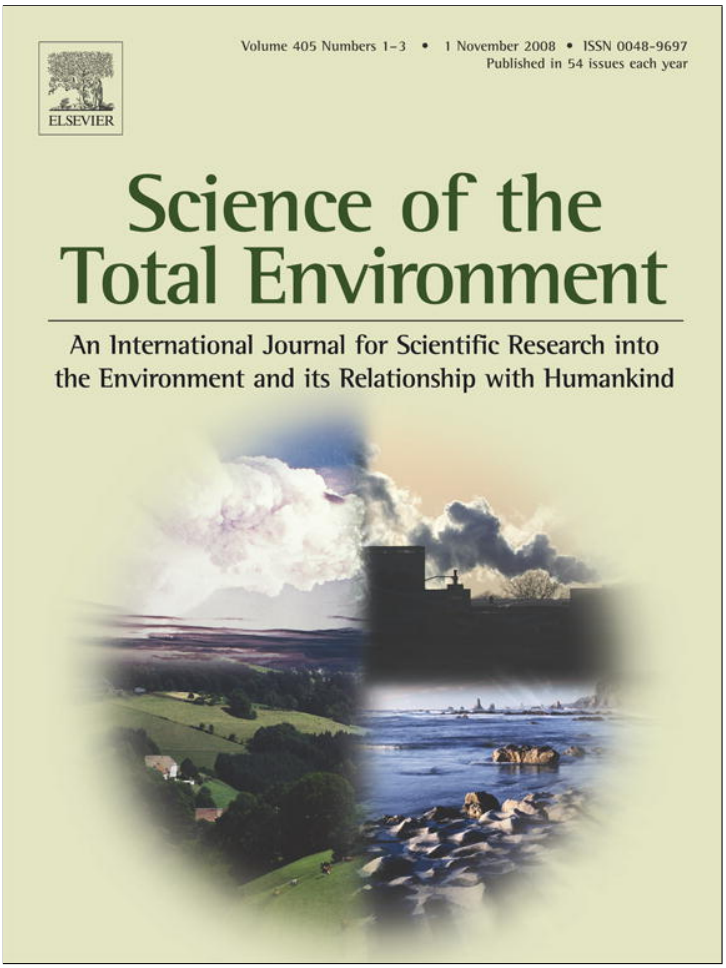

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Sources of endocrine-disrupting chemicals in urban wastewater, Oakland, CA

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ABSTRACT

Synthetic endocrine-disrupting chemicals (EDCs) have been found in surface waters throughout the United States, and are known to enter waterways via discharge from wastewater treatment plants (WWTPs). Studies addressing EDCs in wastewater do not examine their specific sources upstream of WWTPs. Presented here are results of a pilot study of potential sources of selected EDCs within an urban wastewater service area. Twenty-one wastewater samples were collected from a range of sites, including 16 residential, commercial, or industrial samples, and five samples from influent and effluent streams at the WWTP. Samples were analyzed for the following known and suspected EDCs: five phthalates, bisphenol A (BPA), triclosan, 4-nonylphenol (NP), and tris(2-chloroethyl) phosphate (TCEP), using well-established methods (EPA 625 and USGS O-1433-01). Twenty of 21 samples contained at least one EDC. Phthalates were widely detected; one or more phthalate compound was identified in 19 of 21 samples. Measurement of two phthalates in a field blank sample suggests that the accuracy of sample detections for these two compounds may be compromised by background contamination. Triclosan was detected in nine samples, BPA in five samples, and TCEP in four samples; NP was not detected. The results of this and future source-specific studies may be used to develop targeted pollution prevention strategies to reduce levels of EDCs in wastewater.

1. Introduction

Endocrine-disrupting chemicals can interfere with natural hormone cycles in humans or animals, potentially affecting metabolism, development, reproduction, and growth. Fish and wildlife can be exposed to exogenous, anthropogenic EDCs through contaminated surface waters (Kolpin et al., 2002; Pait and Nelson, 2002). Concentrations of some EDCs in surface waters are detected in the parts per trillion or parts per billion range, but evidence is mounting that, even at these low levels, EDCs may adversely impact wildlife, especially water-dwelling animals (Pait and Nelson, 2002; Wozniak et al., 2005; Veldhoen et al., 2006). Impacts of EDCs on wildlife have been documented in animals at all levels of the food chain, from polar bears, whales, fish, and predatory sea birds (Jenssen, 2006; Kavanagh et al., 2004), to *Ceriodaphnia*, the water flea (Henry et al., 2004).

Numerous studies identify WWTPs as sources of EDCs in surface water bodies (Barnes et al., 2002; Harrison et al., 2006; Pryor et al., 2002), but do not test upstream of WWTPs to identify sources of EDCs. Measuring EDC levels from individual sources could increase understanding of the full range and magnitude of EDCs in WWTP influent, as well as provide insights into potential pollution prevention strategies to reduce the levels of EDCs in WWTP effluent. The East Bay Municipal Utility District (EBMUD) and the non-profit Environmental Working Group (EWG) collaborated on a joint study of sources of EDCs to the EBMUD WWTP, located in Oakland,

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CA (Fig. 1). Sixteen wastewater samples were collected from residential, commercial, or industrial locations upstream of the WWTP. Two pre-treatment influent and three post-treatment effluent samples were also collected. Wastewater samples were examined for five phthalates, bisphenol A (BPA), triclosan, 4-nonylphenol (NP), and tris(2-chloroethyl) phosphate (TCEP), all persistent, synthetic chemicals found to disrupt hormone systems in laboratory studies (Table 1). Results from this preliminary examination can inform the design of future studies that probe upstream sources of EDCs.

2. Methods

2.1. Wastewater sample collection

Wastewater samples were collected within the East Bay Municipal Utility District's (EBMUD) wastewater service area, on the eastern shore of San Francisco Bay (Fig. 1). A total of 16 samples were drawn from the following locations: a residential area (two samples); a variety of commercial locations, including a nail salon, two industrial laundry facilities, a residential coin laundry, a diaper service, a pet wash, a veterinary clinic, a hospital, and an outpatient medical clinic; and several industrial locations, including facilities manufacturing pharmaceuticals, plastic bags, paper products, beverages, and adhesives. Samples were drawn from sanitary sewer cleanouts, sewer lines, and other access points to waste streams prior to their commingling with wastewater from other sources.

In addition, five samples of wastewater were collected from waste streams entering (two samples) and exiting (three samples) the EBMUD wastewater treatment plant before discharge into the Bay. The EBMUD WWTP treats approximately 75 million gallons of wastewater per day from roughly 640,000 residents, as well as commercial businesses and industries. Pre-treatment influent sampling was intended to provide snapshots of the total loading of selected EDCs for the region, and treated wastewater effluent sampling was intended to provide a post-treatment indication of which EDCs may reach San Francisco Bay at detectable concentrations. Comparison of pre- and post-treatment samples does not provide an indication of the effectiveness of treatment in removal of EDCs from the wastewater stream, because the samples collected represent water characteristics over a discrete time period only, and do not capture variation in the levels of EDCs in wastewater that may occur diurnally, seasonally, or annually. Removal rates by wastewater treatment can be found in other comprehensive studies (e.g. Oppenheimer et al., 2007; Snyder et al., 2007).

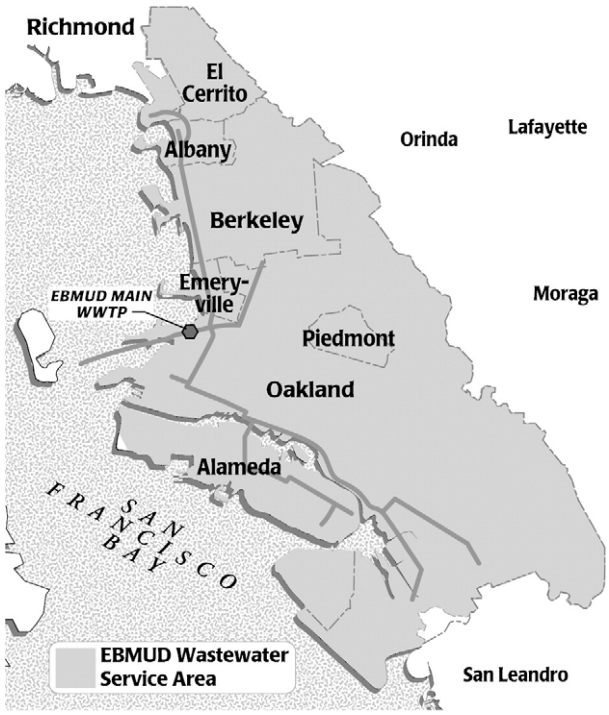

Fig. 1 – The East Bay Municipal Utility District wastewater service area.

Wastewater samples were collected on three days, August 16, September 6, and November 28, 2006. Sampling occurred on dry days, at least 48 h after a rain event, to reduce the effect of dilution by stormwater infiltration into the wastewater collection system.

At each sampling location, EBMUD field staff collected two 1-liter samples of wastewater. Because each site had different access and safety requirements, to maintain consistency across sampling sites all samples were grab samples, taken within a 15-minute period. Samples were collected in amber glass bottles pre-cleaned using Alconox®, an anionic cleanser that passes residue tests for water analysis. The amber glass containers were completely filled to reduce air contamination and/or volatilization. EBMUD staff also collected two "field blank" samples of de-ionized, carbon-filtered water for analysis of potential contamination from sampling protocol and equipment, one on each of the first two days of sample collection.

Because EDCs may be found in housekeeping and personal care products, prior to sample collection EBMUD field staff avoided contact with soaps and detergents, cleansers, pesticides, fragrances, and sunscreen.

2.2. Laboratory analysis

All samples were placed in a 4 °C refrigerator for preservation until analysis could be completed. Half of the samples collected on August 16 and September 6 were chilled overnight, then packaged in a cooler and sent via overnight delivery to Montgomery Watson Harza (MWH) Laboratories in Monrovia, CA.

Two standardized gas chromatography/mass spectrometry (GCMS) methods for chemical analysis were used, EPA 625 (phthalates; EPA, 2007) and USGS O-1433-01 (BPA, TCEP, triclosan, NP; USGS, 2007), each of which requires a 1-liter sample. East Bay Municipal Utility District laboratory staff analyzed all samples with EPA Method 625 for semi-volatile organic compounds. Samples collected August 16 and September 6 were subjected to USGS Method O-1433-01, a screen for EDCs, by MWH Laboratories, and those collected November 28 were subjected to the same analysis by EBMUD.

These analytical methods were designed to detect trace amounts of contamination in natural waters, as opposed to the

Table 1 – Properties of selected endocrine-disrupting chemicals

Endocrine-disrupting chemical	Uses	Hormone system concerns	Impacts to aquatic biota
Phthalates	Plasticizer used to make flexible plastics, widely used ingredient of "fragrance" found in personal care products and other consumer products, common component of nail polish, many other uses	Estrogen, androgen, thyroid	Phthalates inhibit estrogen receptors in fish (Jobling et al., 1995); phthalates bioaccumulate in the aquatic plant *Elodea canadensis*, the clam *Sphaeriun striatinum*, and the water flea *Daphnia magna* (Metcalf et al., 1973).
Bisphenol A	Building block of polycarbonate plastics, epoxy lining of food and beverage cans, also used in dental sealants	Estrogen, thyroid possible	Male brown trout exposed to BPA at concentrations of 1.75, 2.40, 5.00 μg/L had reduced sperm quality, and females exhibited reduced or inhibited ovulation (Lahnsteiner et al., 2005); BPA exposure impacts tadpole tail development in the frog species, *Xenopus* (Iwamuro et al., 2006); BPA bioaccumulates in spotted halibut, *Varaspar variegates*, with exposures of 70 μg/L (Lee et al., 2004).
Triclosan	Antibacterial agent in liquid hand soap, dish soap, toothpaste, cutting boards, countertops and many other consumer products; pesticide	Thyroid, androgen, estrogen	Triclosan, in combination with natural thyroid hormones, triggered increased rates of metamorphosis and tail fin gene expression in the North American bullfrog, *Rana catesbeiana*, at 0.15 μg/L (Veldhoen et al., 2006); triclosan produced weak androgenic effects in Japanese medaka fry (*Oryzias latipes*) (Foran et al., 2000), and weak anti-estrogenic effects in male South African clawed frogs (*Xenopus laevis*) (Matsumura et al., 2005); triclosan produces chronic or acute toxicity in aquatic species (e.g. Samsøe-Petersen et al., 2003; Orvos et al., 2002; Ishibashi et al., 2004); triclosan is bioaccumulative and has been detected in aquatic species tissue and fish bile samples (Remberger et al., 2002; Adolfsson-Erici et al., 2002).
4-Nonylphenol	Common degradation product of alkylphenol ethoxylates, surfactants in personal care products, detergents and cleaners, paints, pesticides, and many other products	Estrogen	4-Nonylphenol induced production of vitellogenin, an egg precursor protein, in male rainbow trout (Jobling et al., 1996) and reduced egg production in female zebrafish (Zoller 2006).
Tris(2-chloroethyl) phosphate	Fire retardant historically used in foam cushions, plastics, textiles, industrial paint, adhesives	Estrogen possible	TCEP exposure is linked to reduced fertility in leghorn chickens (Sprague et al., 1981). Studies indicate modest acute toxicity to a variety of aquatic organisms (ECB, 2006).

broader range of contaminant levels expected in a complex wastewater matrix consisting of highly concentrated and chemically diverse organic matter. Where possible, wastewater extracts containing contaminants at levels exceeding the calibration range were diluted by ratios as wide as 1:250 to obtain accurate measurements for all target chemicals. Detection limits varied by sample and chemical as a function of concentration, and are documented for each non-detect test shown in Table 2.

While wastewater extracts were processed to remove particulate matter, in many cases the filtered material contained such a complex and concentrated mixture of components that matrix interference prevented accurate measurement of contaminant levels. Some samples caused significant damage to the analytical equipment as well, necessitating column replacement and precluding additional analysis. As a result, some of the measurements obtained are considered estimates, because the concentrations of particular contaminants fell substantially outside the range of standards used to calibrate the analytical techniques, or because matrix effects limited quantification. While the accuracy of these estimates is unknown, the measurements verify the presence of these contaminants in the samples at levels above the limit of detection.

Upon analysis, field blank 1 showed no presence of the selected EDCs; however, field blank 2 (collected September 6, 2006) showed contamination by two types of phthalates (butylbenzyl phthalate (BBzP) 1.5 μg/L; di-2-ethylhexyl phthalate (DEHP) 8.7 μg/L) and BPA (0.121 μg/L). Phthalates and BPA are frequent sampling and laboratory contaminants, such that low-level detection in blanks is not surprising. While measured concentrations of these three constituents were in the range of those detected in the field blank in some samples, measured concentrations in other samples exceeded these values by as much as two orders of magnitude. All measurements are reported in Table 2, with values less than double those measured in field blank 2 footnoted appropriately. All BPA concentrations detected in samples were greater than twice the level detected in the contaminated blank.

Table 2 – Concentrations of endocrine-disrupting chemicals in wastewater samples

Sample	DEP (μg/L)	DBP (μg/L)	BBzP [a] (μg/L)	DEHP [a] (μg/L)	DOP (μg/L)	BPA [a] (μg/L)	Triclosan (μg/L)	NP (μg/L)	TCEP (μg/L)
Residential 1	4.0	ND/<0.36	0.76 [b]	9.1 [b]	0.6	ND/<2.5	ND/<5	ND/<2.5	ND/<2.5
Residential 2	9.1	ND/<0.34	1.0 [b]	3.3 [b]	ND/<0.14	ND/<2.5	ND/<5	ND/<2.5	ND/<2.5
Nail salon	ND/<1	0.46	0.74 [b]	1.2 [b]	0.2	ND/<1.25	ND/<2.5	ND/<1.25	ND/<1.25
Industrial laundry 1	ND/<1	ND/<0.36	ND/<0.14	30	1.5	21.5	9.24	ND/<2.5	3.72
Industrial laundry 2	ND/<24	86	95	2700 [c]	ND/<0.0036	ND/<6.25	ND/<12.5	ND/<6.25	ND/<6.25
Residential coin laundry	16	ND/<3.6	ND/<1.4	66	13	ND/<2.5	24.7	ND/<2.5	ND/<2.5
Diaper service	ND/<1	12 [c]	0.2 [b]	0.63 [b,c]	ND/<0.15	ND/<0.36	ND/<0.65	ND/<0.25	ND/<0.29
Pet wash	1.3	0.76	2.3 [b]	6.5 [b]	1.6	ND/<2.5	ND/<5	ND/<2.5	ND/<2.5
Veterinary clinic	ND/<51	ND/<18	ND/<7.1	ND/<11	ND/<7.7	ND/<3.7	14	ND/<2.5	ND/<2.9
Hospital	ND/<1	ND/<0.36	0.82 [b]	2.7 [b]	ND/<0.15	ND/<2.5	237 [c]	ND/<2.5	ND/<2.5
Medical clinic	ND/<0.98	0.66	0.74 [b]	1 [b]	ND/<0.15	ND/<1.25	18.2	ND/<1.25	ND/<1.25
Pharmaceutical manufacturer	ND/<1	0.58	0.27 [b]	0.99 [b]	ND/<0.15	0.295	ND/<0.05	ND/<0.025	ND/<0.025
Plastic bag manufacturer	ND/<1	0.36	2.3 [b]	49	10	ND/<2.5	6.69	ND/<2.5	ND/<2.5
Paper products manufacturer	ND/<1	ND/<0.36	0.14 [b]	6.8 [b]	ND/<0.15	0.753	ND/<0.5	ND/<0.25	ND/<0.25
Beverage manufacturer	ND/<20	ND/<7.1	ND/<2.7	ND/<4.1	ND/<2.9	ND/<3.6	ND/<6.4	ND/<2.4	ND/<2.9
Adhesives manufacturer	ND/<100	120 [c]	39	47 [c]	ND/<15	ND/<0.41	ND/<0.74	ND/<0.28	1.4 [c]
Pre-treatment influent 1	ND/<10	ND/<3.6	14	33	4.2	ND/<5	ND/<10	ND/<5	ND/<5
Pre-treatment influent 2	ND/<10	ND/<3.6	1.9 [b]	9.2 [b]	ND/<1.5	ND/<1.25	6.74	ND/<1.25	ND/<1.25
Treated wastewater 1	ND/<1	ND/<0.36	0.84 [b]	2.9 [b]	0.39	0.38	ND/<0.5	ND/<0.25	0.373
Treated wastewater 2	ND/<1	0.57	0.74 [b]	1 [b]	ND/<0.15	ND/<0.25	0.9	ND/<0.25	ND/<0.25
Treated wastewater 3	ND/<1	5.5 [c]	ND/<0.14	0.21 [b,c]	ND/<0.15	0.31	0.42	ND/<0.024	0.28 [c]

[a] Field blank 2 (September 6, 2006) contained 1.5 μg/L BBzP, 8.7 μg/L DEHP, and 0.121 μg/L BPA. Background contamination with phthalates and BPA is common in commercial laboratories. Samples may be contaminated at collection through exposure to dust, consumer products, and other sources.

[b] Measured values are less than twice the level of contamination detected in field blank 2.

[c] Estimated concentrations.

In addition, contamination with one particular phthalate, dimethyl phthalate (DMP), is suspected for the batch of samples collected in November and analyzed by the EBMUD analytical laboratory, and for which no field blank was collected. This phthalate had not been detected in any previously collected wastewater samples, but was detected in all samples collected in November. As a result, all measurements of DMP were considered suspect and are not documented here.

Measurements of other chemicals obtained using the EPA and USGS methods and not reported here are available upon request, and include a variety of industrial chemicals and pesticides.

3. Results and discussion

Analyses of EDCs in grab samples of wastewater provide snapshots of EDC concentrations in 16 upstream wastewater samples taken from the EBMUD service area, as well as in influent and effluent at the WWTP. The results suggest widespread discharge of the selected EDCs to the sanitary sewer. Phthalate presence was ubiquitous, and triclosan, BPA, and TCEP were also detected at some locations; NP was not detected in any of the wastewater samples. While this pilot study did not probe trends in contaminant concentrations over time, the detections reported are largely consistent with known commercial and industrial uses of the chemicals in question.

3.1. *Phthalates*

Analyses indicate the presence of phthalates in wastewater samples was ubiquitous. One or more types of phthalates were detected in 19 of 21 samples (Table 2), though some detections of BBzP and DEHP are questionable given contamination noted in one of the field blanks. Diethyl phthalate (DEP), a common component of fragrance in personal care products, housekeeping products, and other consumer items, and occasionally used in pill coatings and insecticides, was detected in wastewater samples from residences, the residential coin laundry, and the pet wash (Table 2). The source of DEP in the wastewater from these locations is likely fragrance added to personal care and housekeeping products, laundry detergents, and pet cleansers, respectively.

Di-*n*-butyl phthalate (DBP) can be found in a number of consumer and industrial products, and was detected in 10 of 21 wastewater samples. Nail polish is the likely source of DBP in wastewater from the nail salon. Di-*n*-butyl phthalate is a component of some pill coatings, which could explain its detection in wastewater from the pharmaceutical manufacturing facility. This phthalate is also used to make adhesives, which could explain its detection in wastewater from the adhesives manufacturing facility. Some of the many other products that can contain DBP include inks, insecticides, carpet, paint, varnish, sealants, paper, rubber, cleaning solutions, and enamels and glasses.

Butylbenzyl phthalate (BBzP), used in adhesives, vinyl-flooring products, sealants, car-care products, stains and texture coatings, and some personal care products, was detected in 16 wastewater samples, though just three of the measured values were greater than double what was detected in the contaminated field blank. Vinyl, sealants, and adhesives may be the sources of BBzP in wastewater from industrial laundry 2, which primarily launders entry mats, kitchen mats, and other plastic floor mats. Butylbenzyl phthalate may be used to make adhesives produced or used at various manufacturing facilities, leading to its presence in most industrial wastewater samples examined. Lower levels of BBzP detected in residential, nail salon, diaper service, and pet wash wastewater may be due to contamination of samples during collection or analysis, or to the presence of BBzP in personal care and cleansing products.

Di-2-ethylhexyl phthalate (DEHP) was detected in 19 samples; six of these 19 values were greater than double the level measured in the contaminated field blank. Of particular interest is the high estimated level of DEHP detected in the wastewater from industrial laundry 2, which, as mentioned previously, launders a variety of plastic floor mats. Phthalate plasticizers from these materials may have entered the wastewater stream in solution, or as components of plastic particles that could dissolve into solution from the solid matrix. This phthalate is also used in some detergents, which could explain its presence in wastewater from industrial laundry 1, which launders uniforms and clothing, and the residential coin laundry.

Significant detection of DEHP in wastewater from the plastic manufacturing facility may indicate its use in the facility's product, polyethylene bags for food packaging. This phthalate was detected in wastewater from both the hospital and the medical clinic, though at levels below what was found in field blank 2. Di-2-ethylhexyl phthalate is used to make flexible plastics including blood and fluid storage bags and intravenous tubing used in medical settings. In addition, DEHP is used to make flexible vinyl plastics, home and garden products, food containers, toys, packaging film, ink, electronics, industrial/lubricating oils, insect repellants and pesticides, lacquer, and rubber, among others.

Di-*n*-octyl phthalate (DOP), used to make flexible plastics, was detected at its highest concentration in wastewater from the plastics manufacturing facility. While also used to make some adhesives, DOP was not detected in wastewater from the adhesives manufacturing facility. This phthalate is also used to make dyes and rubber, which may explain its presence in other wastewater samples.

Influent and effluent wastewater samples did not contain detectable levels of DEP. Detection of other phthalates in treated wastewater indicates these phthalates can enter San Francisco Bay through the treated wastewater stream. Low levels of DEP, DBP, BBzP, and DEHP have been detected in San Francisco Bay (Oros, 2002; Oros and David, 2002).

While few distinct trends emerge from analysis of detections of phthalates in wastewater from specific sources, measurements are largely consistent with known consumer and industrial uses for individual phthalates. Our data confirm that phthalates are widely used chemicals that enter the waste stream from numerous sources. Detection of BBzP and DEHP within a field blank is further evidence of the ubiquitous presence of this contaminant in the environment.

3.2. *Bisphenol A*

Laboratory analysis detected BPA at five sample locations (Table 2). All of the values measured in samples of wastewater exceed twice the level of BPA measured in the contaminated blank. Industrial laundry 1 had the highest levels of BPA, for reasons that are unclear. This particular laundry facility, as indicated above, launders primarily uniforms and clothing. However, some of the companies it serves are chemical and manufacturing facilities that may use BPA in their industrial processes, thereby potentially contaminating the clothing that the laundry cleans. Detection of BPA from the pharmaceutical company is not surprising, given that many laboratories use polycarbonate plastic bottles and containers. Two of three treated effluent samples contained BPA, indicating that BPA is not completely removed by the wastewater treatment process and, therefore, is released into San Francisco Bay.

3.3. *Triclosan*

Triclosan was detected in nine of 21 wastewater samples. Residential samples did not show the presence of triclosan above the detection limit of the method (0.5–5 μg/L). It is possible that the households sampled did not use antimicrobial products; alternatively, given that triclosan-containing consumer products are widely used, our method may have lacked the sensitivity needed to detect it in these waste streams. A survey of 23 stores in 10 states from December 1999 to April 2000 revealed the presence of the antibacterial agents triclosan and triclocarban in 76% of liquid soaps and 29% of bar soaps available (Perencevich et al., 2001). More sensitive testing may be needed to quantify levels of triclosan in residential wastewater.

Triclosan was found well above the detection limits at all three types of medical facilities — a hospital, a medical clinic, and a veterinary clinic. Triclosan is widely used in medical settings as an antibacterial agent, consistent with these findings.

Pre- and post-treatment grab samples of wastewater in this study are not meant to provide a robust indication of the extent of removal of EDCs during treatment, since concentrations of these chemicals in this study's grab samples are only snapshots of contaminant levels, and do not necessarily represent median levels over longer time frames. However, it is interesting to note that levels of triclosan in treated wastewater effluent were significantly lower than those in untreated wastewater influent. These lower concentrations in the treated effluent are consistent with studies of triclosan fate and transport in WWTPs, as a

proportion of triclosan is thought to sorb to biosolids (Halden and Paull, 2005; Stasinakis et al., 2007). In addition, triclosan can undergo biological methylation during treatment, forming methyl triclosan (Lindstrom et al., 2002), a chemical that was not targeted in this study. Methyl triclosan is a more persistent chemical with characteristics similar to DDT (Lindstrom et al., 2002), and has been detected in water samples from San Francisco Bay (Oros and David, 2002).

3.4. 4-Nonylphenol, as an indicator for alkylphenol ethoxylates

Alkylphenols such as NP can form through degradation of alkylphenol ethoxylates, industrial chemicals in common use in detergents, housekeeping products, personal care products, paints, and pesticides, among others. No NP was detected in any of the wastewater samples collected (detection limits 0.024–6.25 μg/L; Table 2). This may indicate that these wastewater samples were impacted by few sources of alkylphenol ethoxylates; alternatively, parent alkylphenol ethoxylate chemicals that had not yet degraded into NP and other alkylphenols may have been present in the samples. Further testing for parent compounds would provide greater insight on their potential to contaminate wastewater. Oros et al. (2003) reported detection of NP at 4 ng/L in a single water sample from San Francisco Bay.

3.5. Tris(2-chloroethyl) phosphate

Laboratory analysis detected the flame retardant TCEP in four samples (Table 2). Since TCEP has applications in textiles, it is not surprising that industrial laundry 1, which launders uniforms, had the highest concentration of TCEP. One industrial discharger, the adhesives manufacturer, produces fire retardant laminates, consistent with TCEP detection in the sample from this location. Limited detection of this compound is consistent with the decline in production and use of TCEP over the last decade (ECB, 2006; Föllmann and Wober 2006).

3.6. Site-based contaminant characterization

Comparison of contaminants detected in wastewater from sites characterized by similar use patterns reveals the limitations of generalization based on use. Our data indicate that all medical facilities, including a hospital, a medical clinic, and a veterinary clinic, produced wastewater contaminated with triclosan, a potentially useful finding for pollution prevention efforts. However, results from a variety of laundry facilities pinpoint no consistent similarities in contamination. Wastewater from industrial laundry 1 contained DEHP (3.4× contaminated blank) DOP, BPA (180× contaminated blank), triclosan, and TCEP, while wastewater from industrial laundry 2 contained DBP, BBzP (63× contaminated blank), and DEHP (estimated 310× contaminated blank). Wastewater from the residential coin laundry contained DEP, DEHP (7.6× contaminated blank), DOP, and triclosan, while wastewater from the diaper service contained DBP, and possibly BBzP and DEHP (levels below contaminated blank). The variation in contaminants detected may be linked to differences in the detergents and cleaning products used, differences in the clothing and other products laundered, or differences in the laundry equipment employed. These analyses have implications for the design of future studies of upstream sources of wastewater pollution, suggesting that large variations in contamination may occur among sites that appear similar with respect to use.

4. Conclusions

The results of this study provide a first look at the local sources of several widely used EDCs to the sanitary sewer system. Analyses of grab samples reveal snapshots at discrete moments in time of levels of contamination present at a variety of residential, commercial, and industrial locations in a typical urban area. Phthalates are widespread contaminants of the region's wastewater, followed in prevalence by triclosan, BPA, and TCEP.

While NP was not detected in wastewater samples, it is unclear whether this is due to low use of parent alkylphenol ethoxylate compounds, or lack of significant degradation of these compounds to the target analyte. The results of this study suggest further testing of urban sites for alkylphenol ethoxylates, rather than NP, can provide more useful information concerning the prevalence of these contaminants in consumer and industrial products, and in the wastewater stream.

Despite the limitations of data derived from a small number of grab samples, these measurements indicate some targeted pollution prevention activities may be effective in reducing wastewater contamination. For example, outreach to particular dischargers, such as medical facilities using triclosan, may help reduce concentrations of EDCs locally. For these and other persistent, synthetic chemicals in the wastewater stream, pollution prevention may be a more efficient and inexpensive method to address pollution concerns than is development of additional treatment methods at WWTPs. By reducing production and use of these compounds, the extent of wastewater contamination would also be reduced.

A future study could include long-term composite samples, a greater number of samples at a greater variety of locations, as well as sample replication at each location tested, to provide a more complete picture of the levels of contamination coming from each source. Future work to characterize contaminants in wastewater samples from sources upstream of WWTPs would benefit greatly from method development to reduce matrix effects that decrease measurement accuracy and damage analytical equipment.

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