# An Assessment of Chemical Contaminants Detected in Passive Water Samplers Deployed in the St. Thomas East End Reserves (STEER)


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# An Assessment of Chemical Contaminants Detected in Passive Water Samplers Deployed in the St. Thomas East End Reserves (STEER)


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|---|---|---|
| Rebecca Blank<br>Deputy Secretary | Kathryn Sullivan<br>Acting Under Secretary | Assistant Administrator |

***Abstract***

***This report is the second in a series from a project to assess land-based sources of pollution (LBSP) and effects in the St. Thomas East End Reserves (STEER) in St. Thomas, USVI, and is the result of a collaborative effort between NOAA's National Centers for Coastal Ocean Science, the USVI Department of Planning and Natural Resources, the University of the Virgin Islands, and The Nature Conservancy.***

***Passive water samplers (POCIS) were deployed in the STEER in February 2012. Developed by the US Geological Survey (USGS) as a tool to detect the presence of water soluble contaminants in the environment, POCIS samplers were deployed in the STEER at five locations. In addition to the February 2012 deployment, the results from an earlier POCIS deployment in May 2010 in Turpentine Gut, a perennial freshwater stream which drains to the STEER, are also reported.***

***A total of 26 stormwater contaminants were detected at least once during the February 2012 deployment in the STEER. Detections were high enough to estimate ambient water concentrations for nine contaminants using USGS sampling rate values. From the May 2010 deployment in Turpentine Gut, 31 stormwater contaminants were detected, and ambient water concentrations could be estimated for 17 compounds.***

***Ambient water concentrations were estimated for a number of contaminants including the detergent/surfactant metabolite 4-tert-octylphenol, phthalate ester plasticizers DEHP and DEP, bromoform, personal care products including menthol, indole, n,n-diethyltoluamide (DEET), along with the animal/plant sterol cholesterol, and the plant sterol beta-sitosterol. Only DEHP appeared to have exceeded a water quality guideline for the protection of aquatic organisms.***

*View into Cowpet Bay, within the St. Thomas East End Reserves (STEER).*

**Introduction**

Located on the southeastern end of the island of St. Thomas, US Virgin Islands, the St. Thomas East End Reserves or STEER is a collection of Marine Reserves and Wildlife Sanctuaries (MRWS) that include Inner Mangrove Lagoon, Cas Cay/Mangrove Lagoon, St James, and Compass Point Salt Pond MRWS (Figure 1). In recognition of the connectivity of the natural, cultural and economic resources of these four Reserves, along with the need to protect and properly manage the area, the USVI Department of Planning and Natural Resources (DPNR), along with the University of the Virgin Islands (UVI), The Nature Conservancy and a local community group began development of a comprehensive management plan in 2008 which was subsequently completed in 2011. The STEER represents one of the most recently protected areas designated by the Territorial Government of the USVI, and is part of a larger, territory-wide system of marine protected areas (STEER, 2011).

<u>STEER Environment</u>

The STEER comprises an area of 9.6 $km^2$, with approximately 34 km of coastline (STEER, 2011). The western boundary of the STEER includes the Mangrove Lagoon/Benner Bay MRWS (Figure 1); the St. James MRWS forms the eastern boundary which includes the marine habitat surrounding the island of Great St. James and the north shore of Little St. James Island; to the south the STEER is bounded by Cas and Patricia Cays and the southwest corner of Little St. James Island; the northern boundary is primarily the St. Thomas shoreline.

Within the STEER there are extensive mangroves and seagrass beds, along with coral reefs, lagoons and cays. The largest remaining mangrove system in St. Thomas occurs along the shores of Mangrove Lagoon/Benner Bay (IRF 1993). Mangroves offer many ecological benefits including natural buffers against shore erosion and shelter


Figure 1. Individual Reserves that comprise the STEER.

for juvenile fish and other organisms among the mangrove roots (DPNR-DFW, 2005). The extensive areas of seagrass in Benner and Jersey Bays provide habitat for many organisms including juvenile fish, and are an important food source for fish, turtles, birds and sea urchins. Conch feed off the epiphytes on the seagrass leaves (DPNR-DFW, 2005). The STEER also contains significant patch and fringing coral reef areas in Jersey Bay and in an area just south of Cas and Patricia Cays, along with St. James Bay. Species of coral found in the STEER include boulder star coral (*Montastraea annularis),* brain corals (*Diploria spp).,* various species of *Porites*, and staghorn coral *(Acropora cervicornis)* (DPNR-DFW, 2005). The STEER is thought to be one of the most valuable nursery areas remaining in St. Thomas, with numerous species of fish and shellfish spending some portion of their lives in the protected areas around the mangrove roots and in the seagrass beds (STEER, 2011).

The watersheds (Jersey Bay and Red Hook watersheds) around the STEER contain a variety of land uses. The Jersey Bay watershed drains to the STEER west of Deck Point. The watershed includes a large active landfill, numerous marinas and resorts, various commercial/industrial activities, an EPA Superfund Site, a horse racetrack, and residential areas served by individual septic systems, all of which have the potential to contribute point and nonpoint source pollution to the STEER. The Red Hook watershed (east of Deck Point) contains various commercial activities along with numerous marinas and resorts.

The area that borders the western side of Mangrove Lagoon contains the Bovoni Landfill, which serves not only all of St. Thomas, but receives solid waste from St. John as well. The landfill covers approximately 330 acres, with 40 acres directly adjacent to Mangrove Lagoon (IRF, 1993). On the northern side of Mangrove Lagoon is the Clinton Phipps Racetrack. There are also numerous marinas in Benner Bay, serving both residents and transient boaters, along with significant residential areas in the Jersey Bay watershed. Along the north shores of Jersey Bay, Cowpet Bay and Great Bay, are a series of resorts/hotels, condominiums (see inset, page 1) and yacht clubs.

Elevated levels of chemical contaminants have been documented in the STEER watersheds (EPA, 2011). However, the extent of chemical contamination and biological effects or bioeffects in the STEER are currently unknown, but data on land-based sources of pollution (LBSP) and effects are needed in order to make better informed decisions regarding both land use and coastal resource management.

NOAA/NCCOS Involvement in the STEER

At the NOAA Coral Reef Ecosystem Integrated Observing System (CREIOS) Meeting in 2009, representatives from DPNR identified the STEER as a priority area and noted there were significant data and information gaps in terms of the types of chemical contaminants present, their concentrations, effects, and the overall health of the biological community within the STEER.

With these needs in mind, NOAA's National Centers for Coastal Ocean Science (NCCOS), in partnership with DPNR's Divisions of Coastal Zone Management, Fish and Wildlife, and Environmental Protection, along with the University of the Virgin Islands and The Nature Conservancy, proposed and received funding from NOAA's Coral Reef Conservation Program (CRCP), to develop an integrated assessment of chemical contamination and biological conditions within the STEER. This work is being done in coordination with development of a watershed management plan and a coastal use assessment.

<u>POCIS</u>

Year 1 of the project included the quantification of chemical contaminants in sediments, a bioeffects and benthic infaunal assessment, initiation of monthly sampling for nutrients and total suspended solids (TSS), and sedimentation using sediment traps at five locations within the STEER (Pait et al., 2013).

Figure 2. Example of a POCIS disk. Image courtesy of the USGS.

Work in Year 1 also included the deployment of passive water samplers, specifically Polar Organic Chemical Integrative Samplers or POCIS, developed by the US Geological Survey (USGS). In developing the POCIS, USGS worked to create a system to monitor water soluble contaminants and estimate their water concentrations.

The goals of using the POCIS in the STEER were to assess the presence, and when possible estimate ambient concentrations of specific contaminants, and to evaluate seasonal differences. Although the concentration and effects of chemical contaminants in sediments in the STEER have been reported (Pait et al., 2013), there are many chemical contaminants that don't readily accumulate in sediments, but are toxic to biota (e.g., some current use pesticides). Determining the presence and estimating the concentration of water soluble, specifically stormwater contaminants, provides additional information on stressors present in the STEER. The first deployment of POCIS in the STEER was made in February 2012 during the dry season in St. Thomas; the second deployment was made in September 2012 during the wet season. This report covers results from the first deployment of the POCIS; the results from the second deployment will be covered in a later publication.

The POCIS (Figure 2) is a disk consisting of a sorbent matrix sandwiched between two membrane sheets (Alvarez et al., 2008). The porous membrane sheets allow water to flow through the sorbent, enabling the sorbent material to sequester (accumulate) the contaminants of interest. The sorbent matrix can be tailored to the types of chemical contaminants of interest (e.g., stormwater chemicals or human use pharmaceuticals). For deployment, the POCIS disks are assembled onto a frame and then placed in the deployment canister (Figure 3).

Many stormwater chemical contaminants, if present in the aquatic environment, are at very low concentrations, typically in the low parts per billion (ppb or ug/L) to parts per trillion (ppt or ng/L) ranges. A classic approach for detecting compounds at very low concentrations in the aquatic environment has been to collect, filter and extract large volumes of water, to enable their detection by analytical instrumentation. The POCIS disk, however, can potentially sample tens to hundreds of liters of water during deployment, providing time-weighted concentration estimates of contaminants present in the water column (Alvarez et al., 2008). This technology also has an advantage over discrete water samples, as POCIS can sequester chemical contaminants that may be present in the water only episodically, such as during storm events or during a small discharge or spill (Alvarez et al., 2008). Typical deployments of the POCIS last approximately 30 days.

The USGS has also devised a method to estimate the ambient water concentration for a number of stormwater contaminants sequestered by the POCIS, using individual sampling rate values ($R_s$). The $R_s$ values are experimentally determined for each chemical, and incorporated into the following equation:

$$C_w = \frac{N}{R_s t}$$

where

$C_w$ is the ambient water concentration of the chemical

N = the amount of chemical accumulated by the POCIS

$R_s$ is the sampling rate (L/d), i.e., liters of water cleared of

analyte per day, and
t is the number of days of deployment for the POCIS.

The number of days the POCIS is deployed is used in calculating estimated concentrations of the chemicals of interest, providing flexibility in the length of time the POCIS is deployed. Additional information on the development and use of POCIS can be found in Alvarez et al. (2004, 2008).

Figure 3. A disassembled POCIS deployment canister with the POCIS disks. Image courtesy of the USGS.

**Materials and Methods**
The POCIS deployment canisters containing the POCIS disks (two stormwater POCIS disks per canister) were shipped on ice to the University of the Virgin Islands in sealed solvent-rinsed metal cans. Upon arrival at UVI, the cans with the canisters were placed in a freezer until deployment.

The POCIS deployment canisters were placed in the STEER on 16 February 2012 at five locations (Figure 4), by scientists from UVI, and DPNR's Division of Fish and Wildlife. The five sites where the POCIS were deployed are the same targeted (not randomly selected) sites currently being used for the monthly sampling in the STEER (nutrients, TSS and sedimentation) by UVI, as part of the project. At each of these sites, sediment traps are attached to rods secured in the sediments. The POCIS deployment canisters were tethered to these same rods, by UVI and DPNR SCUBA divers. An example of one of the POCIS canisters deployed in the STEER can be seen in Figure 5.

A summary of conditions at each site at the time of POCIS canister deployment is provided in Table 1. The depth of the POCIS deployment canisters ranged from 1 meter at the site in Benner Bay, to 12.2 meters at the site adjacent to Great St. James Island. Each POCIS deployment canister was set between 20 and 50 cm from the bottom.

As part of some preliminary work in 2010, a POCIS deployment canister was placed in Turpentine Gut, the only perennial stream in St. Thomas (Nemeth and Platenberg,

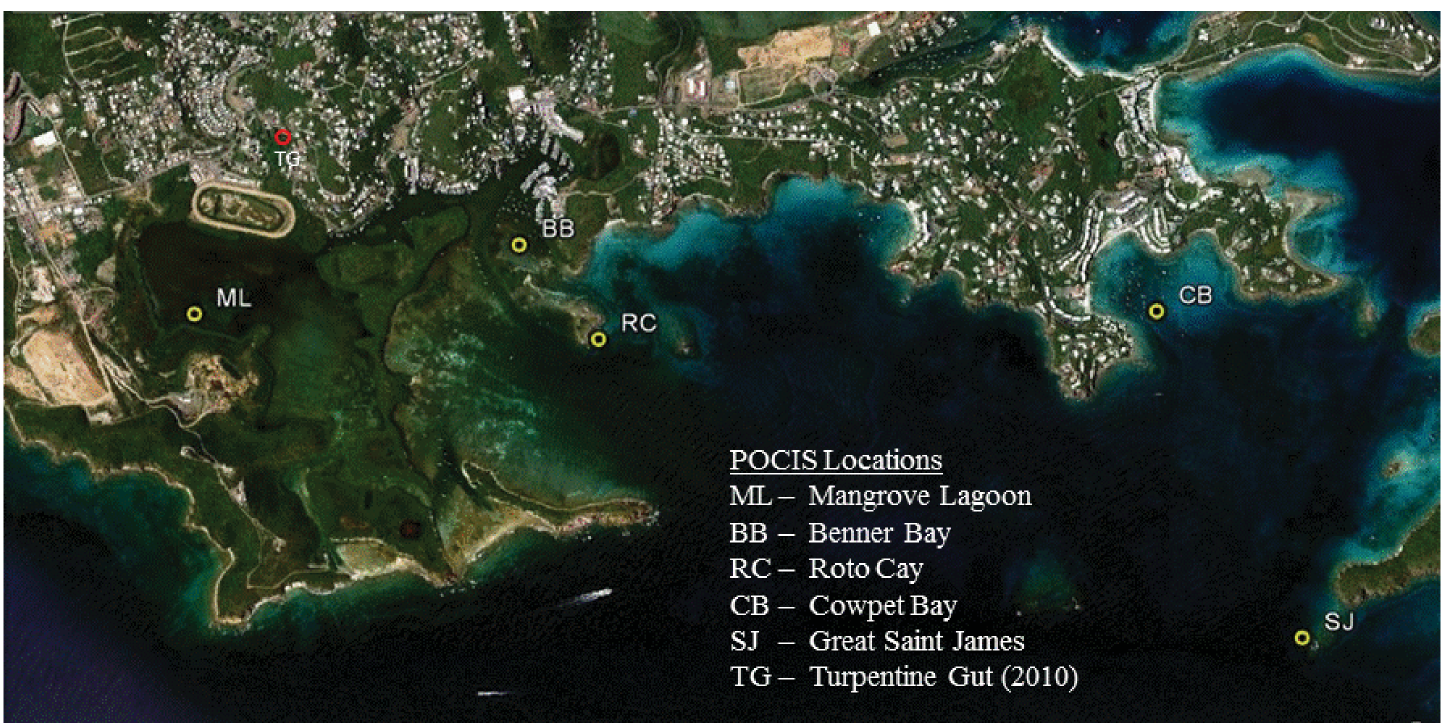


Figure 4. Locations of passive water samplers (POCIS) in the STEER.

2007). Although Turpentine Gut is not within the boundaries of the STEER, it drains directly to Mangrove Lagoon (Figure 4), and is not only a significant source of freshwater to the STEER, but also of sediments (STEER, 2011), and other types of nonpoint source pollution including chemical contaminants.

The POCIS deployment canister in Turpentine Gut was suspended in the water column at a depth of approximately 1.5 meters (Table 1). As with the 2012 deployment, two POCIS stormwater disks were included in the deployment canister. NOAA and DPNR Division of Fish and Wildlife personnel placed the POCIS deployment canister approximately 20 meters south of the "Bridge to Nowhere" on the east bank of Turpentine Gut.

Figure 5. POCIS deployment canister (arrow) among the sediment traps at a site in the STEER.

Field blank canisters were used in both the 2012 and 2010 deployments. The field blank, a POCIS disk and frame, was exposed to the air during the time the POCIS canisters were being deployed, in order to assess the presence of airborne contamination.

During the 2012 deployment in the STEER, the same field blank was exposed to the air at each of the five sites, and served as a cumulative field blank. For the 2010 deployment in Turpentine Gut, one field blank was used. After a POCIS deployment canister entered the water, the POCIS field blank was placed back in its protective canister (solvent-rinsed metal container also used for shipping), sealed and then returned to UVI and placed in a freezer.

The five POCIS deployment canisters from the STEER were retrieved by UVI and DPNR Division of Fish and Wildlife scientists using SCUBA on 14 March 2012. During the time the POCIS deployment canisters were out of the water, the field blank was again opened and exposed to the air. Once retrieved, the POCIS deployment canisters were returned to their protective canisters, and then placed in the freezer at UVI until they were shipped on ice along with the field blank to the USGS for analysis. Additional information on POCIS deployment techniques can be found in Alvarez (2010).

At the USGS laboratory, the POCIS disks were removed from the deployment canisters, and dichloromethane and methyl-tert-butyl ether were used to extract the stormwater contaminants accumulated by the POCIS, for analysis.

Table 1. Location and conditions during deployment of the POCIS canisters in February 2012 and May 2010.

| Site | Date | Latitude | Longitude | Deployment Depth (m) | Water Conditions |
|---|---|---|---|---|---|
| Great St. James (SJ) | 2/16/2012 | 18.30302 | -64.83671 | 12.2 | Clear, calm |
| Cowpet Bay (CB) | 2/16/2012 | 18.31487 | -64.84267 | 5.5 | Clear, calm |
| Rotto Cay (RC) | 2/16/2012 | 18.31331 | -64.86423 | 5.5 | Clear, calm |
| Benner Bay (BB) | 2/16/2012 | 18.3167 | -64.8674 | 1 | High turbidity |
| Mangrove Lagoon (ML) | 2/16/2012 | 18.31385 | -64.87988 | 1.3 | High turbidity |
| Turpentine Gut (2010) (TG) | 5/5/2010 | 18.32046 | -64.87719 | 1.5 | Moderate flow, high turbidity |

Note - depth of POCIS canister in meters (m)

Table 2. Stormwater contaminants analyzed from the POCIS deployed in the St. Thomas East End Reserves (STEER) in 2012, and from Turpentine Gut (2010).

| Compound | Use/Source | Compound | Use/Source |
|---|---|---|---|
| 1,4-Dichlorobenzene | Moth repellant, fumigant, deodorizer | Ethyl citrate | Plasticizer |
| 1-Methylnapthalene | Alkylated PAH (polycyclic aromatic hydrocarbon) | Fluoranthene | Polycyclic aromatic hydrocarbon (PAH) |
| 2,6-Dimethylnapthalene | Alkylated PAH (polycyclic aromatic hydrocarbon) | Galaxolide (HHCB) | Synthetic fragrance |
| 2-Methylnapthalene | Alkylated PAH (polycyclic aromatic hydrocarbon) | Indole | Component of fragrances |
| 3,4-Dichlorophenyl isocyanate | Degradation product of the herbicide diuron or linuron | Isoborneol | Natural insect repellent |
| 3-Beta-coprostanol | Fecal indicator | Isophorone | Solvent |
| 4-Cumylphenol | Detergent metabolite | Isoquinoline | Flavor and fragrance ingredient |
| 4-n-Octylphenol | Detergent metabolite | Menthol | Decongestant |
| 4-Tert-octylphenol | Detergent metabolite | Metalaxyl | Fungicide |
| 5-Methyl-1H-benzotriazole | Anticorrosive used in antifreeze | Methyl salicylate | Liniment, flavoring agent |
| Acetophenone | Fragrance used in detergent and tobacco | Metolachlor | Herbicide |
| Anthracene | Polycyclic aromatic hydrocarbon (PAH) | N,N-diethyltoluamide (DEET) | Mosquito repellent |
| Anthraquinone | Used in the manufacture of dyes/textiles and seed treatment | Naphthalene | Polycyclic aromatic hydrocarbon (PAH), also a fumigant |
| Atrazine | Herbicide | NPEO1 | Detergent metabolite |
| Benzo(a)pyrene | Polycyclic aromatic hydrocarbon (PAH) | NPEO2 | Detergent metabolite |
| Benzophenone | Component of perfumes and soaps | OPEO1 | Detergent metabolite |
| Beta-sitosterol | Plant sterol | OPEO2 | Detergent metabolite |
| BHA | Food additive, preservative | Para-cresol | Wood preservative |
| Bisphenol A | Manufacturing resin | Para-nonylphenol | Detergent metabolite |
| Bromacil | Herbicide | PBDE-47 | Flame retardant |
| Bromoform | Byproduct of water chlorination | Pentachlorophenol | Wood preservative |
| Caffeine | Stimulant | Phenanthrene | Polycyclic aromatic hydrocarbon (PAH) |
| Camphor | Fragrance in personal-care products | Phenol | Disinfectant, manufacturing intermediate |
| Carbaryl | Insecticide | Prometon | Herbicide |
| Carbazole | Used in the manufacture of dyes and lubricants | Pyrene | Polycyclic aromatic hydrocarbon (PAH) |
| Chlorpyrifos | Insecticide | Skatol | Present in feces and coal tar |
| Cholesterol | Plant/animal sterol | Stigmastanol | Plant sterol |
| Cotinine | Nicotine metabolite | Tetrachloroethylene | Dry cleaning |
| Cumene | Paint thinner, used in the production of phenol and acetone | Tonalide (AHTN) | Synthetic fragrance |
| Diazinon | Insecticide | Tri(2-chloroethyl)phosphate | Plasticizer, flame retardant |
| Dichlorvos | Insecticide (e.g., used in pet collars) | Tri(dichlorisopropyl)phosphate | Flame retardant |
| Diethyl phthalate | Plasticizer | Tributylphosphate | Anti-foaming agent, fire retardant |
| Diethylhexyl phthalate | Plasticizer | Triclosan | Disinfectant, antimicrobial |
| d-Limonene | Antimicrobial, fungicide, fragrance | Triphenyl phosphate | Plasticizer, flame retardant |
| Ethanol,2-butoxy-,phosphate | Flame retardant | | |

Abbreviations: BHA, Butylated hydroxyanisole, PBDE-47 polybrominated diphenyl ether congener 47; NPEO1, nonlyphenol monoethoxyalte; OPEO2, octylphenol diethoxylate

The analysis of the extracts from the POCIS was carried out using gas chromatography/mass spectrometry in the selected ion monitoring mode, and results were reported in a quantity of each chemical per POCIS extract (i.e., ng/ampoule). The sampling rate values ($R_s$) mentioned earlier were then used to estimate ambient water concentrations of those compounds found to be above the Quantitation Level. The Quantitation Level is the minimum concentration of the stormwater contaminant in the POCIS extract needed to ensure confidence in the reported values, and ultimately in the estimated ambient water concentration. Additional information on the analysis of the POCIS disks can be found in Alvarez et al. (2008).

The 69 stormwater contaminants analyzed from the POCIS are listed in Table 2, and include a number of pesticides, detergent metabolites, animal and plant sterols, flame retardants, fecal indicators and ingredients in personal care products.

Pesticides include the herbicides atrazine, metolachlor and bromacil, and the insecticides chlorpyrifos, carbaryl, and diazinon. The metabolites of the surfactants/detergents included 4-octylphenol and para-nonylphenol, along with nonyl- and octylphenol polyethoxylates such as NPEO1 (nonylphenol monoethoxylate) and OPEO2 (octylphenol diethoxylate).

*The Bovoni Landfill in the western end of the STEER receives solid waste from both St. Thomas and St. John.*

The environmentally ubiquitous phthalate ester plasticizers diethyl phthalate (DEP) and diethylhexyl phthalate or DEHP, are also sequestered by POCIS. DEHP has been linked to endocrine disruption.

A number of animal and plant-related compounds accumulated by the POCIS include the animal/plant sterol cholesterol, and the plant sterols beta-sitosterol and stigmastanol. Fecal indicators 3-beta-coprostanol and skatol are also sequestered by POCIS.

**Results and Discussion**

The raw data from the POCIS deployed in February 2012 at the five sites in the STEER can be found in Appendix A; the raw data from the May 2010 deployment in Turpentine Gut can be found in Appendix B. These appendices provide the concentration of each contaminant which resulted from extracting the two POCIS disks in each deployment canister. The units, ng/ampoule, represents the concentration of each analyte in the ampoule of the final extract from the POCIS disks.

A total of 26 stormwater contaminants were detected at least once in the STEER (Appendix A), although the majority (65%) of detections for these 26 were below the Quantitation Level. In Turpentine Gut, 31 stormwater contaminants were detected, a little over half (55%) of these 31 were below the Quantitation Level. Concentrations above the Quantitation Level are used to estimate ambient water concentrations.

Table 3 presents the estimated ambient water concentrations of the stormwater contaminants accumulated by the POCIS disks in the STEER and also in Turpentine Gut. The shading in Table 3 indicates those stormwater contaminants in the POCIS that were high enough to estimate ambient water concentrations. The Reporting Limit in Table 3 represents the lower limit for estimating the ambient water concentration of a stormwater contaminant, and is calculated from the Quantitation Level (see Appendix A).

There are fewer stormwater contaminants listed in Table 3 than in Appendix A and B. A number of compounds, including the polycyclic aromatic hydrocarbons (PAHs) such as 1-methylnapthalene, anthracene and benzo(a)pyrene, along with the polybrominated flame retardant PBDE-47 and the wood preservative pentachlorophenol are not included in Table 3. The POCIS disks are not efficient samplers of these compounds and as a result are only occasionally detected in the POCIS (Alvarez, pers. comm.).

Estimated Concentrations of Stormwater Contaminants in the STEER (2012)

There appear to be few published studies quantifying concentrations of the types of compounds analyzed for this project, particularly in the US Caribbean. The concentrations of stormwater contaminants estimated from this study are compared with recent results from St. John USVI, South Florida, California and also from the northwest Mediterranean Sea.

Table 3. Estimated water column concentrations of stormwater contaminant residues sampled by POCIS in the STEER.

| | February 2012 POCIS Deployment | | | | | | May 2010 POCIS Deployment | |
|---|---|---|---|---|---|---|---|---|
| | Mangrove Lagoon | Benner Bay | Rotto Cay | Cowpet Bay | Great St. James | Reporting Limit | Turpentine Gut | Reporting Limit |
| Compound | ng/L | ng/L | ng/L | ng/L | ng/L | ng/L | ng/L | ng/L |
| 1,4-Dichlorobenzene | <RL | <RL | <RL | <RL | <RL | 130 | <RL | 100 |
| 3,4-Dichlorophenyl isocyanate (m) | <RL | <RL | <RL | <RL | <RL | 240 | <RL | 190 |
| 3-Beta-coprostanol (m) | <RL | <RL | <RL | <RL | <RL | 240 | <RL | 190 |
| 4-Cumylphenol (m) | <RL | <RL | <RL | <RL | <RL | 12 | <RL | 10 |
| 4-n-Octylphenol (m) | <RL | <RL | <RL | <RL | <RL | 5.2 | <RL | 4.2 |
| 4-Tert-octylphenol | <RL | <RL | <RL | <RL | <RL | 5.2 | 17 | 4.2 |
| 5-Methyl-1H-benzotriazole | <RL | <RL | <RL | <RL | <RL | 110 | 140 | 86 |
| Acetophenone | <RL | <RL | <RL | <RL | <RL | 29 | 41 | 24 |
| Anthraquinone (m) | <RL | <RL | <RL | <RL | <RL | 18 | <RL | 15 |
| Atrazine | <RL | <RL | <RL | <RL | <RL | 20 | <RL | 16 |
| Benzophenone | <RL | <RL | <RL | <RL | <RL | 36 | <RL | 30 |
| Beta-sitosterol (m) | <RL | <RL | 620 | <RL | <RL | 480 | <RL | 380 |
| BHA (m) | <RL | <RL | <RL | <RL | <RL | 73 | <RL | 61 |
| Bisphenol A (m) | <RL | <RL | <RL | <RL | <RL | 1.9 | 6.2 | 1.5 |
| Bromacil | <RL | <RL | <RL | <RL | <RL | 72 | <RL | 60 |
| Bromoform | 230 | 84 | 230 | 160 | 160 | 49 | <RL | 41 |
| Caffeine | <RL | <RL | <RL | <RL | <RL | 19 | <RL | 16 |
| Camphor | <RL | <RL | <RL | <RL | <RL | 35 | 45 | 29 |
| Carbaryl (m) | <RL | <RL | <RL | <RL | <RL | 35 | <RL | 29 |
| Carbazole | <RL | <RL | <RL | <RL | <RL | 8.1 | <RL | 6.7 |
| Chlorpyrifos | <RL | <RL | <RL | <RL | <RL | 180 | <RL | 150 |
| Cholesterol (m) | <RL | 1100 | 550 | 800 | 380 | 240 | 610 | 190 |
| Cotinine (m) | <RL | <RL | <RL | <RL | <RL | 70 | <RL | 58 |
| Cumene | <RL | <RL | <RL | <RL | <RL | 16 | <RL | 13 |
| Diazinon | <RL | <RL | <RL | <RL | <RL | 22 | <RL | 18 |
| Dichlorvos | <RL | <RL | <RL | <RL | <RL | 110 | <RL | 94 |
| Diethyl phthalate | 97 | 92 | 72 | 100 | 120 | 20 | 120 | 16 |
| Diethylhexyl phthalate | 77 | 66 | 65 | 83 | 300 | 29 | 1100 | 24 |
| d-Limonene | <RL | <RL | <RL | <RL | <RL | 70 | <RL | 58 |
| Ethanol,2-butoxy-,phosphate | <RL | <RL | <RL | <RL | <RL | 170 | 220 | 140 |
| Ethyl citrate | <RL | <RL | <RL | <RL | <RL | 4.5 | <RL | 3.7 |
| Galaxolide (HHCB) | <RL | <RL | <RL | <RL | <RL | 5.4 | 18 | 4.4 |
| Indole | <RL | 17 | <RL | <RL | <RL | 14 | 110 | 11 |
| Isoborneol | <RL | <RL | <RL | <RL | <RL | 35 | <RL | 29 |
| Isophorone | <RL | <RL | <RL | <RL | <RL | 4.5 | <RL | 3.6 |
| Isoquinoline | <RL | <RL | <RL | <RL | <RL | 14 | <RL | 12 |
| Menthol | <RL | 200 | <RL | <RL | <RL | 150 | <RL | 120 |
| Metalaxyl | <RL | <RL | <RL | <RL | <RL | 90 | <RL | 74 |
| Methyl salicylate | <RL | <RL | <RL | <RL | <RL | 30 | <RL | 25 |
| Metolachlor | <RL | <RL | <RL | <RL | <RL | 2.7 | <RL | 2.2 |
| n,n-Diethyltoluamide (DEET) | 7.6 | <RL | <RL | <RL | <RL | 4.9 | 95 | 4.0 |
| NPEO1-total (m) | <RL | <RL | <RL | <RL | <RL | 100 | <RL | 83 |
| NPEO2-total (m) | <RL | <RL | <RL | <RL | <RL | 170 | <RL | 140 |
| OPEO1 (m) | <RL | <RL | <RL | <RL | <RL | 17 | <RL | 13 |
| OPEO2 (m) | <RL | <RL | <RL | <RL | <RL | 17 | 21 | 14 |
| Para-cresol | <RL | <RL | <RL | <RL | <RL | 27 | 520 | 23 |
| Para-nonylphenol-total (m) | <RL | <RL | <RL | <RL | <RL | 76 | <RL | 63 |
| Phenol | 150 | 250 | <RL | 29 | <RL | 25 | 35 | 20 |
| Prometon | <RL | <RL | <RL | <RL | <RL | 10 | <RL | 9 |
| Skatol | <RL | <RL | <RL | <RL | <RL | 21 | 20 | 17 |
| Stigmastanol (m) | <RL | <RL | <RL | <RL | <RL | 240 | <RL | 190 |
| Tetrachloroethylene (m) | <RL | <RL | <RL | <RL | <RL | 54 | <RL | 45 |
| Tonalide (AHTN) | <RL | <RL | <RL | <RL | <RL | 5.2 | <RL | 4.3 |
| Tri(2-chloroethyl)phosphate | <RL | <RL | <RL | <RL | <RL | 15 | <RL | 13 |
| Tri(dichlorisopropyl)phosphate | <RL | <RL | <RL | <RL | <RL | 190 | <RL | 150 |
| Tributylphosphate | <RL | <RL | <RL | <RL | <RL | 7.9 | 7.3 | 6.5 |
| Triclosan | <RL | <RL | <RL | <RL | <RL | 4.9 | <RL | 4.0 |
| Triphenyl phosphate | <RL | <RL | <RL | <RL | <RL | 47 | <RL | 39 |

Contaminant residues sampled by POCIS in the STEER; concentrations above the Reporting Limit for a compound are indicated by shading. POCIS, polar organic chemical integrative sampler; ng/L, estimated water concentration reported; (m), indicates a highly variable compound; <RL, less than the reporting limit.

From the February 2012 deployment in the STEER, ambient water concentrations could be estimated for nine stormwater contaminants (Table 3). The highest estimated concentration for any of the compounds detected in the STEER was the animal/plant sterol cholesterol at the Benner Bay site (1,100 ng/L), followed by Cowpet Bay (800 ng/L) and Rotto Cay (550 ng/L). Somewhat surprisingly, cholesterol was not detected in the POCIS deployed in Mangrove Lagoon which receives direct input from Turpentine Gut.

Bargar et al. (2013) conducted a study on nearby St. John, in the Virgin Islands National Park and the Virgin Islands Coral Reef National Monument. Cholesterol concentrations detected by Bargar et al. (2013) ranged from 240 ng/L at Round Bay, to 440 ng/L at Whistling Cay in the POCIS deployed, similar to the concentrations found in the STEER. Along the South Florida coast (Miami to Looe Key), concentrations ranged from below the detection limit to 2,896 ng/L (Singh et al. (2010).

*View into the St. Thomas East End Reserves (STEER).*

Cholesterol is an essential and natural component of cell membranes in animals, and is an ingredient in some personal care products. Cholesterol is found to a lesser degree in some plant and fungal species, and has sometimes been used as a fecal indicator (Francy et al., 2003).

Another class of stormwater contaminant detected in the STEER by POCIS were two phthalate esters, diethylhexyl phthalate (DEHP), and diethyl phthalate (DEP). Phthalate esters are used to increase the flexibility of plastics, particularly polyvinyl chloride (PVC), and have been used in a variety of products worldwide including table cloths, furniture, toys, medical tubing, personal care products, and food packaging. The highest estimated concentration of DEHP detected in the STEER was 300 ng/L at Great St. James. Due to health concerns regarding DEHP, including evidence that DEHP may be an endocrine disruptor (Gray et al., 2000) and a possible carcinogen (USDHHS, 2011), the use of DEHP has been reduced or eliminated for some applications.

The highest estimated concentration of DEHP detected in St. John, USVI by Bargar et al. (2013) was 820 ng/L at Whistling Cay, somewhat higher than what was estimated in the current study at Great St. James. As noted earlier, the deployment of the POCIS in the STEER was made in February 2012, during the dry season. Lower rainfall levels would likely lead to less runoff, which in turn could result in lower concentrations of contaminants in the water column. The deployment of POCIS in St. John occurred in May, which Bargar et al. (2013) identified as the beginning of the rainy season.

Alvarez et al. (*in press*) quantified contaminants of emerging concern at 11 sites along the California coast including the Southern California Bight and San Francisco Bay. The mean estimated concentration of DEHP using POCIS was 400 ng/L, somewhat higher than the results in the STEER, and ranged from not detected to 1,100 ng/L. In a study to assess organic micropollutants in coastal waters from the northwestern Mediterranean Sea (Catalonia to Valenica, Spain), Sánchez-Avila et al. (2012) sampled coastal seawater from 22 sites. DEHP was detected in over 90 percent of the water samples collected. The mean concentration was 145 ng/L, the maximum detected in coastal seawaters was 617 ng/L (Sánchez-Avila et al., 2012).

The highest estimated ambient water concentration of DEP from the STEER was 120 ng/L, at the Great St. James site. The mean concentration of DEP estimated by Alvarez et al. (*in press*) in California from the POCIS was 150 ng/L, similar to the highest estimated concentration in the STEER; the highest concentration estimated by Alvarez et al. (*in press*) was 600 ng/L. In the northwestern Mediterranean, the mean concentration of DEP detected in coastal seawaters was 253 ng/L with a maximum of 483 ng/L. DEP has also been identified as a possible endocrine disruptor (Cólon et al., 2000). As noted earlier, the phthalate esters are ubiquitous environmental contaminants, and low levels of phthalates also appeared in the POCIS fabrication and field blanks (Appendix A).

Phenol had an estimated ambient water concentration of 250 ng/L at the Benner Bay site, and 150 ng/L in Mangrove Lagoon. Phenol is a common intermediate used in the production of many types of compounds including detergents (e.g., alkylphenols) and plastics. Phenol is also used in oral antiseptics and as a disinfectant. Phenols can be released into the environment through wastewater treatment systems from either the direct use of phenol or degradation of phenolic compounds, and also as leachate from landfills, as materials containing phenols degrade (Masoner and Mashburn, 2004). As with the phthalate esters, phenol was a low level contaminant in the POCIS fabrication and field blanks (Appendix A). Phenol was not detected in the POCIS deployed by Bargar et al. (2013) in St. John.

In the marine environment, the presence of bromoform is often the result of algal metabolism (Palmer and Reason, 2009). In freshwater, bromoform can be an indicator of the effects of chlorination or ozonation of drinking water, or from the chlorination of treated wastewater. The highest estimated bromoform concentration from the POCIS deployed in the STEER was 230 ng/L in Mangrove Lagoon and Rotto Cay, followed by 160 ng/L in Cowpet Bay and Great St. James Bay. In St. John, Bargar et al. (2013) detected concentrations of bromoform ranging from 73 ng/L to 170 ng/L, similar to what was found in the STEER. In their work along the California coast, Alvarez et al. (*in press*), detected concentrations of bromoform ranging from 5 ng/L to 77 ng/L; bromoform was detected in all POCIS samples.

A number of fragrance-related compounds were detected in the POCIS in the STEER as well. Indole is used as a fragrance in personal care and household products (Lawrence and LaFontaine, 2010). The concentration of indole at the Benner Bay site was estimated at 17 ng/L, just above the Reporting Limit of 14 ng/L (Table 3). Indole was detected at two of the four sites in St. John, by Bargar et al. (2013) and the highest estimated concentration was 17 ng/L, the same as the Benner Bay site in the STEER.

A number of other fragrances, including acetophenone, benzophenone, d-limonene, and galaxolide (HHCB) were detected at most of the STEER sites (Appendix A), but the concentrations were below the Reporting Limit (Table 3). Acetophenone and galaxolide were also below the Reporting Limit at the sites sampled by POCIS in St. John (Bargar et al., 2013).

Estimates of the concentration of two other personal care product ingredients, including menthol and n,n-diethyltoluamide (DEET) could be made for the STEER. Menthol is used as a decongestant and analgesic and is an ingredient in some cigarettes. There was only one detection of menthol, at an estimated ambient water concentration of 200 ng/L from the POCIS placed in Benner Bay. The menthol could be related to cigarettes, however cotinine, a degradation product of nicotine, was not found in any of the POCIS deployed in the STEER or in Turpentine Gut.

The highest estimated concentration of DEET in the STEER was 7.6 ng/L from the POCIS deployed in Mangrove Lagoon. DEET is an insect repellent and its use would not be surprising given the likely need for protection against mosquitos and other insect pests in the area. In St. John, DEET was detected but it was below the method detection limit (Bargar et al., 2013). On the California coast, DEET was detected in 60 percent of the POCIS deployed, with an average concentration of 10 ng/L, with a maximum concentration of 69 ng/L, lower than in the STEER (Alvarez et al., *in press*). Along the South Florida coast, DEET ranged from not detected to 68 ng/L (Singh et al., 2010).

Finally, an estimated water concentration could be made for beta-sitosterol. The presence of this plant sterol typically results from the decay of plant materials from natural sources, and from the use and decay of paper products. The only occurrence for which an ambient water concentration of beta-sitosterol could be made in the STEER was at Rotto Cay with an estimated concentration of 620 ng/L, although beta-sitosterol was detected (but below the Reporting Limit) at all the other sites.

A comparison of the number of compounds with estimated water concentrations in the STEER can be seen in Figure 5. Turpentine Gut had a greater number of compounds detected than the sites in the STEER. Where the same compound was detected in Turpentine Gut and in the STEER, the estimated concentration was typically higher in Turpentine Gut, but not always.

Although Mangrove Lagoon receives inputs from the Bovoni Landfill through runoff and inputs from surrounding residential/commercial areas and from Turpentine Gut, this did not seem to result in a greater number of stormwater contaminants in Mangrove Lagoon compared to the other POCIS sites in the STEER, as was expected. The sites in the STEER in Figure 5 are ordered in a west to east fashion. There did not appear to be an obvious pattern or gradient in the number of compounds in the STEER, moving west to east away from Turpentine Gut and Mangrove Lagoon. There were four compounds with estimated ambient water concentrations in Mangrove Lagoon, however, there were five compounds each at Benner Bay, Rotto Cay and Cowpet Bay. This also held true for the total number of compounds detected in the POCIS (Appendix A). Additional POCIS, perhaps offshore of these areas would provide more information, including the possibility of gradients.

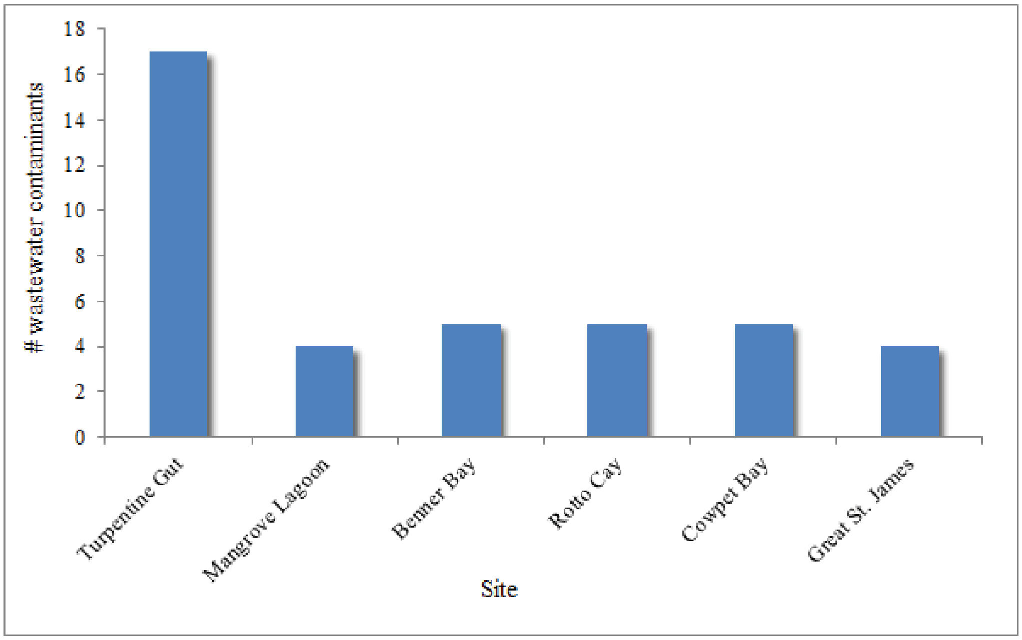


Figure 5. Number of stormwater contaminants with estimated water column concentrations in the STEER and in Turpentine Gut.

<u>Estimated Concentrations of Stormwater Contaminants in Turpentine Gut (2010)</u>

The deployment of the POCIS in Turpentine Gut was almost two years earlier than the POCIS deployed in the STEER. In addition, the deployment in Turpentine Gut and the STEER were done at somewhat different times of the year; mid-spring for Turpentine Gut, and mid to late winter for the POCIS deployment in the STEER. Nevertheless, the earlier POCIS deployment in Turpentine Gut provides a useful characterization of stormwater contaminants present in St. Thomas' only perennial stream, and offers the opportunity to make some comparisons to what was found in the STEER.

As noted, ambient water concentrations could be estimated for a greater number of compounds in Turpentine Gut than in the STEER (Figure 5). Disregarding the temporal aspects of the deployment, these findings are not surprising, as Turpentine Gut runs through the heart of the Jersey Bay watershed before it empties into Mangrove Lagoon, and likely receives input from a variety of sources. Land use in the Jersey Bay is roughly 30% low- and mid-density urban development, with the remaining land use primarily forest and shrub (62%) (Cadmus, 2011).

Two compounds, the plasticizer DEHP (1,100 ng/L) and the insect repellent DEET (95 ng/L), had higher estimated ambient water concentrations in Turpentine Gut than in the STEER sites. Both DEHP and DEET are common stormwater/wastewater contaminants, and their appearance in Turpentine Gut is not surprising. The higher DEHP concentration in Turpentine Gut was similar to the maximum concentration found by Bargar et al. (2013) in St. John (820 ng/L), and was the same as the maximum found by Alvarez et al. (*in press*), along the California coast (1,100 ng/L). The estimated concentration of DEET found in Turpentine Gut was higher than the highest concentrations estimated by Alvarez et al. (*in press*) (69 ng/L) along the California coast, and by Singh et al (2010) (68 ng/L) in South Florida.

There were 10 compounds in the POCIS for which ambient water concentration estimates could be made from Turpentine Gut, that were either not found or were below Reporting Limits at the sites in the STEER. Two of these were the detergent metabolites 4-tert-octylphenol and OPEO2. The estimated concentration of 4-tert-octylphenol in Turpentine Gut was 17 ng/L (Table 3). Bargar et al. (2013) did not detect 4-tert-octylphenol in the POCIS deployed in St. John.

Bisphenol-A is also a plasticizer, used in the production of polycarbonate plastic, and in epoxy resins commonly applied to the insides of food and beverage cans. The estimated ambient water concentration in Turpentine Gut was 6.2 ng/L. Bisphenol-A was detected by Singh et al. (2010) at concentrations up to 190 ng/L in South Florida. In coastal seawater, Sánchez-Avila et al. (2012) detected an average bisphenol-A concentration of 18 ng/L, ranging from 2.3 ng/L to 102 ng/L. Bisphenol-A has also been identified as an endocrine disruptor (Lindholst et al., 2000).

There were three personal care product ingredients detected above the Reporting Limit in Turpentine Gut. Camphor (45 ng/L) and galaxolide (18 ng/L) are fragrance ingredients. Acetophenone, used as a fragrance in laundry detergent and in cigarettes, was also identified in Turpentine Gut at an estimated ambient concentration of 41 ng/L. As noted earlier, acetophenone was detected in the STEER at all sites, but below the Reporting Limit. Along the California coast, galaxolide was present in 80 percent of the POCIS samples, with a mean concentration of 150 ng/L, and acetophenone was also present in 80 percent of the samples from POCIS, with a mean concentration of 11 ng/L (Alvarez et al., *in press*).

The fecal marker 3-methyl-1(H)-indole, or skatol, was detected at an estimated ambient water concentration in Turpentine Gut of 20 ng/L, just above the Reporting Limit of 17 ng/L. A second fecal indicator, 3-beta-coprostanol was also detected in Turpentine Gut (Appendix B), however, at a level too low to estimate a water concentration. The presence of both these fecal indicators from Turpentine Gut would seem indicative of inputs from septic systems and from animal (e.g., dog) waste.

As noted earlier, no cotinine or caffeine was detected in the POCIS deployed in Turpentine Gut or in the STEER, which was somewhat surprising given the density of the population in this part of St. Thomas, and likely use of these compounds in tobacco products or in caffeinated beverages. Neither of these compounds were detected in POCIS deployed in St. John (Bargar et al., 2013).

Table 4. Comparison of estimated concentrations of stormwater contaminants with available water quality criteria.

| Wastewater Contaminant | Water Quality Criteria | | | | Estimated Concentrations (ug/L) - STEER and Turpentine Gut | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Marine (ug/L) | | Freshwater (ug/L) | | Mangrove Lagoon | Benner Bay | Rotto Cay | Cowpet Bay | St. James | Turpentine Gut |
| | Acute | Chronic | Acute | Chronic | | | | | | |
| Bromoform | – | – | 2,300 | 320 | 0.023 | 0.084 | 0.23 | 0.16 | 0.16 | – |
| Diethyl phthalate | 2,944 | 3.4 | 1,800 | 110 | 0.097 | 0.092 | 0.072 | 0.1 | 0.12 | 0.12 |
| Diethylhexyl phthalate | 400 | 360 | 400 | 0.3-16 | 0.077 | 0.066 | 0.065 | 0.083 | 0.3 | 1.1 |
| Para-cresol | – | – | <230 | <13 | – | – | – | – | – | 0.52 |
| Phenol | 5,800 | 400 | 10,200 | 180-320 | 0.15 | 0.25 | – | 0.029 | – | 0.035 |
| Tetrachloroethylene | 10,200 | 450 | 830 | 45 | – | – | – | – | – | – |

Note: Marine/freshwater criteria and STEER concentrations are in ug/L or parts per billion, to make table more readable. Marine and freshwater criteria represent water guidelines developed by the USEPA and othes. Water Quality Criteria values taken from NOAA Screening Quick Reference Tables (SQuiRTs, Buchman, 2008).

In Turpentine Gut, 5-methyl-1H-benzotriazole was detected at an estimated concentration of 140 ng/L. This compound is used as a corrosion inhibitor especially for copper and its alloys (e.g., brass), and is commonly found in antifreeze formulations for automobiles.

Two flame retardants, ethanol,2-butoxy-,phosphate (220 ng/L), and tributylphosphate (7.3 ng/L) were only found in the Turpentine Gut POCIS. Ethanol,2-butoxy-,phosphate is also used as a plasticizer and an antifoaming agent. In addition to being a flame retardant, tributylphosphate has a number of other uses including as a defoamer in detergent solutions and in paints and adhesives. Alvarez et al. (*in press*), estimated a mean tributylphosphate concentration of 6.6 ng/L along the California coast, similar to the concentration estimated in Turpentine Gut.

Para-cresol, used as a wood preservative, was detected in Turpentine Gut with an estimated water concentration of 520 ng/L. As with a number of the other stormwater contaminants, para-cresol was detected in the POCIS from all sites in the STEER, but was below the Reporting Limit (Appendix A).

<u>Comparison with Water Quality Criteria</u>

Table 4 compares the concentrations of stormwater contaminants quantified in the STEER and Turpentine Gut with available water quality criteria developed by the US Environmental Protection Agency (EPA) and others. It should be noted that the estimated water column concentrations represent ambient concentration, and as such would not reflect peak concentrations as might occur after a rainstorm.

The values in Table 4 for the STEER and Turpentine Gut have been converted to ug/L or ppb, in order to make the table more readable. It can be seen that almost all the estimated water concentrations of the contaminants listed in Table 4 from both the STEER and Turpentine Gut were below, in most cases orders of magnitude below, the criteria listed. The only exception was the plasticizer DEHP from Turpentine Gut. The estimated water concentration in Turpentine Gut (1.1 ug/L or 1,100 ng/L) is above a lower chronic (longer-term exposure) criteria (0.3 ug/L) listed in Table 4.

Finally, the compound tetrachloroethylene was included in Table 4. Within the watershed that drains to Turpentine Gut and the STEER, is the Tutu Wellfield Superfund Site. The EPA Superfund site was established due to contamination of groundwater and wells in the area by chlorinated volatile organic compounds (CVOC), including tetrachloroethylene. This compound was used extensively for dry cleaning by a textile plant located in the watershed that operated from 1969 to 1982 (EPA, 2011). Contamination of the groundwater along with commercial and private wells in the Tutu area resulted in EPA establishing the Superfund site and installing groundwater treatment systems to remove CVOCs, including tetrachloroethylene (EPA, 2011).

From Table 4, it can be seen that there were no estimated water concentrations for tetrachloroethylene in either Turpentine Gut or in Mangrove Lagoon. There was one detection of tetrachloroethylene from the POCIS deployed adjacent to Great St. James Island, however, the level (30 ng/ampoule) was below the Quantitation Level (Appendix A), that would have allowed an ambient water concentration estimate to be made. The location of this POCIS adjacent to Great St. James, would make a connection to the Tutu Wellfield Superfund Site appear unlikely, due to the distance from the Superfund site, along with the lack of detections in the POCIS deployed in Turpentine Gut and Mangrove Lagoon, both of which are closer to the Superfund site.

**Summary and Conclusions**

The deployment of five POCIS in the STEER in February 2012, and one in Turpentine Gut in May 2010 provides valuable information on the presence of stormwater contaminants that might be missed if sediments alone were sampled. Although Turpentine Gut is not within the boundaries of the STEER, this perennial stream drains most of the Jersey Bay watershed and empties into the STEER through Mangrove Lagoon. Although the deployment in Turpentine Gut occurred nearly two years before the POCIS were deployed in the STEER, the Turpentine Gut POCIS provides additional information on the presence of stormwater contaminants that can be transported to the STEER via Mangrove Lagoon.

The analysis of the POCIS from both the STEER and Turpentine Gut resulted in the identification of a number of stormwater contaminants, the majority at concentrations below USGS Reporting Limits. Stormwater contaminants including phthalate ester plasticizers, wood preservatives, personal care product/fragrance ingredients, plant sterols and a fecal indicator were present at levels that enabled estimates of ambient water concentrations. The stormwater contaminants detected appear fairly representative of the low- and mid-density urban development in the watershed.

Significantly, none of the nine pesticides, primarily agricultural use herbicides and insecticides, were detected in the POCIS. This would appear to reflect the low level of agriculture in the watersheds surrounding the STEER and in St. Thomas in general.

A total of 26 stormwater contaminants were detected at least once during the February 2012 deployment at the five sites in the STEER, and estimates of ambient water concentrations could be made for nine of these stormwater contaminants. In Turpentine Gut, 31 contaminants were detected in 2010, and ambient water concentrations could be estimated for 17 of these contaminants. The higher number of contaminants present in Turpentine Gut, including those for which estimated ambient water concentrations could be made, might be expected given that Turpentine Gut drains the primary watershed that empties into the STEER.

The most common contaminants identified in the POCIS were the phthalate ester plasticizers DEP and DEHP. Both were present in the POCIS at all sites, and their concentrations were high enough to estimate ambient water concentrations. Both of these phthalates are ubiquitous environment contaminants, as they have had global use as plasticizers in industry and in the home. The estimated water concentration of DEHP in Turpentine Gut (1,100 ng/L) was above a chronic water quality criteria, and was the only stormwater contaminant found to be above an available water quality criteria. Both DEHP and DEP have been identified as endocrine disruptors.

The wood preservative para-cresol was found in Turpentine Gut at an estimated concentration of 520 ng/L. This compound was also present but below the Reporting Limit at all sites in the STEER, indicating possible widespread use.

Bromoform, a natural byproduct of algal metabolism in marine environments, and byproduct of drinking water or wastewater chlorination, was present in quantifiable levels at all sites in the STEER, but not in Turpentine Gut. This was somewhat surprising, and suggests that the bromoform found in the STEER may be natural, and related to algal metabolism. All estimated concentrations were below established water quality criteria.

A number of fragrance components were also detected in the STEER and in Turpentine Gut. Acetophenone, a fragrance used in detergents and in cigarettes, was detected in Turpentine Gut, and was present at all sites in the STEER, but concentrations could not be estimated as they were below the Reporting Limit. Indole was detected in the POCIS deployed in Benner Bay. The fragrance ingredients camphor and galaxolide were also found at quantifiable levels in Turpentine Gut. Other fragrance compounds including benzophenone, d-limonene and tonalide were present but below the Reporting Limit at all sites. Other personal care products detected included the insect repellent DEET (n,n-diethyltoluamide), methyl salicylate (liniment), and menthol (decongestant).

Finally, the animal/plant sterol cholesterol was detected above the Reporting Limit at all but one site in the STEER and also in Turpentine Gut. The fecal indicator skatol was detected in Turpentine Gut. A second fecal indicator 3-beta coprostanol was detected in Turpentine Gut but below the Reporting Limit.

The POCIS passive water samplers represent a fairly new technology used by NOAA's National Centers for Coastal Ocean Science along with project partners. The use of POCIS provides the opportunity to assess the presence of water soluble chemical contaminants in coral reef environments.

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Appendix A. Raw data from deployment of POCIS in five locations in the STEER, February 2012.

| Compound | Mangrove Lagoon ng/ampoule | Benner Bay ng/ampoule | Rotto Cay ng/ampoule | Cowpet Bay ng/ampoule | Saint James ng/ampoule | Quantitation Level ng/ampoule |
|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | 25.8 | LQL | 20.3 | 16.3 | 20.9 | 128 |
| 1-Methylnapthalene | LQL | LQL | LQL | LQL | 8.1 | 64 |
| 2,6-Dimethylnapthalene | LQL | LQL | LQL | LQL | LQL | 64 |
| 2-Methylnapthalene | 9.85 | 12.9 | 8.93 | LQL | 12.6 | 64 |
| 3,4-Dichlorophenyl isocyanate (m) | LQL | LQL | LQL | LQL | LQL | 1020 |
| 3-Beta-coprostanol (m) | LQL | LQL | LQL | LQL | LQL | 512 |
| 4-Cumylphenol (m) | LQL | LQL | LQL | LQL | LQL | 64 |
| 4-n-Octylphenol (m) | LQL | LQL | LQL | LQL | LQL | 32 |
| 4-Tert-octylphenol | LQL | LQL | LQL | LQL | LQL | 32 |
| 5-Methyl-1H-benzotriazole | LQL | LQL | LQL | LQL | LQL | 512 |
| Acetophenone | 91.2 | 86.3 | 92.3 | 79.5 | 71.5 | 128 |
| Anthracene | LQL | LQL | LQL | LQL | LQL | 32 |
| Anthraquinone (m) | LQL | LQL | LQL | LQL | LQL | 64 |
| Atrazine | LQL | LQL | LQL | LQL | LQL | 256 |
| Benzo(a)pyrene | LQL | LQL | LQL | LQL | LQL | 32 |
| Benzophenone | 45.2 | 58 | 36.7 | 32.4 | 44.6 | 128 |
| Beta-sitosterol (m) | 962 | 883 | 1340 | 728 | 455 | 1020 |
| BHA (m) | LQL | LQL | LQL | LQL | LQL | 256 |
| Bisphenol A (m) | LQL | LQL | LQL | LQL | LQL | 64 |
| Bromacil | LQL | LQL | LQL | LQL | LQL | 256 |
| Bromoform | 1180 | 438 | 1220 | 844 | 840 | 256 |
| Caffeine | LQL | LQL | LQL | LQL | LQL | 128 |
| Camphor | LQL | LQL | LQL | LQL | LQL | 128 |
| Carbaryl (m) | LQL | LQL | LQL | LQL | LQL | 128 |
| Carbazole | LQL | LQL | LQL | LQL | LQL | 32 |
| Chlorpyrifos | LQL | LQL | LQL | LQL | LQL | 512 |
| Cholesterol (m) | 481 | 2350 | 1180 | 1710 | 808 | 512 |
| Cotinine (m) | LQL | LQL | LQL | LQL | LQL | 128 |
| Cumene | 25.8 | 27.4 | 27 | 24.9 | 13.2 | 64 |
| Diazinon | LQL | LQL | LQL | LQL | LQL | 512 |
| Dichlorvos | LQL | LQL | LQL | LQL | LQL | 128 |
| Diethyl phthalate | 317 | 301 | 236 | 328 | 384 | 64 |
| Diethylhexyl phthalate | 170 | 146 | 144 | 183 | 658 | 64 |
| d-Limonene | 89.1 | 148 | 92.2 | 116 | 137 | 256 |
| Ethanol,2-butoxy-,phosphate | LQL | LQL | LQL | LQL | LQL | 1020 |
| Ethyl citrate | LQL | LQL | LQL | LQL | LQL | 64 |
| Fluoranthene | LQL | LQL | LQL | LQL | LQL | 32 |
| Galaxolide (HHCB) | 15.4 | LQL | 16.1 | 15.9 | 12.8 | 62.7 |

Note: Quantitation level based on lowest standard; two POCIS disks were deployed at each site; m, highly variable compound; LQL, not detected above quantitation level; all results below quantitation level are considered estimated. Surrogates are internal standards used to measure extraction efficiency.

Appendix A. Raw data from deployment of POCIS in five locations in the STEER, February 2012 (continued).

| Compound | NWQL spike % Recovery | NWQL blank ng/ampoule | POCIS field blank ng/ampoule | POCIS Fab Blank ng/ampoule |
|---|---|---|---|---|
| 1,4-Dichlorobenzene | 84.8 | LQL | 75.6 | LQL |
| 1-Methylnapthalene | 76.97 | LQL | 4.58 | LQL |
| 2,6-Dimethylnapthalene | 83.35 | LQL | LQL | LQL |
| 2-Methylnapthalene | 83.87 | LQL | 8.87 | 9.65 |
| 3,4-Dichlorophenyl isocyanate (m) | 64.62 | LQL | LQL | LQL |
| 3-Beta-coprostanol (m) | 85.38 | LQL | LQL | LQL |
| 4-Cumylphenol (m) | 100.62 | LQL | LQL | LQL |
| 4-n-Octylphenol (m) | 88.12 | LQL | LQL | LQL |
| 4-Tert-octylphenol | 88.28 | LQL | LQL | LQL |
| 5-Methyl-1H-benzotriazole | 97.18 | LQL | LQL | LQL |
| Acetophenone | 87.29 | LQL | 55 | 24.7 |
| Anthracene | 81.35 | LQL | LQL | LQL |
| Anthraquinone (m) | 97.77 | LQL | LQL | LQL |
| Atrazine | 83.95 | LQL | LQL | LQL |
| Benzo(a)pyrene | 76.24 | LQL | LQL | LQL |
| Benzophenone | 87.86 | LQL | 22.8 | 23.4 |
| Beta-sitosterol (m) | 85.95 | LQL | LQL | LQL |
| BHA (m) | 85.33 | LQL | LQL | LQL |
| Bisphenol A (m) | 88.15 | LQL | LQL | LQL |
| Bromacil | 89.92 | LQL | LQL | LQL |
| Bromoform | 83.79 | LQL | LQL | LQL |
| Caffeine | 89.39 | LQL | LQL | LQL |
| Camphor | 85.15 | LQL | LQL | LQL |
| Carbaryl (m) | 89.84 | LQL | LQL | LQL |
| Carbazole | 78.75 | LQL | LQL | LQL |
| Chlorpyrifos | 78.13 | LQL | LQL | LQL |
| Cholesterol (m) | 86.47 | LQL | 106 | LQL |
| Cotinine (m) | 97.82 | LQL | LQL | LQL |
| Cumene | 70.75 | LQL | LQL | LQL |
| Diazinon | 79.61 | LQL | LQL | LQL |
| Dichlorvos | 96.23 | LQL | LQL | LQL |
| Diethyl phthalate | 88.47 | LQL | 148 | 87.6 |
| Diethylhexyl phthalate | 86.56 | LQL | 189 | 80 |
| d-Limonene | 88.84 | LQL | 114 | 65.8 |
| Ethanol,2-butoxy-,phosphate | 81.11 | LQL | LQL | LQL |
| Ethyl citrate | 93.47 | LQL | LQL | LQL |
| Fluoranthene | 74.41 | LQL | LQL | LQL |
| Galaxolide (HHCB) | 76.42 | LQL | 7.74 | LQL |

Note: Quantitation level based on lowest standard; two POCIS disks were deployed at each site; m, highly variable compound; LQL, not detected above quantitation level; all results below quantitation level are considered estimated. Surrogates are internal standards used to measure extraction efficiency; NWQL, National Water Quality Laboratory.

Appendix A. Raw data from deployment of POCIS in five locations in the STEER, February 2012 (continued).

| Compound | Mangrove Lagoon ng/ampoule | Benner Bay ng/ampoule | Rotto Cay ng/ampoule | Cowpet Bay ng/ampoule | Saint James ng/ampoule | Quantitation Level ng/ampoule |
|---|---|---|---|---|---|---|
| Indole | LQL | 78.3 | LQL | 22.2 | LQL | 64 |
| Isoborneol | LQL | LQL | LQL | LQL | LQL | 128 |
| Isophorone | LQL | LQL | LQL | LQL | LQL | 64 |
| Isoquinoline | LQL | LQL | LQL | LQL | LQL | 64 |
| Menthol | LQL | 698 | LQL | LQL | LQL | 512 |
| Metalaxyl | LQL | LQL | LQL | LQL | LQL | 256 |
| Methyl salicylate | 51.8 | 44.3 | 43 | 38.7 | 29.6 | 128 |
| Metolachlor | LQL | LQL | LQL | LQL | LQL | 64 |
| N,N-diethyltoluamide (DEET) | 99 | 48.4 | 16.4 | LQL | LQL | 64 |
| Naphthalene | 20.1 | 15.8 | 17.5 | 17.9 | 20.2 | 32 |
| NPEO1 (m) | LQL | LQL | LQL | LQL | LQL | 513 |
| NPEO2 (m) | LQL | 584 | 357 | 368 | 334 | 1020 |
| OPEO1 (m) | LQL | LQL | LQL | LQL | LQL | 63.4 |
| OPEO2 (m) | LQL | LQL | LQL | LQL | LQL | 87 |
| Para-cresol | 32.6 | 70.3 | 36.2 | 34.9 | 37.5 | 128 |
| Para-nonylphenol (m) | LQL | LQL | LQL | LQL | LQL | 455 |
| PBDE-47 (m) | LQL | LQL | LQL | LQL | LQL | 67.8 |
| Pentachlorophenol (m) | LQL | LQL | LQL | LQL | LQL | 512 |
| Phenanthrene | LQL | LQL | 9.15 | 11.1 | 9.68 | 32 |
| Phenol | 794 | 1320 | 60.3 | 151 | 102 | 128 |
| Prometon | LQL | LQL | LQL | LQL | LQL | 256 |
| Pyrene | LQL | LQL | LQL | LQL | 4.51 | 32 |
| Skatol | LQL | LQL | LQL | LQL | LQL | 64 |
| Stigmastanol (m) | LQL | 321 | 233 | LQL | 220 | 512 |
| Tetrachloroethylene (m) | LQL | LQL | LQL | LQL | 30 | 256 |
| Tonalide (AHTN) | LQL | LQL | LQL | LQL | LQL | 62.7 |
| Tri(2-chloroethyl)phosphate | LQL | LQL | LQL | LQL | LQL | 256 |
| Tri(dichlorisopropyl)phosphate | LQL | LQL | 45.4 | LQL | LQL | 512 |
| Tributylphosphate | LQL | LQL | LQL | LQL | LQL | 64 |
| Triclosan | LQL | LQL | LQL | LQL | LQL | 512 |
| Triphenyl phosphate | LQL | LQL | LQL | LQL | LQL | 128 |
| Surrogates | | | | | | |
| decafluorobiphenyl | 89.5 | 95.05 | 90.86 | 89.84 | 96.48 | |
| d9-Caffiene | 100.62 | 103.29 | 101.98 | 93.73 | 105.54 | |
| d10 - fluoranthene | 97.79 | 96.99 | 94.39 | 90.65 | 103.24 | |
| d16 bisphenol A | 106.37 | 108.04 | 105.33 | 42.89 | 103.68 | |

Note: Quantitation level based on lowest standard; two POCIS disks were deployed at each site; m, highly variable compound; LQL, not detected above quantitation level; all results below quantitation level are considered estimated. Surrogates are internal standards used to measure extraction efficiency.

Appendix A. Raw data from deployment of POCIS in five locations in the STEER, February 2012 (continued).

| Compound | NWQL spike % Recovery | NWQL blank ng/ampoule | POCIS field blank ng/ampoule | POCIS Fab Blank ng/ampoule |
|---|---|---|---|---|
| Indole | 88.95 | LQL | LQL | LQL |
| Isoborneol | 77.04 | LQL | LQL | LQL |
| Isophorone | 90.89 | LQL | LQL | LQL |
| Isoquinoline | 94.51 | LQL | LQL | LQL |
| Menthol | 89.43 | LQL | LQL | LQL |
| Metalaxyl | 90.15 | LQL | LQL | LQL |
| Methyl salicylate | 93.49 | LQL | 24 | LQL |
| Metolachlor | 85.22 | LQL | LQL | LQL |
| N,N-diethyltoluamide (DEET) | 96.6 | LQL | LQL | LQL |
| Naphthalene | 81.79 | LQL | 11.2 | 9.77 |
| NPEO1 (m) | 108.93 | LQL | LQL | LQL |
| NPEO2 (m) | 97.71 | LQL | LQL | LQL |
| OPEO1 (m) | 87.52 | LQL | LQL | LQL |
| OPEO2 (m) | 95.86 | LQL | LQL | LQL |
| Para-cresol | 89.66 | LQL | LQL | LQL |
| Para-nonylphenol (m) | 73.82 | LQL | LQL | LQL |
| PBDE-47 (m) | 84.19 | LQL | LQL | LQL |
| Pentachlorophenol (m) | 100.12 | LQL | LQL | LQL |
| Phenanthrene | 78.45 | LQL | 6.34 | 8.38 |
| Phenol | 87.96 | LQL | 45.9 | 33.6 |
| Prometon | 89.04 | LQL | LQL | LQL |
| Pyrene | 82.83 | LQL | LQL | LQL |
| Skatol | 86.53 | LQL | LQL | LQL |
| Stigmastanol (m) | 89.9 | LQL | LQL | LQL |
| Tetrachloroethylene (m) | 57.1 | LQL | LQL | LQL |
| Tonalide (AHTN) | 84.5 | LQL | LQL | LQL |
| Tri(2-chloroethyl)phosphate | 77.44 | LQL | LQL | LQL |
| Tri(dichlorisopropyl)phosphate | 84.29 | LQL | LQL | LQL |
| Tributylphosphate | 92.18 | LQL | LQL | LQL |
| Triclosan | 89.77 | LQL | LQL | LQL |
| Triphenyl phosphate | 83.65 | LQL | LQL | 17.2 |
| Surrogates | | | | |
| decafluorobiphenyl | 92.53 | 92.17 | 91.2 | 96.71 |
| d9-Caffiene | 95.65 | 79.8 | 101.74 | 100.9 |
| d10 - fluoranthene | 95.59 | 94.81 | 100.45 | 103.04 |
| d16 bisphenol A | 102.05 | 56.4 | 102.35 | 94.5 |

Note: Quantitation level based on lowest standard; two POCIS disks were deployed at each site; m, highly variable compound; LQL, not detected above quantitation level; all results below quantitation level are considered estimated. Surrogates are internal standards used to measure extraction efficiency; NWQL, National Water Quality Laboratory.

Appendix B. Raw data from deployment of POCIS in Turpentine Gut in May 2010.

| Compound | Turpentine Gut ng/ampoule | Report Level based on lowest standard (0.16) ng/ampoule | Lab Solution Spike % Recovery | Lab procedure Blank ng/ampoule | Equipment Blank ng/ampoule | Field Blank ng/ampoule |
|---|---|---|---|---|---|---|
| 1,4-Dichlorobenzene | ++ | 130 | 96.2 | ++ | ++ | ++ |
| 1-Methylnapthalene | ++ | 64 | 92.2 | ++ | ++ | ++ |
| 2,6-Dimethylnapthalene | ++ | 64 | 93.6 | ++ | ++ | ++ |
| 2-Methylnapthalene | ++ | 64 | 94.5 | ++ | ++ | ++ |
| 3,4-Dichlorophenyl isocyanate | ++ | 1000 | 45.3 | ++ | ++ | ++ |
| 3-Beta-coprostanol | 220 | 510 | 85.7 | ++ | ++ | ++ |
| 4-Cumylphenol | ++ | 64 | 104.5 | ++ | ++ | ++ |
| 4-n-Octylphenol | ++ | 32 | 93.5 | ++ | ++ | ++ |
| 4-Tert-octylphenol | 130 | 32 | 83.5 | ++ | ++ | ++ |
| 5-Methyl-1H-benzotriazole | E 830 | 510 | 84.9 | ++ | ++ | ++ |
| Acetophenone | 210 | 130 | 93.5 | ++ | ++ | ++ |
| Anthracene | ++ | 32 | 88.9 | ++ | ++ | ++ |
| Anthraquinone | ++ | 64 | 107.6 | ++ | ++ | ++ |
| Atrazine | ++ | 260 | 95.3 | ++ | ++ | ++ |
| Benzo(a)pyrene | ++ | 32 | 91.6 | ++ | ++ | ++ |
| Benzophenone | 46 | 130 | 95.1 | ++ | 20 | 24 |
| Beta-sitosterol | 670 | 1000 | 98.2 | ++ | ++ | ++ |
| BHA | ++ | 260 | 89.1 | ++ | ++ | ++ |
| Bisphenol A | 250 | 64 | 89.9 | ++ | U-Deleted | U-Deleted |
| Bromacil | ++ | 260 | 94.7 | ++ | ++ | ++ |
| Bromoform | ++ | 260 | 93.1 | ++ | ++ | ++ |
| Caffeine | ++ | 130 | 95.1 | ++ | 12 | ++ |
| Camphor | 200 | 130 | 93.2 | ++ | ++ | ++ |
| Carbaryl | ++ | 130 | 93.6 | ++ | ++ | ++ |
| Carbazole | ++ | 32 | 96.7 | ++ | ++ | ++ |
| Chlorpyrifos | ++ | 510 | 93.6 | ++ | ++ | ++ |
| Cholesterol | 1600 | 510 | 87.9 | ++ | ++ | ++ |
| Cotinine | ++ | 130 | 96.2 | ++ | ++ | ++ |
| Cumene | ++ | 64 | 94.1 | ++ | ++ | ++ |
| Diazinon | ++ | 510 | 89.3 | ++ | ++ | ++ |
| Dichlorvos | ++ | 130 | 85.4 | ++ | ++ | ++ |
| Diethyl phthalate | 480 | 64 | 87.1 | ++ | 700 | 120 |
| Diethylhexyl phthalate | 3000 | 64 | 91.5 | ++ | 3300 | 3500 |
| d-Limonene | 160 | 260 | 101.4 | ++ | ++ | ++ |
| Ethanol,2-butoxy-,phosphate | 1600 | 1000 | 89.0 | ++ | ++ | ++ |
| Ethyl citrate | ++ | 64 | 90.0 | ++ | ++ | ++ |
| Fluoranthene | ++ | 32 | 98.5 | ++ | 5.4 | 4.8 |
| Galaxolide (HHCB) | 250 | 63 | 93.4 | ++ | 12 | 9.6 |

Note: Reporting level based on lowest standard; two POCIS disks were deployed at each site; ++, not detected above reporting leve; E, estimated due to some chromatographic interference; <, raised report level - chromatographic interference; U-deleted - bisphenol A due to uncertainty of recovery due to no labeled bisphenol A surrogate recovery. Surrogates are internal standards used to measure extraction efficiency.

Appendix B. Raw data from deployment of POCIS in Turpentine Gut in May 2010 (continued).

| Compound | Turpentine Gut ng/ampoule | Report Level based on lowest standard (0.16) ng/ampoule | Lab Solution Spike % Recovery | Lab procedure Blank ng/ampoule | Equipment Blank ng/ampoule | Field Blank ng/ampoule |
|---|---|---|---|---|---|---|
| Indole | 620 | 64 | 95.3 | ++ | ++ | ++ |
| Isoborneol | ++ | 130 | 86.8 | ++ | ++ | ++ |
| Isophorone | < 71 | 64 | 82.8 | ++ | ++ | ++ |
| Isoquinoline | ++ | 64 | 90.5 | ++ | ++ | ++ |
| Menthol | 340 | 510 | 101.0 | ++ | ++ | ++ |
| Metalaxyl | ++ | 260 | 99.3 | ++ | ++ | ++ |
| Methyl salicylate | 62 | 130 | 98.0 | ++ | 36 | 24 |
| Metolachlor | ++ | 64 | 94.9 | ++ | ++ | ++ |
| N,N-diethyltoluamide (DEET) | 1500 | 64 | 96.9 | ++ | 10 | ++ |
| Naphthalene | 30 | 32 | 93.6 | ++ | ++ | ++ |
| NPEO1 | ++ | 510 | 107.9 | ++ | ++ | ++ |
| NPEO2 | ++ | 1000 | 97.3 | ++ | ++ | ++ |
| OPEO1 | < 170 | 63 | 81.4 | ++ | ++ | ++ |
| OPEO2 | 130 | 87 | 63.4 | ++ | ++ | ++ |
| Para-cresol | 3000 | 130 | 98.6 | ++ | ++ | ++ |
| Para-nonylphenol | ++ | 460 | 82.7 | ++ | ++ | ++ |
| PBDE-47 | ++ | 68 | 89.7 | ++ | ++ | ++ |
| Pentachlorophenol | 81 | 510 | 97.5 | ++ | ++ | ++ |
| Phenanthrene | ++ | 32 | 93.8 | ++ | 9.5 | 9.2 |
| Phenol | 210 | 130 | 102.7 | ++ | ++ | ++ |
| Prometon | ++ | 260 | 96.1 | ++ | ++ | ++ |
| Pyrene | ++ | 32 | 96.4 | ++ | 3.1 | 2.8 |
| Skatol | 75 | 64 | 95.7 | ++ | ++ | ++ |
| Stigmastanol | 280 | 510 | 89.7 | ++ | ++ | ++ |
| Tetrachloroethylene | ++ | 260 | 75.4 | ++ | ++ | ++ |
| Tonalide (AHTN) | 44 | 63 | 91.7 | ++ | ++ | ++ |
| Tri(2-chloroethyl)phosphate | 200 | 260 | 85.2 | ++ | ++ | ++ |
| Tri(dichlorisopropyl)phosphate | 480 | 510 | 93.5 | ++ | ++ | ++ |
| Tributylphosphate | 72 | 64 | 71.8 | ++ | ++ | ++ |
| Triclosan | ++ | 510 | 91.1 | ++ | ++ | ++ |
| Triphenyl phosphate | ++ | 130 | 96.0 | ++ | ++ | ++ |
| ***Method Surrogates*** | | | | | | |
| DECAFLUOROBIPHENYL | 87.37 | | 92.6 | 83.74 | 84.64 | 95.72 |
| d9-CAFFEINE | 104.29 | | 92.5 | 79.11 | 110.76 | 107.68 |
| d10-FLUORANTHENE | 99.26 | | 96.0 | 92.75 | 117.03 | 110.74 |
| d16-BISPHENOL A | 114.85 | | 87.8 | 60.65 | 0 | 0 |

Note: Reporting level based on lowest standard; two POCIS disks were deployed at each site; ++, not detected above reporting leve; E, estimated due to some chromatographic interference; <, raised report level - chromatographic interference; U-deleted - bisphenol A due to uncertainty of recovery due to no labeled bisphenol A surrogate recovery. Surrogates are internal standards used to measure extraction efficiency.

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**National Ocean Service**
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