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## **CHAPTER 5**

### **SUMMARY OF FINDINGS**

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This chapter summarizes the major findings of EPA's detailed analyses described in Chapters 1, 3, and 4. It describes findings on vessel classes that are covered by this study. It summarizes major findings from the characterization of select discharges from the study vessels, including EPA's interpretation of these findings in the context of the level of potential risk from these pollutant loadings. Additionally, it discusses major findings of EPA's assessment of the predicted impacts of these discharges to a hypothetical harbor. This chapter also briefly summarizes possible benefits to human health, welfare, and the environment from reducing, eliminating, controlling, or mitigating discharges from study vessels.

#### **5.1 SUMMARY OF CLASSES OF VESSELS COVERED BY THIS STUDY**

EPA estimates there is a population of approximately 140,000 study vessels. According to the U.S. Coast Guard's Marine Information for Safety and Law Enforcement (MISLE) database, there are approximately 70,000 commercial fishing vessels operating in the United States. These vessels represent the largest category of study vessels. Passenger vessels comprise the second highest number of vessels within the study population, with approximately 21,000 vessels. These vessels are further classified by subtypes according to the types of activities in which they are involved, such as diving vessels, charter fishing vessels, ferries, harbor cruise vessels, and sailing vessels. The study population also includes over 11,000 utility vessels, including tugs/towing vessels, school ships, research vessels/ships, mobile offshore drilling units, offshore vessels, offshore supply vessels, oil recovery vessels, and industrial vessels. Other vessel categories such as freight barges (approximately 8,000 vessels), tank barges (approximately 900 vessels), freight ships (approximately 800 vessels), unclassified public vessels (approximately 600 vessels), and tank ships (approximately 200 vessels) account for the remainder of other non-recreational study vessels. An additional 27,375 vessels in the MISLE database are also believed to be study vessels; however, the database does not indicate their type of service. See Chapter 1 for additional discussions of the study vessel and recreational vessel populations.

#### **5.2 SUMMARY OF EFFLUENT CHARACTERIZATION OF SELECT DISCHARGES FROM THE STUDY VESSELS**

The major findings of EPA's analysis of the vessel discharge characterization data for study vessels are summarized below. For this study, EPA sampled 61 vessels in nine states generating over 22,000 data points. EPA tested for 301 analytes and detected 154 of these analytes in at least one sample; therefore, 158 of the tested analytes were never found in the

discharges. Section 5.2.1 discusses the estimated volumes of the discharges and Section 5.2.2 discusses the detected pollutants that may have the potential to pose a risk to human health or the environment. See chapters 3 and 4 for more technical, in-depth discussions of these results.

### **5.2.1 Estimated Volumes of Select Discharges from the Study Vessels**

EPA estimated volumes for each discharge from the study vessels based on data and field observations from EPA's vessel sampling efforts, as well as information from secondary data sources. Discharge volumes are important to both characterize the discharge and to analyze the potential risk of the pollutant concentrations discharged from vessels. EPA also used these discharge volumes to calculate flow rates for the modeling of pollutant loadings to a hypothetical harbor in Chapter 4.

Bilgewater generation rates are highly variable. EPA observed as little as 2 gallons of bilgewater discharged from a tow/salvage vessel following a tow activity to as much as 750 gallons of bilgewater discharged during the daily bilge pump-out from a 62-foot shrimp boat from the Gulf of Mexico. In general, based on observations from dozens of vessel operations, EPA estimates that small (less than 79 feet), nonrecreational vessels typically generate between 10 and 15 gallons per day (gpd) of bilgewater.

Stern tube packing gland effluent is by nature limited to the small amount of water needed to provide cooling and lubrication to the gland around the drive shaft. The range in estimated discharge for stern tube packing gland effluent is approximately 4 to 8 gpd.

For deckwash water from tour boats, water taxis, and tow boats, EPA estimates a discharge volume of between 20 and 30 gpd. Fishing boats are estimated to generate more deckwash water and the volumes generated vary with the type of boat. Trollers, trawlers, gillnetters, and purse seiners may wash their decks three to four times per day while fishing, producing as much as an estimated 750 to 900 gpd of deckwash water.

The volume of fish hold effluent generated by a fishing vessel depends on the size of the vessel and the method used to keep the product fresh. Smaller fishing vessels such as small salmon trollers or long-liners may discharge an estimated fish hold volume ranging from 70 to 200 gpd. Mid-size fishing vessels, such as gill netters and purse seiners found in Alaska and shrimp boats in the Gulf of Mexico may discharge approximately 333 to 1,000 gpd. Larger fishing vessels such as off-shore trawlers found in New England and tenders found in Alaska, however, can have refrigerated seawater holding tanks or ice hold tanks as large as 15,000 gallons. These vessels are expected to offload seafood and discharge the fish hold effluent every three to five days, resulting in an estimated flow rate ranging from 900 to 2,000 gpd. EPA estimates the volume of fish hold cleaning effluent discharged by certain fishing vessels to be anywhere from 300 to 400 gallons per cleaning, which occur typically every three to five days

when the fish holds are emptied (discharge volumes range from an estimated 60 to 200 gpd depending on frequency of offloading).



**Fisherman unloading their catch to the dock from a trawler (dragger) in Massachusetts.**

Graywater volumes also vary considerably depending on the class of vessel and its use, size, number of crew and passengers onboard, and types of graywater-generating activities onboard (e.g., galleys, sinks, showers, and washing machines). For example, EPA estimated that tugboats, some of which provide living quarters for three to five crew members, generate approximately 130 gpd of graywater. Water taxis typically have considerably more people onboard, but less graywater is generated per person because the discharge is typically limited to bathroom sinks with an estimated 75-gpd discharge. Graywater generation on commercial fishing boats might range from a few to hundreds of gpd, depending on the length of the trip and the size of the crew.

Finally, the volume of engine effluent discharged depends on the type of engine and power level of operation. Vessels with outboard propulsion engines are estimated to discharge between 1 to 2 gallons per minute (gpm) of raw cooling water per engine. The cooling water discharge rate from inboard marine diesel engines varies based on power levels, but typically averages around 20 gpm for the study vessels. Marine diesel generator sets require approximately 5 to 6 gpm of cooling water for smaller units, and up to 20 to 25 gpm of cooling water for larger marine generator sets. Daily discharge rates for these engines are a function of the daily operating time.

### 5.2.2 Analytes of Potential Risk in Select Discharges from Study Vessels

EPA compared the measured concentration of any given analyte to its most stringent benchmark<sup>1</sup> (Table 3-1) as one means to identify pollutants in vessel discharges that may have a potential to pose a risk to human health or aquatic life. EPA divided the concentration of an analyte by its corresponding benchmark to calculate a potential hazard quotient (PHQ). If a PHQ is less than 1, there is less of a concern that the pollutant in the discharge will have impacts to human health or aquatic life. An exception to this determination is when the pollutant is persistent and/or bioaccumulative and may increase in concentration within the ecosystem food chain to harmful levels. If a PHQ is equal to or greater than 1, then there is more of a concern. However, PHQs of greater than 1 do not provide conclusive evidence of risk to human health or the environment for the following reasons:

1. Samples were collected at the “end of pipe” as the vessels discharged into larger waters (e.g., harbors, rivers). However, the discharge is typically diluted in the water body. Therefore, accounting for possible dilution in the receiving water could result in ambient PHQ of less than 1 (except possibly small harbors or marinas with limited or no flushing or where the receiving water PHQ is already above 1 due to other factors).
2. The benchmarks used to evaluate the potential for risk were always the most protective, even if it was not the most commonly applicable screening benchmark for that particular analyte. Given this, the potential for risk might be over-stated.
3. The surrounding ambient water or source water (vessel service<sup>2</sup> or city water supply) used in the vessel systems that generated these discharges (e.g., engine cooling water drawn from ambient water or potable water used for deck cleaning) may already contain high concentrations of some of these analytes. In these instances, a high analyte concentration measured at the “end of pipe” may not originate from vessel activities, but rather from the water used in these operations.

EPA made the following general observations based on its review of the vessel discharge data (see Chapter 3 for EPA’s detailed analysis of the data):

- Dissolved copper was the analyte detected in vessel discharges at concentrations that consistently posed the greatest potential risk for local impacts and for contributing to exceedances of water quality standards in larger water bodies. Copper is a heavy metal that can restrict the growth and reproduction of plants and algae and can produce both acute (short-term) and chronic (long-term) toxic effects on reproduction, growth, and

<sup>1</sup> To provide a context for the level of contaminant concentrations presented, EPA used National Recommended Water Quality Criteria (NRWQC) and several other benchmarks as a preliminary screen for all discharge data with the potential to cause or contribute to the nonattainment of a water quality standard in a given receiving water body.

<sup>2</sup> Service water here means the vessel potable water supply. For study vessels, vessel service water generally originates from municipal water supply rather than produced on board.

survival in fish and shellfish. Prolonged exposure to elevated copper concentrations can lead to long-term liver and kidney damage in humans. Concentrations of dissolved copper exceeding the most protective screening benchmark were found in at least some samples for every sampled discharge type, except for outboard engine and generator engine effluents.

Dissolved copper was detected at the highest concentrations in the deck washdown, graywater, fish hold, and bilgewater discharges from most vessel classes, particularly utility vessels (e.g., towboats, supply boats). PHQs for mean dissolved copper concentrations ranged from a low of 1.1 in graywater discharges to a high of approximately 200 in fish hold effluent. Based on concentration and average discharge volume, deck washdown and fish hold discharges contribute the most dissolved copper.

Copper is released (leached) from antifouling hull coatings used on certain vessels to prevent buildup of organisms such as barnacles and algae. Copper can also be released via underwater hull cleaning, hull coating removal operations, and paint application. Although copper antifouling discharges were not measured, previous studies have shown it can be a major contributor to copper concentrations in harbors, especially marinas with large vessel populations (see Section 3.2.8.1).

Average ambient dissolved copper concentrations in the harbors sampled in this study were also slightly higher than the most protective benchmark (mean PHQ of 1.6). However, discharge concentrations still exceeded the benchmark even after subtracting the potential contribution of copper from ambient waters.

- Total arsenic<sup>3</sup> concentrations in vessel discharges were also notably higher than the most protective screening benchmark. In samples where arsenic was detected, PHQs for mean total arsenic concentrations ranged from a low of 110 in graywater discharge to a high of 2,900 in bilgewater discharge. Arsenic is a metalloid (a nonmetallic element with some metal properties) that is easily absorbed by aquatic plants, algae, fish, and shellfish. Arsenic can cause a variety of acute and chronic toxic effects in aquatic organisms, as well as in humans who ingest arsenic via drinking water and contaminated seafood. Arsenic is a known carcinogen, and prolonged high exposures via ingestion can cause cancer, skin irritation, kidney and liver damage, and neurological damage.

Despite the high potential toxicity of total arsenic, the risk posed to aquatic life is lower than what is suggested by this analysis for two reasons. First, the screening benchmark for total arsenic is a human health criterion to prevent cancer-causing agents in drinking water and is over 100 times lower than that of any other metal in this study. The high

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<sup>3</sup> See discussion in Section 3.1.3 regarding potential positive interference which may have resulted in elevated measured concentrations of arsenic for a subset of samples.

total arsenic PHQs in vessel discharges are the result of this low benchmark for human health, which is 2,000 times lower than the dissolved arsenic benchmark that is based on chronic, long-term toxicity to saltwater aquatic life. Many of the waters where many study vessels operate, particularly for certain vessel types such as commercial fishing vessels, are not typically used as drinking water sources (i.e., ocean and coastal waters). However, some waters where study vessels operate (e.g., the Mississippi River) do serve as drinking water sources and high arsenic loadings in these waters could contribute to human health concerns.

Second, between 20 to 100 percent of the total arsenic measured in the various vessel discharges can be attributed to ambient water that is used as source water for vessel systems. Vessel discharges most influenced by ambient total arsenic concentrations include those from stern tube packing glands, outboard engines, and firemain systems. However, less than half of the total arsenic measured in bilgewater, deckwash, and fish hold discharges appears to be contributed by concentrations in ambient water, indicating that these discharges potentially contribute to arsenic toxicity in receiving waters. Based on concentration and average discharge volume, deck washdown and fish hold discharges appear to contribute the most total arsenic.

- Total aluminum concentrations exceeded benchmark concentrations in at least some samples for all discharge types; however, some of the aluminum concentrations in the discharge may be due to background concentrations (e.g., not added to the discharge by the vessel). Average PHQs for total aluminum ranged from a high of 39 in deck washdown discharge to a low of 1.8 in outboard engine effluent. The metalloid aluminum is most toxic to aquatic organisms in acidic conditions (i.e., waters with a pH < 7). When pH is neutral (7) or higher, aluminum can still inhibit growth of aquatic organisms but to a lesser extent. The pH measured in the vessel discharges and ambient water sampled in this study was generally 7 or higher. Chronic exposure to high concentrations can cause aluminum to accumulate in bones of fish (and humans) and lead to loss of kidney function.

Indications are that the potential risk from total aluminum is greatest in deck washdown discharges, followed by fish hold discharges, and then stern tube packing gland discharges. For deck washdown, there is an elevated risk because of the high aluminum concentrations (possibly from the leaching of the abundant amount of aluminum found on the surfaces of many vessels), as well as the potentially large discharge volume (up to 900 gpd). Fish hold discharge also contains high total aluminum concentrations with discharges up to 1,000 gpd. Although concentrations in the stern tube packing gland discharge are nearly as high as those in fish hold effluent, potential for risk from stern tube packing gland effluent is lower due to the lower volume of the discharge.

Ambient concentrations of total aluminum were high (ranging from 29 to 3,950  $\mu\text{g/L}$  – see Appendix E) in all of the sampled harbors for this study. The average concentration of total aluminum in ambient water is higher than the average concentration of total aluminum for all discharge types except for deck washdown, fish hold effluent, and stern tube/packing gland effluent. For fish hold<sup>4</sup> and stern tube packing gland discharges, it appears half of the measured total aluminum likely originates from the ambient water. Deck washdown discharge from vessels that use ambient water to clean decks have an estimated 20 percent of the measured total aluminum concentrations contributed by ambient water. In contrast, only 2 percent of the measured total aluminum concentrations were attributable to background concentrations for vessels that used service water to clean their decks (primarily tugboats/utility vessels).

- Concentrations of other metals such as total iron and manganese and dissolved cadmium, lead and zinc above their respective screening benchmarks were measured in some samples of deck washdown effluents (PHQs ranging from 1 to 11). These heavy metals are all known to produce acute and chronic toxic effects in aquatic organisms and humans, in the following order: cadmium is more toxic than lead, which is more toxic than zinc, which is more toxic than iron. These elevated concentrations were particularly prevalent in the deck washdown discharges from utility vessels. However, decks of utility vessels (tugboats) are washed less frequently than fishing vessel decks, so overall metal loads from the two types of vessels are more comparable than concentrations alone might suggest. Although background concentrations of these metals in the ambient and service waters used to wash decks were generally low (except for dissolved zinc in some background samples), average PHQs of all these metals in vessel discharges were not significantly greater than 1, indicating that these metals likely pose minimal potential risk to the environment.
- Total phosphorus concentrations were elevated in some samples of bilgewater, deck washdown, fish hold, and graywater discharges. Average PHQs for total phosphorus in these discharge categories ranged from a high of 130 in fish hold effluent to a low of 14 in graywater. Total phosphorus in some vessel discharges comes from detergents and soaps. Other total phosphorus loadings come from decaying seafood (in fish hold) or leftover food (graywater). Based on concentration and average discharge volume, fish hold effluent contributes the most total phosphorus.

Phosphorus is an important macronutrient limiting reproduction and growth of plant material and algae (so called “primary production”). Elevated levels of phosphorus can

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<sup>4</sup> The assertion that background concentrations contribute approximately half of aluminum concentrations for fish hold effluent assumes that vessels either took in the original fish hold water from the surrounding harbor waters, or that the fishing grounds where the vessel took in the fish hold water share similar characteristics with surrounding harbor waters.

contribute to nuisance algal blooms, eutrophication (nutrient enrichment), and low dissolved oxygen levels in the water column (hypoxia). Ambient concentrations of total phosphorus, averaged across all sampled harbors, were twice the concentration of the PHQ screening benchmark.

- The concentrations of reactive nitrogen compounds (e.g., nitrate, nitrite, ammonia) and the parameter TKN were generally not significantly elevated; except for in fish hold and fish hold cleaning effluents. Concentrations of ammonia exceed the most stringent recommended acute aquatic life criterion. Concentrations of TKN also exceeded the most stringent screening value. TKN in fish hold and fish hold cleaning effluent were also typical of concentrated raw sewage.
- Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were elevated in bilgewater, deck washdown, fish hold, and graywater discharges. BOD and COD are measures of oxygen-demanding substances present in the discharges (e.g., organic matter) that can contribute to hypoxia (low dissolved oxygen) in receiving waters. Average BOD concentrations were highest in fish hold effluents (as high as 25 times the concentrations in raw sewage), followed by graywater and then bilgewater and deck washdown water. The BOD levels in fish hold effluent and graywater are comparable to BOD concentrations in raw sewage. Fish hold effluent also has a relatively high discharge volume, so this discharge can contribute a significant BOD/COD loading to receiving waters, particularly when multiple vessels discharge at the sample location (e.g., pierside at a fish processing facility). Hence, depending upon receiving water characteristics, BOD and COD from fish hold effluent may significantly impact the local environment and contribute to water quality exceedances in receiving waters.
- Pathogen indicators, *E. coli*, enterococci, and fecal coliforms, were also found in elevated concentrations in some samples of bilgewater and deck washdown (fishing vessels only), fish hold, and graywater discharges. These three types of bacteria are all found in animal digestive tracts. Epidemiological studies suggest a link between high concentrations of *E. coli* and enterococci in ambient waters and incidents of gastrointestinal illnesses associated with swimming. Accordingly, they are used as indicators of the possible presence of intestinal pathogens. The highest concentrations by far of all three pathogen indicators were found in graywater, with PHQs of around 1,000 for all three bacteria. The estimated discharge volume of graywater from study vessels, however, is relatively small (130 gpd maximum). Larger vessels with additional crew or passengers are expected to generate considerably more graywater (see EPA's Cruise Ship Discharge Assessment Report, USEPA, 2008c). Fish hold effluent contained the second highest concentrations of these pathogen indicators and may pose a potential level of risk considering the relatively high volume of this discharge and possible discharge by multiple vessels in the same location. However, EPA notes that most of the pathogen concentrations in fish hold

effluent were well below or similar to ambient water concentrations, and this study is inconclusive as to whether fish hold effluent results in additional discharge of pathogen indicators<sup>5</sup>.

- The semivolatile organic compound bis(2-ethylhexyl) phthalate was found in elevated concentrations in some samples of bilgewater, stern tube packing gland, deck washdown, firemain, and inboard engine and engine generator discharges. The highest PHQ of 59 for bis(2-ethylhexyl) phthalate was found in a bilgewater discharge sample. Even though bis(2-ethylhexyl) phthalate was found at elevated concentrations in multiple discharges, the overall frequency of detection was low and generally detected at concentrations just slightly above the benchmark. This compound is a plasticizer that is added to an ever-increasing variety of plastics to provide flexibility and is the most common phthalate in the environment. Although no conclusive evidence exists demonstrating bis(2-ethylhexyl) phthalate affects humans, high concentrations have been shown to feminize males of other species. Bis(2-ethylhexyl) phthalate was not analyzed for in fish hold or graywater discharge samples.
- Benzene was the only volatile organic compound found with any frequency at concentrations above, but generally close to, the PHQ benchmark. Benzene is a known carcinogen that is a common constituent of fuel. Benzene can also be formed as a product of incomplete combustion of fuel. Elevated concentrations of benzene were detected in a bilgewater sample and in samples from both outboard engine and generator engine discharges.
- Long- or short-chain nonylphenol and octylphenol ethoxylates (two distinct subsets of alkylphenol ethoxylates) were detected in some samples of bilgewater, stern tube/packing gland, deck washdown, and graywater discharges, and total nonylphenol was detected in one sample from bilgewater. Nonylphenols were not analyzed for in samples of the remaining discharge types.

Nonylphenols (a term used generally here to identify a specific group of alkylphenols of potential human and environmental concern which also includes the octylphenols) are manmade organic compounds that are used in a wide variety of applications, such as the manufacturing of detergents, because of their surfactant properties. Nonylphenols are synthetic estrogens, which means they can mimic the natural vertebrate hormone estrogen

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<sup>5</sup> Fish hold water may also serve as a potential pathway for the spread of aquatic nuisance species (ANS). This might occur where fish and water are taken onboard in one place and then transported significant distances for sale or unloading and the water is discharged. Organisms discharged with the water may include parasites and commensals taken in with fish, as well as organisms taken in with water used for refrigerated seawater. EPA did not study the potential for these discharges to transport ANS; however, the Agency is identifying this as a potential area of concern that may warrant further research.

and evoke an estrogen-like response. An example of such a response is the disruption of male sexual development, causing female characteristics to emerge.

Commercial nonylphenol is most accurately described by CAS number 84852-15-3 (phenol, 4-nonyl-branched), but CAS numbers 104-40-5 (phenol, 4-nonyl-) and 25154-52-3 (phenol, nonyl) have also been used to describe these compounds. The commercial nonylphenol mixtures tested that correspond with EPA's criteria are those with CAS numbers 84852-15-3 and 25154-52-3. The analyte category named "total nonylphenol" in the database generated for this study is directly equivalent to the commercial mixture of nonylphenol isomers specified under CAS Number 84852-15-3, and thus is directly comparable to the NRWQC.

Total nonylphenol (or NP) was not detected, except in one bilgewater sample with a PHQ of 4. Long-chain nonylphenol and octylphenol ethoxylates were detected with far greater frequency, but these longer chain compounds are more water soluble and less toxic than NP. The long-chain nonylphenol and octylphenol ethoxylates will all degrade into NP over time; however, research is ongoing with regard to proportion and duration of the conversion.

Table 5.1 summarizes the major findings discussed above.

**Table 5.1. Analytes of Potential Risk by Discharge<sup>1</sup>**

Discharge Type (Volume/vessel)	Analyte Group								Comments
	Microbiologicals	Volatile and Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Classical Pollutants	Nutrients	Nonylphenols <sup>32</sup>	
<b>Bilgewater</b> (2 to hundreds of gpd; average between 10 and 15 gpd)	<b>enterococci</b> (detected in only sample collected – shrimping boat; PHQ=124)	<b>Benzene</b> (Detected in 4 of 7 samples – highest PHQ = 187; towboat)  <b>Bis(2-ethylhexyl) phthalate</b> (detected in 4 of 7 samples – non-fishing vessels only; PHQs up to 59)	<b>Copper</b> (detected in all of 7 samples; PHQ up to 113 - tour boat)  <b>Cadmium</b> (detected in only 1 sample; PHQ value of 40 – tour boat).	<b>Arsenic</b> (detected in all of 7 samples; PHQs 72 to 1,790)	<b>HEM</b> (detected in all of 7 samples; only one sample where PHQ exceeds factor of 2 – conc. = 44 mg/L; towboat)	<b>Sulfide</b> (detected in only 2 samples; PHQ as high as 210 from a fishing boat)  <b>TRC</b> (highest conc. 0.16 mg/L, tour boat; PHQ = 21)  <b>BOD/COD</b> (elevated in 3 of 5 samples; conc. roughly equivalent to raw sewage)	<b>Total phosphorus</b> (elevated in 3 of 5 samples; highest PHQ=130 – longliner fishing boat)	<b>Long- and short-chain</b> (NP in single sample-shrimping boat; PHQ = 4)	Tour and tow/salvage boats (utility boats) tended to have highest concentrations of metals and VOCs/SVOCs
<b>Stern tube packing gland effluent</b> (from 4 to 8 gpd)	NA	<b>Bis(2-ethylhexyl) phthalate</b> (detected in 3 of 9 samples – max. conc. = 24 µg/L; PHQ = 20)	<b>Nickel</b> (detected in 6 of 9 samples; PHQs in 4 samples from 13 to 126)  <b>Copper</b> (detected in 4 of 9 samples; PHQs from 5 to 30)	<b>Arsenic</b> (detected in 3 of 9 samples; PHQs possibly exceed 250)		<b>TSS</b> (detected in all of 9 samples – max conc. = 270 mg/L; PHQ = 9)			HEM detected at a max conc. = 67 mg/L; max SGT HEM = 56 mg/L – PHQs approx. 4, respectively.  No nonylphenol polyethoxylates (NPEOs) detected, only longer chain octylphenol polyethoxylates (OPEOs) indicative of contamination from lubricants.

**Table 5.1. Analytes of Potential Risk by Discharge<sup>1</sup>**

Discharge Type (Volume/vessel)	Analyte Group								
	Microbiologicals	Volatile and Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Classical Pollutants	Nutrients	Nonylphenols <sup>32</sup>	Comments
Deck washdown and/or runoff (from 20 to 30 gpd utility; 750 to 900 gpd fishing)	Fecal coliform, enterococci <i>E. coli</i> (detected in all 5 samples collected - fishing vessels only. Concentrations of fecal coliform highest in samples; PHQs as high as 40)		<p><b>Copper</b> (detected in 29 of 31 samples - PHQs from 2 to 65; highest for utility vessels)</p> <p><b>Zinc</b> (detected in all of 31 samples - 67% of PHQs between 1 and 10. Max. conc. of 1,200 µg/L in tugboat; PHQ = 14)</p> <p><b>Lead</b> (detected in 15 of 31 samples - PHQs in 2 samples from 10 to 21)</p> <p><b>Cadmium</b> (detected in 2 of 31 samples - max. conc. = 22 µg/L in tow boat; PHQ = 90)</p>	<p><b>Arsenic</b> (detected in 23 of 31 samples; conc. from 4 to 83 µg/L - PHQs from 200 to 4,000 because very low NRWQC)</p> <p><b>Aluminum</b> (detected in 30 of 31 samples - PHQs between 7.5 and 150. Max. conc. of 13,000 µg/L in tugboat)</p> <p><b>Iron</b> (detected in 18 of 19 samples - PHQs between 3.1 and 48. Max. conc. of 14,500 µg/L in tugboat)</p> <p><b>Manganese</b> (detected only in tugboats and water taxi - PHQs between 1.2 and 13. Max. conc. of 12,800 µg/L in water taxi)<sup>2</sup></p>	<p><b>HEM</b> (detected in 26 of 29 samples - only 3 samples with PHQ &gt; 2. Range of concentrations 1.1 to a max of 133 mg/L in a tugboat)</p> <p><b>SGT HEM</b> (detected in 22 of 29 samples - only 1 sample with PHQ &gt; 2. Range of concentration 0.91 to a max of 84 mg/L in a tugboat)</p>	<p><b>BOD and COD</b> (detected in 29 of 31 BOD samples- all COD samples; concentrations roughly equivalent to raw sewage- all vessel types)</p> <p><b>TSS</b> (detected in all of 32 samples - PHQs between 1 and 17; max. concentrations in tugboats)</p> <p><b>TRC</b> (detected in 7 of 31 samples - PHQs between 23 and 100. Max. conc. of 0.8 mg/L in fish trolling boat)</p>	<b>Total phosphorus</b> (detected in all of 31 samples; PHQ as high as 220 in a tugboat)		<p>Concentrations of many dissolved metals in so-called "utility" or non-fishing vessels statistically higher compared with fishing vessels.</p> <p>Elevated concentrations of total arsenic, aluminum and iron strongly influenced by surrounding ambient water concentrations.</p> <p>TOC detected in all of 25 samples at concentrations from a low of 3.5 to a very high 350 mg/L (tugboat).</p> <p>Bis(2-ethylhexyl)-phthalate detected in only 1 sample (PHQ = 5.6).</p> <p>Only 3 of 29 vessels sampled had detectable concentrations of NPEOs of the shortest chain (NP3EO) indicative of detergents; concentrations ranging from 0.80 to 29 µg/L.</p>

**Table 5.1. Analytes of Potential Risk by Discharge<sup>1</sup>**

Discharge Type (Volume/vessel)	Analyte Group								Comments
	Microbiologicals	Volatile and Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Classical Pollutants	Nutrients	Nonylphenols <sup>32</sup>	
<p><b>Fish hold/ Fish hold cleaning effluent - Fishing vessels only</b> (tens to several hundred or a few thousand gpd (or gallons per several days dependent upon offloading frequency) based on fishing vessel type and platform)</p>	<p><b>Fecal coliform, enterococci</b> (detected in only 1 sample well above ambient concentrations; PHQs of 8,900 and 68 respectively)</p>	<p>NA</p>	<p><b>Copper</b> (detected in 23 of 26 samples - PHQs from 1 to 300. Max. conc. of 921 µg/L in shrimper)</p>	<p><b>Arsenic</b> (detected in 16 of 26 samples; conc. from 3.1 to 380 µg/L – PHQs from 170 to potentially 21,000 because very low NRWQC)</p>		<p><b>BOD and COD</b> (detected in 24 of 26 BOD samples- all COD samples; median concentrations of BOD and COD were 440 and 940 mg/L with max of 5,100 and 8,700 mg/L equivalent to sewage sludge)</p> <p><b>Sulfide</b> (detected in 7 of 25 samples – PHQs between 5 and 80; max. concentrations = 0.16 mg/L in fish trawler)</p> <p><b>TSS</b> (detected in all of 26 samples – PHQs of 4 samples between 17 and 37)</p> <p><b>DO</b> (hypoxic, i.e., ≤ 2.0 mg/L in 3 of 26 samples – all purse seiners)</p>	<p><b>Ammonia</b> (detected in 25 of 26 samples; conc. from 0.087 to 160 µg/L – PHQ at max conc. = 133)</p> <p><b>TKN</b> (detected in 25 of 26 samples; values indicative of strong sewage)</p> <p><b>Total phosphorus</b> (detected in 25 of 26 samples - all but 3 samples resulting in PHQs above 10; highest PHQ=760)</p>	<p>NA</p>	<p>Level of detection of all analytes similar in fish hold cleaning effluent, although concentrations somewhat reduced.</p> <p>HEM detected at a max conc. = 16 mg/L; PHQ = 1.</p>

**Table 5.1. Analytes of Potential Risk by Discharge<sup>1</sup>**

Discharge Type (Volume/vessel)	Analyte Group								
	Microbiologicals	Volatile and Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Classical Pollutants	Nutrients	Nonylphenols <sup>32</sup>	Comments
<p><b>Graywater</b> (tugs – 130 gpd; taxis – 75 gpd; fishing – a few to few hundred gpd)</p>	<p><b><i>E. coli</i>, Fecal coliform, enterococci</b> (detected in 7 of 8 samples collected - concentrations of fecal coliform generally highest in mixed shower/sink samples; PHQs as high as 1,000)</p>	<p>NA</p>	<p><b>Copper</b> (detected in all of 8 samples - PHQs from 1.7 to 90. Max. conc. of 280 µg/L in tugboat)</p> <p><b>Zinc</b> (detected in all of 8 samples - max. conc. = 1,500 µg/L in sink water from a water taxi; PHQ = 19)</p>		<p><b>HEM</b> (detected in all of 8 samples - 4 samples with PHQ 2 or more. Concentrations from 9.4 to a max of 100 mg/L in tugboats)</p> <p><b>SGT HEM</b> (detected in 6 of 8 samples – only 1 sample with PHQ &gt;2. Range of concentration 1.3 to a max of 35 mg/L from a tugboat)</p>	<p><b>Sulfide</b> (detected in 5 of 8 samples – PHQs between 4.8 and 370; max. concentration = 0.73 mg/L in tugboat)</p> <p><b>BOD and COD</b> (detected in all of 8 samples; median concentration of BOD and COD were 260 and 440 mg/L, respectively with max of 1,200 and 4,000 mg/L indicative of strong sewage)</p>	<p><b>Total phosphorus</b> (detected in 8 of 8 samples – all but 3 PHQs above 10; highest PHQ=34 in tugboat)</p>		<p>Only 1 of 8 vessels sampled had detectable concentrations of NPEOs of the shortest chain (NP3EO) indicative of detergents; concentration of 0.99 µg/L.</p>

**Table 5.1. Analytes of Potential Risk by Discharge<sup>1</sup>**

Discharge Type (Volume/vessel)	Analyte Group								Comments
	Microbiologicals	Volatile and Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Classical Pollutants	Nutrients	Nonylphenols <sup>32</sup>	
<b>Propulsion Engine Effluent – inboard</b> (20 gpm – high power)	NA	<b>PAHs</b> (6 probable carcinogenic PAHs detected in sample from a recreational vessel with a gasoline engine. Measured concentrations result in PHQs from 2,100 to 4,800)	<b>Copper</b> (detected in 12 of 13 samples - PHQs from 3 samples from 11 to 17. Max. conc. of 53 µg/L in sample from water taxi at idle)			<b>Temperature</b> (high idle only; temperature increases of up to 20°C)	NA	NA	Note: Though the recreational vessel with the gasoline engine is not a “study vessel”, it represents EPA’s only samples from a gasoline engine. EPA assumes gasoline engines from similarly designed study vessels would have similar characteristics.
<b>Propulsion Engine Effluent – outboard</b> (1 to 2 gpm)	NA	<b>Benzene</b> (detected in 6 of 6 samples – only one sample with a PHQ above 10; value of 28 based on a max. conc. of 62 µg/L in sample from research vessel averaged from variable speeds)					NA	NA	

**Table 5.1. Analytes of Potential Risk by Discharge<sup>1</sup>**

Discharge Type (Volume/vessel)	Analyte Group								
	Microbiologicals	Volatile and Semivolatile Organic Compounds	Metals (dissolved)	Metals (total)	Oil and Grease	Classical Pollutants	Nutrients	Nonylphenols <sup>32</sup>	Comments
<b>Engine Effluent - Generator</b> (5 to 25 gpm)	NA	<b>Benzene</b> (detected in 3 of 5 samples – only one sample with a PHQ approaching 10; value of 9 based on a max. conc. of 21 µg/L in sample from a fire boat)					NA	NA	
<b>Firemain Systems</b> (no volume estimated- used infrequently)	NA		<b>Copper</b> (detected in 4 of 6 samples - PHQs from 3.8 to 23; highest for a tour boat)				NA	NA	

Notes:

(1) Generally includes analytes when a large proportion of the samples have concentrations exceeding the NRWQC, when several of the samples have PHQs > 10, when a few samples result in PHQs greatly exceeding the screening benchmark (i.e., 100s to 1,000s), or, in the case of oil and grease and for nonylphenol, when one or more samples exceed an existing regulatory limit by more than a factor of 2. See text above and in Section 3.1.3 for a definition of PHQs and Table 3.1 for screening benchmarks used to calculate these values.

(2) Longer chain nonylphenol and octylphenol ethoxylates degrade to shorter chained ethoxylates under aerobic conditions. In general, the shorter the chain, the more hydrophobic, persistent, and toxic the substance becomes. 4-Nonylphenol (NP) is a shorter-chain nonylphenol that has been found in surface water and is toxic to aquatic life. NP is formed from the longer chain nonylphenol and octylphenol ethoxylates as they break down. The time span from time of use on the vessel to time of sampling of the discharge was probably not long enough for this to occur, except for discharges of bilgewater.

gpm = gallons per minute

gpd = gallons per day

NA - Not applicable; discharge not analyzed for this analyte group.

## **5.3 SUMMARY OF PREDICTED IMPACTS FROM SELECT POLLUTANTS IN STUDY VESSEL DISCHARGES**

### **5.3.1 Potential Watershed-Wide Impacts from Study Vessels**

Using estimated discharge volumes and average pollutant concentrations, EPA evaluated the potential for cumulative effects of the discharges from an assemblage of study vessels on a large hypothetical harbor. The evaluation used a screening-level water quality model to estimate the pollutant concentration into several hypothetical harbors based on different scenarios of vessel groups. Model assumptions included instantaneous and universal dilution of vessel discharges in the harbor and a background concentration of zero for all analytes in the harbor environment (i.e., the model is not able to evaluate whether vessel discharges are likely to cause environmental or human health impacts in the immediate vicinity of the vessel discharges or in small water bodies). Instead, the model can only analyze potential vessel loadings to and impacts on hypothetical large water bodies. Furthermore, the model is not able to analyze parameters that do not have numeric aquatic life or human health based criteria such as BOD or nutrients.

The model did not predict that discharges from the study vessels solely exceeded aquatic life or human health NRWQC for any of the hypothetical harbor scenarios evaluated. This is primarily due to the large dilution predicted in these large harbors (even with low flushing). However, some of these pollutants from these vessels could reasonably have more significant local impacts (although determining this is outside the scope of the model used in this study). In smaller water bodies with many vessels or in more confined areas of a harbor with little to no flushing, EPA believes study vessel discharges have the potential to cause or contribute to exceedances of NRWQC in receiving waters.

Under the low-dilution scenarios, dissolved copper and total arsenic discharges represent the greatest environmental concern and are more likely than other pollutants to contribute to exceedances of water quality standards, particularly if there are other sources of these pollutants (e.g., stormwater runoff) present. These results are summarized below.

#### Dissolved Copper

EPA determined that the loading rates of dissolved copper from a metropolitan harbor likely posed the greatest potential risk to human health and aquatic life from study vessels on a large scale. Compared to other types of harbors, a metropolitan harbor has a higher level of activity from its vessel population and has more support utility vessels such as supply boats, tow/salvage vessels, and tugboats. The model predicted that discharges from study vessels have the reasonable potential to contribute a significant load of dissolved copper to a water body. Furthermore, when considering the loadings of dissolved copper from other sources (e.g., recreational vessels, large commercial vessels, stormwater runoff, and industrial and municipal

point sources), the model results suggest a reasonable potential for the concentrations of dissolved copper to exceed the NRWQC in this type of harbor.

The results of this study are consistent with real-world observations that metals are frequently associated with vessel discharges in concentrations of potential environmental concern. Environmental impacts from dissolved copper leaching from antifouling hull coatings have been well documented in low-flushing environments in harbors with large numbers of recreational vessels, such as the Shelter Island Yacht Basin near San Diego, California, and Marina Del Rey Harbor in Los Angeles, California (see Section 3.3.8.1 of this report). The impacts from the high levels of dissolved copper include reduced primary production and productivity; accumulation of copper in sediments, reducing sediment quality; and chronic low-level toxicity to aquatic organisms, especially sensitive mollusks, crustaceans, and echinoderms.

### Total Arsenic

EPA determined that the loading rates of total arsenic (and to a certain extent, dissolved arsenic) may pose a potential risk to human health and the environment in low-dilution or low-flushing environments. Arsenic was found to be ubiquitous in this study, both in vessel discharges and in ambient water<sup>6</sup>. Although arsenic concentrations in ambient water can be quite high in select harbors, certain discharges from study vessels contribute to the overall arsenic load. While the source of total arsenic in vessel discharges is unknown, EPA suspects that atmospheric deposition contributes to total arsenic concentrations in deck washdown and possibly in bilgewater. Total arsenic in fish hold discharges may be biological in origin (from seafood catch) or from sediment entrained in the catch. The biological contribution of arsenic may be significant in that total arsenic concentrations are substantially greater in seawater organisms than in freshwater organisms (Francesconi and Kuehnelt, 2002; USEPA 2003b).

The greatest impact of high total arsenic in harbors is primarily via the food chain and subsequent bioaccumulation to high levels in seafood consumed by humans. Arsenic exposure through drinking water is also of concern where receiving water is used as a source for drinking water. Arsenic is strongly linked to cancer in humans and a potent inhibitor of certain enzymes in vertebrates.

### **5.3.2 Potential Localized or Near-Field Impacts of Vessel Discharges to Receiving Waters**

EPA found that some study vessel incidental discharges may pose an environmental threat in confined water bodies with low flushing rates and a large population of vessels, in water bodies that are hypoxic or hypereutrophic, and/or where the background concentrations or other

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<sup>6</sup> See discussion in Section 3.1.3 regarding potential positive interference which may have resulted in elevated measured concentrations of arsenic for a subset of samples.

sources of these pollutants are significant. In addition to the parameters (copper and arsenic) discussed in Section 5.3.1, the following classical pollutants may likely exhibit near-field effects.

### BOD and COD

In general, oxygen-demanding compounds in vessels discharges (measured as BOD and COD) are expected to pose little risk to the environment due to the relatively low volume of vessel discharges that contain these pollutants. However, the frequency and magnitude of BOD and COD in certain discharges (as much as 25 times the concentrations found in raw sewage) warrant additional discussion.

Specifically, the relatively high BOD and COD concentrations in fish hold and fish hold cleaning effluent could pose a localized water quality impact in areas such as small side embayments where flushing rates are low or where portions of the water body are already low in dissolved oxygen. The high levels of BOD result from the degradation of organic material and its by-products in the fish hold. Higher volume discharges with high BOD concentrations (e.g., certain fish hold effluent) may contribute to localized hypoxic conditions in receiving waters, depending on the volume of effluent discharged, the number of vessels discharging in confined areas, and other factors such as season and water temperature.

### Pathogen Indicators

Bacteria such as *E. coli*, enterococci, and fecal coliforms are generally of limited concern for most discharges where the pathogens were present (i.e., bilgewater, deck washdown, and fish hold discharges). However, high levels of pathogens in graywater (and potentially other discharge types) may pose some risk to human health and larger vessels with additional crew or passengers are expected to generate considerably more graywater than smaller vessels. However, looked at on a relative basis, the risk from pathogens in graywater is substantially lower than risks from other sources that cause very high concentrations of pathogen indicators in surrounding ambient water. For example, during sampling for this study in Massachusetts that took place in wet weather, a sanitary sewer overflow and a combined sewer overflow caused extremely high pathogen indicator counts in two different harbors, relative to what would be expected from graywater discharges from study vessels.

### Total Phosphorus

Nutrients in vessel discharges are generally expected to pose little risk to the environment. However, the frequency and magnitude of total phosphorus in certain discharges warrants some additional discussion.

The environmental effects of nutrients are driven by site-specific environmental conditions (e.g., receiving water temperature, types of algae present, and limiting nutrient conditions). For example, nutrients in vessel discharges may contribute to an environmental

effect in one water body, but not another depending on a variety of environmental conditions that control eutrophication (excess productivity in a water body). While EPA has not developed NRWQC for total phosphorus and other nutrients in coastal waters, some states have established water-body-specific or state-wide standards for nutrients based on site-specific evaluations.

As mentioned above, the water quality impact of concern for total phosphorus is eutrophication. The first indications of potential problems are the increased ambient levels of total phosphorus, often followed by an immediate increase in the density (biomass) of the planktonic algal community. This increased algal biomass usually blocks light and reduces water clarity and may contribute to nuisance algal blooms and declining dissolved oxygen. Of note in this study was that the mean total phosphorus concentration in the 15 ambient water samples collected was two times the screening benchmark, suggesting that the incremental effect of discharges from study vessels may be small.

#### **5.4 POSSIBLE BENEFITS TO HUMAN HEALTH, WELFARE, AND THE ENVIRONMENT FROM REDUCING, ELIMINATING, CONTROLLING, OR MITIGATING ONE OR MORE OF THE DISCHARGES FROM THE STUDY VESSELS**

Some vessel discharges from commercial fishing vessels and commercial vessels less than 79 feet in length may have the potential to impact the aquatic environment and/or human health. As noted above, using the results obtained in this study, EPA modeled a hypothetical large harbor to evaluate the potential water quality impacts caused by the nine vessel discharge types EPA sampled. Based on this evaluation, EPA determined that the incidental discharges from study vessels to a relatively large water body are not likely to solely cause an exceedance of any NRWQC (i.e., these discharges are unlikely to pose acute or chronic excursions of the NRWQC across an entire large water body). However, many of the pollutants in the vessel discharges were at end-of-pipe concentrations that exceeded an NRWQC, and therefore have the potential to contribute to an exceedance of water quality standards at a more localized scale. The study results indicate that total arsenic and dissolved copper are the most significant water quality concern for the study vessels as a whole. These pollutants are more likely than other pollutants to contribute to exceedances of water quality standards, particularly if there are other sources of pollutants or the receiving water already has high background concentrations.



**Gloucester Harbor faces many environmental stressors including Combined Sewer Overflows and Urban Stormwater Runoff. For most pollutants, the impact of these sources may be more significant than from study vessels. However, some pollutants, such as copper or BOD are discharged in notable quantities from certain study vessel discharges.**

Like an individual house in an urban watershed, most individual vessels have only a minimal environmental impact. However, the impacts caused by these vessels is potentially significant where there are high vessel concentrations, low circulation in waters, additional environmental stressors, or pollutant loadings from other sources (e.g., recreational vessels, large commercial vessels, stormwater runoff, and industrial and municipal point sources). Reducing certain discharges or certain pollutants in discharges from these vessels in sensitive waters may result in significant environmental benefits to those waters; however, EPA did not analyze the feasibility or cost of managing these discharges as part of this study.