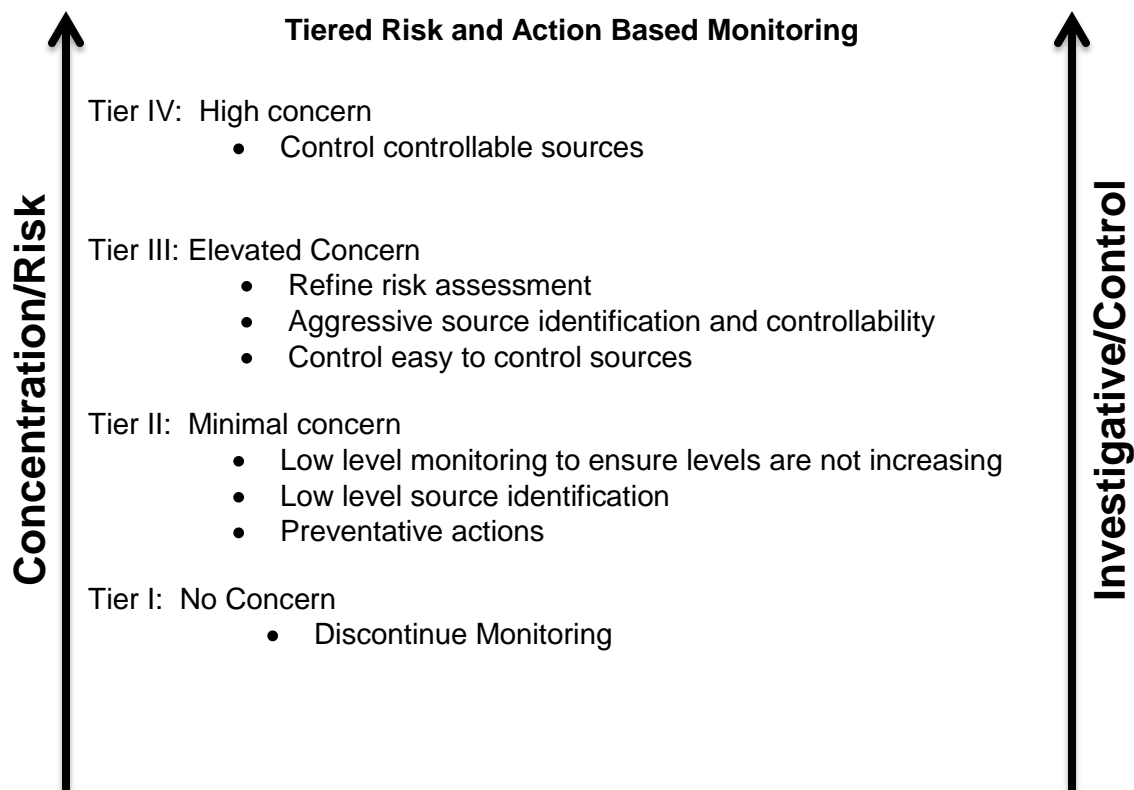
Phase 3 is for updating the list of CECs based on the Phase 2 monitoring results. The results of the environmental fate model developed in Phase 2 would be used to assess and prioritize future monitoring.

In essence, Phase 3 is the evaluation of the results within the context of a tiered risk monitoring and response framework similar to the diagram below (Figure 1). This conceptual model balances risk potential with increasing actions. CECs may be added or removed from the list based on trends in production or use, occurrence, or results of the Phase 2 studies.

The goal of Phase 3 is to develop a final list of CECs that are recommended for routine monitoring as part of discharge permits. The Panel encouraged the State Water Board to compare the potential risk associated with the CECs to the potential risk posed by other monitoring environmental stressors (pollutants). This assessment is vital for determining future funding towards those stressors that present the highest potential risk to aquatic ecosystems.

The Panel recommended that Phase 3 be conducted by an independent panel of experts; preferably a single non-project based (unbiased) entity, such as the science advisory panel that developed the monitoring strategy.

Figure 1



The Phase 1 and 2 monitoring recommendations are to be used for the purposes of research and not for compliance.

During Phase 3, the appointed panel would consider the basis of the initial MTLs, their potential health effects, sources, control methods, and treatment strategies. To update and confirm the environmental matrix data in Phase 1 and the CEC monitoring list, the Panel recommended the following actions during Phase 3.

- Collect and review readily available toxicity data and update the MTLs.
- Collect and review California wastewater treatment plant effluent data and update MECs and PECs.
- Update the list of CECs to be monitored to include newly identified CECs where the monitoring trigger quotient (MTQ) is greater than one, and remove CECs from the previous list of CECs, where recent data indicates a MTQ less than one. MTQ is the ratio of the measured environmental concentration to the monitoring trigger level ($MTQ = MEC/MTL$). Monitoring trigger quotient (MTQ) greater than one indicates a potential to pose a risk.
- Review CECs that have come off the monitoring list to see whether use patterns have changed and whether this change warrants their re-listing for monitoring.
- Review and update guidance for monitoring frequency, location and special studies.
- Review and update conclusions regarding laboratory analytical methods.
- Review and update biological and chemical screening methods, and provide guidance on potential new monitoring methods or tools that would significantly enhance conventional chemical monitoring methods.

- Review results of environmental fate models and provide guidance to the state on potential control actions and plans to be developed and reviewed for implementation in Phase 4.
- Review and update Panel guidance for selecting viable surrogate methods and future investigations.

The Panel recommends that they or a similar panel review and update the list of priority CECs after the collection of three years of monitoring data.

Phase 4 – Action Plans to Minimize

The environmental fate models developed in Phase 2 to predict CEC concentrations in surface water, sediment and tissues will allow managers to improve their ability to predict, prioritize and optimize actions to protect and improve water quality and decrease exposure of humans and other organisms to CECs. If the assessment performed in Phase 3 indicates that a CEC will persist and present significant risks to public health or the environment, the Water Boards in Phase 4 would instruct a science advisory panel to develop guidance on the development of action plans for mitigating the risk.

Panel's Recommendations for Further Research

The Panel Report provides recommendations for further research to respond to issues such as data or technology gaps. More explanation of the need for further research is on Pages 62 through 65 of the Panel Report. The Panel recommended that the state seek out and capitalize on opportunities to collaborate with local, other state, regional and federal efforts in addressing these issues.

1. *Develop bio-analytical tools for efficient, integrated monitoring and assessment of CECs in receiving water and to improve assessments of CECs in the environment.* High throughput (HTP) *in vitro* bioassays with endpoints that respond to CEC exposure in organism biological receptors (e.g., endocrine disrupting activity) can screen for multiple CECs, reducing the need for chemical-specific monitoring and expensive, time-consuming chemical-by-chemical risk screening. Research is also needed to identify adverse outcome pathways at the molecular level that are linked to higher order effects, such as fish reproduction. The Panel recommends further development and application of the latest genetic microarrays and targeted toxicity testing for species of highest relevance in California receiving waters to establish this linkage. The State Water Board currently has a contract with the Southern California Coastal Water Research Project to assess available bio-analytical tools.
2. *Filling data gaps on sources, fates, occurrence and effects of CECs.* Information on CEC occurrence and toxicity (e.g., MEC and NOECs) is needed for CECs for which there is little or no data for California's aquatic ecosystems. These include newly developed pharmaceuticals, replacement flame retardants, and recently registered pesticides. The Panel recommends development and refinement of environmental fate models to predict environmental concentrations of CECs based on their production volume, use, and environmental fate, as a means for prioritizing chemicals for analytical method development and toxicological investigation.
3. *Assessing the relative risk of CEC and other monitored chemicals.* The Panel urged the State Water Board to compare the potential risks associated with CECs with the

potential risks posed by other currently monitored environmental stressors. This assessment is essential for directing future monitoring investments toward those stressors that present the highest potential risk to beneficial uses of the state's receiving water.

Implementation Options

Staff has identified six options for implementing the monitoring and assessment described in the Panel Report as Phases 2 and 3.

Option 1 – Request organizations to voluntarily provide funding to regional monitoring programs. The State Water Board may be able to allocate some federal grant funds for the monitoring and assessment, but most of the funding would have to come from other sources.

Option 2 – Under the authority of Water Code section 13383, the State Water Board would require dischargers with NPDES permits to monitor the CECs the Panel identified in its initial list or to participate in a regional monitoring program that would implement the Panel recommendations. Under this option, the dischargers would provide the funding to implement the monitoring and assessment.

Option 3 – Adopt a resolution requesting that Regional Water Boards consider requiring in the monitoring and reporting programs for NPDES permits monitoring of the CECs the Panel identified in its initial list or participation in a regional monitoring program that would implement the Panel recommendations.

Option 4 – Adopt a State Policy for Water Quality Control that creates a new requirement for one or more categories of dischargers to monitor for the CECs identified in the initial list or to participate in a regional monitoring program that would implement the panel recommendations.

Option 5 – Initiate a budget change proposal to increase the permit fee surcharge for the Surface Water Ambient Monitoring Program (SWAMP). After approval, SWAMP would issue contracts to contractors that would perform the monitoring and assessment.

Option 6 – Redirect existing SWAMP monitoring funds and efforts to perform the monitoring and assessment.