SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT AUTHORITY

THEMATIC RESEARCH PLAN

FOR

CONTAMINANTS OF EMERGING CONCERN

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CONTAMINANTS OF EMERGING CONCERN (CECs)

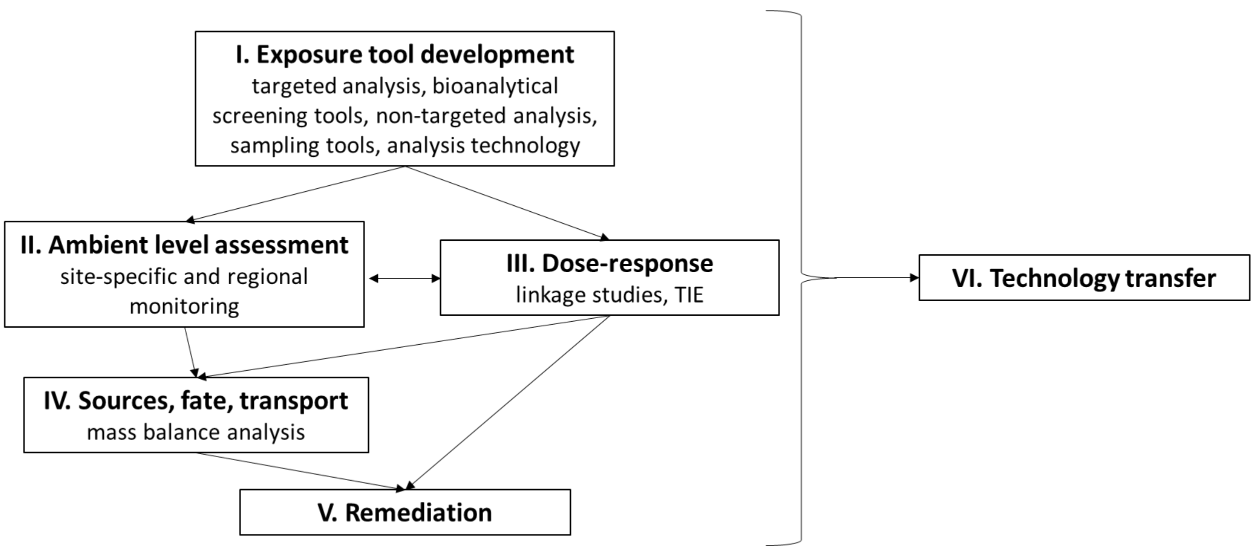
Contaminants of emerging concern (CECs), or constituents of emerging concern as they are also called, are "chemicals and other substances that have no regulatory standard, have been recently 'discovered' in natural streams (often because of improved analytical chemistry detection levels), and potentially cause deleterious effects in aquatic life at environmentally relevant concentrations (USEPA, 2008). Thus, CECs refer to the myriad of synthetic contaminants that may be introduced to the environment through human activities that environmental managers are working to detect, understand, and monitor. Although the knowledge base for CECs is limited, scientists are constantly learning more about their ambient environmental occurrence, dose-response, sources, fate and transport, and remediation. With literally tens of thousands or more of CECs to evaluate, the traditional chemical-by-chemical approach to monitoring, assessment and regulation has become unwieldy and obsolete. Moreover, constantly changing human activities have made CECs a "moving target," with new CECs continually being substituted for ones being phased out. Confounding this challenge is that even if every CEC in every water sample could be identified, these chemicals typically come together as complex mixtures, potentially exerting combined biological effects that cannot be determined through traditional assessment methods. Furthermore, in contrast to currently regulated chemicals, the potential for CEC impacts can occur at much lower levels and be manifested over longer periods of time. Finally, not all contaminants that can be considered as CECs are molecules that can be dissolved in water. Contaminants such as microplastics can be considered CECs also, as all the issues involving CECs described above are also applicable to them. Recognizing these challenges, SCCWRP is working closely with experts in the field and the management community to develop and evaluate a comprehensive framework for improved monitoring and assessment of CECs in receiving waters statewide.

Conceptual Model

SCCWRP's conceptual model combines monitoring and assessment of CECs, defined for this Research Theme as synthetic chemicals and microplastics, to address knowledge gaps across six main, interconnected information needs in an efficient, relevant, and comprehensive manner (**Figure 1**). Perhaps most importantly, this model is adaptable to changes in pollution sources and sinks. These information needs are necessary in characterizing the likelihood that humans and aquatic life will be exposed to harmful substances in the aquatic environment, and are key to determining whether existing levels of CEC exposure are causing adverse impacts to wildlife and humans. The conceptual model is described in detail in this section, with SCCWRP's CEC research priorities following.

In **Information Need I**, development of state-of-the-art exposure measurement tools aids in measuring, screening, and/or identifying both known and unknown CECs. **Information Need II** ascertains the environmental occurrence of CECs, which provides a means for interpreting how extensive contamination is, and whether exposure trends are getting better or worse. For **Information Need III**, dose-response relationships characterize what concentrations may trigger toxicity and what physiological pathways lead to toxicity. In **Information Need IV**, applying exposure measurement tools developed in Information Need I, as needed and in conjunction with predictive models, characterizes sources, fate, and transport of CECs. In **Information Need V,** these same exposure measurement tools evaluate the effectiveness of management actions (e.g., best management practices, or BMPs). Finally, **Information Need VI** provides tools and knowledge on CECs to end-users managing these contaminants.

Figure 1. A series of interconnected information needs to direct management action: SCCWRP's conceptual model for monitoring and assessment of CECs. Develop exposure measurement tools to measure, screen, and identify unknown and known CECs (Information Need I), understand their ambient environmental occurrence (Information Need II), determine concentrations of problematic CECs triggering toxicity (Information Need III), characterize the source, fate, and transport of key CECs (Information Need IV), inform management actions that address impacts on water quality (Information Need V), and make measurement tools and knowledge accessible to end-users (Information Need VI).



SCCWRP's conceptual model for CEC research was originally formulated in close collaboration with a panel of international experts convened on behalf of the State Water Board to make recommendations on monitoring of CECs in aquatic ecosystems. This CEC Expert Panel finalized its recommendations (Anderson et al., 2012), and the original conceptual model became the basis for the design of a statewide CEC pilot monitoring program (Dodder et al., 2015). The new conceptual model (Figure 1) expands the original tiered CEC monitoring framework into one with a series of information needs for developing and validating flexible and robust measurement tools, that lead to a comprehensive understanding of CEC chemical exposure and toxicity specifically to inform and address management actions. As an integral part of its formulation in these collaborative efforts, the model has been reviewed and endorsed by CTAG

-- made up of dischargers and regulators -- as well as public interest and commercial services communities.

This review led to the inclusion of one new element: microplastics. Unlike chemical CECs, microplastics may exhibit ecotoxicological effects because they are particles, often heterogeneous, with a wide variety of sizes, shapes, and chemical composition (e.g., plastic particles accumulating and blocking gastrointestinal tracts of wildlife ingesting them, irrespective of the type of polymer). In this manner, they differ from chemical CECs, for which exposure is generally limited to the molecular level. As with other particles, microplastics may be a vector for exposure to other CECs through sorption of dissolved phase contaminants. Given such differences, microplastics are evaluated under the six Information Needs as a subcategory of CECs with a study design and objectives that may be separate from chemical CECs as appropriate, as approaches for chemical CECs may not necessarily work or be relevant for microplastics, and vice versa. For example, bioanalytical tools are harder to apply for microplastics than for chemical CECs.

This model also allows for the ability to add additional subcategories of CECs. For example, algal toxins can conceptually be considered a CEC, and therefore fall within SCCWRP's current conceptual model as a new subcategory of CECs. However, SCCWRP's interactions with CTAG review suggest that this class of contaminant is better covered under SCCWRP's Eutrophication research theme.

Information Need I: Development of Exposure Measurement Tools

This Information Need is a critical part of the conceptual model for CECs. Given that the number of CECs of interest is large and ever-growing, the development of new and better ways to measure CEC exposure is a vital and necessary part of assessing exposure and effects of CECs.

Chemical CECs: Traditional monitoring relies on sampling methodologies requiring extensive pre-concentration of samples, followed by measurement of individual chemicals using **targeted chemical analysis**, and subsequent comparison of measured occurrence to pre-established thresholds (e.g., measured vs. maximum allowable concentration). In contrast, bioanalytical screening using *in vitro* bioassays integrates the response of multiple chemicals present in a sample based on a common mode of action (MOA) (e.g., the sum total response of all estrogenic chemicals). Since it is impossible to use targeted chemical methods to monitor for all biologically active chemicals, incorporation of **bioanalytical tools** is an important complementary approach that can provide information on bioactivity as well as the occurrence of chemicals that may impact water quality. **Non-targeted chemical analysis (NTA),** including **suspect screening**, using high resolution mass spectrometry has shown its utility in identifying existing and novel chemicals. **Sample collection methods**, such as **passive sampling methods (PSMs**) that rely on simple, cheap, pre-calibrated devices, have evolved to the point where sampling of exceedingly low levels of chemicals in water and sediment can be achieved in a more cost-effective manner than older sampling methods. Each measurement tool has limitations, but the tools provide a robust chemical measurement methodology when combined.

- **Targeted chemical analysis** of known chemicals utilizes standardized protocols for robust quantitative measurement of occurrence in water, sediment and/or tissue. Targeted measurements can be validated against well-established QA/QC criteria (e.g., accuracy, precision), and measured values can be directly compared to thresholds of interest, including trigger levels (MTLs) that the CEC Expert Panel convened by SCCWRP derived for water, sediment and tissue (Anderson et al., 2012); these thresholds were subsequently adopted by the State Water Board. ***Limitations:*** Targeted analysis excludes measurement of all other chemicals, including bioactive chemicals, transformation products of known chemicals, and unknown or unexpected chemicals. The availability of validated measurement methods, as well as scientifically credible, matrix-specific thresholds for individual chemicals of interest, can also be a limiting factor. Establishing robust methods and credible thresholds for "new" chemicals is costly and time-consuming.

- **Bioanalytical tools** for detection of chemicals utilizes engineered cell lines designed to respond to chemicals that act through a common MOA. An aliquot of a pre-concentrated sample extract is applied to test cells under controlled laboratory conditions, incubated, and analyzed using plate (light) readers. Bioassay results are semi-quantitative and translatable into an equivalent concentration for comparison to thresholds referenced to a known MOA-specific toxicant. Bioanalytical screening was the Panel's top recommendation to address unknown chemicals in ambient waters (Anderson et al., 2012) and recycled/reclaimed waters (Drewes et al., 2018). ***Limitations:*** Comprehensive bioscreening requires a battery of *in vitro* bioassays, but only few cell assays are standardized for environmental application. Existing bioassays adapted for water quality monitoring cannot measure the effects of inorganic or unstable chemicals, and sample pre-concentration is still needed before bioanalysis.
- **Non-targeted chemical analysis** broadens the scope for identification of contaminants that are bioactive and/or toxic, including unexpected or previously unknown chemicals that elude targeted chemical methods. This diagnostic technique captures mass spectra data of all amenable compounds in a given sample, then identifies the compounds using mass spectral libraries/databases and/or through manual interpretation. NTA allows for a focus on specific classes of chemicals. For example, either hydrophobic or hydrophilic chemicals can be targeted if different instrumentation is utilized. As NTA techniques mature, creation of non-targeted "fingerprint" libraries is useful in diagnosing toxicity and in identifying and tracking sources (e.g., wastewater vs. stormwater runoff).
  Limitations: Methods and databases for identifying chemicals, particularly for water soluble chemicals, are not standardized and must be developed. Indeed, positive identification of unexpected or previously unknown chemicals is predicated on the availability of purified standards and/or needs complementary verification from nuclear magnetic resonance spectroscopy. Furthermore, managing and interpreting non-targeted data require specialized training and expertise. NTA is also qualitative by nature; targeted analysis is generally needed to quantify exposure levels of CECs. Finally, capital equipment to perform non-targeted analysis is more expensive than instruments used for targeted analysis and require more expertise to use.
- **Sample collection methods** such as PSMs use sorbents or exchange media to isolate and/or accumulate target chemicals from the media of interest (e.g., water, contaminated sediment). Passive samplers can detect extremely low levels of chemicals (e.g., parts per quadrillion), providing a time-weighted-average concentration without the need to collect, filter and transport copious quantities of sample in the field for pre-concentration of chemicals to use for targeted analysis, bioanalytical tools, or NTA techniques. PSMs can be applied under controlled lab conditions (*ex situ*) or in the field (*in situ*), e.g., where sentinel biota such as bivalves are not

available. Moreover, PSMs target the freely dissolved, or bioavailable, fraction of a chemical, a better predictor of bioaccumulation and toxicity.
Limitations: PSMs must be pre-calibrated in the lab for the chemical of interest. They can be sensitive to changes in environmental conditions and can require extended periods of exposure (weeks to months) for accurate measurement. Finally, PSMs can be subject to damage and vandalism, and thus measures to protect their integrity are often necessary.

Microplastics: Microplastics are a rapidly expanding subcategory of CECs for which standardized measurement protocols are urgently needed, as noted in the State's draft microplastics strategy to address contamination of coastal waters (OPC, 2021). There has historically been little consensus on methods by which to collect samples of environmental media for microplastics, ranging in matrix complexity from drinking water to surface water to wastewaters for water, to sediment, and to biological tissues. The same is true for the processing, analysis, and quantification of microplastics, as a plethora of widely diverging methodologies exist. Moreover, quality assurance and quality control protocols are generally lacking. These factors all make it difficult to evaluate the quality of studies on environmental microplastics, both on their own and particularly in comparison among different studies (Schymanski et al., 2021). Accordingly, several major research needs have been identified as crucial for the development of microplastics measurement protocols and tools:

- **Standardization and advancement of methodologies** are key for consistent and reproducible microplastics occurrence data. Analysis of this subcategory of CECs has reached the point where major methods generally considered suitable for characterizing microplastics have emerged. The general strategy to process raw samples is to eliminate interfering particulates either by chemical transformation (e.g., wet peroxide oxidation and/or enzymatic digestion of organic materials) or by physical removal (e.g., density separation of minerals in porous media matrices). For analytical techniques, these include visual microscopy, typically coupled with confirmation of material identity by spectroscopic (FTIR, Raman) or mass spectrometric techniques (pyrolysis GC/MS). However, the processing and analytical techniques to measure microplastics vary widely among studies, as do the quality assurance measures, including best laboratory practices around cleanliness and mitigation of contamination, handling of blanks, spike-and-recovery, and reference materials. Harmonization and adoption of consistent methodologies are crucial. Improvements in instrumental technologies (e.g., laser direct infrared spectroscopy or LDIR, optical photothermal infrared spectroscopy or O-PTIR) and adaptation of methodologies from related fields (e.g., environmental nanoparticle analysis) may have the potential to revolutionize knowledge on microplastics by providing data not currently possible to collect (e.g., measurement of nanoplastics, which are <1 μm).
- **Development of screening methods** is highly desirable. Existing methodologies typically rely on visual microscopy for an initial examination and for enumeration of particle count of a processed sample, followed by spectroscopy (e.g., FTIR, Raman) for confirmation of the material type of particles. While these methods are effective, they are also extremely time-consuming and labor-intensive, making them unwieldy for routine and frequent monitoring. Rapid and inexpensive screening methods are needed to inform when more complete characterization (e.g., by existing validated means) is justified. These potential methods may include touch-probe and macro spectroscopic techniques that can provide the plastic content of a raw or processed sample within moments, to indirect methods that can detect particle loads in real-time, to advancement of

pyrolysis GC/MS to provide quantitative mass-based concentrations of polymers in a fraction of the time needed for spectroscopy, in a robust and reliable manner suitable for monitoring purposes. Significant development and evaluation of such potential methods is required before screening capability can exist.

- **Improvement of sample collection methods.** Most sampling for microplastics involves either discrete grab sampling or sending water through nets or meshes of known size. Such methods can be subject to bias (e.g., manta trawling cannot sample microplastics below a standard trawl's mesh size of 335 µm). It is unclear how representative current collection methods are in collecting microplastics in space (e.g., within a water column or across a stream) or time (e.g., episodic events such as storms, for which the initial flush is likely to carry much larger loads of microplastics from runoff than later flow). It is also unclear what volumes of water are necessary to provide representativeness for microplastics, especially given the fact that there are generally many more smaller particles than larger ones (Kooi et al., 2021), leading to potential requirements from 1 L up to thousands of liters of water, depending on particle size (Koelmans et al., 2019). Chemical collection methods are generally not relevant, as microplastics have differing densities and therefore may not be homogenous from top to bottom of a water column.

Information Need II: Ambient Environmental Occurrence

For both chemical CECs and microplastics, the immediate application of developed measurement tools is to answer fundamental questions: What chemicals enter the environment? How often and at what levels do they occur? Where are the "hotspots" of particular concern? Addressing such questions requires occurrence data. This is particularly true for chemical CECs recommended by the CEC Expert Panel (Anderson et al., 2012), as these are likely present at levels warranting concern, even as information about them is limited. For microplastics, very little occurrence data exist at all, particularly for Southern California. With the advent of appropriate methods (Information Need I), monitoring of additional CECs will enhance the value of knowledge gleaned not just from standalone projects, but also from regional monitoring programs, such as Southern California Bight Regional Monitoring Program and the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program. In particular, the use of NTA in monitoring would greatly expand knowledge of the impact of CECs in the region. Characterizing ambient environmental occurrence is a necessary part of understanding CEC exposure.

Information Need III: Dose-Response

The presence of CECs in the environment, by itself, is not necessarily a problem. Rather, problems arise if that presence is at high enough concentrations of exposure to cause deleterious biological effects or have the potential to do so. We need to understand what concentrations trigger toxicity, and what physiological pathways lead to toxicity. These needs differ for chemical CECs vs. microplastics as a result of differing states of knowledge for each class.

Chemical CECs: The impact of chemicals on wildlife and humans may differ profoundly from effects associated with historically regulated contaminants. For example, chemicals affecting endocrine function, such as synthetic hormones, are potent at low levels of exposure (e.g., at ng/L concentrations in water), and their biological effects may take weeks, months and sometimes years to manifest. Considerable knowledge gaps exist in three areas, for which development has been limited due to the complexities and challenges involved in evaluating them in a robust and reproducible manner:

- **Developing bioanalytical screening thresholds:** Bioanalytical screening responses occur at levels typically much lower than those eliciting toxicity responses in whole organisms. As such, understanding the relationship between cellular and organismal responses is critical to interpret bioanalytical screening data and establish thresholds above which further chemical and toxicity test are warranted. To facilitate the application of bioanalytical tools, exposure studies with single and mixtures of CECs should be conducted to identify the effects thresholds protective of sentinel fish and invertebrate species.
- **Coupling NTA with in vitro or in vivo bioassays to identify CEC toxicants:** Both whole animal toxicity tests and cell bioassays can help assess the potential effects of bioactive chemicals. However, novel tools such as NTA are needed to narrow down the list of causative agents. Identifying the cause of toxicity in environmental samples, or toxicity identification evaluation (TIE), traditionally has relied on methods targeting specific classes of chemicals (e.g., pyrethroids, metals). This approach often falls short because the number of potentially toxic chemicals greatly exceeds the capabilities of these methods. NTA, including sample fractionation and suspect screening analyses, can enhance TIE by broadening the scope of contaminants subject to identification, and by identifying chemicals most likely to cause toxicity.
- **Developing molecular TIE methods to improve mixture toxicity assessment:** Whole animal toxicity testing remains necessary to determine if exposure to chemicals can lead to severe damage to aquatic life. However, characterizing whole organism and population-level responses requires considerable time and resources. Moreover, whole organism responses (e.g., growth, survival) are not chemical-specific, making identification of specific toxicants difficult. Development of molecular biomarkers can help identify sublethal effects of single and mixture CECs before irreversible damage occur (e.g., population collapse). Molecular tools also offer rapid tools to evaluate chemical-specific toxicity pathways, thus providing key information to managers on the classes of chemicals to prioritize and monitor.

Microplastics: As with chemical CECs, assessing the risks of microplastics exposure requires an understanding of their ecotoxicological impact in aquatic habitats. Microplastics are particularly challenging, as the toxicity exerted can be influenced by various particle characteristics, including size, shape, or composition. While a large body of literature is available on the effects of microplastics, the majority of published data are deemed inadequate for environmental assessment. To effectively implement a microplastics strategy, additional research is needed to understand the characteristics of concern and determine microplastics exposure levels that may be harmful to aquatic life. These research needs include:

- **Identification of ecologically relevant mechanisms of biological effects:** Knowledge of microplastic toxicity is still emerging as many potential toxicological mechanisms have yet to be explored or are only partially understood. Additional research is needed to identify and fully describe the ways in which microplastics may cause adverse health effects in aquatic organisms. This effort may be facilitated by connecting microplastics to existing or novel adverse outcome pathways, which can provide a powerful tool for linking molecular level responses to whole organism or population-level outcomes. Elucidating these mechanisms is essential to identify which characteristics and types of microplastics are the most harmful. In addition, organisms most sensitive to microplastic exposure may also be identified and their protection prioritized during the development of environmental management strategies for microplastics.

- **Development of thresholds for microplastics:** A framework for deriving thresholds for microplastics in water has been developed, but the resulting values are imperfect due to a lack of high-quality, fit-for-purpose data. There is a severe lack of robust dose-response data for microplastics. These data are needed to capture the critical concentrations at which microplastics begin to elicit adverse health effects in aquatic organisms. A confounding factor is that the concept of microplastics "concentration" differs from that of chemical CECs. Abundances of microplastics can be expressed in terms of either mass (e.g., ng polymer/volume) or particle count. Further, microplastics vary considerably in size, shape, and composition, so "concentrations" need to be applied accordingly (e.g., number of particles of a given polymer type, morphology, and size range per unit volume). In addition, thresholds for microplastics in other environmental matrices, such as sediment, have yet to be derived. Expanding our knowledge of microplastic dose-response relationships and developing thresholds across all relevant matrices are necessary to effectively evaluate the risks of microplastic exposure in aquatic habitats.

Information Need IV: Sources, Fate, and Transport

When Information Needs II and III indicate that exposure and toxicity are of concern, additional characterization of contaminant sources, fate, and transport is warranted. However, occurrence monitoring alone only provides information on hotspots and less impacted areas of CEC contamination, and by itself says nothing about where these contaminants arise and in what quantity, nor what is triggering their removal and at what rate. Ultimately, establishing a holistic mass balance is necessary for comprehensive characterization of the sources and sinks of a CEC. Accordingly, additional tools and focused monitoring and/or modeling efforts are needed to inform a directed response by managers and the selection of effective solutions. These efforts, for both chemical CECs and microplastics, are focused around three major areas:

- **Source identification and apportionment:** Identification of sources for both chemicals and microplastics allows managers to tailor corrective action, as warranted, on source inputs responsible for the impact in question. Cataloguing of chemicals observed in receiving waters impacted by different source inputs (e.g., discharge from WWTPs, stormwater, direct emissions such as from industrial complexes, agriculture, atmospheric deposition, resuspension or upwelling events), as applicable, using tools such as measurement, source tracking via marker compounds or NTA fingerprints, and modeling serves as the basis for identifying problematic chemical and microplastic CEC source inputs. Identification of sources of both chemical CECs and microplastics also includes quantitative estimation of loadings, i.e., calculation of release rates from such sources to the environment.
  Challenges: As with currently regulated contaminants, both chemical CECs and microplastics may enter waterways of interest via diffuse pathways, e.g., atmospheric deposition. Thus, parsing the contribution of CECs among point and diffuse sources and among the various types of diffuse sources (e.g., stormwater runoff, atmospheric input) is a major challenge, as is understanding what factors affect these contributions and estimates.
- **Fate and transport**: Understanding how a contaminant moves and behaves once it has entered the environment is also crucial for informed management to understand exposure and hence effects. Contaminants that degrade may no longer be of concern unless exposure to the

transformation product(s) triggers toxicity, although confounding factors exist (e.g., continuous input of contaminants, slow degradation).Those that transfer to other phases could require different management approaches; for example, sorption to sediments would imply that strategies for sediments and suspended particulate matter are more useful than those for the dissolved phase. In a similar vein, contaminants that volatilize may represent more of an air pollution problem. Finally, contaminants that rapidly move or disperse away from their sources may become less of a local issue and need appropriate action in other locales or over a larger region.
Challenges: The fate and transport of CECs can be extremely complex and variable, both spatially and temporally. Characterizing transformation processes is typically best performed under controllable conditions in the laboratory, or at mesocosm scale; however, applying results from small-scale experiments to the "real world" can be difficult for many reasons, ranging from limited knowledge of parameters affecting transformation (e.g., concentrations of other reactants, mass transfer limitations) to representativeness (e.g., mesocosm edge effects). Field experiments also can be difficult and costly to conduct. For microplastics, understanding loadings from aerial deposition and the hydrodynamics of aquatic transport is particularly important, as particles and polymers less dense than water ("floaters") may be transported by currents and waves very differently than those that are denser ("sinkers").

- **Mass balance analysis:** Both source apportionment as well as fate and transport are integral parts of mass balance analysis, which is the ultimate aim of Information Need IV. Data on sources, fluxes, and rates of contaminant input and removal into an area of interest – as appropriate for the contaminant of interest – allow modeling of the environmental behavior of the contaminant. Such modeling can predict concentrations and hence exposure, and also allow "what-if" scenarios to inform managers what decision-making pathway to take based on a given exposure.
Challenges: Obtaining reliable and complete data for mass balance analysis is often difficult, time-consuming, and costly. This problem is partially ameliorated by determining what parameters are the most important to evaluate mass balance; however, such an approach must be done on a case-by-case basis.

Information Need V: Remediation

Studies to understand the problem of CECs, as noted in the previous Information Needs, are helpful and valuable irrespective of CEC type. However, in order to solve environmental problems with CECs, it is also necessary to investigate the efficacy of potential actions to deal with them. These strategies are wide-ranging. For example, green chemistry initiatives can eliminate sources of CECs in consumer and commercial products before they are introduced to the environment. Similarly, **best management practices (BMPs)** can reduce levels of CECs *in situ* to acceptable levels, e.g., below established MTLs, or disable exposure pathways, such as sand capping of contaminated sediment. Monitoring of receiving waters pre- and post-implementation of remediation strategies is thus necessary to determine how management action correlates with risk reduction, and informs how to manage remediation strategies adaptively. Case studies from Information Needs II-IV can inform which parameters are most useful for intensive monitoring, and the diagnostic exposure measurement tools from Information Need I can be applied and integrated to evaluate remediation performance.

- **BMP effectiveness** requires an evaluation of conditions before and after implementation of corrective action. Exposure and biological responses from Information Needs II-IV provide the data necessary to determine whether conditions downstream of the BMP are met and can also characterize the degree of "removal" of chemicals or the reduction of these CECs in receptors. ***Challenges***: BMPs targeting individual chemicals or classes of chemicals that share common MOAs require diagnostic tools to determine if the chemicals of interests are in fact being attenuated. Targeting transformation products of targeted or non-targeted chemicals is also challenging and could require non-targeted chemical analysis for identification. Ensuring stable operation of BMPs is another challenge to their effectiveness.

Information Need VI: Technology Transfer

For both chemical CECs and microplastics, it is not enough to describe and understand the problem posed by CECs in the environment. The products of CEC research need to be accessible to decision-makers. Having a viable analytical protocol (Information Need I) is necessary but not sufficient, as a method that is not used has little value. This is true irrespective of whether such methodology is developed in-house at SCCWRP or elsewhere, and whether the methodology is adopted by consensus with participating organizations having appropriate expertise or selected thorough study of available literature. Onboarding and adoption of methods so that they can be used to obtain data for management decisions is the hallmark to truly successful methodology. Likewise, the data, information, and insights from occurrence (Information Need II), dose-response (Information Need III), and source and sink assessment (Information Need IV) must be usable by decision-makers and end-users to be truly complete.

SCCWRP is in a strong position to onboard and adopt new information, given our research focus and our emphasis on applying our research to serve water-quality monitoring and regulatory needs. Much of our research efforts, particularly around CECs, has been directed towards methods development and validation within a single laboratory. This provides basic information about performance (e.g., accuracy, precision) to be adopted into draft Standard Operating Procedures (SOPs) that can then be stress-tested through exercises such as intercalibration studies. These activities provide insights on capabilities and limitations that may not be apparent when evaluated by only a single laboratory – a common limitation for many organizations working toward widespread adoption of new methods Refinements of SOPs from such exercises are needed to develop accreditation procedures to establish basic proficiency for laboratories and organizations needing these methods. Appropriate training (e.g., courses) serves to familiarize these procedures and promote their adoption. SCCWRP's long-standing commitment to addressing water quality management and regulatory needs provides a unique position for it to work with its member agencies to onboard new methods throughout the technology transfer process, ensuring they become accessible for widespread practical use.

Research Directions

Information Need I: Development of Exposure Measurement Tools

In response to recommendations of the CEC Expert Panel (Anderson et al., 2012), SCCWRP and its collaborators have made significant strides in adapting existing technology and developing new technology to measure exposure of chemical CECs in water. The successful development and implementation of a comprehensive toolbox of these technologies will allow for data on both known and unknown chemicals to be captured during environmental monitoring. The toolbox, including targeted chemical analysis, bioanalytical tools, non-targeted chemical analysis, and passive sampling, has been vetted by scientists, engineers, and water managers across the state. SCCWRP will focus on applying these exposure measurement tools to receiving waters impacted by wastewater treatment plant (WWTP) and stormwater discharge.

SCCWRP has also made considerable recent progress in the emerging area of microplastics analysis. While many knowledge gaps remain, SCCWRP's efforts have provided some consensus in this rapidly evolving area of research and have provided clear directions to address knowledge gaps.

RESEARCH DIRECTIONS FOR CHEMICAL CECS

Targeted Chemical Analysis

Accomplishments

SCCWRP has a long history of developing and applying targeted analytical methods for characterizing the occurrence of contaminants, including several classes of chemicals. Methods for a suite of hormones were developed and applied to explain steroidal responses in inland waterways (Harraka et al., 2021). The risk-based screening framework established by the Panel incorporated current information, leading to the addition of new and removal of existing CECs from the monitoring list (Drewes et al., 2018).

Priorities for Future Research

The primary goal for future research is to develop targeted methods for high-priority chemical CECs, in appropriate matrices for evaluating ecosystem health (including sediments and biological tissues), that exhibit toxicity (e.g., 6PPD-quinone from tires in stormwater runoff) or have potential for deleterious effects. Accurate quantification of bioactive chemicals is needed to strengthen assessments linking exposure (screening results) to effects (diagnostic evaluation). Robust, targeted methods for these chemicals are needed to support studies that address adverse health outcomes in humans and animals.

***Future project*: Multiresidue pesticide methods validation**
Effective pesticide monitoring programs require robust methods, particularly to detect and quantify the many agrochemicals currently used to support California agriculture. This project will validate multi-class methods, using GC/MS and LC/MS/MS, to process and quantify 155 pesticides in water samples. Such a method would allow for quantitative trace analysis of a wide range of pesticides, rather than requiring a number of methods with mutually inconsistent or incompatible sampling or processing needs to measure the same set of analytes.

***Future focus area*: Targeted methods for chemicals recommended by CEC Expert Panel**
Targeted methods will be needed to generate robust occurrence data for high priority chemicals recommended by the current CEC Expert Panel, anticipated to provide its report by late-2022. Selection criteria of the Panel for these chemicals include occurrence in the State's waters (or likely occurrence based on studies elsewhere, if not currently measured in California), as well as likelihood to have deleterious human or ecological effects. Upon successful method development and optimization, we will investigate the occurrence and fate of these high-priority chemicals in aquatic ecosystems where exposure may present elevated human and ecosystem risk.

Bioanalytical Tools

Accomplishments

In vitro cell bioassays have shown promise as rapid bioscreening tools for water quality assessment (Escher et al., 2014; Mehinto et al., 2015). SCCWRP is part of an international group of researchers that have worked to optimize and standardize commercially available products for screening of endocrine active (e.g., estrogen receptor assays) and dioxin-like (e.g., aryl hydrocarbon receptor assay) chemicals (Mehinto et al., 2016). These protocols were used in pilot studies to screen water and sediment from the Russian River, a watershed with minimal urban impact, and Los Angeles River, an effluent-dominated watershed. Results of these studies revealed that bioanalytical screening is a cost-effective method to prioritize samples that contain bioactive chemicals and require further chemical analyses (Maruya et al., 2018). The first large-scale bioanalytical screening was also conducted on marine sediments as part of Bight survey, and results revealed that bioanalytical screening shows the potential to identify contaminated sites and detect early signs of toxicity (Mehinto et al. *in prep*).

Ongoing Research

SCCWRP's priority is to standardize a battery of cell bioassays that are transferrable to the broader monitoring communities. While initial work focused on endocrine-related cell bioassay endpoints, the emphasis now is to standardize cell bioassays for different toxicity pathways and evaluate their suitability to screen for bioactive CECs in ambient matrices, including fresh and brackish water, stormwater, recycled water, sediment, and fish tissues.

> ***Present project*: Expansion of cell bioassay toolbox**
> The current toolbox consists of a handful of endpoints largely targeting endocrine-active chemicals. For effective monitoring of known and unknown chemicals, a more comprehensive set of cell bioassays for various MOAs are needed. SCCWRP is investing in the development of endpoints to monitor non-estrogenic MOAs, including the peroxisome proliferated accelerated receptor and glucocorticoid receptor. Protocols that are semi-quantitative and include performance-based criteria will be optimized and evaluated during interlaboratory comparison exercises.

Priorities for Future Research

The majority of bioanalytical tools adapted for water quality monitoring have been applied to aqueous matrices, including treated wastewater effluent and their receiving waters. To date, only a few studies have examined the water quality of raw and treated stormwater runoff. The State of California is considering the use of stormwater capture for groundwater recharge. Therefore, assessing the occurrence of chemicals and their potential for impact in captured stormwater runoff is a high priority.

> ***Future project*: Demonstration of bioanalytical screening for stormwater and sediment**
> Based on previous investigations, stormwater could contain bioactive chemicals that are measurable using *in vitro* screening assays and that could potentially contaminate groundwater and/or pose a risk to ecological health. Thus, research is needed to characterize and compare bioassay response in stormwater runoff from different landscapes and post-BMP. In this project, optimized cell bioassay endpoints will be utilized to screen stormwater runoff samples for their potential of exerting toxic effects on aquatic life. Additionally, because sediments can accumulate

contaminants, riverine and estuarine sediment from habitats impacted by wastewater or stormwater runoff will be screened to better understand the bioaccumulation of CECs. This project will help develop a reliable battery of cell assay endpoints specific to sediment quality assessment.

Non-Targeted Chemical Analysis

Accomplishments

For decades, SCCWRP and collaborators have developed and implemented targeted chemical monitoring methods. With increased focus on CECs, these methods fall short of identifying all chemicals that may cause adverse effects. In response, SCCWRP has initiated research on non-targeted analytical methods that can detect unexpected and previously unknown chemicals. Non-targeted analysis utilizing liquid chromatography-quadrupole time-of-flight mass spectrometry was applied for (i) identification of causal CECs to coho salmon die-off (Tian et al., 2021); (ii) development of initial source fingerprints for urban waters (Du et al., 2020); and (iii) identification of habitat-related chemical fingerprints in Bight sediments (Mehinto et al. *in prep*).

Priorities for Future Research

This area is not currently a major priority. While SCCWRP has no defined project here currently, we will seek opportunities in this area as they arise.

Sample Collection Methods

Accomplishments

In this area, SCCWRP has focused on developing passive sampling methods to measure the freely dissolved concentrations of contaminants in water or sediment, a better parameter than bulk or total concentration as an exposure metric for observed bioaccumulation and toxicity (Parkerton and Maruya, 2014). SCCWRP participated in an international lab round-robin exercise to characterize the benefits of employing standardized PSM protocols (Jonker et al., 2018). SCCWRP also has developed PSMs to quantify PFAS and microcystins in water column applications (Wang et al., 2021, 2022).

Priorities for Future Research

SCCWRP's overall goal is to adapt and integrate PSMs, as opportunities arise, as a tool for characterizing chemical CEC exposure, leading to streamlined evaluation of water quality – be it for stormwater, wastewater, recycled water, potable water, or other types of natural or processed water.

> ***Future project*: Sampler characterization for multiresidue pesticide analysis**
> The multiresidue methods development project, while applicable to grab samples of water, is even more effective when combined with passive samplers, given their ability to sequester and concentrate analytes. In this project, passive samplers, such as the popular Chemcatcher, as well as semi-passive samplers such as the C.L.A.M. (Continuous Low-Level Aquatic Monitoring), will be evaluated for their capability to provide quantitative data sufficient for regulatory purposes. This will be done by assessing sampling rates for pesticide analytes and correlating these with their physical-chemical properties as well as hydrodynamic conditions at deployment sites.

RESEARCH DIRECTIONS FOR MICROPLASTICS

Standardization and advancement of methodologies

Accomplishments

SCCWRP has made significant strides in microplastics analysis, leading an intercalibration measurements study with 40 laboratories in 6 countries to determine performance, capabilities, limitations, and feasibility of methods for processing and analyzing microplastics in clean water, dirty water, sediment, and fish tissue. Results from the clean water matrix (De Frond et al., 2022), a proxy for drinking water, have been used to develop the first required monitoring program in the world for microplastics in drinking water, including the development of Standard Operating Procedures for measurement of microplastics with microscopy combined with spectroscopy (FTIR and Raman). As part of this project, SCCWRP has also been evaluating methodologies for surface water, sediment, and fish tissue, demonstrating how recovery and spectroscopic performance is affected by the presence of a matrix compared to those of clean water.

Ongoing Research

***Current project*: Adaptation of techniques for analysis of microplastics in wastewater**
A current research direction is the adaptation of techniques to process and analyze microplastics in wastewater, which often require more cleanup and isolation procedures than less complex matrices that SCCWRP and others have already studied. Methods addressing limitations of existing methodology (e.g., from ASTM) would make these techniques far more robust and applicable for routine monitoring.

Priorities for Future Research

***Future project*: Performance assessment of advanced spectroscopic instrumentation for microplastics analysis**
This project will use samples from drinking water monitoring to characterize the capabilities and limitations of new spectroscopic techniques, such as LDIR and O-PTIR, against existing validated technologies (FTIR, Raman). Particular emphasis will be placed on the potential capabilities of such new instrumentation to analyze small particles (< 20 µm and particularly <1 µm), and on their ability to automate mapping in a robust manner amenable for monitoring. The latter feature is a vital need, as current spectroscopic analysis is heavily dependent on manual mapping and identification of individual particles one at a time, which is laborious and time-consuming. Automated mapping and spectroscopic confirmation are currently areas of active research (Primpke et al., 2020). Such efforts could further the more widespread availability of these methods (e.g., through interlaboratory calibration research).

Development of screening methods

Accomplishments

The intercalibration measurements study recognized that the methods for which SOPs were developed were extremely time-consuming. Accordingly, the study recommended criteria for potential screening methods, and potential candidate methods. These have been recommended as future research needs in the proposed monitoring program by the State Water Board.

Priorities for Future Research

***Future project*: Evaluation of potential screening tools for microplastics in water**
This project will investigate the feasibility of rapid and inexpensive screening tools for microplastics in drinking water. These tools were identified as necessary by the microplastics measurement intercalibration study, along with a list of candidate methods. SCCWRP will evaluate selected candidate methods, through analysis of samples from drinking water treatment in monitoring work characterized by validated comprehensive techniques.

Improving sample collection methods

Priorities for Future Research

***Future project*: Refinement of online sample collection for microplastics in drinking water**
This project will refine and standardize sampling for microplastics in drinking water via online filtration. Such waters are likely to have low abundances of microplastic particles, requiring collection of up to thousands of liters of water. Such collection is prone to contamination from atmospheric particle deposition. SCCWRP will work with water utilities and ASTM to refine the latter's online sample collection methods throughout the drinking water treatment and distribution system (i.e., source to tap). This will provide needed insights on both stress-testing of the method, and data on the volumes of water necessary for such sampling.

Information Need II: Ambient Environmental Occurrence

Ongoing research by SCCWRP and other leading researchers in developing exposure measurement tools for water quality assessment have focused on standardization of protocols. The protocols being developed will need to be tested in regional monitoring studies to assess the environmental occurrence of CECs.

Ongoing Research

Current research focuses on understanding the occurrence of CECs, whether chemical or microplastic, within the region and the State. For example, the lack of knowledge of microplastic abundance in the California aquatic environment is being addressed through current monitoring work on this type of CEC in wastewater effluent, and in receiving surface waters, sediments, and aquatic biota.

***Future project*: Occurrence of microplastics in drinking water**
This project will measure the occurrence of microplastics in source waters, finished drinking waters, and "at-the-tap" waters for drinking water treatment plants across California, using the procedures developed in the microplastics measurement intercalibration study. These results will determine the magnitude of microplastics contamination in drinking water, as required by SB 1422, and set a benchmark for potential for human health effects. It will also evaluate efficacy of removal processes for microplastics in drinking water treatment. Furthermore, this work will serve as a testbed for further methods development for microplastics analysis (Information Need I).

Priorities for Future Research

***Future focus area*: Further integration of CEC analysis into regional monitoring programs**

Regional monitoring programs for CECs are designed and carried out to serve as a reality check for monitoring results and exposure measurement tools. This work will incorporate new methods for CEC measurement, for both chemical CECs and microplastics, into future regional monitoring programs to identify problematic chemicals, to map hot spots of occurrence to drive studies on effects (Information Need III) and on fate and transport (Information Need IV), and to characterize historical regional contaminant deposition from analysis of dated sediment cores (e.g., microplastics).

***Future focus area*: Measurement of CECs in marine mammals of coastal southern California**
This research initiative will develop a catalog of chemical CECs in coastal marine mammals via targeted and non-targeted analysis, and microplastics through techniques established by SCCWRP in Information Need I. Investigation of causal chemicals associated with specific health conditions will also benefit from coupling NTA with TIE. This project will also compare CEC occurrence within different marine mammal species to select ideal sentinel species for monitoring coastal habitats.

Information Need III: Dose-Response

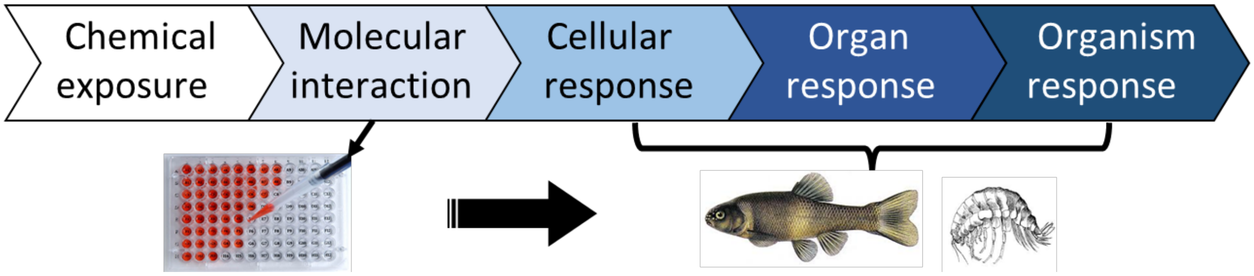
RESEARCH DIRECTIONS FOR CHEMICAL CECS

Linking Molecular/Cellular Responses to Whole Organism/Population

Accomplishments

Historically, SCCWRP has provided methods to establish linkage between chemical exposure and biological effects using targeted chemical analysis and whole animal toxicity testing and, when responses warrant, through TIE. With the advent of *in vitro* screening bioassays (see Bioanalytical Tools section, above), linkage of molecular/cellular level responses to *in vivo* effects represents a new challenge (**Figure 2**). In recent years, SCCWRP and collaborators have demonstrated that it is possible to quantify the linkage between *in vitro* activity (e.g., for the estrogen receptor cell assay), altered gene expression (e.g. choriogenin, vitellogenin) and impaired gonadal development in the inland silverside *Menidia beryllina* (Mehinto et al., 2018). This study is evidence that cell bioassay responses can provide a more sensitive and conservative screen than traditional toxicity tests. Additional work in field studies showed that such relationship is also observed in field-based studies (Mehinto et al., 2021).

Figure 2. Linking cell bioassay results to *in vivo* (whole animal) responses is key to develop bioscreening thresholds protective of aquatic life.



Ongoing Research

Lab studies have been initiated to characterize the relationship among cellular screening responses, gene expression and adverse outcomes in sentinel organisms. Due to the high potential for establishing linkage, ongoing work is focused on evaluating the concordance between screening and diagnostic-level responses for non-estrogenic MOAs.

> ***Ongoing project*: Developing ambient bioscreening thresholds for glucocorticoids and dioxin-like chemicals**
> This project will develop screening thresholds through lab and field studies to establish the relationship among cells, tissue, and whole organism responses for priority species. SCCWRP is evaluating dose-response relationship in *Menidia* and fathead minnows, starting with exposure to GR-active chemicals. This study will help establish conservative bioscreening thresholds above which additional testing will be warranted.

Priorities for Future Research

Beyond the top-priority estrogenic chemicals, there are several other classes of endocrine-active chemicals present in receiving waters. Future linkage studies will investigate these MOAs. In addition, future efforts are needed to develop bioanalytical screening thresholds based on linkage to higher-level responses for ambient biota.

> ***Future project*: Developing bioanalytical screening thresholds based on link to higher-level responses for ambient biota**
> As new cell bioassays are optimized, linkage testing protocols for bioactive chemicals will need modification to include MOA-specific endpoints and response times. Bioscreening thresholds and an interpretation framework will be developed and validated concurrently.

Coupling Non-Targeted Analysis to Bioassays to Identify CEC Toxicants

Currently available toxicity tests do not adequately address the action of many chemicals, which can activate adverse outcome pathways at exceedingly low concentrations and over extended periods of exposure. Conventional targeted chemical analysis is limited to chemicals for which robust methods exist. SCCWRP's research priorities lie in developing *in vivo* or *in vitro* toxicity tests that capture the activity of chemicals, and non-targeted chemical analysis would enhance diagnostic capabilities for identifying causal toxicants.

Priorities for Future Research

***Future focus area*: Using analytical chemistry tools to identify chemicals associated with positive cell assay responses**

This project will identify chemicals that exhibit bioactivity and toxicity in biological screening and diagnostic testing (see Information Need I) in mixtures. This project will initially focus on assessment of simple toxicant mixtures to demonstrate robustness and to modify, as appropriate, TIE assessment procedures. Samples with increasing complexity have the potential to expand the content of libraries/databases cataloguing chemicals, to include data on observed *in vitro* and *in vivo* activity.

Evaluation of Chemical CEC Mixtures

Chemical CECs are generally present as mixtures in environmental media. However, traditional toxicity typically evaluates effects for one analyte at a time to avoid the confounding effects of multiple toxicants. Evaluating every combination of a complex mixture for toxicity is laborious and time intensive. Thus, finding suitable means by which to identify and quantify mixture toxicity is important.

Priorities for Future Research

***Future focus area*: Developing molecular biomarkers for chemical CEC mixtures**

Environmental levels of chemical CECs are unlikely to affect traditional toxicity endpoints (e.g., survival, growth). Therefore, developing sensitive and reliable biomarkers to predict toxicity for various chemical CEC classes is needed. This project will complement the previous information needs under dose responses and develop molecular biomarkers for sentinel species. The outcomes of this work will be useful for future ecological risk assessment.

RESEARCH DIRECTIONS FOR MICROPLASTICS

Accomplishments

SCCWRP, with its partners, convened a Microplastics Health Effects Workshop with international leaders in the field that summarized available literature and identified next steps to advance collective knowledge of microplastic toxicity. Experts also developed quality standards to ensure that microplastic toxicity data is fit for threshold development and future risk assessments.

Priorities for Future Research

***Future focus area*: Improving understanding of adverse effects and developing biomarkers/endpoints for relevant mechanisms of toxicity**

This project area will be focused on identifying sensitive, relevant endpoints for microplastic toxicity and understanding dose-response relationships for those endpoints, particularly for types of microplastics or microplastic characteristics (e.g., size, shape, polymer) that are understudied or predicted to be harmful relative to other microplastics. SCCWRP is currently evaluating the toxicity of microplastic fibers in early life stage fish across multiple levels of biological organization (i.e., molecular, tissue, whole organism). This study will provide much needed information on the potential toxicity of fibers, a historically understudied class of microplastic, and will be designed to meet study quality standards developed by the Microplastics Health Effects Workshop experts.

***Future focus area*: Refining and developing microplastic exposure thresholds**
A framework for developing thresholds for microplastics was developed by the previously described expert workshop. Although an initial set of thresholds was derived for water, the data utilized were not ideal in terms of quality. These data also represented a haphazard variety of species and habitats based on the available studies. SCCWRP will work to generate habitat-specific data fit for the purpose of refining and developing thresholds for specific environmental matrices (i.e., marine waters, marine sediment, freshwater, and riverine sediment).

Information Need IV: Sources, Fate, and Transport

Understanding the absolute and relative contribution of sources and sinks of CECs to an impacted area of interest is necessary for informed and timely decisions on sampling, cleanup, and restoration. To do such mass balance evaluation, knowledge of the sources, fate, and transport of contaminants, including in waterbodies and water treatment infrastructure, is needed. SCCWRP research focuses on developing, identifying and quantifying the necessary pieces for mass balance evaluation: source identification, exposure routes, and fate and transport of contaminants in receiving waters impacted by wastewater and stormwater. This research includes working at laboratory or pilot-scale to develop, refine and validate exposure assessment measurement tools. While the ongoing and future work described in this section focus on microplastics as representative examples, analogous approaches hold for other CECs as well.

Source Characterization

The study of source characterization for CECs encompasses has two major aspects. The first is the identification of major classes of CECs that are entering the environment. This can be further categorized into major sources that are contributing these CECs (e.g., wastewater, stormwater, atmospheric deposition) and/or more specific sources (e.g., from a particular stream, from a particular product type such as tire wear), depending on specific needs. The second is quantitative estimation of CEC loadings from major sources to the aquatic environment. Such information is necessary for managers to focus efforts on mitigating these sources, which could include setting appropriate TMDLs.

Accomplishments

SCCWRP has refined the chemical fingerprints of contamination sources and evaluated the utility of the fingerprinting approach to identify and track contamination sources (Du et al., 2020). SCCWRP has also focused on case studies, such as in the Southern California Bight, to optimize NTA methods coupled with TIE to identify sources for contaminants of interest (Mehinto et al. *in prep*).

Ongoing Research

SCCWRP is addressing a significant information need in determining the magnitude of microplastics loadings from California coastal wastewater treatment facilities. This work will establish wastewater discharge levels for the State, currently known only for San Francisco Bay (Sutton et al., 2019).

***Current project:* Loadings estimation of microplastics from wastewater**
This project is estimating the amount of microplastics entering California coastal waters from wastewater discharge. In addition, removal efficiencies during treatment are assessed, to provide

a better understanding of the performance of California's wastewater treatment technologies in handling this type of contaminant.

Current project: **Loadings estimation of microplastics from stormwater**
SCCWRP, in collaboration with partners, is making the first estimation of microplastics loadings from stormwater by analyzing water samples taken in dry and wet season in the southern California region. This will help determine if the recent finding in San Francisco Bay that stormwater loadings dwarf wastewater emissions (Sutton et al., 2019) is relevant elsewhere as well.

Priorities for Future Research

The need to identify major microplastics sources not only includes characterization of waterborne pathways, but also evaluating the potential for atmospheric inputs as well, given that small airborne microplastic particles, as with any other particles, can enter surface waters by dry and wet deposition.

Future focus area**: Loadings estimation for microplastics from atmospheric deposition**
This project will quantify the importance of microplastics inputs to the ambient aquatic environment from atmospheric deposition. In conjunction with research on wastewater and stormwater loadings, this assessment will determine the overall magnitude of microplastic contamination in California, as well as the relative contributions of each major source, so that appropriate control strategies can be developed. Further characterization would quantify the amount of microplastics in recycled source water, to understand its contamination status compared with other drinking water sources.

Fate and Transport

Priorities for Future Research

This area is not currently a major priority. While SCCWRP has no defined project here currently, we will seek opportunities in this area as they arise. For example, understanding sinks of CECs is a logical extension of work to identify and quantify sources as noted above.

Mass Balance Analysis

Priorities for Future Research

This area requires characterization of individual major sources and their loadings, as appropriate for CECs at locations of interest, before comprehensive mass balance analysis becomes feasible. SCCWRP endeavors to address mass balance for CECs once such projects have provided sufficient high-quality data to support this work, as exemplified by the microplastics work described above.

Information Need V: Remediation

Issues arising from monitoring and assessment from Information Needs II-IV that warrant management action may require additional tools and assessment. Green chemistry initiatives can minimize or eliminate source chemicals in consumer and commercial products before they are introduced to the environment, to permit focus on problematic chemicals. If chemical elimination efforts fall short of their intended goal, implementation of BMPs may reduce concentrations of chemicals *in situ* to acceptable levels. Monitoring of receiving waters before and after BMP implementation is thus necessary to determine how management action correlates with a reduction in risk. SCCWRP will be opportunistic in the pursuit of research in remediation involving CECs, but currently has no specific projects planned.

Information Need VI: Tech transfer

The final information need in the conceptual model for chemical management is technology transfer, in which the products, insights, and knowledge gained from addressing the other five Information Needs are disseminated to end-users. Many of these products are in the form of analytical methodologies (Information Need I) that were developed in-house at SCCWRP, developed elsewhere and then adopted through the consensus of participating organizations with appropriate expertise, or selected thorough study of available literature. They can also be data and information resulting from other priority Information Needs, such as those characterizing and assessing exposure, sources, sinks, and effects (e.g., Information Needs II-IV). The means by which such technology transfer occurs is a range of training activities and exercises. These are crucial in making the fruit of SCCWRP's research available for practical use, and is a highlight of SCCWRP's unique position to make cutting-edge science accessible to the regulatory and regulated communities.

Accomplishments

The State of California has adopted the use of bioanalytical screening tools for recycled waters, for which SCCWRP and collaborators developed guidance documents describing all procedures, from sample collection to data analyses, to support implementation of Era and AhR bioassays for recycled water utilities (NWRI 2020). Additionally, SCCWRP conducted informal seminars, webinars, and lab training sessions to explain how cell bioassays work and train staff from member agencies.

In addition, the microplastics measurement study completed by SCCWRP for drinking water has formed the basis for ongoing monitoring of drinking water facilities proposed by the State Water Board and required by State legislation. Likewise, the health effects expert workshop on microplastics has informed a draft strategy, also required by State mandate, for managing microplastics pollution in the State's coastal waters.

Ongoing Research

Current work along these lines includes assisting the California Environmental Laboratory Accreditation Program with the development of an accreditation program for analysis of microplastics for drinking water monitoring. This work includes creation of training courses, both in-person as well as by video-on-demand. Also ongoing are intercalibration exercises, such as that by the Southern California Stormwater Monitoring Coalition, to standardize proficiency for contract laboratories desiring to conduct chemical analysis for the SMC's regional monitoring program.

Priorities for Future Research

SCCWRP will focus on evolving draft methodology to understand strengths and weaknesses through interlaboratory comparison studies, and to adapt these to deployment through accreditation and training endeavors.

***Future project*: Intercalibration and accreditation of multiresidue pesticide methods**
The methods development for multiresidue pesticide analysis described in Information Need I will be stress-tested by interlaboratory calibration studies. The results of this exercise will be used to develop an accreditation program for these methods, along with appropriate training procedures.

***Future focus area*: Evaluation and technology transfer of methods for new CECs**
This work will further accreditation efforts (e.g., for standardized cell assay endpoints) as well as intercalibration efforts with regard both to training for existing methods (including bioassays) and to development of new analyses (e.g., PFAS) and matrices (e.g., microplastics for ambient environments).

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