Contaminants of Emerging Concern in San Francisco Bay: A Strategy for Future Investigations

2015 Update

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About this Update

The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) has been investigating contaminants of emerging concern (CECs) since 2001. CECs can be broadly defined as synthetic or naturally occurring chemicals that are not regulated or commonly monitored in the environment but have the potential to enter the environment and cause adverse ecological or human health impacts.

The RMP Emerging Contaminants Workgroup (ECWG), established in 2006, includes representatives from RMP stakeholder groups, regional scientists, and an advisory panel of expert researchers that work together to address the workgroup's guiding management question – Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay? The overarching goal of the ECWG is to develop cost-effective strategies to identify and monitor CECs to minimize impacts to the Bay.

To this end, the RMP published a CEC Strategy document in 2013 (Sutton et al. 2013). The strategy is a living document that guides RMP special studies on CECs, assuring continued focus on the issues of highest priority to the health of the Bay. A key focus of the strategy is a tiered risk and management action framework that guides future monitoring proposals. The strategy also features a multi-year plan indicating potential future research priorities.

This 2015 CEC strategy update features revised designations of CECs in the tiered risk and management action framework based on monitoring and research conducted since 2013. Brief summaries of relevant RMP findings are provided. In addition, a proposed multi-year plan for future RMP Special Studies on CECs is outlined. A full revision of the CEC strategy is anticipated in 2016.

The RMP's Tiered Risk and Management Action Framework: 2015 Update

The RMP assigns CECs monitored in Bay water, sediment, and wildlife to tiers in the program's risk and management action framework (framework in Table 1; CEC tier assignments in Table 2). The degree of concern associated with a particular chemical or chemical class guides both RMP monitoring and management actions, as outlined in Table 1. The criteria listed below were used for placement in each tier (Sutton et al. 2013).

Tier I (Possible Concern) – Uncertainty in measured or predicted Bay concentrations or toxicity thresholds suggest uncertainty in the level of effect on Bay wildlife.

Tier II (Low Concern) – Bay occurrence data or PECs suggest a high probability of no effect on Bay wildlife (i.e., Bay concentrations are well below toxicity thresholds and potential toxicity to wildlife is sufficiently characterized).

Tier III (Moderate Concern) – Bay occurrence data suggest a high probability of a low level effect on Bay wildlife (e.g., frequent detection at concentrations greater than the PNEC[1] or NOEC[2] but less than EC_{10}[3] or another low level effects threshold).

Tier IV (High Concern) – Bay occurrence data suggest a high probability of a moderate or high level effect on Bay wildlife (e.g., frequent detection at concentrations greater than the EC_{10}).

Updated assignments for CECs that have been monitored in the Bay through 2015 are provided in Table 2. A CEC is only assigned to a tier in the framework if it has been analyzed in Bay samples. Secondary factors that may impact tier assignments for each CEC include trends in use of the chemical or trends in Bay concentrations. The tier assignments for each CEC in this report were based on information available in 2015 and will be updated as new information on the potential risk of the CEC becomes available.

[1] PNEC, predicted no effect concentration
[2] NOEC, no observed effect concentration
[3] EC_{10}, effect concentration where 10% of the population exhibits a response

Table 1. The Conceptual Tiered Risk and Management Action Framework for San Francisco Bay. See Sutton et al. 2013 for more information.

Risk Level Description	Monitoring Strategy	Water Quality Management Actions
Tier IV (High Concern) – Bay occurrence data suggest a high probability of a moderate or high level effect on Bay wildlife	Studies to support TMDL or alternative management plan	303(d) listing* TMDL or alternative management plan* Aggressive control/treatment actions for all controllable sources
Tier III (Moderate Concern) – Bay occurrence data suggest a high probability of a low level effect on Bay wildlife	Consider including in Status and Trends monitoring Special studies of fate, effects, and sources, pathways, and loadings	Action plan/strategy Aggressive pollution prevention Low-cost control/treatment actions
Tier II (Low Concern) – Bay occurrence data or predicted environmental concentrations suggest a high probability of no effect on Bay wildlife	Discontinue or conduct periodic screening level monitoring in water, sediment, or biota Periodic screening level monitoring for chemical(s) detected in wastewater or runoff to track trends	Low-cost source identification and control Low-level pollution prevention Track product use and market trends
Tier I (Possible Concern) – Potential for concerns or uncertainty in measured or predicted Bay concentrations or toxicity thresholds suggest uncertainty in the level of effect on Bay wildlife	Screening level monitoring to determine presence in water, sediment, or biota Screening level monitoring for presence in wastewater or runoff	Maintain (ongoing/periodic) effort to identify and prioritize emerging contaminants of potential concern Track international and national efforts to identify high priority CECs Develop biological screening methods and identify available analytical methods

*Subject to Regional Water Quality Control Board action with public review

Table 2. Current status of CECs in the tiered risk and management action framework for San Francisco Bay, 2015.

Management Tier	Contaminant/Class	Rationale
Tier III: Moderate Concern	PFOS	Bird egg concentrations have been greater than PNEC and are currently in the range of concentrations linked to reproductive effects in wild birds; high concentrations in seal blood; high volume use of precursors
	Fipronil	Sediment concentrations are in the range of toxicity thresolds for degradates; use is high and increasing in urban areas
	Nonylphenols, Nonylphenol ethoxylates	Bay concentrations below most toxicity thresholds; possible impacts on larval barnacle settlement; possible synergistic effects with pyrethroids; estrogenic activity; previously high volume use may be decreasing
	PBDEs	Concentrations in Bay wildlife and sediment have decreased over time, though detections remain at levels of potential concern for benthic organisms and fish; tern egg concentrations are below toxicity threshold; sport fish concentrations are below CA fish contaminant goal; possible blood/immune system impacts on seals; production and use phased out in U.S.
Tier II: Low Concern	Pyrethroids	Detected infrequently and in low concentrations in Bay sediment; of concern in watersheds, as tributary sediment concentrations are comparable or higher than toxicity thresholds; previously high volume use may be decreasing; lower impact professional application methods have been prescribed via state regulations
	Pharmaceuticals, Personal care product ingredients*	Concentrations below toxicity thresholds, toxicity to aquatic species sufficiently characterized
	HBCD	Concentrations are low; reduction in use anticipated worldwide
	PBDD/Fs	Low concentrations; synthetic sources declining with PBDE phase-out

Tier I: Possible Concern	Alternative Flame Retardants (organophosphates including TPhP, hydrophobic brominated and hydrophobic chlorinated [Dechlorane-type] compounds and metabolites)	Detection of several in water, sediment, and/or tissue; limited toxicity data for aquatic species; endocrine disrupting properties; additive/synergistic exposure effects unknown; high volume use or potentially increasing use as PBDE replacements
	Bisphenol A	Analyzed but not detected in surface waters (< 2500 ng/L) or sediments (< 2600 ng/g), PNEC=60 ng/L
	Bis(2-ethylhexyl) phthalate (BEHP or DEHP)	Sediment concentrations in the same range as low apparent effects threshold (but threshold not directly linked to DEHP)
	Butylbenzyl phthalate (BBzP)	Sediment concentrations exceed low apparent effects threshold (threshold not directly linked to BBzP or effects in macrobenthos)
	PFASs other than PFOS	Detection of several compounds in Bay matrices; indications of contamination with as-yet unidentified PFASs; indications of increasing levels of PFOA and short-chain PFAS, the latter likely due to increasing use; possible impacts to marine mammals from PFOA; toxicity to aquatic species not sufficiently characterized
	Short-chain chlorinated paraffins	Concentrations below toxicity thresholds; uncertainties in toxicity data; high volume use
	Other pesticides**	Concentrations below toxicity thresholds; uncertainty in toxicity to Bay wildlife
	Single-walled carbon nanotubes	Not detected; toxicity information not available
	Microplastics	Detected in Bay surface water; uncertainty in toxicity to Bay wildlife
	Newly identified tissue contaminants (2,2'-dichlorobenzil, dichloroanthracenes, 4-tert-butylamphetamine, methyl triclosan)	Detected in Bay tissue samples via non-targeted analysis; uncertainties in toxicity data

*For full list of PPCPs considered in this group see Klosterhaus et al. 2013a, Appendix Tables B1 and B2

**For full list of pesticides considered in this classification see Klosterhaus et al. 2013a, Appendix Table B6.

RMP CEC Tier Assignments: Recent Findings

Summarized below are relevant recent findings relating to contaminants assigned to the RMP's tiered risk and management action framework for CECs. These include moderate concern (Tier III) contaminants PFOS, fipronil, and PBDEs; low concern (Tier II) contaminant HBCD; and possible concern (Tier I) contaminants alternative flame retardants, PFASs other than PFOS, microplastics, and specific tissue contaminants newly identified via non-targeted analysis. The latter two groups, microplastics and newly identified tissue contaminants, represent the only significant changes to the tiered framework.

At this time, no CECs are considered to be a high concern (Tier IV) for the Bay. For information on contaminants assigned to tiers but not discussed in this update, see Sutton et al. (2013).

PFOS (Tier III, Moderate Concern) and other PFASs (Tier I, Possible Concern)

The RMP has analyzed bivalves, sport and prey fish, bird eggs, and seals for PFOS. Low to nondetectable PFOS concentrations have been observed in Bay bivalves (Dodder et al. 2014) and sport fish (Davis et al. 2012). For example, of the 21 fish analyzed, only 4 had detectable concentrations with a maximum concentration of 18 ppb. California has not established consumption guidelines; however, the Minnesota Department of Public Health has established fish consumption guideline of no restrictions for consumption of fish containing less than 40 ppb.

In contrast, concentrations of PFOS in bird egg and harbor seal blood are quite high relative to other monitoring sites around the world. Concentrations of PFOS in South Bay bird eggs have declined from approximately 1,200 ppb (2006/2009) to 390 ppb (2012). Although bird egg concentrations have declined below the PNEC of 1,000 ppb (Newsted et al. 2005), they remain at levels that have shown impaired hatchling success in tree swallows in Minnesota (Custer et al. 2012).

Similarly, concentrations of PFOS in seal blood have also declined from approximately 1,000 ppb (2004) to 350 ppb (2014). There are few studies of the toxicological effects of perfluorinated compounds on marine mammals; however, PFOS studies in other mammals suggest that these concentrations may be of concern.

For these reasons, PFOS remains a moderate concern (Tier III CEC) for the Bay.

The RMP also tracks a number of related poly and perfluoroalkyl substances (PFASs). A key member of this chemical family, perfluorooctanoic acid (PFOA) is a full fluorinated eight-chain-carbon molecule (also referred to as C8 compound). Historically, PFOA was widely used in such diverse applications as the manufacture of fluoropolymers (e.g., Teflon), stain/water repellant coatings for textiles and food packaging, and fire-fighting foams. Some PFAS precursor compounds, such as the fluorotelomer alcohols, can break down to PFOA. Eight major manufacturers of PFOA agreed to phase-out production of PFOA by 2015, replacing it with shorter chained compounds such as C6 and C4 that are thought to be less bioaccumulative and toxic.

An independent science panel found that there was a probable link between PFOA exposure and high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, and pregnancy-induced hypertension (C8 Panel). The Office of Health Hazard Exposure and Assessment is currently considering listing PFOA and PFOS as Proposition 65 reproductive or developmental toxicants.

The RMP has analyzed water, sediment, bivalves, sport and prey fish, bird eggs, and seals for PFOA as well as some of the shorter chained C6, C5 and C4 PFASs. In addition, PFOA and the shorter chained PFASs have been monitored in Bay Area effluent and storm water (Houtz and Sedlak 2012, Houtz et al. in preparation, Sedlak et al. submitted). PFOA concentrations are generally an order of magnitude lower in biota than PFOS concentration (Sedlak and Greig 2012; Sedlak et al. submitted). However, in some animals, concentrations of PFOA, unlike PFOS, are not declining (Sedlak et al. submitted).

Many PFASs in Bay Area stormwater, effluent, and Bay sediment remain uncharacterized (Houtz and Sedlak 2012, Higgins et al. 2005, Houtz et al. in preparation). In a study of Bay Area stormwater runoff, up to 60 percent of the total perfluorinated compounds were unidentified. Similar percentages of unidentifiable perfluorinated compounds were observed in effluent from eight Bay Area wastewater treatment facilities.

Little information exists regarding the environmental toxicity of precursors and the shorter-chained PFASs. As a result, this class of chemicals is considered a possible concern (Tier I contaminant) for the Bay.

Fipronil and Degradates (Tier III, Moderate Concern)

Fipronil, a broad-spectrum insecticide of particular concern due in part to growing urban uses, has been detected in Bay sediment and urban creeks. Observed concentrations of fipronil and its degradation products in sediment have exceeded effect thresholds on occasion, suggesting these compounds may pose risks to Bay aquatic life. The 2014 sediment monitoring data featured detections of one degradate at levels comparable to a toxicity threshold reported by Maul et al. (2008), indicating its designation as a moderate concern (Tier III contaminant) for the Bay is still warranted.

The RMP has funded a study in 2016 that will provide key information on this pesticide in wastewater, including the effects of secondary and more advanced treatment on concentrations of fipronil and its degradates.

PBDEs (Tier III, Moderate Concern)

A major success story for the Bay, RMP scientists published a study documenting declines in a toxic flame retardant family, polybrominated diphenyl ethers (PBDEs), in wildlife and sediment following an industry phase-out and state ban (Sutton et al. 2015). The study expanded on trends first described in a more detailed RMP report summarizing the state of the science on PBDEs in San Francisco Bay (Sutton et al. 2014). More recent Status and Trends monitoring results are consistent with continuing declines of PBDEs.

Despite the declining levels in sediment and biota (Sutton et al. 2015) and reduced concern with respect to sport fish consumption (Sutton et al. 2014) and adverse effects in bird populations (Sutton et al. 2014), the potential for low-level risks for seals, fish, and benthic organisms described in Sutton et al. (2014) have led to the classification of PBDEs as a moderate concern (Tier III) contaminant for the Bay.

Alternative Flame Retardants (Tier I, Possible Concern) including HBCD (Tier II, Low Concern)

Manufacturers now use alternative, non-PBDE flame retardants in their products to meet flammability standards. Recent changes to California's flammability standards have reduced the use of flame retardants in some consumer goods, which may result in lower levels of contamination in the Bay. Nevertheless, preliminary results from the most recent RMP study of Bay water, sediment, stormwater, treated wastewater, harbor seals, and bivalves indicate many of these alternatives are present in the Bay. Samples were collected in 2013 and 2014 and were tested for 15 phosphate flame retardants, 6 phosphate flame retardant metabolites, 25 hydrophobic, brominated flame retardants, and 21 hydrophobic, chlorinated (Dechlorane-type) flame retardants. Samples were also tested for 20 PBDE congeners.

One flame retardant, triphenyl phosphate, was detected in Bay water at concentrations that at a few sites were comparable to a conservative toxicity threshold for marine ecosystems (ECHA 2014). Other phosphate flame retardants were present at levels significantly lower than aquatic toxicity thresholds, where available.

However, for most of these chemicals, the risks are unknown due to a lack of information on toxicity. While some aquatic toxicity thresholds exist, few sediment thresholds have been established, and there is particularly little information on risks posed to marine mammals. Many of these flame retardant chemicals have been found to have endocrine disrupting properties in laboratory tests, but potential risks to Bay wildlife are not well understood. Lack of ecotoxicity information is a concern, particularly because the effects of long-term exposure to low levels of

these contaminants are largely unknown. In addition, the effects of exposure to multiple phosphate flame retardants have not been examined.

In general, a lack of information on toxicity has resulted in the designation of alternative flame retardants as possible concern (Tier I) contaminants for the Bay.

One exception is HBCD, a brominated flame retardant detected at low levels in sediment and wildlife, and considered a low concern (Tier II) contaminant for the Bay. HBCD concentrations were comparable to or lower than those measured in biota in other ecosystems (reviewed in Klosterhaus et al. 2012). Levels in wildlife were also significantly lower than toxicity thresholds reported in the literature (reviewed in Sutton et al. 2013). HBCD is a high production volume chemical; however, reductions in use are expected as a result of its addition to the Stockholm Convention list of banned persistent organic pollutants, albeit with a five-year phase-out period for use in polystyrene building insulation.

Microplastics (Tier I, Possible Concern)

Motivated by recent state and federal efforts to ban microbeads in personal care products, the RMP funded a study to characterize Bay surface waters and wastewater treatment plant effluents for microplastic contaminants. Microplastic is a term used to describe fragments of plastic that are 5 mm or smaller. Nine Central and South Bay surface water samples were collected and samples of effluent were collected from eight facilities discharging to the Bay. Microplastics in samples were characterized by size, type, and abundance.

Preliminary results from this survey will be presented at the State of the Estuary Conference in September. Microplastics were widely detected in the Central and South Bays, and found at levels higher than other water bodies near highly urbanized regions of the U.S. (Erikson et al. 2013; Yonkos et al. 2014). Bay WWTPs were found to discharge microplastics at levels higher than New York WWTPs (Chaskey et al. 2014). The monitoring data do not suggest a difference in the concentration of microplastics in effluent for WWTPs employing secondary vs. advanced secondary treatment. Fragments and fibers were seen in the greatest abundance in both Bay surface water and effluent. Microbeads in personal care products, a recent policy focus,

consist primarily of small plastic fragments, and to a lesser extent the more iconic, colorful, bead-like small pellets; our findings indicate microbeads can be found in the Bay, and are likely discharged via treated wastewater.

Microplastic contamination of aquatic ecosystems is associated with a number of potential concerns. Due to the hydrophobic properties of the plastic material, persistent organic chemicals including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), dioxins, and pesticides such as DDT have been shown to preferentially sorb to microplastics (Seltenrich 2015). Lower trophic organisms can mistake microplastics for food; ingestion can lead to physical harm, exposure to sorbed contaminants, and bioaccumulation of microplastics in higher trophic organisms (Fendall and Sewell 2009; Desforges et al. 2015; Seltenrich 2015).

However, no clear toxicity thresholds exist for this contaminant, leading to its assignment as a possible concern (Tier I contaminant) for San Francisco Bay.

Newly Identified Tissue Contaminants (Tier I, Possible Concern)

San Francisco Bay wildlife were tested for previously unmonitored contaminants using a non-targeted analysis that screens mainly for long-lived, fat-soluble, chlorine and bromine-rich chemicals. Bay mussels and harbor seals contained five contaminants not previously identified in Bay wildlife, and for which toxicity is largely unknown: 2,2'-dichlorobenzil, 9,10-dichloroanthracene and a similar, unspecified dichloroanthracene, 4-tert-butylamphetamine, methyl triclosan (Sutton and Kucklick 2015).

The RMP has detected the parent amphetamine compound in previous Bay studies, but has not targeted 4-tert-butylamphetamine for analysis. Similarly, while a few studies have characterized triclosan contamination in the Bay, relatively little information exists for methyl triclosan. The chemicals identified in this study have been the subject of little or no targeted tissue monitoring elsewhere in the world, and have not been identified in non-targeted studies of wildlife in other areas, with the exception of dichloroanthracenes observed in freshwater species exposed to combustion byproducts (Myers et al. 2014).

Relevant toxicity thresholds have not been established for these contaminants, so they have been designated a possible concern (Tier I contaminant) for San Francisco Bay.

The non-targeted analysis of tissue samples revealed that most of the Bay chemical contamination was from high priority contaminants that the RMP already monitors, such as PCBs, or closely related compounds. An RMP Special Study for 2016 will employ a similar method to identify previously unmonitored, water-soluble contaminants in the Bay.

RMP CEC Multi-Year Plan

Assembled below are recommended studies that have grown out of the RMP's CEC strategy, structured as a multi-year research plan (Tables 3-6). Given the breadth of the program, a summary table is provided (Table 3) in combination with tables providing more detailed descriptions of: a) studies on moderate concern contaminants (Tier III; Table 4); b) studies on possible or low concern (Tiers I & II) or newly monitored contaminants (Table 5); and non-targeted and other studies (Table 6). The multi-year plan focuses on RMP Special Studies, but also provides information on Status and Trends and other RMP monitoring efforts relevant to CECs, along with external, pro bono collaborations.

Special Studies are primarily designed in response to the RMP priority question for emerging contaminants:

1. What emerging contaminants have the potential to adversely impact beneficial uses of the Bay?

The purpose of this multi-year plan is to guide program management. These recommendations will be revisited and revised each year as part of the RMP budget planning process. The plan will be adapted to reflect advances in science and changes in policy needs.

Table 3. RMP CEC Research Strategy – Multi-Year Plan Summary, 2015.

Task	Funder	Questions addressed	2013	2014	2015	2016	2017	2018	2019	2020
CEC Strategy*	RMP - SS	1	20	20	20	48	40	40	40	50
Moderate Concern CECs[4]	RMP - SS	1	36	26	55	30	72	80	60	50
	pro bono	1	0	30	50	50				
Possible/Low/New CECs[5]	RMP - SS	1	15	107	9	0	72	50	160	65
	pro bono	1	0	135	42	10				
Non-targeted/Other Studies[6]	RMP - SS	1	70	56	0	52	30	80	0	60
	pro bono	1	0	125	0	16				
RMP Special Studies TOTALS			**141**	**209**	**84**	**130**	**214**	**250**	**260**	**225**
pro bono studies TOTALS			0	290	92	76				

*Includes full revision of CEC strategy document in 2016 and 2020

For planning purposes: S&T monitoring matrices									
	water	sediment bivalves fish	water	bivalves eggs	water	sediment bivalves eggs	water fish	bivalves

[4] See Table 4 for details
[5] See Table 5 for details
[6] See Table 6 for details

Table 4. RMP CEC Research Strategy – Moderate Concern CECs (Tier III), 2015.

Task	Funder	Questions addressed	2013	2014	2015	2016	2017	2018	2019	2020
PFOS/PFASs	RMP - SS	1		harbor seals 26	effluent 27.5**		synthesis to inform mgmt 72	modeling exercise 30		identify unknown PFAS 50
	RMP - S&T	1				eggs		eggs *add to sediment S&T?*		
	AXYS pro bono	1		sediment effluent precursor monitoring (30)						
	DTSC pro bono	1			effluent TOF analysis: IDs presence of unknown PFAS (50)	tissue TOF analysis: IDs presence of unknown PFAS (50)				
NP/NPE	RMP - SS	1							tissue/time trends 60	
PBDE	RMP - SS	1	synthesis 36							
	RMP - S&T	1		sediment bivalves		bivalves eggs		bivalves eggs	fish	bivalves
Fipronil	RMP - SS	1			27.5**	effluent 30				
	RMP - S&T	1						*add to sediment S&T?*		
	RMP - SPL	1				stormwater	stormwater	stormwater	stormwater	stormwater
Determine effects of new LID/wastewater treatment methods on Moderate Concern CECs	RMP - SS	1						effluent stormwater 50		
RMP Special Studies TOTALS			**36**	**26**	**55**	**30**	**72**	**80**	**60**	**50**
pro bono studies TOTALS			0	30	50	50				

**2015 $55K Effluent study focused on PFASs and fipronil; funds are split between these two contaminants

Table 5. RMP CEC Research Strategy – Possible/Low Concern CECs (Tier I & II) and Newly Identified CECs, 2015.

Task	Funder	Questions addressed	2013	2014	2015	2016	2017	2018	2019	2020
Alternative flame retardants	RMP - SS	1		water sediment tissue 107			phosphate FRs in water 50		water 35	
	Env. Canada pro bono	1		water (2)						
Microplastics	RMP - SS	1			water effluent 9		margins small fish 22			water/fish 15
	SF Baykeeper in-kind contrib.				vessel & crew (2)					
Pharmaceuticals	RMP - SS	1						sediment 50		water 50
	POTWs pro bono	1				effluent (10)				
Bisphenols/plastic additives	RMP - SS	1								
	Da Chen SIU pro bono	1			water (25)					
Personal care and cleaning product ingredients (e.g., fragrances, surfactants)	RMP - SS	1							water 50	
Pesticides	RMP - SS	1	15						Napa ag pesticides 75	
Siloxanes	Env. Canada pro bono	1		bivalves (5)						
Halogenated carbazoles	Da Chen SIU pro bono	1			sediment tissue (15)					
SDPA/BZT	Env. Canada pro bono	1		water sediment (3)						
OH-BDEs/triclosan	Bill Arnold UMinn pro bono	1		water sediment cores (125)						
New state priorities*** (hormones, BPA, galaxolide)	State Water Board	1					water (?)			
RMP Special Studies TOTALS			**15**	**107**	**9**	**0**	**72**	**50**	**160**	**65**
pro bono studies TOTALS			0	135	42	10				

Table 6. RMP CEC Research Strategy – Non-targeted and Other Studies, 2015.

Task	Funder	Questions addressed	2013	2014	2015	2016	2017	2018	2019
Non-targeted analysis: Tissue	RMP - S&T	1					*add to S&T?*		
Non-targeted analysis: Water	RMP - SS Lee Ferguson Duke pro bono AXYS pro bono	1 1 1				water effluent 52 in-kind (10) targeted chemistry add-on (6)		follow-up targeted study 80	
Bioanalytical tools	RMP - SS SCCWRP pro bono	1 1	70	water effluent 56 in-kind (125)					
Brine disposal - investigating alternatives	RMP - SS	1					30		
RMP Special Studies TOTALS			**70**	**56**	**0**	**52**	**30**	**80**	**0**
pro bono studies TOTALS			0	125	0	16			

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