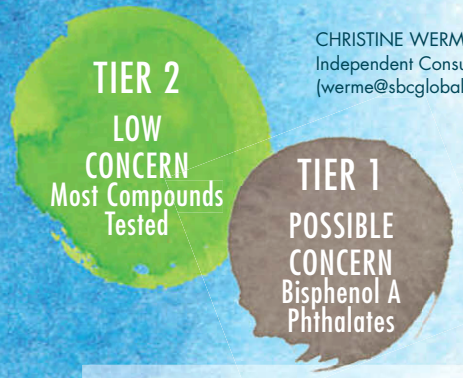
Pharmaceuticals and Personal Care Products



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Quick Summary

Pharmaceuticals and personal care products (PPCPs) include a wide variety of prescription and over-the-counter drugs, cosmetics, sunscreens, fragrances in personal and home care products, and other products used in homes, medical facilities, and even agriculture. PPCPs enter the wastestream through excretion, bathing, laundering, and flushing of unused medicines. Although scientists have long been aware of their presence in the environment, only recently have analytical methods been developed to detect the low concentrations found in aquatic ecosystems such as the Bay. Of the thousands of chemicals used in these products, the RMP has targeted about 100 for analysis. The compounds detected in water samples include antibiotics, beta blockers, stimulants, nicotine metabolites, headache relievers, lipid reducers, antidepressants, anxiety reducers, hypertension relievers, plasticizers, and insect repellents. Many of these chemicals have also been detected in Bay sediment and wildlife samples. Concentrations of PPCPs in the Bay are lower than those found in wastewater-dominated rivers and streams where there is less dilution, and about the same as reported for other estuarine or marine areas. Risks are largely unknown due to the wide variety of chemical compounds, the generally low concentrations at which they are found, and the lack of information on the effects of these compounds on estuarine organisms. However, concentrations are generally below the thresholds that do exist.

What Are They?

- A wide variety of prescription, over-the-counter, and veterinary drugs and their metabolites; diagnostic agents; vitamins and other nutritional supplements; ingredients in cosmetics, sunscreens, and lotions; insect repellants; and fragrance ingredients used in many products.
- A few additional compounds are often measured along with PPCPs, including bisphenol A and plasticizers known as phthalates.

What Are They Used For?

- Pharmaceutical drugs are used as antibiotics, antidepressants, anti-epileptics, estrogenic steroids, and in many other human or veterinary health applications.
- Triclosan (PAGE 75) and triclocarban are antibacterial agents commonly added to soaps and other consumer products.
- Synthetic musks and other natural and artificial fragrance ingredients are used in cosmetics, perfumes, detergents, cleaning supplies, and other household products.
- Bisphenol A is used in plastics and epoxy resins and in the linings of food cans.
- Phthalates are added to plastics to increase flexibility and longevity. Some are also found in nail polish, home care products like treatments for wood floors, and in fragrance mixtures in personal care products and cleaning supplies.
- N,N-diethyl-m-toluamide, known as DEET, is the most widely used insect repellent.
- Siloxanes are common ingredients in personal care products like antiperspirants and deodorants, shampoos, conditioners, and cosmetics. They are also used in dry-cleaning.

How Are They Getting into the Bay?

- Municipal wastewater treatment plant effluent is probably the major pathway to the Bay, although more information is needed on other potential pathways.
  - PPCPs enter the sewage wastestream through excretion, bathing, laundering, and flushing of unused medicines.
  - Municipal sewage systems are not engineered for removal of the wide variety of these chemical compounds, but standard treatment methodologies are effective at removing some PPCPs. Removal efficiencies vary by compound.
  - Harrold et al. (2009) detected 18 of 39 target pharmaceuticals in influent, effluent, and water samples in the Lower South Bay, with findings comparable to similar studies in other regions.
- Urban stormwater, which flows directly into the Bay untreated, is another potential pathway.
- Flow through the Delta may be a source, particularly for veterinary pharmaceuticals used in agriculture.

What Happens to Them in the Bay?

General Properties

- Depending upon their individual physical and chemical characteristics, PPCPs may be subject to adsorption to sediment particles, degradation, volatilization to the atmosphere, or uptake into organisms.

Patterns of Occurrence in the Bay and in Other Aquatic Ecosystems

- Until recently, there were no reliable methods for quantifying PPCPs in ecosystems like the Bay, in which wastewater effluents are quickly diluted, and concentrations in sediment and wildlife samples are expected to be low (Klosterhaus et al. 2013a.)
- There are now occurrence data for about 100 PPCPs and metabolites in the Bay (Klosterhaus et al. 2013a,b).
- Chemicals detected in water samples make up a soup of antibiotics, beta blockers, stimulants, nicotine metabolites, headache relievers, lipid reducers, antidepressants, anxiety reducers, hypertension relievers, and insect repellent (TABLE 1).
  - The maximum concentration of a pharmaceutical in Bay water was 1,060 nanograms per liter (ng/L) for sulfamethoxazole, an antibiotic.
  - Sulfamethoxazole, valsartan (used to treat high blood pressure, heart failure, and progressive

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kidney disease related to diabetes), erythromycin hydrate (an antibiotic degradation product), and gemfibrozil (used to lower blood lipid levels) were detected consistently in a special RMP PPCP study of five sites in the Bay.

- Other compounds detected in water samples included carbamazepine and caffeine. These compounds have low removal efficiencies by wastewater treatment plants and are persistent in the environment.
- The maximum concentration of a non-pharmaceutical PPCP was 459 ng/L of bis(2-ethylhexyl) phthalate, a plasticizer.
- PPCP concentrations in Bay water samples were generally highest in the southern Bay segments, where dilution is lowest, and residence times are highest.

- Fewer PPCPs have been detected in sediment samples than in water or wildlife (TABLE 1).
  - Pharmaceuticals detected in Bay sediment include stimulants, antibiotics, and a diuretic, with a maximum concentration of 678 parts per billion (ppb) for ciprofloxacin (an antibiotic).
  - The maximum concentration of other PPCPs in sediment was 605 ppb bis(2-ethylhexyl) phthalate.
  - Triclocarban, an antibacterial agent used in disinfectants and soaps, was unusual among PPCPs in that it was detected in sediment samples but not in water. The maximum measured concentration was 33 ppb.
- Compounds detected in biota include Benadryl®, the popular insect repellent DEET, antidepressants such as Zoloft®, other pharmaceuticals, and fragrance ingredients (TABLE 1).
  - The maximum concentration of pharmaceuticals in Bay mussels was about 90 ppb for both lomefloxacin, an antibiotic, and sulfamethazine, an antibiotic mostly used for veterinary applications.
  - Compounds measured in mussels at a majority of sites included amitriptyline, DEET, sertraline (Zoloft®), and dehydronifedipine.
  - The maximum concentration of other PPCPs in mussels was 2,620 ppb of di-n-butyl phthalate, a plasticizer.
  - In Bay cormorant eggs, maximum concentrations of bis(2-ethylhexyl) phthalate, a plasticizer, reached 1,880 ppb.
- The NOAA Mussel Watch California CEC Pilot Study (Mussel Watch) measured a variety of PPCPs in mussels from the Bay.
  - The antidepressant sertraline was detected frequently in California, with a maximum concentration in the Bay (FIGURE 1).
  - The antihistamine diphenhydramine (Benadryl®) was also found at relatively high levels in the Bay (FIGURE 2).

TABLE 1
PPCPs detected in Bay samples (from Klosterhaus et al. 2013b). Data collected as part of RMP studies, other research, and mussel samples collected in 2010 and analyzed as part of NOAA's Mussel Watch Program.

PHARMACEUTICALS					
COMPOUND	USE	WATER	SEDIMENT	MUSSELS	EGG
Albuterol	Bronchodilator – asthma, breathing issues	x			
Amitriptyline	Antidepressant – pain, minor depression	x		x	
10-hydroxy-amitriptyline	Metabolite of amitriptyline	x			
Amphetamine	Psychostimulant – fatigue, appetite	x	x	x	
Atenolol	Beta blocker – blood pressure, angina	x		x	
Benzoylecgonine	Analgesic and metabolite of cocaine	x			
Caffeine	Stimulant	x	x		
Carbamazepine	Mood stabilizer and anti-epileptic	x		x	
Ciprofoxacin	Antibiotic – diarrhea, nausea, vomiting		x		
Clarithromycin	Antibiotic – ulcers, tonsillitis, other infections	x			
Cocaine	Local, topical anesthetic	x	x	x	
Cotinine	Metabolite of nicotine	x			
Dehydronifedipine	Metabolite of difedipine (blood pressure)	x		x	
Desmethyldiltiazem	Metabolite of diltiazem	x			
Diazepam	Valium – anxiety, muscle spasms, seizures	x			
Digoxigenin	Steroid found in Digitalis – immuno-tag			x	
Diltiazem	Calcium channel blocker – blood pressure	x		x	
Diphenhydramine	Benadryl® – allergies, cold, nausea, hives	x		x	
Enalapril	ACE inhibitor – blood pressure, heart			x	
Enrofloxacin	Antibiotic – veterinary issues			x	
Erythromycin-H2O	Antibiotic degradation product	x	x	x	
Fluoxetine	Prozac – depression, panic disorders			x	
Gemfibrozil	Fibrate – high cholesterol, trigleridea	x			
Hydrocodone	Analgesic – pain relief, cough	x			
Ibuprofen	Analgesic – pain relief, inflammation	x			
Lomefloxacin	Antibiotic – urinary tract, other infection			x	
Meprobamate	Tranquilizer – tension, anxiety, nervousness	x			
Methylprednisolone	Corticosteroid – inflammation, allergy			x	
Metoprolol	Beta blocker – blood pressure, angina	x			
Naproxen	Anti-inflammatory – fever, pain	x			
Ofloxacin	Quinolone – ear infection			x	
Propoxyphene	Analgesic – no longer available in US	x			
Propranolol	Beta blocker – blood pressure, angina			x	
Ranitidine	Antihistamine – heartburn, ulcers			x	
Sertraline	Zoloft® – OCD, PTSD, other depression disorders			x	
Sulfamethazine	Antibacterial – veterinary			x	
Sulfamethizole	Antibacterial – urinary tract infection	x		x	
Sulfamethoxazole	Antibacterial – usually used in combinations	x	x		
Thiabendazole	Parasiticide – roundworm, pinworm	x	x		
Triamterene	Diuretic – hypertension, edema	x	x	x	
Trimethoprim	Antibacterial – urinary, ear infection	x	x		
Valsartan	Angiotension receptor blocker – heart, stroke	x			
Verapamil	Calcium channel blocker – blood pressure, angina			x	
Virginiamycin	Antibiotic – veterinary			x	
OTHER PPCPS					
COMPOUND	USE	WATER	SEDIMENT	MUSSEL	EGG
N,N-diethyl-m-toluamide	DEET – insect repellant	x	x	x	
Celestolide	Musk (fragrance ingredient)			x	
Galaxolide	Musk (fragrance ingredient)			x	x
Tonalide	Musk (fragrance ingredient)			x	x
Versalide	Musk (fragrance ingredient)			x	
Bis(2-ethylhexyl) phthalate	Plasticizer	x	x	x	x
Butylbenzyl phthalate	Plasticizer	x	x		x
Di-n-butyl phthalate	Plasticizer, adhesives, printing inks	x	x	x	x
Triclocarban	Antibacterial soap		x	x	
Triclosan	Antibacterial soap, toothpaste, other consumer goods		x		

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- The antibiotic lomefloxacin was detected throughout California, with a relatively high level in the Bay (FIGURE 3).

- Concentrations of PPCPs in the Bay are typically one-tenth to one-hundredth of those reported for sites in freshwater systems, which are often close to wastewater outfalls, and about the same as reported for other estuarine or marine areas, where wastewater outfalls may also occur but where dilution is greater (Klosterhaus et al. 2013a).
- Concentrations of PPCPs in Bay water were typically one-tenth of those at a Southern California ocean wastewater outfall.

Trends in the Bay and Nationally

- No general trend data are available for the Bay or nationally.
- Globally, the World Health Organization reports increasing use of pharmaceuticals across all income groups (Hoebert et al. 2011).
- Reductions in inputs, should they occur, would depend on source control, more prudent use, and source separation. Examples of these measures include reductions in product use in humans and livestock, controlled returns of unused products, consumer education, on-site treatment, and conceivably, separation of urine from the general waste stream.

Is There a Risk of Harm in the Bay?

- Risks are largely unknown due to the wide variety of chemical compounds, the generally low concentrations at which they are found, and the lack of information on the effects of these compounds on estuarine organisms. However, concentrations are generally below the thresholds that do exist.
  - All pharmaceuticals are inherently biologically active, and their presence in water, sediments, and wildlife samples may be indicative of potential effects, even at low concentrations.
  - Three of 15 measurements of sulfamethoxazole in Bay surface water samples were similar to or greater than those associated with a "predicted no effect concentration" calculated based on chronic toxicity to blue-green algae (Grung et al. 2008). These more contaminated samples were obtained from the southern arm of the Bay. Further study may be warranted to see if this antibiotic could be harming Bay algae.
  - Triclocarban has been shown to be an endocrine disruptor in the laboratory and may promote development of antibiotic-resistant bacteria. Similar concerns exist for triclosan (PAGE 75).
  - Synthetic musks are persistent and bioaccumulative. Few studies exist on potential adverse health effects.

FIGURE 1 *(below)*
The antidepressant sertraline, sold under the trade name Zoloft, was detected in 14 of 22 Mussel Watch stations in 2010. The highest concentrations (5.5 parts per billion or ppb) were in mussels from the San Francisco Bay Yerba Buena station (SFYB). High levels were also found at some Southern California sites. Red lines indicate limit of detection.

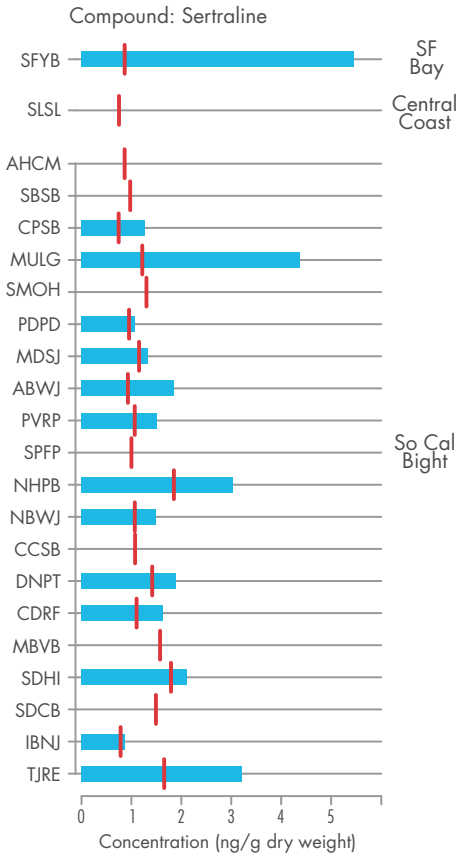
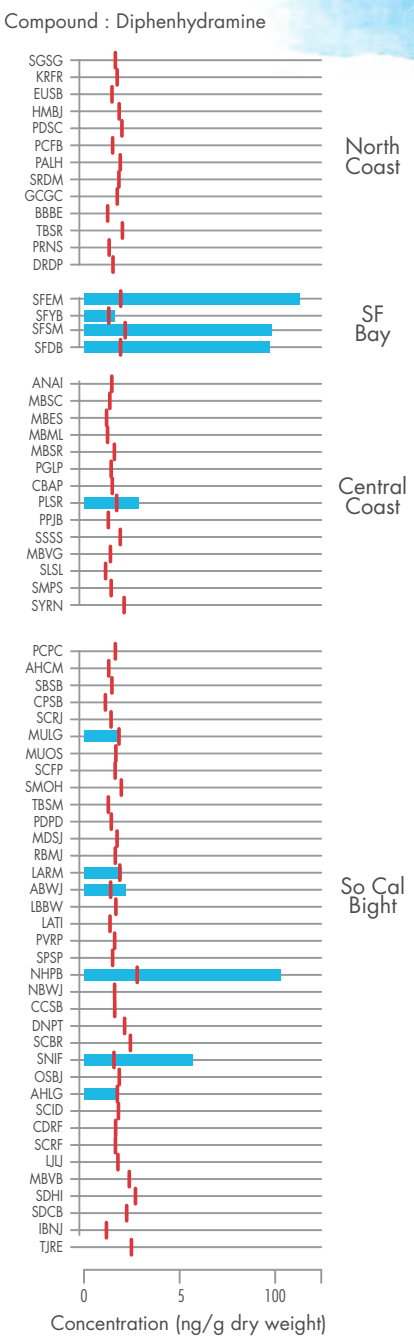


FIGURE 2 *(right)*
Diphenhydramine, widely known as Benadryl®, is an antihistamine used mostly to fight allergy symptoms. Mussel Watch detected it at only 11 of 68 stations. The highest concentration was in mussels from Emeryville (11 ppb). High levels were also detected at other Bay stations and at a Newport Harbor station in Southern California. Red lines indicate limit of detection.



TIER 2

TIER 1

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- Bisphenol A is a known endocrine disruptor.
- Many phthalates are known to be endocrine disruptors and may cause other health effects. Phthalates included on California's Proposition 65 list of chemicals known to be harmful include butylbenzyl phthalate (developmental effects), bis(2-ethylhexyl) phthalate (cancer, developmental effects, male reproductive toxicity), diisodecyl phthalate (developmental effects), di-n-butyl phthalate (developmental effects, male and female reproductive toxicity) and di-n-hexyl phthalate (male and female reproductive toxicity).

- A recent study (Brodin et al. 2013) reported behavior and feeding-rate alteration in fish from natural populations exposed to a psychoactive drug (the anxiety reducer oxazepam).
- The Science Advisory Panel for CECs in California's Aquatic Ecosystems identified the hormone-mimic bisphenol A and the synthetic musk galaxolide for monitoring in coastal embayments.

Key Information Gaps

- Information about occurrence, sources, fates, and potential effects of PPCPs is evolving. While most PPCPs examined in Bay samples were found at levels that do not appear to be harmful, for a few there is greater uncertainty (bisphenol A, bis(2-ethylhexyl) phthalate, butylbenzyl phthalate).
- Many basic questions remain.
  - What PPCPs are reaching the Bay and in what concentrations?
  - What are the sources and pathways?
  - What is the fate of PPCPs in the Bay?
  - What PPCPs are bioaccumulating in organisms?
  - What are the acute and chronic effects?
  - Which compounds are endocrine disruptors, and how may they affect marine life?
  - How do observed concentrations compare to effect levels?
  - How are inputs and Bay concentrations changing through time?
- Continued efforts to understand potential effects of mixtures, as well as of individual chemicals, is necessary.

Management Timeline