EPA842-R-07-005

United States
Environmental Protection
Agency

Draft Cruise Ship Discharge Assessment Report

U.S. Environmental Protection Agency

Oceans and Coastal Protection Division
Office of Wetlands, Oceans, and Watersheds

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December 2007

ACKNOWLEDGMENTS AND DISCLAIMER

Today's Draft Report does not substitute for any statute or regulation, nor is it a regulation itself. The document assesses five primary cruise ship wastestreams, specifically, sewage, graywater, bilge water, solid waste, and hazardous waste. For each wastestream, the Draft Report discusses: the nature and volume of the wastestream generated; existing federal regulations applicable to the wastestream; environmental management, including treatment, of the wastestream; potential adverse environmental impacts of the wastestream; and actions by the federal government to address the wastestream. The Draft Report includes a discussion the existing federal regulations application to each wastestream to illuminate the Agency's current thinking and, among other things, invites public comment. As a draft upon which EPA invites comment, the discussion of existing regulations does not represent the consummation of the Agency's decision-making on the matters discussed. By its terms, the Draft Report itself does not impose binding requirements on any party. The regulations themselves, not the Draft Report, govern parties' legal obligations.

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1.1 Overview

Cruise ships operate in every ocean worldwide, often in pristine coastal waters and sensitive marine ecosystems. Cruise ship operators provide amenities to their passengers that are similar to those of luxury resort hotels, including pools, hair salons, restaurants, and dry cleaners. As a result, cruise ships have the potential to generate wastes similar in volume and character to those generated by hotels.

The cruise industry is one of world's fastest growing tourism sectors, with the number of cruise ship passengers growing nearly twice as fast as any other travel sector over the last 10 years (CELB, 2003). In addition, average ship size has been increasing at the rate of roughly 90 feet every five years over the past two decades (Bell, 2007). As the cruise industry continues to expand, there is an increasing concern about the impacts cruise ships may have on water quality.

In March 2000, an environmental advocacy group called the Bluewater Network, representing 53 environmental organizations, submitted a petition to the U.S. Environmental Protection Agency (EPA) requesting that EPA identify and take regulatory action on measures to address pollution by cruise ships. Specifically, the petition requested an in-depth assessment of the volumes and characteristics of cruise ship waste streams; analysis of their potential impact on water quality, the marine environment, and human health; examination of existing federal regulations governing cruise ship waste streams; and formulation of recommendations on how to better control and regulate these waste streams. The petition also included specific requests related to sewage, graywater, oily bilge water, solid wastes, and hazardous wastes, as well as monitoring, record-keeping, and reporting. In addition, the petition requested that EPA prepare a report of the requested assessment.

This Draft Cruise Ship Discharge Assessment Report (Draft Report) responds in part to the petition from Bluewater Network. The Draft Report examines five primary cruise ship waste streams—sewage, graywater, oily bilge water, solid waste, and hazardous waste. For each waste stream, the Draft Report discusses (1) what the waste stream is and how much is generated; (2) what laws apply to the waste stream; (3) how the waste stream is managed; (4) potential environmental impacts of the waste stream; and (5) actions by the federal government to address the waste stream.

The most significant new analysis provided in this Draft Report relates to the generation and treatment of sewage and graywater onboard cruise ships. Pursuant to federal legislation entitled "Certain Alaskan Cruise Ship Operations" (33 U.S.C. 1901 Note), EPA has carried out a multi-year project to determine whether revised or additional standards for sewage and graywater discharges from large cruise ships operating in Alaska are warranted under that legislation. Much of the information and data collected for the Alaska effort are summarized in this Draft Report.

There are a number of other waste streams that may be generated onboard cruise ships, some of which may be considered incidental to the normal operation of a vessel (e.g., ballast water, deck runoff, hull coat leachate), as well as air pollution. This Draft Report does not present an assessment of any of these other waste streams. However, as part of a separate effort, EPA has begun an administrative process to prepare for regulation of discharges incidental to the normal operation of a vessel that, as of September 30, 2008, will no longer be excluded from Clean Water Act permitting requirements by virtue of a recent Court decision, which vacated the EPA regulation that had excluded these discharges from those requirements (see 72 FR 34241, June 21, 2007; notice of intent; request for comments and information). In addition, under the Clean Air Act, EPA established emissions standards for nitrous oxides (NOx) from "Category 3" marine diesel engines, which are very large marine engines used primarily for propulsion power on ocean-going vessels such as container ships, tankers, bulk carriers, and cruise ships (68 FR 9746, 9747, Feb. 28, 2003). EPA promulgated those regulations in 40 CFR Part 94. Recently, EPA solicited public comment on the scope of the rules that EPA should propose for a second tier for Category 3 engines (72 FR 69522, Dec. 7, 2007). Finally, EPA has proposed regulations to establish more stringent standards for particulate matter, NOx, and hydrocarbons from Category 2 marine engines (72 FR 15938, April 3, 2007).

1.2 Other EPA Cruise Ship Efforts

In addition to developing this Draft Report, EPA has engaged in a number of activities addressing the potential environmental impacts of cruise ships. These efforts are summarized below.

Cruise Ship White Paper, August 2000
This White Paper provided preliminary information regarding cruise ship discharges and waste management practices in response to the petition submitted by the Bluewater Network on March 17, 2000. The White Paper can be accessed at:
www.epa.gov/owow/oceans/cruise_ships/white_paper.pdf

Cruise Ship Public Hearings, September 2000
As part of its effort to gather information on cruise ship discharges and waste management practices, EPA, together with the U.S. Coast Guard and other federal agencies, solicited public input from industry officials, government agencies, environmental groups, and concerned citizens through three regional public information hearings in Los Angeles, CA (September 6, 2000), Juneau, AK (September 8, 2000), and Miami, FL (September 12, 2000). Summaries and transcripts of these public hearings can be accessed at:
www.epa.gov/owow/oceans/cruise_ships/publichearings.html

Cruise Ship Plume Tracking Survey, Summer 2001
EPA conducted a survey to study the dilution of discharges from cruise ships in June 2001. This survey tracked plumes of water and Rhodamine WT dye released through normal wastewater effluent discharge systems in ships operating off the Florida coast to provide information on dilution of cruise ship discharges in offshore waters. This survey also provided preliminary information on whether cruise ship sewage or graywater discharge plumes behave as predicted

by a model developed for Alaska waters. The Cruise Ship Plume Tracking Survey Report can be accessed at: www.epa.gov/owow/oceans/cruise_ships/plumerpt2002/plumereport.pdf
The Cruise Ship Plume Tracking Survey Plan can be accessed at:
www.epa.gov/owow/oceans/cruise_ships/surveyplan.pdf

Cruise Ship Hazardous Waste Tracking System, December 2001

On December 4, 2001, EPA Headquarters urged the Agency's Regions to assign a single tracking number for each cruise ship entering waters of multiple states for purposes of the Resource Conservation and Recovery Act (RCRA). RCRA imposes management requirements on generators, transporters, and other handlers of hazardous waste. Cruise ships regularly use chemicals for operations ranging from routine maintenance to passenger services, such as dry cleaning, beauty parlors, and photography labs. Thus, cruise ships are potentially subject to RCRA requirements to the extent those chemicals result in the generation of hazardous wastes. Under RCRA, each state assigns a hazardous waste tracking number to each cruise ship that enters its waters. However, assignment of tracking numbers by multiple states can result in a single ship having several different tracking numbers for the same waste. Assigning a single tracking number for each cruise ship entering waters of multiple states for purposes of RCRA should result in improved tracking of hazardous wastes generated on cruise ships, increased compliance with RCRA requirements, as well as reduce paperwork for the cruise ships. The EPA memorandum of December 4, 2001, can be accessed at:
www.epa.gov/owow/oceans/cruise_ships/haz_tracking.html

Evaluation of Standards for Sewage and Graywater Discharges from Cruise Ships in Alaska

On December 12, 2000, Congress passed HR 4577, "Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriations Act, 2001," which contained Title XIV, a section called "Certain Alaskan Cruise Ship Operations" (33 U.S.C. 1901 Note) (Title XIV). Title XIV established enforceable discharge standards for sewage and graywater from large cruise ships (those authorized to carry 500 or more passengers for hire) while operating in the Alexander Archipelago and the navigable waters of the United States in the State of Alaska and within the Kachemak Bay National Estuarine Research Reserve. This law authorizes EPA to develop revised and/or additional standards for these discharges in Alaska.

Pursuant to Title XIV, EPA has carried out a multi-year project to determine whether revised and/or additional standards for sewage and graywater discharges from large cruise ships operating in Alaska are warranted under that law. EPA sampled wastewater from four cruise ships that operated in Alaska during the summer of 2004 and 2005. The purpose of this sampling was to characterize graywater and sewage generated onboard and to evaluate the performance of various advanced sewage and graywater treatment systems. EPA also distributed a "Survey Questionnaire to Determine the Effectiveness, Costs, and Impacts of Sewage and Graywater Treatment Devices for Large Cruise Ships Operating in Alaska " to all cruise ships authorized to carry 500 or more passengers for hire that operated in Alaska in 2004. The information collected by the survey includes general vessel information; sources of graywater and sewage; ship-board plumbing systems; data on the effectiveness of sewage and graywater treatment systems in removing pollutants; and costs of these systems.

Using these sampling results, survey responses, and other relevant information, EPA is performing environmental, economic, and engineering analyses to determine whether revised or additional standards in Alaska are warranted under Title XIV. EPA anticipates announcing its determination and making its analyses publicly available in 2008. Much of the information and data collected for EPA's effort under Title XIV are summarized in this Draft Report. More information, including EPA's 2004 and 2005 Alaska cruise ship sampling results, EPA's Generic Sampling and Analysis Plan, and EPA's cruise ship survey questionnaire, can be accessed at: www.epa.gov/owow/oceans/cruise_ships/sewage_gray.html

1.3 Cruise Ship Industry Efforts to Reduce Potential Environmental Impacts

The Cruise Lines International Association (CLIA) was formed in 1975 to promote the benefits of cruising. In 2006, CLIA merged with the International Council of Cruise Lines (ICCL), a sister entity created in 1990 to participate in the regulatory and policy development process on behalf of the cruise industry. According to CLIA, it is now the world's largest cruise association, composed of 24 of the major cruise lines serving North America and representing 97% of the cruise capacity marketed from North America. CLIA operates pursuant to an agreement filed with the Federal Maritime Commission under the Shipping Act of 1984 and serves as a non-governmental consultative organization to the International Maritime Organization.

CLIA members have agreed to adopt mandatory environmental standards for all of their member line cruise ships. Compliance with these standards is a condition of membership in CLIA. All CLIA member cruise ship operators must implement the adopted standards, which address, among others, the following waste streams: graywater and blackwater (sewage) discharges; bilge and oily water residues; incinerator ash; hazardous chemical waste such as photo processing fluid and dry-cleaning chemicals; unused and outdated pharmaceuticals; used batteries; burned out fluorescent and mercury vapor lamps; and glass, cardboard, aluminum and steel cans.

Each CLIA member line operating internationally under the Safety of Life at Sea (SOLAS) Convention (a major international convention dealing with maritime safety that covers a wide range of measures to improve vessel safety including design, construction, and equipment standards) has agreed to integrate these industry standards into its Safety Management System (SMS), which is required by the International Safety Management (ISM) Code (a component of SOLAS). CLIA member lines are thus subject to the internal and external audits mandated by the ISM code. SMS Plans frequently employ the use of third party verification companies (also known as classification societies) such as Det Norske Veritas, Lloyds Register, and American Bureau of Shipping to certify compliance with ISM standards. Oversight for compliance with ISM requirements is carried out through ISM audits by the classification societies and by inspections by the flag states and the U.S. Coast Guard.

For U.S. flagged cruise vessels that are not required to have SOLAS certificates but who are CLIA members (i.e., a small number of very small river cruisers and coastal operators), the U.S. Coast Guard has direct oversight and inspection authority. Further, CLIA member lines falling into this category have included the industry standards in their company safety management system and undertake equivalent auditing measures as well.

In addition, CLIA member cruise lines have committed to these principles (CLIA, 2006):

- Designing, constructing and operating vessels to minimize their impact on the environment;
- Developing improved technologies to exceed current requirements for protection of the environment;
- Implementing a policy goal of zero discharge of MARPOL, Annex V solid waste products (garbage) and equivalent US laws and regulations, by use of more comprehensive waste minimization procedures to significantly reduce shipboard-generated waste;
- Expanding waste reduction strategies to include reuse and recycling to the maximum extent possible, to deposit even smaller quantities of waste products ashore;
- Improving processes and procedures for collection and transfer of hazardous waste; and
- Strengthening comprehensive programs for monitoring and auditing of onboard environmental practices and procedures in accordance with the International Safety Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code).

References

Bell, Tom. 2007 (September 28). Experts: Mega-berth needed for cruise ships. *Portland Press Herald*. (www.pressherald.mainetoday.com/story_pf.php?id=137059&ac=PHnws)

Center for Environmental Leadership in Business (CELB). 2003. *A Shifting Tide: Environmental Challenges and Cruise Industry Responses.* Washington, DC. (www.celb.org/ImageCache/CELB/content/travel_2dleisure/cruise_5finterim_5fsummary_2epdf/v1/cruise_5finterim_5fsummary.pdf)

Cruise Line International Association (CLIA). 2006. *CLIA Industry Standard: Cruise Industry Waste Management Practices and Procedures*. Fort Lauderdale, FL. (www.cruising.org/industry/PDF/CLIAWasteManagementAttachment.pdf and www.cruising.org/industry/PDF/CLIAWasteManagement.pdf)

Section 2: Sewage

Sewage from vessels, also known as "black water," generally means human body wastes and the wastes from toilets and other receptacles intended to receive or retain body wastes. On most cruise ships, sewage is treated using a marine sanitation device that biologically treats and disinfects the waste prior to discharge. On some cruise ships, especially many of those traveling to Alaska, sewage and often graywater are treated using Advanced Wastewater Treatment systems that provide higher levels of biological treatment, solids removal, and disinfection as compared to traditional marine sanitation devices.

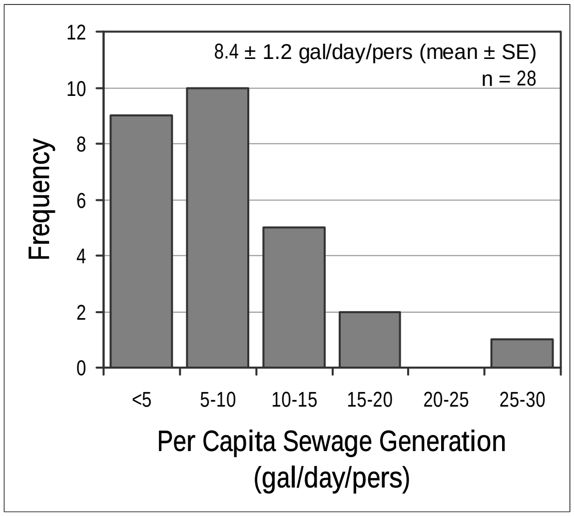
This section discusses the current state of information about vessel sewage, the laws regulating sewage discharges from vessels, the types of equipment used to treat sewage generated on cruise ships and how well they remove various pollutants, the potential environmental impacts of cruise ship sewage discharges, and federal actions taken to address sewage from cruise ships.

2.1 What is sewage from vessels and how much is generated on cruise ships?

Sewage from vessels, also known as "black water," generally means human body wastes and the wastes from toilets and other receptacles intended to receive or retain body wastes. On some ships, medical sink and medical floor drain wastewater is commingled with sewage for treatment.

Cruise ship sewage systems generally use fresh water to reduce corrosion, and vacuum flushing and conveyance to reduce water use. According to responses to EPA's survey of 29 cruise ships operating in Alaska in 2004, the average amount of water needed per toilet flush is 0.3 gallons. Only one of the ships surveyed uses seawater in their sewage system; this gravity system uses 1 gallon of seawater per toilet flush. For comparison, the latest water-saving, high-efficiency domestic toilets for land-based use typically use about 1.3 gallons per flush.

Sewage generation rates reported in response to EPA's 2004 survey ranged from 1,000 to 74,000 gallons/day/vessel or 1.1 to 27 gallons/day/person. EPA is not able to independently confirm the accuracy of these estimated rates. Average reported sewage generation rates were 21,000 gallons/day/vessel and 8.4 gallons/day/person (see Figure 2-1). There appears to be no relationship between per capita sewage generation rates and number of persons onboard (see Figure 2-2).



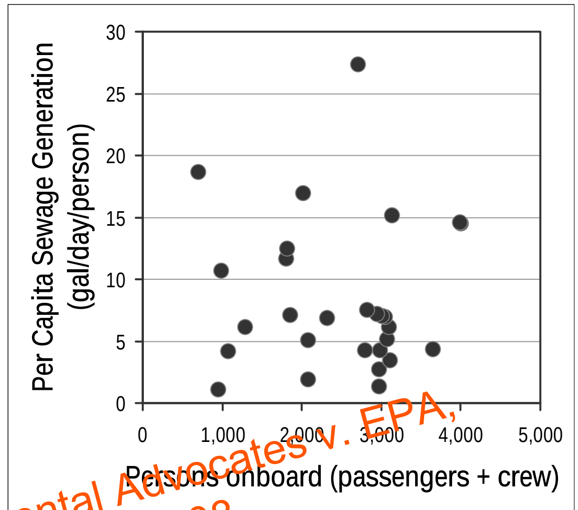


Figure 2-1. Per Capita Sewage Generation as Reported in EPA's 2004 Cruise Ship Survey

Figure 2-2. Sewage Generation by Persons Onboard as Reported in EPA's 2004 Cruise Ship Survey

During EPA's 2004 sampling of four ships with Advanced Wastewater Treatment systems (AWTs), sewage generation was measured on one ship at 17 gal/day/person (EPA, 2006a). On other ships, measurements were made of sewage plus graywater sources treated by the AWT (see Section 3 for more information on graywater).

Treated sewage discharge rates are nearly equivalent to sewage generation rates. Differences between these two rates are attributed to the volume of wastewater treatment sludge, if any, that is removed during wastewater treatment (see subsection 2.3.3 below).

Cruise ship capacity to hold untreated sewage varies significantly. According to responses to EPA's 2004 cruise ship survey, sewage holding capacity ranges from 0.5 to 170 hours, with an average holding capacity of 62 hours.

2.2 What laws apply to sewage from cruise ships?

2.2.1 Clean Water Act Section 312

Section 312 of the Clean Water Act (CWA; 33 U.S.C. § 1322) requires that vessels with installed toilet facilities be equipped with an operable marine sanitation device (MSD), certified by the Coast Guard to meet EPA performance standards, in order to operate on the navigable waters of the United States, including the territorial seas. CWA section 312 also establishes procedures for the designation of no-discharge zones for vessel sewage. Section 312 is implemented jointly by EPA and the Coast Guard. EPA is responsible for developing performance standards for MSDs and working with states to establish no-discharge zones. The Coast Guard is responsible for certification of MSDs prior to sale, introduction or delivery into interstate commerce, or import into the United States for sale or resale. States may not adopt or enforce any statute or regulation of the state or a political subdivision with respect to the design, manufacture, installation or use of MSDs (except on houseboats). The Coast Guard and states are vested with authority to enforce the requirements of section 312. Persons who tamper with certified MSDs or sell non-certified MSDs, or who operate vessels required to have MSDs but do not, are subject to statutory penalties of up to $5,000 and $2,000, respectively, for each violation.

Marine Sanitation Devices
The term "marine sanitation device" (MSD) means equipment for installation onboard a vessel which is designed to receive, retain, treat, or discharge sewage, and any process to treat such sewage. CWA section 312(a)(6) defines sewage as human body waste and the wastes from toilets and other receptacles intended to receive or retain body waste. There are three types of MSDs recognized by the Coast Guard:

- Type I MSDs are flow-through treatment devices that commonly use maceration and disinfection for treatment of the sewage. Type I devices may be used only on vessels less than or equal to 65 feet in length. EPA's performance standard for Type I MSDs is an effluent with a fecal coliform count not to exceed 1000 per 100 millimeters of water, with no visible floating solids.
- Type II MSDs also are flow-through treatment devices, generally employing biological treatment and disinfection. Some Type II devices use maceration and disinfection. Type II MSDs may be used on vessels of any size. EPA's performance standard for Type II MSDs is an effluent with a fecal coliform count not to exceed 200 per 100 milliliters of water and total suspended solids no greater than 150 milligrams per liter of water.
- Type III MSDs are holding tanks, where sewage is stored until it can be properly disposed of at a shore-side pumpout facility or out at sea (beyond three miles from shore). Type III MSDs also may be used on vessels of any size. EPA is not aware of any cruise vessels that use Type III MSDs. However, a Type II MSD may serve as a Type III MSD if the vessel maintains all waste products onboard the vessel and transfers to a shore-side facility or discharges at least three nautical miles offshore.

The Coast Guard is responsible for certification of MSDs based on EPA's performance standards (listed above). The Coast Guard can certify a product line of MSDs for vessel installation and use if that product line complies with Coast Guard design and testing criteria (33 CFR Part 159), as confirmed by testing conducted at a qualified independent laboratory. After Coast Guard review and approval, each MSD model is designated an approval number ("certification"), typically valid for five years. MSDs manufactured before the certification expiration date are deemed to have met Coast Guard standards and may be installed on vessels; MSDs manufactured after the expiration date do not meet Coast Guard approval. Under Coast Guard policy, foreign-flagged vessels may use MSDs that have received a compliance test certificate under Annex IV of MARPOL (discussed below). The Coast Guard does not test the effluent from certified MSDs once installed onboard a vessel (except in Alaska under Title XIV; see subsection 2.2.3 below).

No-Discharge Zones
CWA section 312(f) authorizes the establishment of no-discharge zones (NDZs), areas in which discharges from vessels of any sewage, whether treated or not, are prohibited. States may establish an NDZ for some or all of their waters if EPA determines that adequate facilities for the safe and sanitary removal and treatment of the sewage are reasonably available. States also may

request that EPA establish NDZs by rulemaking (1) if EPA determines that the protection and enhancement of the quality of the waters require such a prohibition, or (2) to prohibit the discharge of vessel sewage into a drinking water intake zone. There are currently 65 NDZs in the United States covering 113 waterbodies; 62 of these NDZs were established by states.

2.2.2 The International Convention for the Prevention of Pollution from Ships

The principal international convention addressing discharge standards for vessel sewage is Annex IV to the International Convention for the Prevention of Pollution from Ships (also known as MARPOL). Annex IV defines sewage as "drainage from medical premises, toilets, urinals, spaces containing live animals and other waste waters when mixed with sewage waste streams." Although Annex IV was adopted in 1973, the Annex did not come into effect until September 2003, after ratification by the requisite number of states (and corresponding shipping fleet tonnage). Subsequent amendments entered into force on 1 August 2005.

Annex IV applies to countries that are a party to the Annex, and all vessels operating under their flags. It generally requires ships to be equipped with either a sewage treatment plant, a sewage comminuting and disinfecting system, or a sewage holding tank. Within three miles of shore, Annex IV requires that sewage discharges be treated by a certified MSD prior to discharge. Sewage discharges made between three and 12 miles of shore must be treated by no less than maceration and chlorination, and sewage discharges beyond 12 miles from shore are unrestricted. In addition, this Annex establishes certain sewage reception facility standards and responsibilities for ports of contracting parties.

Annex IV also establishes a model International Sewage Pollution Prevention Certificate. Vessel certification requires that a vessel install (1) a sewage treatment unit that meets IMO standards (MEPC.2(VI), Recommendation on International Effluent Standards and Guidelines for Performance Tests for Sewage Treatment Plants), (2) a holding tank with an established sewage holding capacity and a visual indicator of actual capacity, and (3) a pipeline to the vessel's exterior for sewage discharge into a reception facility at port.

The United States is not a party to MARPOL Annex IV. Under Coast Guard policy, however, foreign-flagged vessels operating in the United States may use MSDs that have received a compliance test certificate under Annex IV of MARPOL. For vessels flagged in countries that are party to MARPOL Annex IV, the vessel owner and flag state have the responsibility to ensure that the vessel complies with MARPOL requirements (as well as the other safety and environmental protection requirements of international conventions). The Coast Guard's responsibility is to verify that the vessel is in substantial compliance with the conventions, a determination that the Coast Guard makes if the treatment unit is in "good and serviceable condition." Because the majority of cruise ships are foreign-flagged, Annex IV certification remains an important aspect of cruise ship inspection activity in U.S. waters.

2.2.3 Certain Alaskan Cruise Ship Operations

On December 12, 2000, Congress enacted an omnibus appropriation that included new statutory requirements for certain cruise ship discharges occurring in Alaska (Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriations Act, 2001, Pub. L. No. 106-554, 114 Stat. 2763, enacting into law Title XIV of Division B of H.R. 5666, 114 Stat. 2763A-315, and codified at 33 U.S.C. § 1901 Note). Title XIV set discharge standards for sewage and graywater from certain cruise ships (those authorized to carry 500 or more passengers for hire) while operating in the Alexander Archipelago and the navigable waters of the United States in the State of Alaska and within the Kachemak Bay National Estuarine Research Reserve (referred to here as "Alaskan waters"). This federal law, referred to here as "Title XIV," also authorized EPA to develop revised or additional standards for discharges of sewage and graywater from cruise ships operating in Alaskan waters, if appropriate. In developing revised or additional standards, EPA must take into account the best available scientific information on the environmental effects of the regulated discharges and the availability of new technologies for wastewater treatment, and ensure that the standards are, at a minimum, consistent with all relevant State of Alaska water quality standards.

Before this law was passed, there was considerable concern about cruise ships discharging untreated sewage and graywater into areas within the Alexander Archipelago (a chain of islands in Southeast Alaska), but beyond three miles from any shore. In these areas, known as doughnut holes, the discharge of sewage was unregulated. Title XIV prohibited discharges of untreated sewage from cruise vessels and set requirements for discharges of treated sewage and graywater from cruise vessels into Alaskan waters, including the doughnut holes.

Specifically, Title XIV requires that discharges within one nautical mile of shore or discharges in any Alaskan waters when the ship is traveling under six knots meet stringent standards for fecal coliform (geometric mean of samples taken during any 30-day period does not exceed 20 fecal coliform/100ml and not more than 10% of the samples exceed 40 fecal coliforms/100ml) and chlorine (total chlorine residual does not exceed 10.0 micrograms/liter), and meet secondary treatment standards for biochemical oxygen demand, suspended solids, and pH (found at 40 CFR 133.102). Title XIV requires that discharges of treated sewage outside of one nautical mile from shore from vessels traveling at least six knots meet EPA's CWA section 312 performance standards for Type II marine sanitation devices (no more than 200 fecal coliforms per 100ml and no more than 150 milligrams total suspended solids per liter).

Title XIV requires the Coast Guard to incorporate an inspection regime into the commercial vessel examination program sufficient to verify compliance with the Act, authorizes the Coast Guard to conduct unannounced inspections and to require logbooks of all sewage and graywater discharges, and provides EPA and the Coast Guard with authority to gather information to verify compliance with the Act. Title XIV also authorizes Alaska to petition EPA to establish no-discharge zones for sewage and graywater from cruise ships.

Pursuant to Title XIV, EPA has carried out a multi-year project to determine whether revised or additional standards for sewage and graywater discharges from large cruise ships operating in Alaska are warranted under that legislation. EPA sampled wastewater from four cruise ships that operated in Alaska during the summer of 2004. The purpose of this sampling was to characterize graywater and sewage generated onboard and to evaluate the performance of various advanced sewage and graywater treatment systems. EPA also distributed a "Survey Questionnaire to Determine the Effectiveness, Costs, and Impacts of Sewage and Graywater Treatment Devices for Large Cruise Ships Operating in Alaska" to all cruise ships authorized to carry 500 or more passengers for hire that operated to Alaska in 2004. Using these sampling results, survey responses, and other relevant information, EPA is performing environmental, economic, and engineering analyses to determine whether revised or additional standards in Alaska are warranted. EPA anticipates announcing its determination and making its analyses publicly available in 2008. Much of the information and data collected for EPA's effort under Title XIV are summarized in this report.

2.2.4 National Marine Sanctuaries Act

The National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.), as amended, established a national program to designate certain areas of marine environments as areas of special national significance that warrant heightened care. The primary purpose of the law is to protect marine resources, such as coral reefs, sunken historical vessels or unique habitats, from degradation while facilitating public or private uses compatible with resource protection.

The Act authorizes NOAA to designate as National Marine Sanctuaries areas of the marine environment that have special aesthetic, ecological, historical, or recreational qualities, and to provide comprehensive and coordinated conservation management for such areas. The National Marine Sanctuary Program manages 13 sanctuaries and the Papahānaumokuākea Marine National Monument. Designated sanctuaries are managed according to site-specific management plans developed by NOAA that typically prohibit the discharge or deposit of most material. Discharges of graywater and treated vessel sewage, however, are sometimes allowed provided they are authorized under the Clean Water Act. In some sanctuaries the discharge of sewage is prohibited in special zones to protect fragile habitat, such as coral. The Act also provides for civil penalties for violations of its requirements or the permits issued under it.

2.3 How do cruise ships treat sewage?

As discussed above, any ship greater than 65 feet in length must use either a Type II (flow through treatment device) or Type III (holding tank) marine sanitation device (MSD). An increasing number of cruise ships are using more effective and expensive Type II MSDs, referred to as "Advanced Wastewater Treatment systems" (AWTs), to treat both sewage and graywater (generally wastewater from sinks, baths, showers, laundry, and galleys; see Section 3 for more information on graywater).

One recent estimate by the cruise industry is that roughly 40% of the International Council of Cruise Lines members' 130 ships (which make up two-thirds of the world fleet) have installed AWTs, with 10 to 15 more systems added each year (Choi, 2007). In 2006, 23 of 28 large cruise ships that operated in Alaskan waters had AWTs in order to meet the more stringent discharge requirements in effect there (see subsection 2.2.3 above). The remainder operated traditional Type II MSDs and held the treated sewage and untreated graywater in double-bottom ballast tanks for discharge outside Alaskan waters.

This subsection provides information on the types of MSDs most often used by cruise ships: traditional Type II MSDs (2.3.1) and AWTs (2.3.2). Specifically, it discusses how these systems work and how well they remove various pollutants from the wastestream. Subsection 2.4 (below) discusses potential environmental impacts of sewage from cruise ships.

2.3.1 Traditional Type II Marine Sanitation Devices

How it works

On most cruise ships with traditional Type II MSDs, sewage is treated using biological treatment and chlorination. Some cruise ships do not treat their sewage biologically, but instead use maceration and chlorination. Of the nine large cruise ships with traditional Type II MSDs that operated in Alaskan waters in 2004, six used biological treatment and chlorination, and three used maceration and chlorination.

Biological-chlorination MSDs operate similarly to land-based biological treatment systems for municipal wastewater treatment. The treatment system typically includes aerobic biological treatment to remove biochemical oxygen demand (BOD_5) and some nutrients, clarification and filtration to remove solids, and final chlorine disinfection to destroy pathogens (see Figure 2-3). The system also may include screening to remove grit and debris. Cruise ships typically install up to four systems, allowing one or two to be placed off-line for maintenance at any one time (ADEC, 2000b).

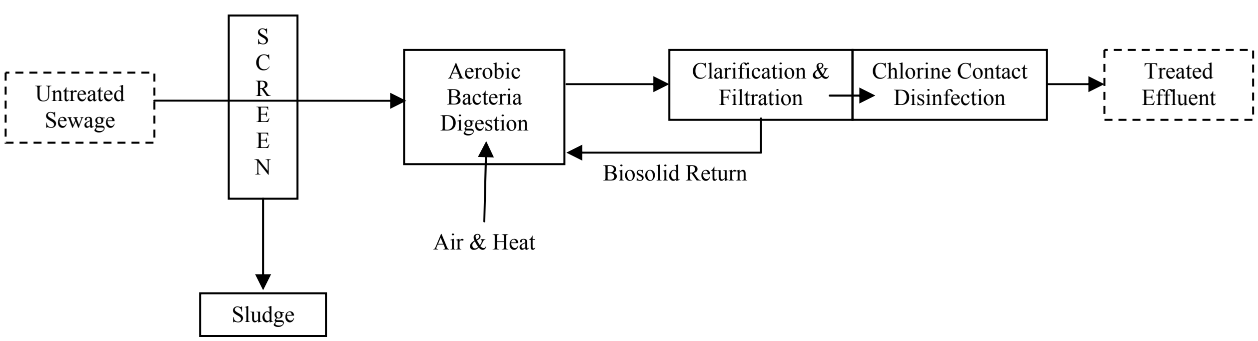


Figure 2-3. Simplified Schematic of Traditional Type II Marine Sanitation Device Using Biological Treatment and Chlorine Disinfection

Maceration-chlorination systems use screening to remove grit and debris, maceration for solids size reduction, and chlorine disinfection to oxidize and disinfect the waste. Chlorine is either added (sodium hypochlorite) or generated by mixing the sewage with sea water and then passing this solution between electrolytic cells to produce hypochlorite.

How well it works in practice

Data Collection

The primary information available on discharges from tradition Type II MSDs is from a voluntary sampling effort in Alaska in 2000 by the Alaska Cruise Ship Initiative (ADEC, 2001). These data are no longer representative of cruise ships operating in Alaska, which have mostly installed AWTs, but they may be indicative of the discharges from vessels with Type II MSDs operating in other waters. Twice during the 2000 cruise season, samples were collected from each sewage and graywater discharge port from each of the 21 large cruise ships operating in Alaska. (All except two of the sampled vessels treated sewage using traditional Type II MSDs. The other two vessels treated mixed sewage and graywater using prototype reverse osmosis Advanced Wastewater Treatment systems. Data from all 21 vessels, including the two vessels with reverse osmosis systems, are included in this summary because in most cases it was not possible to identify results from the two vessels with reverse osmosis systems.)

ACSI sampling was scheduled randomly at various ports of call on all major cruise routes in Alaska. Individual discharge samples characterized different types of wastewater depending on ship-specific discharge configurations. As a result, individual samples characterized one or more graywater sources, treated sewage, or combined graywater and treated sewage. Analytes included total suspended solids (TSS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pH, fecal coliform, total residual chlorine (TRC), free residual chlorine, and ammonia for all samples, and priority pollutants (metals, hydrocarbons, organochlorines) for one sample per ship. Samples were not taken of the influent to the treatment systems; therefore, percent removals achieved by these systems cannot be determined.

The results of this ACSI sampling are discussed in more detail below, but in summary, 43% of the samples for fecal coliform met the MSD standard of 200 fecal coliform per 100 ml, 32% of the samples for TSS met the MSD standard of 150 mg/l, and only 1 blackwater sample out of 70 samples met both the TSS and fecal coliform standards (ADEC, 2001).

The Coast Guard inspected six of the cruise ships with poor effluent samples and found that five out of the six were either operating the MSDs improperly or failing to maintain them (ADEC, 2000a).

Pathogen Indicators

Based on data collected by ACSI in 2000, the average fecal coliform concentration in traditional Type II MSD effluent was 2,040,000 MPN/100 mL (total of 92 samples, calculation used detection limits for nondetected results). The range was from nondetect (detection limit of 2) to 24,000,000 MPN/100 mL. Of the 92 samples, 51 were greater than 200 MPN/100 mL, 35 were greater than 100,000, and 22 were greater than 1,000,000. This compares to typical fecal coliform concentrations in untreated domestic wastewater of 10,000 to 100,000 MPN/100 mL (Metcalf & Eddy, 1991). Fecal coliform is the only pathogen indicator analyzed by ACSI. As mentioned above, these data are primarily for traditional Type II MSDs, but two of the 21 vessels sampled were using prototype reverse osmosis treatment systems.

Conventional Pollutants and Other Common Analytes

Table 2-1 shows ACSI sampling results for some conventional pollutants and other common analytes in MSD effluent, as well as typical concentrations in untreated domestic wastewater. These key analytes are commonly used to assess wastewater strength.

Table 2-1. Comparison of Traditional Type II MSD Effluent Concentrations to Untreated Domestic Wastewater–Conventional Pollutants and Other Common Analytes

Analyte	Average Conc. (± SE) of Cruise Ship Type II MSD Effluent[1]	Concentration in Untreated Domestic Wastewater[2]
Total Suspended Solids (mg/L)	627 (±94.3) (21 detects out of 21 samples)	100 to 350
Biochemical Oxygen Demand (5-Day) (mg/L)	133 (±15.2) (21 detects out of 21 samples)	110 to 400
Chemical Oxygen Demand (mg/L)	1,040 (±271) (3 detects out of 3 samples)	250 to 1,000
pH	90.5% of the pH samples are between 6.0 and 9.0 (21 detects out of 21 samples)	between 6.0 and 9.0
Total residual chlorine (µg/L)	1,070* (±499) (12 detects out of 18 samples)	No data

[1] Based on data collected by ACSI in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
[2] Metcalf & Eddy, 1991.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Metals

ACSI sampled for 13 priority pollutant metal analytes, of which 8 were detected in greater than 10% of the Type II MSD effluent samples (less frequent detection of analytes is considered not representative of the wastestream; in fact, of the metal analytes detected in any samples, none were detected in fewer than 10% of the samples) (see Table 2-2). Copper and zinc were detected in the greatest amounts.

Table 2-2. Traditional Type II MSD Effluent Concentrations–Metals

Analyte	Average Conc. (± SE) of Cruise Ship Type II MSD Effluent[1]
Cadmium (Total) (μg/L)	0.0624* (±0.0205) (3 detects out of 24 samples)
Chromium (Total) (μg/L)	5.99* (±2.50) (8 detects out of 24 samples)
Copper (Total) (μg/L)	954* (±398) (19 detects out of 24 samples)
Lead (Total) (μg/L)	6.94* (±2.72) (7 detects out of 24 samples)
Mercury (Total) (μg/L)	0.206* (±0.0574) (8 detects out of 22 samples)
Nickel (Total) (μg/L)	15.8* (±7.34) (5 detects out of 22 samples)
Silver (Total) (μg/L)	0.527* (±0.166) (9 detects out of 22 samples)
Zinc (Total) (μg/L)	514* (±97.3) (19 detects out of 22 samples)

[1] Based on data collected by ACSI in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Volatile and Semivolatile Organics

ACSI sampled for almost 140 volatile and semivolatile organic analytes. Of these, 16 were detected in at least 10% of effluent samples (less frequent detection of analytes is considered not representative of cruise ship effluent; analytes that were detected in fewer than 10% of samples were detected in only one or two samples). Table 2-3 presents the average volatile and semivolatile organic concentrations in Type II effluent for these 16 analytes. Some of the analytes in this table with the highest concentrations are chlorine byproducts, likely generated by sewage chlorination.

Table 2-3. Traditional Type II MSD Effluent Concentrations–Volatile and Semivolatile Organics

Analyte	Average Conc. (± SE) of Cruise Ship Type II MSD Effluent[1]
1,2-Dichloroethane (μg/L)	0.879* (±0.0666) (8 detects out of 21 samples)
1,4-Dichlorobenzene (μg/L)	17.4* (±16.6) (4 detects out of 21 samples)
Bis(2-ethylhexyl) phthalate (μg/L)	3.45* (±0.837) (16 detects out of 21 samples)
Bromodichloromethane (μg/L) [2]	33.7* (±12.7) (14 detects out of 21 samples)
Bromoform (μg/L) [2]	43.6* (±21.9) (13 detects out of 22 samples)
Carbon tetrachloride (μg/L)	1.96* (±1.12) (5 detects out of 24 samples)
Chloroform (μg/L) [2]	111* (±63.3) (21 detects out of 24 samples)
Chloromethane (μg/L)	24.4* (±12.9) (5 detects out of 22 samples)
Dibromochloromethane (μg/L) [2]	27.4* (±12.0) (11 detects out of 24 samples)
Diethyl phthalate (μg/L)	1.00* (±0.204) (5 detects out of 24 samples)
Di-n-butyl phthalate (μg/L)	2.65* (±0.445) (13 detects out of 24 samples)
Ethylbenzene (μg/L)	0.624* (±0.181) (5 detects out of 24 samples)
Methylene chloride (μg/L)	4.02* (±1.81) (3 detects out of 22 samples)
Phenol (μg/L)	26.5* (±13.5) (7 detects out of 22 samples)

Analyte	Average Conc. (± SE) of Cruise Ship Type II MSD Effluent[1]
Tetrachloroethylene (µg/L)	12.5* (±10.5) (3 detects out of 22 samples)
Toluene (µg/L)	0.620* (±0.0771) (5 detects out of 22 samples)

[1] Based on data collected by ACSI in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
[2] Trihalomethanes are water system disinfection byproducts.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Nutrients

Table 2-4 shows average ammonia concentration in effluent from traditional Type II MSDs, as well as typical concentrations in untreated domestic wastewater.

Table 2-4. Comparison of Traditional Type II MSD Effluent Concentrations to Untreated Domestic Wastewater–Ammonia

Analyte	Average Conc. (± SE) of Cruise Ship Traditional Type II MSD Effluent[1]	Concentration in Untreated Domestic Wastewater[2]
Ammonia as Nitrogen (mg/L)	145 (±36.7) (21 detects out of 21 samples)	12 to 50

[1] Based on data collected by ACSI in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
[2] Metcalf & Eddy, 1991.

2.3.2 Advanced Wastewater Treatment Systems

How it works

On some cruise vessels, especially many of those traveling to Alaska (see subsection 2.2.3 above), sewage and often graywater are treated using Advanced Wastewater Treatment systems (AWTs). AWTs generally provide improved screening, biological treatment, solids separation (using filtration or flotation), disinfection (using ultraviolet light), and sludge processing as compared to traditional Type II MSDs. The AWTs currently used by cruise ships operating in Alaskan waters are discussed in this subsection.

Hamworthy's Membrane Bioreactor (MBR) system uses aerobic biological treatment followed by ultrafiltration and ultraviolet (UV) disinfection. One example of this system is in operation on the Princess Cruises vessel Island Princess. On this vessel, the Hamworthy MBR system treats wastewater from accommodations and sewage. Wastewater is first treated in screen presses to remove paper and other coarse solids. Next, the wastewater enters a two-stage bioreactor, where bacteria digest the organic matter in the waste. Following biological treatment, the wastewater is filtered through tubular ultrafiltration membranes to remove particulate matter and biological mass, which are returned to the bioreactors. In the final stage of treatment, the wastewater undergoes UV disinfection. See EPA, 2006c, for more detailed information on this system.

ROCHEM's ROCHEM LPRO and ROCHEM Bio-Filt® system treats high concentration and low concentration wastestreams with different processes. One example of this system is in operation on the Holland America Line vessel Oosterdam. On this vessel, the ROCHEM LPRO part of the system treats wastewater from laundry and accommodations (low concentration wastestreams) while the ROCHEM Bio-Filt® treats wastewater from galley and sewage, as well as the membrane concentrate from the ROCHEM LPRO system (high concentration wastestreams). The ROCHEM LPRO system uses screens to remove fibers and hair, reverse osmosis membranes to remove particulates and dissolved solids, and UV disinfection to destroy pathogens. The ROCHEM Bio-Filt® system uses vibratory screens to remove coarse solids, bioreactors to biologically oxidize the waste, ultrafiltration membranes to remove particulate matter and biological mass (which are returned to the bioreactors), and UV disinfection to destroy pathogens. See EPA, 2006d, for more detailed information on this system.

The Zenon ZeeWeed® MBR system uses aerobic biological oxidation followed by ultrafiltration and UV disinfection. One example of this system is in operation on the Holland America Line vessel Veendam. On this vessel, graywater from the laundry, galley, accommodations, and food pulper combines with sewage and flows through two coarse screens into a collection tank. From the collection tank, the wastewater is pumped to an aerated bioreactor. After the bioreactor, the wastewater flows through the proprietary ZeeWeed® hollow-fiber ultrafiltration membrane system under a vacuum. In the final stage of treatment, the combined wastewater from the membranes undergoes UV disinfection. The Zenon system is the only system that EPA sampled that treats all graywater and sewage sources. See EPA, 2006a, for more detailed information on this system.

The Scanship treatment system uses aerobic biological oxidation followed by dissolved air flotation and UV disinfection. One example of the Scanship system is in operation on the Norwegian Cruise Line vessel Star. On this vessel, sewage and graywater from the galley, accommodations, and laundry combine in one graywater and sewage holding tank. The combined wastewater is pumped through a coarse drum filter and then through two separate aerated bioreactors. Each bioreactor contains free-floating plastic beads to support biological growth, eliminating the need for recycled biological mass. After aeration, the wastewater is pumped to two dissolved air flotation (DAF) units to separate solids. From the DAF units, the wastewater is pumped to polishing screen filters. In the final stage of treatment, the wastewater undergoes UV disinfection for destruction of bacteria and viruses. See EPA, 2006b, for more detailed information on this system.

The Hydroxyl CleanSea® system uses aerobic biological oxidation followed by dissolved air flotation and ultraviolet (UV) disinfection. Sewage and graywater are combined and pumped to a fine wedgewire screen for coarse solids removal. Next, the wastewater enters the ACTIVECELL™ biological reactors where free-floating plastic beads support biological growth without the need for recycled biological mass. The wastewater then enters the ACTIVEFLOAT™ dissolved air flotation units for solids separation. Final treatment steps include polishing filters and UV disinfection (Hydroxyl Systems, 2007). None of the ships that EPA sampled in 2004 and 2005 used the Hydroxyl CleanSea® system. Through 2007, EPA is not aware of any ships using the Hydroxyl system that have been approved for continuous discharge in Alaskan waters.

How well it works in practice

In 2004 and 2005, EPA sampled wastewater from four cruise ships that operated in Alaska to characterize graywater and sewage generated onboard and to evaluate the performance of the Zenon, Hamworthy, Scanship, and ROCHEM AWTs (see EPA, 2006 a-e). EPA also has evaluated cruise ship compliance monitoring data for AWT effluent provided by the Alaska Department of Environmental Conservation (ADEC) and the Coast Guard for 2003 through 2005, and self-monitoring data for AWT effluent submitted by the cruise industry in response to EPA's 2004 cruise ship survey.

These sampling results, which are described in greater detail below, indicate that AWTs are very effective in removing pathogens, oxygen demanding substances, suspended solids, oil and grease, and particulate metals. AWTs remove some of the dissolved metals (37 to 50%). Most volatile and semi-volatile organics are removed to levels below detection limits, while others show moderate removal. AWTs achieve moderate nutrient removals, likely resulting from nutrient uptake by the microorganisms in the bioreactors.

<u>Data Collection</u>

<u>*EPA Sampling*</u>*:* In 2004 and 2005, EPA analyzed the effluent from Zenon, Hamworthy, Scanship, and ROCHEM AWTs (see EPA, 2006 a-e) for over 400 analytes, including pathogen indicators, suspended and dissolved solids, biochemical oxygen demand, oil and grease, dissolved and total metals, organics, and nutrients.

<u>*ADEC/Coast Guard Sampling*</u>*:* AWT effluent data are collected through compliance monitoring required by state and federal law for all cruise ships that discharge in Alaskan waters. Since 2001, Alaska state law requires a minimum of two discharge samples per year for large cruise ships. Both samples are analyzed for fecal coliform and other common pollutants, and one sample is also analyzed for priority pollutants. This program is managed by the Alaska Department of Environmental Conservation (ADEC). Additionally, the federal law entitled "Certain Alaska Cruise Ship Operations" requires compliance monitoring of discharges from vessels approved for continuous discharge in Alaskan waters (see subsection 2.2.3 above). Sampling frequency and analytes are at the discretion of the Captain of the Port (COTP). The COTP requires discharge sampling twice per month for fecal coliform and other common pollutants. Although AWT compliance monitoring data are available beginning in 2001, EPA is using data collected beginning in 2003 as representative of AWT discharges due to sampling constraints prior to 2003.

<u>*Data from EPA's 2004 Cruise Ship Survey*</u>*:* EPA's 2004 cruise ship survey asked cruise ships operating in Alaska in 2004 to submit any additional monitoring data collected in Alaska that was not previously provided to EPA through ADEC or the Coast Guard. EPA received a small amount of additional AWT effluent monitoring data from six ships in response to this request (monitoring is seldom performed other than for compliance). These data comprise less than 2% of the data summarized below.

To date, all available AWT effluent monitoring data are from four AWT systems: Hamworthy Membrane Bioreactor (MBR); ROCHEM LPRO and ROCHEM Bio-Filt®; Zenon ZeeWeed® MBR; and Scanship. This is because these were the only AWT systems certified for continuous discharge in Alaska through 2005. All four of these AWTs treat sewage and at least some graywater sources. Therefore, these results apply to graywater treatment as well.

<u>*Pathogen Indicators*</u>

EPA analyzed both the influent and the effluent from AWTs (mixed graywater and sewage), as well as the influent to UV disinfection, for the pathogen indicators fecal coliform, enterococci, and *E. coli*. Fecal coliform were analyzed for comparison to the MSD and Title XIV standards. EPA chose to sample for *E. coli* and enterococci because epidemiological studies suggest a positive relationship between high concentrations of *E. coli* and enterococci in ambient waters and incidents of gastrointestinal illnesses associated with swimming (EPA, 1984b, and EPA, 1983).

ADEC/Coast Guard analyzed for fecal coliform to assess compliance with the fecal coliform discharge standards. EPA also received some fecal coliform data in response to the survey.

Sampling data indicate that AWTs remove pathogen indicators to levels below detection (>99% removal) (see Table 2-5). Over 96% of pathogen indicators were removed by the bioreactors and solids separation units; any remaining pathogen indicators were generally removed by UV disinfection to levels below detection (overall system efficiency >99%). When detected, pathogen indicators were generally at levels close to the detection limit.

Table 2-5. AWT Effluent Concentrations and Removals–Pathogen Indicators

Analyte	Unit	Average Concentration in Cruise Ship AWT Influent[1]	Average Concentration after bioreactors but before UV Disinfection[1]	Average Concentration in Cruise Ship AWT Effluent[2]	Overall AWT Percent Removal[1]
Fecal Coliform	CFU / 100 mL	103,000,000* (61 detects out of 62 samples)	25,500# (39 detects out of 56 samples)	14.5* (26 detects out of 285 samples)	>99
	MPN / 100 mL			10.1* (47 detects out of 320 samples)	
E. coli	MPN / 100 mL	12,700,000 (63 detects out of 63 samples)	727* (38 detects out of 55 samples)	1.98* (6 detects out of 59 samples)	>99
Enterococci	MPN / 100 mL	4,940,000* (63 detects out of 64 samples)	97.4# (33 detects out of 54 samples)	1.28* (9 detects out of 58 samples)	>99

[1] Based on data collected by EPA in 2004.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Average includes at least one nondetect value (calculation uses detection limits for nondetected results) and at least one result flagged by the laboratory as not diluted sufficiently.
The “>” symbol indicates a minimum level of removal.

Conventional Pollutants and Other Common Analytes

Table 2-6 presents AWT effluent sampling data for various common analytes including conventional pollutants (other than fecal coliform), chlorine, and temperature. Each of the three data sources (sampling by ADEC/Coast Guard from 2003 to 2005; sampling by EPA in 2004; sampling data collected through EPA’s 2004 cruise ship survey) includes data for some of these analytes; however, not all sources analyzed for all of them. At a minimum, all three data sources analyzed the key analytes commonly used to assess wastewater strength: biochemical oxygen demand, chemical oxygen demand, and total suspended solids.

The AWTs remove almost all biochemical oxygen demand, chemical oxygen demand, and total organic carbon. The systems also remove settleable residue and total suspended solids to levels at or near detection.

Table 2-6. AWT Effluent Concentrations and Removals–Conventional Pollutants and Other Common Analytes

Analyte	Unit	Average Concentration in Cruise Ship AWT Influent[1]	Average Conc. (± SE) in Cruise Ship AWT Effluent[2]	Percent Removal[1]
Alkalinity	mg/L CaCO	325 (25 detects out of 25 samples)	178 (±9.61) (127 detects out of 127 samples)	32 to 78
Biochemical Oxygen Demand (5-day)	mg/L	526 (24 detects out of 24 samples)	7.99* (±0.798) (358 detects out of 568 samples)	>99
Chemical Oxygen Demand	mg/L	1,140 (50 detects out of 50 samples)	69.4* (±4.03) (139 detects out of 147 samples)	>93 to 97
Chloride	µg/L	294 (25 detects out of 25 samples)	389 (±93.9) (20 detects out of 20 samples)	NC to 16
Conductivity	umhos/cm		1,450 (±268) (105 detects out of 105 samples)	
Hardness	mg/L	135 (25 detects out of 25 samples)	120 (±30.5) (20 detects out of 20 samples)	
Hexane extractable material (HEM)	mg/L	95.6 (25 detects out of 25 samples)	5.74* (±0.154) (13 detects out of 127 samples)	>91 to >96
pH	SU		99.5% of samples within range of 6.0 to 9.0 (921 detects out of 921 samples)	
Residual Chlorine, Free	mg/L		0.249* (±0.0993) (22 detects out of 511 samples)	
Residual Chlorine, Total	mg/L		0.338* (±0.129) (41 detects out of 547 samples)	
Salinity	ppt		1.93* (±0.606) (76 detects out of 77 samples)	
Silica Gel Treated Hexane Extractable Material (SGT-HEM)	mg/L	22.1* (17 detects out of 25 samples)	ND (0 detects out of 20 samples)	NC to >92
Temperature	°C		31.3 (±0.198)	

Analyte	Unit	Average Concentration in Cruise Ship AWT Influent[1]	Average Conc. (± SE) in Cruise Ship AWT Effluent[2]	Percent Removal[1]
			(403 detects out of 403 samples)	
Total Dissolved Solids	mg/L	776 (25 detects out of 25 samples)	819 (±169) (20 detects out of 20 samples)	NC to 34
Total Organic Carbon	mg/L	169 (25 detects out of 25 samples)	19.0* (±1.20) (123 detects out of 127 samples)	86 to 94
Total Settleable Solids	mL/L	33.5* (23 detects out of 24 samples)	0.141* (±0.0385) (3 detects out of 83 samples)	>99
Total Suspended Solids	mg/L	545 (50 detects out of 50 samples)	4.49* (±0.193) (73 detects out of 587 samples)	>99
Turbidity	NTU		2.31* (±0.894) (62 detects out of 76 samples)	

[1] Based on data collected by EPA in 2004 and 2005.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004 and 2005; and data collected through EPA's 2004 cruise ship survey.
"NC" indicates that percent removal not calculated because the effluent concentration was greater than the influent concentration or the analyte was not detected in the influent samples from one or more sampled ships.
"ND" indicates not detected.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
The ">" symbol indicates a minimum level of removal.

Metals

EPA sampled for 54 total and dissolved metal analytes. ADEC/Coast Guard analyzed for priority pollutant metal analytes (total and dissolved). Survey respondents provided some priority pollutant metals data.

Table 2-7 presents AWT effluent sampling data for priority pollutant metals that were detected in greater than 10% of influent and/or effluent samples (less frequent detection of analytes is considered not representative of the wastestream).

Metals are present in both particulate and dissolved forms in the influents to the treatment systems. Metals in the effluent are predominantly in the dissolved form. This suggests that the treatment systems are very efficient in removing particulate metals, as would be expected for membrane and dissolved air flotation solids separation systems (and as supported by nearly complete removal of settleable solids and TSS). Sampling results indicate that AWTs remove 37 to 50% of dissolved metals on average.

Table 2-7. AWT Effluent Concentrations and Removals–Metals

Analyte[1]	Unit	Average Concentration in Cruise Ship AWT Influent[2]	Average Conc. (± SE) in Cruise Ship AWT Effluent[3]	Percent Removal[2]
Antimony, Total	µg/L	ND	2.38* (±0.219) (15 detects out of 71 samples)	
Antimony, Dissolved	µg/L	4.0* (1 detect out of 25 samples)	2.38* (±0.219) (11 detects out of 71 samples)	
Arsenic, Total	µg/L	2.2* (3 detects out of 25 samples)	2.51* (±0.203) (22 detects out of 71 samples)	NC to >3.8
Arsenic, Dissolved	µg/L	ND	2.28* (±0.166) (19 detects out of 71 samples)	NC
Cadmium, Total	µg/L	0.45* (13 detects out of 25 samples)	0.824* (±0.147) (2 detects out of 71 samples)	>0.6 to 78
Chromium, Total	µg/L	6.64* (24 detects out of 25 samples)	4.29* (±0.992) (27 detects out of 71 samples)	>44 to 95
Chromium, Dissolved	µg/L	1.51* (15 detects out of 25 samples)	3.71* (±0.786) (28 detects out of 71 samples)	49 to 67
Copper, Total	µg/L	519 (25 detects out of 25 samples)	16.6* (±2.74) (69 detects out of 71 samples)	96 to 98
Copper, Dissolved	µg/L	81.5 (25 detects out of 25 samples)	13.7* (±2.40) (65 detects out of 71 samples)	62 to 94
Lead, Total	µg/L	9.25* (22 detects out of 25 samples)	1.50* (±0.135) (27 detects out of 71 samples)	42 to >84
Lead, Dissolved	µg/L	2.36* (13 detects out of 25 samples)	1.35* (±0.138) (20 detects out of 71 samples)	NC to >30
Mercury, Total[4]	µg/L	0.310* (21 detects out of 25 samples)	0.165* (±0.00895) (10 detects out of 70 samples)	60 to 92
Mercury, Dissolved[4]	µg/L	0.120* (10 detects out of 25 samples)	0.176* (±0.00941) (10 detects out of 68 samples)	NC to 32
Nickel, Total	µg/L	22.4 (25 detects out of 25 samples)	13.6* (±2.01) (70 detects out of 71 samples)	NC to 48
Nickel, Dissolved	µg/L	17.1 (25 detects out of 25 samples)	13.3* (±1.96) (69 detects out of 71 samples)	NC to 32
Selenium, Total	µg/L	9.68* (13 detects out of 25 samples)	5.86* (±1.20) (33 detects out of 71 samples)	12 to 38
Selenium, Dissolved	µg/L	8.39* (10 detects out of 25 samples)	6.14* (±1.48) (29 detects out of 71 samples)	NC to 24
Silver, Total	µg/L	1.70* (14 detects out of 25 samples)	1.15* (±0.109) (17 detects out of 71 samples)	>0.5 to >74
Silver, Dissolved	µg/L	ND	1.00* (±0.0844) (10 detects out of 71 samples)	NC
Thallium, Total	µg/L	0.860* (2 detects out of 25 samples)	1.02* (±0.194) (11 detects out of 71 samples)	NC to 3.2
Zinc, Total	µg/L	986 (25 detects out of 25 samples)	198* (±22.7) (69 detects out of 71 samples)	NC to 86
Zinc, Dissolved	µg/L	209 (25 detects out of 25 samples)	185* (±21.4) (70 detects out of 71 samples)	NC

[1] Priority pollutant metal analytes detected in at least 10% of AWT influent and/or effluent samples.
[2] Based on data collected by EPA in 2004.
[3] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
[4] Because it was not possible to incorporate "clean" sampling and analysis methodologies for mercury when sampling onboard ships, there is no way for EPA to determine whether mercury reported here is present in AWT influent and effluent or if the mercury was the result of contamination from nearby metal or sources of airborne contamination.
"NC" indicates that percent removal not calculated because the effluent concentration was greater than the influent concentration or the analyte was not detected in the influent samples from one or more sampled ships.
"ND" indicates not detected.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Volatile and Semivolatile Organics

EPA's volatile and semivolatile organics analyte list includes 84 volatile and semivolatile organics and focuses primarily on priority pollutants. ADEC/Coast Guard's volatile and semivolatile organic analytes include approximately 155 organics (including all 84 analytes on EPA's list) and is nearly identical to that analyzed for during the 2000 voluntary sampling program. Survey respondents also provided some organics data.

Table 2-8 presents AWT effluent sampling data for priority pollutant volatile and semivolatile organics that were detected in greater than 10% of influent and/or effluent samples (less frequent detection of analytes is considered not representative of the wastestream). AWTs generally remove volatile and semivolatile organics to below detection limits.

Table 2-8. AWT Effluent Concentrations and Removals–Volatile and Semivolatile Organics

Analyte[1]	Unit	Average Concentration in Cruise Ship AWT Influent[2]	Average Conc. (± SE) in Cruise Ship AWT Effluent[3]	Percent Removal[2]
2,4-Dichlorophenol	µg/L	ND	8.48* (±1.08) (8 detects out of 71 samples)	
Bis(2-ethylhexyl) phthalate	µg/L	46.1* (21 detects out of 25 samples)	6.66* (±0.721) (2 detects out of 71 samples)	>37 to >90
Chloroform	µg/L	10.1* (5 detects out of 25 samples)	3.74* (±0.351) (27 detects out of 71 samples)	NC to >67
Diethyl phthalate	µg/L	13.1* (8 detects out of 25 samples)	8.57* (±1.06) (7 detects out of 71 samples)	NC to >51
Di-n-butyl phthalate	µg/L	ND	8.32* (±1.07) (8 detects out of 71 samples)	
Phenol	µg/L	75.0* (24 detects out of 25 samples)	20.7* (±3.00) (25 detects out of 71 samples)	25 to 45
Tetrachloroethylene	µg/L	255* (8 detects out of 25 samples)	5.59* (±1.05) (10 detects out of 71 samples)	>44 to 97
Toluene	µg/L	7.67* (5 detects out of 25 samples)	3.44* (±0.346) (10 detects out of 71 samples)	>1.4 to >17
Trichloroethene	µg/L	15.1* (5 detects out of 25 samples)	3.54* (±0.337) (1 detects out of 71 samples)	>75

[1] Priority pollutant volatile and semivolatile organics detected in at least 10% of AWT influent and/or effluent samples.
[2] Based on data collected by EPA in 2004.
[3] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
"NC" indicates that percent removal not calculated because the effluent concentration was greater than the influent concentration or the analyte was not detected in the influent samples from one or more sampled ships.
"ND" indicates not detected.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
The ">" symbol indicates a minimum level of removal.

Nutrients

EPA sampled for nutrients in 2004 and found that some of the 2004 results for nitrogen compounds were anomalous. Therefore, EPA performed additional nutrient sampling in 2005 onboard the same four cruise vessels. ADEC/Coast Guard also monitor nutrients, and survey respondents provided some nutrient data.

Table 2-9 presents AWT effluent sampling data for nutrients. AWTs reduce ammonia, total Kjeldahl nitrogen, and total phosphorus by moderate amounts. Nitrate/nitrite levels were low and remained relatively unchanged by treatment. Nitrogen and phosphorus are likely taken up by microorganisms in the bioreactor and removed from the system in the waste sludge. It is unlikely that ammonia is removed by nitrification, as nitrification would have resulted in an increase in nitrate/nitrite concentration, but these levels remained relatively unchanged.

Table 2-9. AWT Effluent Concentrations and Removals–Nutrients

Analyte	Unit	Average Concentration in Cruise Ship AWT Influent[1]	Average Conc. (± SE) in Cruise Ship AWT Effluent[2]	Percent Removal[1]
Ammonia As Nitrogen	mg/L	78.6 (35 detects out of 35 samples)	36.6* (±5.50) (136 detects out of 138 samples)	58 to 74
Nitrate/Nitrite as Nitrogen	mg/L	0.325* (26 detects out of 50 samples)	3.32* (±0.653) (66 detects out of 152 samples)	NC
Total Kjeldahl Nitrogen	mg/L	111 (50 detects out of 50 samples)	32.5* (±3.27) (169 detects out of 170 samples)	70 to 76
Total Phosphorus	mg/L	18.1 (25 detects out of 25 samples)	5.05* (±0.460) (146 detects out of 154 samples)	41 to 98

[1] Based on data collected by EPA in 2004 and 2005.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004 and 2005; and data collected through EPA's 2004 cruise ship survey.
"NC" indicates that percent removal not calculated because the effluent concentration was greater than the influent concentration or the analyte was not detected in the influent samples from one or more sampled ships.
"ND" indicates not detected.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Pesticides

EPA analyzed for 121 organohalide and organophosphorus pesticides in AWT influent (pesticides were not analyzed for in AWT effluent). Simazine was the only pesticide detected (concentration of 0.96 μg/L in one sample). EPA lists simazine as a General Use Pesticide (GUP) that has been used to control broad-leaved weeds and annual grasses in fields, berry fruit, and vegetables. Simazine is classified by EPA to be slightly toxic to practically non-toxic. In the past, simazine has been used to control algae in swimming pools, hot tubs, and whirlpools. (Extoxnet, 1996).

ADEC also analyzed for organophosphorus pesticides in AWT effluent in 2003. None were detected.

2.3.3 Sewage Sludge

Waste Sludge

In addition to the treated sewage discharge generated by cruise ships, waste sludge (excess biological mass from the bioreactors) is generated in varying amounts by all vessels that use biological treatment, including traditional Type II MSDs and AWTs. Waste sludge contains organic material, often with high concentrations of bacteria and viruses, unless treated further.

In biological treatment, microorganisms (e.g., bacteria) consume the biological matter in sewage, which produces biological mass (e.g., more bacteria). The biological mass is then separated from the treated effluent using a solids separation step such as clarification and/or filtration. A portion or all of the biological mass is recycled to the bioreactors to treat additional sewage.

Of the six large cruise ships with traditional biological Type II MSDs that operated in Alaskan waters in 2004, all recycle all of their separated biological mass to the bioreactors. This means that excess biological mass typically exits these systems entrained in the treated effluent. (Treated effluent is disinfected prior to discharge to destroy pathogens.) However, for three of the six systems, excess biological mass also accumulates in the bioreactors to unacceptable levels over time. Once or twice per month, these systems are “desludged” by removing a portion of the contents of the bioreactors. According to responses to EPA’s 2004 cruise ship survey, this waste sludge is discharged without treatment outside 12 nautical miles (nm) from shore. EPA has no sampling data for waste sludge from traditional Type II MSDs.

In AWTs, improved biological treatment results in the generation of large amounts of biological mass, while improved solids separation does not allow for the entrainment of biological mass in the treated effluent. Biological mass is recycled to the bioreactors; however, excess biological mass is removed from the AWT bioreactors on a daily or weekly basis. On all four ships sampled by EPA in 2004 and 2005, excess sludge is pumped to a double-bottom holding tank for discharge without treatment outside 12 nm from shore. The volume of sludge discharged by these four ships ranged from 370 to 6,600 gallons/day.

EPA collected one-time grab samples of waste sludge from three of the four vessels sampled in 2004 (see Table 2-10). Most of the analytes detected in the sludge also were detected in the influent to treatment. For many analytes, concentrations in the sludge exceeded those in the influent to treatment, suggesting that these analytes accumulate in the system until removed in the waste sludge stream. In particular, there were elevated metals concentrations in the waste sludge. This is expected as the AWTs are highly efficient in removing particulate metals from the effluent and retaining them in the bioreactors.

Table 2-10. AWT Sludge Concentrations for Selected Analytes

Analyte	Unit	Average Concentration in Cruise Ship AWT Influent[1]	Average Concentration in Cruise Ship AWT Waste Sludge[1]	Average Concentration in Cruise Ship AWT Screening Solids[1]
Conventional Pollutants				
Biochemical Oxygen Demand (5-Day)	mg/L	526 (24 detects out of 24 samples)	3,870 (1 detect out of 1 sample)	6,610 (1 detect out of 1 sample)
Chemical Oxygen Demand	mg/L	1,140 (50 detects out of 50 samples)	9,840 (3 detects out of 3 samples)	46,200 (3 detects out of 3 samples)
Metals				
Chromium, Total	µg/L	6.64* (24 detects out of 25 samples)	200 (3 detects out of 3 samples)	565 (3 detects out of 3 samples)
Copper, Total	µg/L	519 (25 detects out of 25 samples)	10,800 (3 detects out of 3 samples)	22,700 (3 detects out of 3 samples)
Lead, Total	µg/L	9.25* (22 detects out of 25 samples)	177 (3 detects out of 3 samples)	49.9* (2 detects out of 3 samples)
Nickel, Total	µg/L	22.4 (25 detects out of 25 samples)	245 (3 detects out of 3 samples)	537 (3 detects out of 3 samples)
Zinc, Total	µg/L	986 (25 detects out of 25 samples)	19,400 (3 detects out of 3 samples)	33,600 (3 detects out of 3 samples)
Volatile and Semivolatile Organics				
Bis (2-ethylhexyl) phthalate	µg/L	46.1* (21 detects out of 25 samples)	40.0 (2 detects out of 2 samples)	6,250* (2 detects out of 3 samples)
Phenol	µg/L	75.0* (24 detects out of 25 samples)	628 (2 detects out of 2 samples)	563* (2 detects out of 3 samples)
Tetrachloroethylene	µg/L	255* (8 detects out of 25 samples)	5.83* (2 detects out of 3 samples)	6.19* (2 detects out of 3 samples)
Trichloroethene	µg/L	15.1* (5 detects out of 25 samples)	3.74* (1 detect out of 3 samples)	ND (0 detects out of 3 samples)
Nutrients				
Ammonia as Nitrogen	mg/L	78.6 (35 detects out of 35 samples)	58.2 (2 detects out of 2 samples)	170 (2 detects out of 2 samples)
Total Kjeldahl Nitrogen	mg/L	111 (50 detects out of 50 samples)	1,030 (3 detects out of 3 samples)	740 (3 detects out of 3 samples)
Nitrate/Nitrite as Nitrogen	mg/L	0.325* (26 detects out of 50 samples)	3.51* (2 detects out of 3 samples)	1.24* (2 detects out of 3 samples)
Total Phosphorus	mg/L	18.1 (25 detects out of 25 samples)	173 (3 detects out of 3 samples)	341 (3 detects out of 3 samples)

[1] Based on data collected by EPA in 2004.

* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Screening Solids

Most sewage treatment systems use coarse screens or presses to remove paper and other coarse solids from sewage. Depending on the specific type of screening technology used, the resulting screening solids waste varies in water content. For the four ships that EPA sampled in 2004 and 2005, two generated relatively dry screening solids and incinerated them onboard. The other two ships generated relatively wet screening solids. One of these ships disposed of the solids on shore. The other stored the solids in double-bottom holding tanks for discharge without treatment outside 12 nm from shore (50 gallons/day of screening solids). EPA collected one-time grab samples of screening solids from three of the four vessels sampled in 2004 (see Table 2-10).

2.3.4 Cruise Industry Practice

Cruise Lines International Association (CLIA) member lines have agreed to incorporate various standards for waste stream management into their Safety Management Systems (see Section 1.3). CLIA members have agreed that all sewage will be processed through a marine sanitation device (MSD), certified in accordance with U.S. or international regulations, prior to discharge (CLIA, 2006). For ships that do not have Advanced Wastewater Treatment systems traveling regularly on itineraries beyond territorial coastal waters, discharge will take place only when the ship is more than four miles from shore and when the ship is traveling at a speed of not less than six knots (for vessels operating under sail, or a combination of sail and motor propulsion, the speed shall not be less than four knots). For vessels whose itineraries are fully within US territorial waters, discharge shall comply fully with U.S. and individual state legislation and regulations.

2.4 What are the potential environmental impacts associated with sewage from cruise ships?

In order to evaluate the potential environmental impacts of sewage waste streams from cruise ships, EPA compared the effluent from traditional Type II Marine Sanitation Devices (MSDs) and Advanced Wastewater Treatment systems (AWTs) discussed in subsection 2.3 (above) to (1) current wastewater discharge standards for ships and land-based sewage treatment plants and (2) EPA's National Recommended Water Quality Criteria.

2.4.1 Comparison to wastewater discharge standards

Table 2-11 shows the comparison of average effluent analyte concentrations from traditional Type II MSDs and from AWTs to:

- EPA's standards for discharges from Type II MSDs on vessels;
- EPA's standards for secondary treatment of sewage from land-based sewage treatment plants; and
- Alaska cruise ship discharge standards under "Certain Alaska Cruise Ship Operations" (also referred to as "Title XIV").

Traditional Type II MSD effluent concentrations exceeded the EPA standards for discharges from Type II MSDs (see Table 2-11). In addition, traditional Type II MSD effluent concentrations exceeded most wastewater discharge standards under Title XIV for continuous discharge and for secondary treatment from land-based sewage treatment plants. (Traditional Type II MSD effluent concentrations are not required to meet, nor are the devices designed to meet, the Title XIV continuous discharge standards or the secondary treatment discharge standards.)

In contrast to traditional Type II MSD effluent, the average effluent concentrations from AWTs are lower than all of the discharge standards presented in Table 2-11, with the exception of total residual chlorine. Chlorination is used to disinfect potable water produced underway or bunkered in port. In 2003 through 2005, many cruise vessels in Alaska converted from chlorine disinfection of treated sewage and graywater to ultraviolet light (UV) disinfection methods during treatment system upgrades from traditional Type II MSDs to AWT systems. The switch to UV disinfection resulted in a decline in the frequency and magnitude of detected total residual chlorine in cruise effluent from AWTs. Based on the change in disinfection methods for AWTs, the likely source for occasional detection of total residual chlorine in AWT effluent is residual chlorine in potable water.

Another factor contributing to the exceedance of the total residual chlorine standard is the difference between the total residual chlorine discharge standard of 10 µg/L and the minimum detection limit reported by most analytical labs of 100 µg/L. The average concentrations presented in Table 2-11 are calculated using the detection limit for samples where chlorine is not detected. Therefore, although total residual chlorine was detected in only 41 of 547 samples, the average is weighted higher due to the use of the detection limit (which is high relative to the standard) for nondetect samples. Alaska Department of Environmental Conservation (ADEC) uses the 100 µg/L minimum detection level as the compliance evaluation level for total residual chlorine. Therefore, cruise ships reporting nondetect values with a detection limit of 100 µg/L are considered in compliance with the Title XIV continuous discharge standards. Based on this evaluation criterion, effluent concentrations from AWT seldom exceed the minimum detection level.

Table 2-11. Comparison of AWT and Traditional Type II MSD Effluent to Wastewater Discharge Standards

Analyte	Average Concentration in AWT Effluent[1]	Average Concentration in Traditional Type II MSD Effluent[2]	Performance Standards for Type II MSDs (33 CFR Part 159 Subpart C)	Secondary Treatment Discharge Standards for Sewage from Land-based Sewage Treatment Plants (40 CFR 133.102)	Title XIV Standard for Continuous Discharge in Alaskan waters (33 CFR Part 159 Subpart E)
Fecal coliform (fecal coliform/ 100 mL)	14.5*	2,040,000* MPN / 100 mL	<200		<20[3]
Total residual chlorine (µg/L)	338*	1,070*			<10

Analyte	Average Concentration in AWT Effluent[1]	Average Concentration in Traditional Type II MSD Effluent[2]	Performance Standards for Type II MSDs (33 CFR Part 159 Subpart C)	Secondary Treatment Discharge Standards for Sewage from Land-based Sewage Treatment Plants (40 CFR 133.102)	Title XIV Standard for Continuous Discharge in Alaskan waters (33 CFR Part 159 Subpart E)
Biochemical oxygen demand (5-day) (mg/L)	7.99*	133		<45[4] <30[5]	<45[4] <30[5]
Total suspended solids (mg/L)	4.49*	627	<150	<45[4] <30[5]	<45[4] <30[5]
pH	99.5% of pH samples between 6.0 and 9.0	90.5% of pH samples between 6.0 and 9.0		between 6.0 and 9.0	between 6.0 and 9.0

[1] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
[2] Based on data collected by the Alaska Cruise Ship Initiative (ACSI) in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
[3] The geometric mean of the samples from the discharge during any 30-day period does not exceed 20 fecal coliform per 100 milliliters (ml) and not more than 10 percent of the samples exceed 40 coliform per 100 ml.
[4] The 7-day average shall not exceed this value.
[5] The 30-day average shall not exceed this value. In addition, the 30-day average percent removal shall not be less than 85%.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

2.4.2 Comparison to EPA's National Recommended Water Quality Criteria

EPA compared average effluent concentrations from traditional Type II MSDs and from AWTs (discussed in subsection 2.3 above) to EPA's 2006 National Recommended Water Quality Criteria (NRWQC) for saltwater aquatic life and for human health (for the consumption of organisms only). Analytes that exceed the NRWQC are discussed in greater detail in this subsection.

EPA's NRWQC are recommended concentrations of analytes in a waterbody that are intended to protect human health and aquatic organisms and their uses from unacceptable effects from exposures to these pollutants. The NRWQC are not directly comparable to analyte concentrations in a discharge because NRWQC not only have a concentration component, but also a duration and frequency component. However, comparison of cruise ship wastewater discharges to NRWQC provides a conservative screen of whether these discharges might cause, have the potential to cause, or contribute to non-attainment of the water quality standards in a given receiving water. If the concentration of a given analyte in cruise ship wastewater is less than the NRWQC, the wastewater should not cause, have the potential to cause, or contribute to non-attainment of a water quality standard based on that criterion. If the concentration of a particular analyte in cruise ship wastewater is greater than the NRWQC, additional analysis would determine whether the discharge would cause, have the potential to cause, or contribute to non-attainment of a water quality standard in a given receiving water.

Pathogen Indicators

Sewage may host many pathogens of concern to human health, including *Salmonella, shigella*, hepatitis A and E, and gastro-intestinal viruses (National Research Council, 1993). Sewage contamination in swimming areas and shellfish beds pose potential risks to human health and the environment by increasing the rate of waterborne illnesses (Pruss, 1998; Rees, 1993; National Research Council, 1993). Shellfish feed by filtering particles from the water, concentrate bacteria and viruses from the water column, and pose the risk of disease in consumers when eaten raw (National Research Council, 1993; Wu, 1999).

The NRWQC for pathogen indicators references the bacteria standards in EPA's 1986 *Quality Criteria for Water*, commonly known as the Gold Book. The Gold Book standard for bacteria is described in terms of three different waterbody use criteria: freshwater bathing, marine water bathing, and shellfish harvesting waters. The marine water bathing and shellfish harvesting waterbody use criteria, shown in Table 2-12, were used for comparison with cruise ship discharge concentrations.

Table 2-12. National Recommended Water Quality Criteria for Bacteria

Waterbody Use	Gold Book Standard for Bacteria
Marine Water Bathing	Based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period), the geometric mean of the enterococci densities should not exceed 35 per 100 ml; no sample should exceed a one sided confidence limit (C.L.) using the following as guidance: 1) Designated bathing beach 75% C.L. 2) Moderate use for bathing 82% C.L. 3) Light use for bathing 90% C.L. 4) Infrequent use for bathing 95% C.L. based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.7 as the log standard deviation.
Shellfish Harvesting Waters	The median fecal coliform bacterial concentration should not exceed 14 MPN per 100 ml with not more than 10% of samples exceeding 43 MPN per 100ml for the taking of shellfish.

Enterococci data were unavailable for traditional Type II MSD effluent. Fecal coliform data for Type II MSD effluent consistently exceeded the NRWQC for shellfish harvesting waters. Fecal coliform concentrations in traditional Type II MSD effluent averaged 2,040,000 MPN/100 mL (total of 92 samples, calculation used detection limits for nondetected results) and ranged from 0 to 24,000,000 MPN/100 mL. Over 50% of the collected samples exceeded 43 MPN/100 mL. Given the consistent exceedance of the NRWQC for bacteria, traditional Type II MSD effluent may cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. Effluent bacteria concentrations from AWT systems are consistently below the pathogen standards in Table 2-12 and therefore should not cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

Conventional Pollutants and Other Common Analytes

Conventional pollutants and other common analytes that have a saltwater aquatic life or human health (for the consumption of organisms) narrative NRWQC include oil and grease, settleable residue, total suspended solids (TSS) (see Table 2-13), and temperature (see Tables 2-13 and 2-14). In addition, the NRWQC include a numeric standard for total residual chlorine (see Table 2-15).

Table 2-13. Narrative National Recommended Water Quality Criteria for Conventional Pollutants and Other Common Analytes

Analyte	Gold Book Standard
Oil and Grease	For aquatic life: (1) 0.01 of the lowest continuous flow 96-hour LC50 to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals. (2) Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed. (3) Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum-derived oils.
Settleable and Suspended Solids	Freshwater fish and other aquatic life: Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.
Temperature	Marine Aquatic Life: In order to assure protection of the characteristic indigenous marine community of a waterbody segment from adverse thermal effects, the maximum acceptable increase in the weekly average temperature resulting from artificial sources is 1°C (1.8 °F) during all seasons of the year, providing the summer maxima are not exceeded; and daily temperature cycles characteristic of the waterbody segment should not be altered in either amplitude or frequency. Summer thermal maxima, which define the upper thermal limits for the communities of the discharge area, should be established on a site-specific basis.

Oil and Grease

Annual worldwide estimates of petroleum input to the sea exceed 1.3 million metric tonnes (about 380 million gallons) (National Research Council, 2003). Levels of oil and grease of any kind can cause a variety of environmental impacts including the drowning of waterfowl because of loss of buoyancy, preventing fish respiration by coating their gills, asphyxiating benthic organisms from surface debris settling on the bottom, and reducing the natural aesthetics of waterbodies (EPA, 1986).

EPA does not have information on traditional Type II or AWT effluent that would allow us to directly evaluate the narrative NRWQC for oil and grease. Oil and grease data were unavailable for traditional Type II MSD effluent. Oil and grease (as measured by Hexane Extractable Material or HEM) was detected in about 10% of the samples from AWT effluent, with detected amounts ranging between 5.2 and 19 mg/L. EPA did not observe any floating oils in their effluent samples, therefore it is unlikely that there would be floating oils in the receiving water

(ADEC/Coast Guard did not provide a visual description of their samples to indicate if floating oils were observed). Based on the limited amount of information available, it seems unlikely that AWT effluent would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

Settleable and Suspended Solids

Levels of solids, either settleable or suspended, in untreated or inadequately treated sewage may harm marine organisms by reducing water clarity and available oxygen levels in the water column. In addition, solids can directly impact fish and other aquatic life by preventing the successful development of eggs and larva, blanketing benthic populations, and modifying the environment such that natural movements and migration patterns are altered (EPA, 1986).

EPA did not directly evaluate traditional Type II or AWT effluent against the narrative NRWQC for settleable and suspended solids because the criterion is based on conditions in a specific waterbody. Total suspended solids were detected in traditional Type II MSD effluent at levels ranging from 200 to 1,480 mg/L, with an average of 627 mg/L. The detected values are substantially higher than the discharge standards for sewage from land-based sewage treatment plants (7-day average shall not exceed 45 mg/L). A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

In contrast, the majority of effluent data from AWTs were nondetect values for both settleable solids and total suspended solids. It is unlikely that effluent from AWT systems would cause or contribute to an exceedance of water quality standards in a given receiving water.

Temperature

Temperature changes can directly affect aquatic organisms by altering their metabolism, ability to survive, and ability to reproduce effectively. Increases in temperature are frequently linked to acceleration in the biodegradation of organic material in a waterbody, which increases the demand for dissolved oxygen and can stress local aquatic communities.

EPA did not directly evaluate traditional Type II or AWT effluent against the narrative NRWQC for temperature because the criterion is based on conditions in a specific waterbody. The average temperature from AWT effluent measured in Alaska was 31.3 °C (temperature data were not available for traditional Type II MSD effluent). Local waterbody temperatures would be needed to determine if the temperature from AWT effluent would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. Table 2-14 provides a few examples of the water temperatures observed in various coastal waters across the United States. The average temperature for AWT effluent is similar to the summer temperatures at some of these locations, and exceeds the winter temperatures by around 10 to 30 degrees Celsius. A site-specific evaluation would determine if the cruise ship discharge volume is significant enough to alter the temperature of a given waterbody. However, considering the size of coastal waterbodies where cruise ships operate, it is unlikely that cruise ship effluent temperatures would cause an increase in waterbody temperature that would exceed the NRWQC.

Table 2-14. Seasonal Coastal Water Temperatures in °C Across the United States

Location	State	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Boston Harbor	MA	4.44	2.22	5.00	7.22	12.22	16.11	18.89	20.00	18.89	14.44	10.56	5.56
Baltimore	MD	4.44	2.78	6.11	10.56	16.11	21.11	25.00	26.11	25.00	18.89	12.22	6.11
Miami Beach	FL	21.67	22.78	23.89	25.56	26.67	28.89	30.00	30.00	28.89	28.33	24.44	22.78
Key West	FL	20.56	21.11	23.89	26.11	27.78	30.00	30.56	30.56	30.00	28.33	24.44	22.22
Seattle	WA	8.33	7.78	7.78	8.89	10.00	11.67	12.78	13.33	13.33	12.22	10.56	9.44
Los Angeles	CA	14.44	14.44	15.56	15.56	16.11	16.67	18.33	20.00	19.44	18.89	17.78	15.56
Galveston	TX	12.22	12.78	16.11	21.67	25.56	28.33	30.00	30.00	28.33	23.89	19.44	15.00
Juneau	AK	2.22	2.22	2.78	4.44	7.78	10.56	11.11	10.56	9.44	6.67	4.44	3.33
Honolulu	HI	24.44	24.44	24.44	24.44	25.56	26.11	26.67	26.67	27.22	27.22	26.11	25.00

Source: National Oceanographic Data Center Coast Water Temperature Guide (www.nodc.noaa.gov/dsdt/wtg12.html)

Total Residual Chlorine

Chlorine is extremely toxic to aquatic organisms. Chlorine concentrations as low as 3 µg/L can result in a high mortality rate for some species (EPA, 1984a). In fish, exposure to low levels of total residual chlorine (<1,000 µg/L) can cause avoidance behavior, respiratory problems, and hemorrhaging (Vetrano, 1998). Fish may recover once removed from the chorine environment, but the severity of the reaction and chance of death increases as the concentration of total residual chlorine increases (Booth et al., 1981). Studies have shown that continuous chlorination can lead to a shift in the composition of phytoplankton communities, thus altering the benthic and fish communities that feed on them (Sanders and Ryther, 1980).

Both traditional Type II MSD and AWT effluent concentrations exceed the NRWQC for total residual chlorine at the end of the pipe (see Table 2-15). A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. As discussed in subsection 2.4.1 above, this may be less of a concern for AWTs because detection limits for these samples are generally higher than the NRWQC (the minimum detection limit reported by most analytical labs is 100 µg/L). This may artificially increase the average concentration from AWTs because the detection limit was used for nondetect samples when calculating an average, and the majority of samples from AWTs were nondetect samples (total residual chlorine was detected in only 41 of 547 samples in Alaska).

Detection limits do not pose a similar issue for traditional Type II MSD discharges, as total residual chlorine was detected in 12 of 18 traditional Type II MSD effluent samples at concentrations above the minimum detection limit. The source for total residual chlorine in traditional Type II MSD effluent is the chlorination step in wastewater treatment. Chlorination is used in traditional Type II MSDs to meet fecal coliform and total suspended solids standards by killing pathogens in the wastewater.

Table 2-15. Comparison of Traditional Type II MSD and AWT Effluent to Numeric National Recommended Water Quality Criteria for Total Residual Chlorine

Analyte	Average Concentration in Traditional Type II MSD Effluent[1]	Average Concentration in AWT Effluent[2]	NRWQC Criteria Maximum Concentration (CMC)	NRWQC Criterion Continuous Concentration (CCC)
Total Residual Chlorine (µg/L)	1,070*	338*	13	7.5

[1] Based on data collected by the Alaska Cruise Ship Initiative (ACSI) in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

<u>*Metals*</u>

In the aquatic environment, elevated concentrations of metals can be toxic to many species of algae, crustaceans, and fish. Exposure to metals at toxic levels can cause a variety of changes in biochemical, physiological, morphological, and behavioral pattern in aquatic organisms. One of the key factors in evaluating metal toxicity is the bioavailability of the metal in a waterbody. Some metals have a strong tendency to adsorb to suspended organic matter and clay minerals, or to precipitate out of solution, thus removing the metal from the water column. The tendency of a given metal to adsorb to suspended particles is typically controlled by the pH and salinity of the waterbody. If the metal is highly sorbed to particulate matter, then it is likely not in a form that organisms can process. Therefore, a high concentration of a metal measured in the total form may not be an accurate representation of the toxic potential to aquatic organisms. Accordingly, NRWQC for the protection of aquatic life for metals are typically expressed in the dissolved form. In contrast, human health criteria (for the consumption of organisms) for metals are commonly expressed in the total metal form. The use of total metals for human health criteria is because human exposure to pollutants is assumed to be through the consumption of organisms, where the digestive process is assumed to transform all forms of metals to the dissolved phase, thus increasing the amount of biologically available metals.

ACSI did not report any dissolved metal data for traditional Type II MSD effluent. ACSI data for total metals in traditional Type II MSD effluent were consistently below the NRWQC for human health (for the consumption of organisms). AWT effluent data show most metals at levels below the NRWQC for human health and aquatic life. Several dissolved metals that are common components of ship piping—copper, nickel, and zinc—were found at levels approximately one to four times above NRWQC for aquatic life (see Table 2-16). A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. However, as discussed in section 2.4.3 below, these analytes would likely meet NRWQC after initial mixing (about 1 to 7 meters from the ship) even when a vessel is at rest.

Table 2-16. Comparison of AWT Effluent to National Recommended Water Quality Criteria for Metals

Analytes that Exceed One or More NRWQC[1]	Average Concentration in Cruise Ship AWT Effluent[2]	NRWQC Criteria Maximum Concentration (CMC)	NRWQC Criterion Continuous Concentration (CCC)
Copper (Dissolved) (µg/L)	13.7*	4.8	3.1
Nickel (Dissolved) (µg/L)	13.3*	74	8.2
Zinc (Dissolved) (µg/L)	185*	90	81

[1] Analytes are not listed in this table if the number of detects was not considered representative of cruise ship effluent (i.e., less than 10% of samples), if the data were not in the correct form for comparison with NRWQC, or if the average concentration was driven by detection limits.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Semivolatile and Volatile Organics

Tables 2-17 and 2-18 present the organic compounds detected in traditional Type II MSD and AWT effluent that exceed NRWQC. Note that effluent from traditional Type II MSDs was not tested for all organic compounds that have a NRWQC. The magnitude of the exceedances of NRWQC for the semivolatile and volatile organic compounds discussed in this subsection ranged from one to four times the standard. A site-specific evaluation would determine if effluent from traditional Type II MSDs or AWTs would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. However, as discussed in section 2.4.3 below, these analytes would likely meet NRWQC after initial mixing (about 1 to 7 meters from the ship) even when a vessel is at rest.

Table 2-17. Comparison of Traditional Type II MSD Effluent to National Recommended Water Quality Criteria for Semivolatile and Volatile Organics

Analytes that Exceed One or More NRWQC[1,2]	Average Concentration in Traditional Type II MSD Effluent[3]	NRWQC Human Health (for the Consumption of Organisms)
Bis(2-ethylhexyl) phthalate (µg/L)	3.5*	2.2
Carbon tetrachloride (µg/L)	2.0*	1.6
Bromodichloromethane (µg/L)	34*	17
Dibromochloromethane (µg/L)	27*	13
Tetrachloroethylene (µg/L)	13*	3.3

[1] Analytes are not listed in this table if the number of detects was not considered representative of cruise ship effluent (i.e., less than 10% of samples), if the data were not in the correct form for comparison with NRWQC, or if the average concentration was driven by detection limits.
[2] Traditional type II MSD effluent data were not available for all analytes that have a NRWQC. Therefore, this table may not include all analytes that exceed NRWQC.

[3] Based on data collected by ACSI in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Table 2-18. Comparison of AWT Effluent to National Recommended Water Quality Criteria for Semivolatile and Volatile Organics

Analytes that Exceed One or More NRWQC[1]	Average Concentration in Cruise Ship AWT Effluent[2]	NRWQC Human Health (for the Consumption of Organisms)
Tetrachloroethylene (µg/L)	5.59*	3.3

[1] Analytes are not listed in this table if the number of detects was not considered representative of cruise ship effluent (i.e., less than 10% of samples), if the data were not in the correct form for comparison with NRWQC, or if the average concentration was driven by detection limits.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Bis(2-ethylhexyl) phthalate is a manufactured chemical that is commonly added to plastics to make them flexible and can be found in a variety of common products such as wall coverings, tablecloths, floor tiles, furniture upholstery, and shower curtains. Carbon tetrachloride is used as an industrial and chemical solvent in a variety of applications such as household cleaning fluids and as a degreaser in industrial settings. Bromodichloromethane and dibromochloromethane are chlorine byproducts that are generated when chlorine used to disinfect drinking water and wastewater reacts with natural organic matter and/or bromide in water. Tetrachloroethylene is widely used in dry cleaning and for metal-degreasing. The likely source of tetrachloroethylene in cruise ship effluent is in the condensate from onboard dry cleaning operations. (Spent tetrachloroethylene from dry cleaning is not discharged with cruise ship wastewater and is handled as a separate stream for disposal.)

Nutrients

Sewage contains nutrients, such as nitrogen and phosphorus, which are important elements for aquatic plant and algae growth. The influx of excess nutrients can negatively affect marine ecosystems, resulting in diebacks of corals and seagrasses, eutrophication (oxygen-depleted "dead" zones), and increases in harmful algal blooms that can alter the seasonal progression of an ecosystem and choke or poison other plants and wildlife (National Research Council, 1993).

Ammonia is the only nutrient for which there is a numeric saltwater or human health (for the consumption of organisms) NRWQC. In the aquatic environment, ammonia exists in the unionized (NH_3) and ionized (NH_4^+) form. Unionized ammonia is the more toxic form of the two with several factors such as pH, temperature, and salinity determining the toxicity to aquatic organisms. Acute levels of NH_3 that are toxic to fish can a cause a loss of equilibrium, hyperexcitability, and increased breathing, cardiac output, and oxygen uptake (WHO, 1986). Extreme concentrations can cause convulsions, coma, and even death.

The marine NRWQC references EPA's1989 *Ambient water quality criteria for ammonia (saltwater)* document, which includes a matrix table for ammonia standards based on the pH, temperature, and salinity of a waterbody. Table 2-19 presents the average concentration of ammonia in traditional Type II MSD and AWT effluent. Table 2-20 presents examples of the ammonia NRWQC calculated from pH, temperature, and salinity for some cruise ship ports of call in the United States.

Table 2-19. Ammonia Concentration in Traditional Type II MSD and AWT Effluent

Analyte	Average Concentration in Traditional Type II MSD Effluent[1]	Average Concentration in Cruise Ship AWT Effluent[2]
Ammonia (NH3-N µg/L)	145,000	36,600*

[1] Based on data collected by ACSI in 2000; of 21 vessels sampled, 19 had traditional Type II MSDs and 2 had prototype reverse osmosis treatment systems.
[2] Based on data collected by ADEC/Coast Guard from 2003 to 2005; data collected by EPA in 2004; and data collected through EPA's 2004 cruise ship survey.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Table 2-20. Calculated Ammonia NRWQC for Some Cruise Ship Ports of Call in the United States

Location	State	pH	Average Temperature (°C)	Salinity (psu)	Ammonia NRWQC Criteria Maximum Concentration (CMC) (NH3-N µg/L)[4]	Ammonia NRWQC Criterion Continuous Concentration (CCC) (NH3-N µg/L)[4]
Galveston Bay[1]	TX	8.1	29.0	14.0	2,140	321
Honolulu Harbor[1]	HI	8.0	25.5	34.4	4,110	617
Los Angeles Harbor[1]	CA	8.1	17.4	32.6	7,110	1,110
Port of Miami[2]	FL	8.0	25.3	32.0	4,110	617
Monterey Harbor[1]	CA	8.1	15.3	32.9	6,860	1,070
New York Harbor[1]	NY	7.5	22.1	22.9	11,500	2,960
Southeast Alaska[3]	AK	7.8	12.5	20.0	15,600	2,340
Portland Harbor[1]	ME	7.8	19.4	29.6	9,040	1,400

[1] Data source: EPA's EMAP National Coastal Database (http://oaspub.epa.gov/coastal/coast.search)
[2] Data source: South Florida Water Management District Monitoring Stations (http://glades.sfwmd.gov/pls/dbhydro_pro_plsql/water_quality_interface.main_page)
[3] Data source: Draft State of Alaska Department of Environmental Conservation Large Commercial Passenger Vessel Wastewater Discharge General Permit No. 2007DB0002 (www.dec.state.ak.us/water/cruise_ships/pdfs/PN%20Version%20LPV%20WWGP%20-%20DRAFT.pdf)
[4] Ammonia standards were calculated based on pH, temperature, and salinity values for each waterbody using the matrix table provided in EPA's 1989 *Ambient water quality criteria for ammonia (saltwater)* document. In cases where measured values fell between column and row headings for pH and temperature the standard was approximated based on the closest value. In addition, the ammonia standards were converted from µg-NH_3/L to µg-NH_3-N/L by multiplying the standard by 0.822.

Average effluent concentrations of ammonia from traditional Type II MSDs and AWTs exceed all of the waterbody ammonia standards presented in Table 2-20. Although ammonia standards can vary from waterbody to waterbody, there is only a small range of pH, temperature, and salinity values that result in an ammonia standard that traditional Type II MSD and AWT average effluent concentrations will not exceed. This suggests that ammonia concentrations in traditional Type II MSDs and AWTs effluent at the end-of-pipe are likely to exceed NRWQC regardless of the receiving water parameters used to calculate the criterion. A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

In addition to the ammonia standard, EPA has established criteria for the general category of nutrients. The NRWQC references EPA's nutrient ecoregional criteria documents for lakes and reservoirs, rivers and streams, and wetlands. At this time, EPA has not developed ecoregional criteria for estuarine or marine systems; however, EPA has developed a guidance manual for establishing nutrient criteria in estuarine and marine waters. In the 2001 *Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters*, EPA states that:

> "nutrient criteria need to be established on an individual estuarine or coastal water system basis and must be appropriate to each waterbody type. They should not consist of a single set of national numbers or values because there is simply too much natural variation from one part of the country to another. Similarly, the expression of nutrient enrichment and its measurement vary from one waterbody type to another. For example, streams do not respond to phosphorus and nitrogen in the same way that lakes, estuaries or coastal waters."

To account for the extreme variations in residence time, salinity, and density profiles observed in estuaries and coastal waters, EPA recommends using a reference condition approach for setting nutrient criteria in marine waters (EPA, 2001). A reference condition is defined as the comprehensive representation of data, such as median total nitrogen, total phosphorus, and chlorophyll values, from minimally impacted or "natural" sites on a waterbody or from within a similar class of waterbodies (EPA, 2001). Once a reference condition is established, modeling and local expert analysis of the data are used to establish a criterion for each nutrient (e.g., total nitrogen and total phosphorus) to reflect the optimal nutrient condition for the waterbody in the absence of cultural impacts.

Although there are no national standards for nutrient criteria in coastal waters, some states have established waterbody-specific or state-wide standards for nutrients based on site-specific evaluations. For example, Hawaii has established nutrient criteria for several different categories of coastal waters, such as estuaries, embayments, open coastal waters, oceanic waters, and specifically for Pearl Harbor. Nutrient criteria in Hawaii include limitations on total nitrogen, ammonia, nitrate/nitrite, total phosphorus, chlorophyll, and turbidity. Hawaiian nutrient criteria are expressed as follows: criteria values which the geometric mean of samples is not to exceed, criteria values which sample values are not to exceed more than 10% of the time, and criteria values which sample values are not to exceed more than 2% of the time. This tiered approach to nutrient criteria allows for the natural variability in nutrient concentrations in the environment. Table 2-21 provides a subset of the criteria values for the different waterbody classifications in Hawaii. Stakeholders interested in site-specific nutrient criteria should consult their state water quality standards for additional information on state-wide or waterbody-specific nutrient criteria.

Table 2-21. Hawaii Nutrient Criteria Values Which the Geometric Mean of Samples Is Not to Exceed

Analyte	All Estuaries Except Pearl Harbor	Pearl Harbor	Embayments	Open Coastal Waters	Oceanic Waters
Total Nitrogen (µg/L)	200	300	200[1] 150[2]	150[1] 110[2]	50
Ammonia Nitrogen (µg N/L)	6	10	6[1] 3.5[2]	3.5[1] 2[2]	1
Nitrate + Nitrite (µg N/L)	8	15	8[1] 5[2]	5[1] 3.5[2]	1.5
Total Phosphorus (µg p/L)	25	60	25[1] 20[2]	20[1] 16[2]	10
Chlorophyll (µg/L)	2	3.5	1.5[1] 0.5[2]	0.3[1] 0.15[2]	0.06
Turbidity (NTU)	1.5	4	1.5[1] 0.4[2]	0.5[1] 0.2[2]	0.03

[1] Wet criteria apply when the average fresh water inflow from the land equals or exceeds 1% of the embayment volume per day.
[2] Dry criteria apply when the average fresh water inflow from the land is less than 1% of the embayment volume per day.

2.4.3 Mixing & Dilution

Although average analyte concentrations in Type II MSD and AWT discharges from cruise ships exceed several NRWQC at the end-of-pipe, the mixing and dilution that occurs following discharge also is relevant to an evaluation of potential environmental impact.

Dilution at Rest

A Science Advisory Panel created by the Alaska Cruise Ship Initiative (ACSI) used the Cornell Mixing Zone Expert System (CORMIX) model to estimate dilution of effluent achieved when a vessel is at rest. Their modeling showed that a discharge rate of 50 m^3/hr yields a dilution factor of 36 at a distance of about 4.5 m from the ship, and a dilution factor of 50 at 7 m from the ship after 43 seconds (ADEC, 2002, Appendix 8, footnote 50).

The Alaska Department of Environmental Conservation (ADEC) modeled the dilution of large cruise ship effluent during stationary discharge under a very conservative scenario (a neap tide in Skagway Harbor), using the Visual Plumes model. Their modeling showed the dilution factors ranging from 5 to 60, which would occur between 1 and 7 meters from the ship (ADEC, 2004).

The initial dilution estimated by ACSI and ADEC for a vessel at rest suggests that most of the pollutants in traditional Type II MSD effluent that were above NRWQC at the end-of-pipe would likely meet NRWQC after initial mixing when the vessel is at rest. However, for three pollutants–fecal coliform (see Table 2-12 and discussion below), total residual chlorine (see Table 2-15), and ammonia (see Tables 2-19 and 2-20)–end-of-pipe discharge levels are high enough that they may not meet NRWQC after initial mixing when the vessel is at rest. A site specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

As discussed in subsection 2.4.2 above, a few dissolved metals, tetrachloroethylene, chlorine, and ammonia in the effluent from AWTs may exceed certain National Recommended Water Quality Criteria (NRWQC) at the end-of-pipe. In the case of the metals and tetrachloroethylene, the exceedances at the end-of-pipe were approximately one to four times the NRWQC. Therefore, these analytes would likely meet NRWQC after initial mixing when the vessel is at rest, based on the initial dilution factors discussed above. In the case of chlorine, the exceedance was 45 times the most stringent NRWQC. However, the detection limit for chlorine is generally about 13 times greater than the NRWQC, and thus may artificially increase the average concentration from AWTs (because the detection limit is used for nondetect samples and chlorine was only detected in 41 of 547 samples). Therefore, chlorine from AWT effluent also may meet NRWQC after initial mixing in most cases.

The NRWQC for ammonia depends on pH, temperature, and salinity of the waterbody, resulting in a large range of potential values for cruise ship ports around the country (see Table 2-20). Consequently, the amount of potential exceedance from AWTs at the end-of-pipe varies, but the range based on the values presented in Table 2-20 is 2 to 114 times, and in most cases is less than 34 times the calculated NRWQC. Therefore, ammonia from AWTs would likely meet most water quality standards after initial mixing when the vessel is at rest, based on the initial dilution factors discussed above.

It is important to note that the initial mixing estimates discussed above are based on ship-specific and waterbody-specific input parameters such as discharge port size, effluent flow, waterbody temperature, and salinity. Therefore, they are not necessarily representative of the dilution factors that would be achieved by cruise ships in other ports of call in the United States. Site-specific and ship-specific calculations would be needed to determine the dilution for ships in other locations.

Dilution Underway

For vessels underway, there is significant additional dilution due to movement of the vessel and mixing by ship propellers. In 2001, EPA conducted dye dispersion studies behind four large cruise ships while underway off the coast of Miami, Florida. The results of this study indicate that dilution of discharges behind cruise ships moving at between 9.1 and 17.4 knots are diluted by a factor of between 200,000:1 and 640,000:1 immediately behind the boat (EPA, 2002). Based on these dilution factors, effluent from traditional Type II MSDs and AWTs would likely meet all NRWQC while underway.

Using this information, the ACSI Science Advisory Panel determined that the dilution for a ship underway is a function of the speed of the cruise ship, the rate of wastewater discharge, the beam (i.e., width) of the cruise ship, and the draft (i.e., depth) of the cruise ship, according to the following equation:

$$\text{Initial Dilution Factor for Ships Underway} = \frac{4 * (\text{Ship Width} \cdot \text{Ship Draft} \cdot \text{Ship Speed})}{\text{Volume Discharge Rate}}$$

2.4.4 Potential Treatment Technologies in Addition to AWTs

As part of its assessment of the large cruise ship sewage and graywater discharge standards in Alaska, EPA is evaluating upgrades to AWTs and technologies that could be added on to AWTs that would improve the quality of the treated effluent in terms of nutrients, metals, and temperature. These technologies have not been used or tested on cruise ships for the treatment of sewage or graywater. However, EPA believes these technologies are potentially feasible for this application because they currently are used in other shipboard applications or because they currently are used in land-based wastewater treatment facilities and could be adapted for shipboard application. Use of these technologies onboard large cruise ships would require engineering studies to adapt existing designs and materials selection (e.g., metallurgy, membrane and resin selection, loading rates, reliability, space constraints), operating parameters (e.g., pressures, temperatures, service and maintenance cycles), and training for operating personnel to ensure effective and consistent performance and minimize operating costs.

Nutrient Removal Technologies

<u>*Ammonia Removal by Biological Nitrification*</u>

Biological nitrification is a two-step process that converts ammonia to nitrate using nitrifying autotrophic bacteria (*nitrosomonas* and *nitrobacter*) in the aerobic activated sludge process. The equation below shows the two-step conversion of ammonia to nitrate in the treatment process (Metcalf & Eddy, 1991).

$$\text{Step 1: } NH_4^+ + 3/2O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$
$$\text{Step 2: } NO_2^- + 1/2O_2 \rightarrow NO_3^-$$

All activated sludge processes, including those sampled on the cruise ships, have nitrifying bacteria present, although their numbers are much lower than the typical microorganisms that use organic carbon (measured as BOD_5) as their food source. To enhance ammonia removal in the combined carbon oxidation and nitrification process, land-based sewage treatment plants (publicly owned treatment works (POTWs)) have made both equipment modications and operational changes. These enhancements have allowed POTWs to achieve ammonia nitrogen levels much less than one mg/L, with a corresponding increase in effluent nitrate concentration.

Cruise ships would require equipment modifications and operational changes to enhance existing AWTs. Possible equipment modifications would include increased hydraulic retention time and additional aeration equipment to increase the amount of oxygen transferred to the activated sludge process. Possible operational modifications would include longer sludge retention times and optimized temperature, pH, and alkalinity control.

Nitrification converts ammonia to nitrate, but does not reduce total nitrogen.

Total Nitrogen Removal by Ion Exchange

Ion exchange for ammonia removal from cruise ship effluent is a process in which effluent from the UV disinfection system would be passed through a cylindrical tank containing a weak-acid ion exchange resin. Ammonia ions (NH_4^+) present at neutral pH would become bound to the resin due to the negative charge on the resin. When the resin is fully saturated with ammonia ions, it could be either regenerated onboard using a highly-concentrated salt solution or regenerated shore side by a waste management company. Theoretically, ion exchange could remove 100% of ammonia. However, wastes generated from resin regeneration onboard would have to be appropriately managed, including an assessment against the RCRA hazardous waste regulations at 40 CFR 262.11 (see Section 6 for further discussion). The costs and potential environmental concerns associated with management of these wastes would need to be considered as part of the assessment of this technology.

Cruise ships would need to either purchase and install the add-on ion exchange technology and all necessary ancillary equipment, or rent ion exchange canisters from a vendor (who would handle resin regeneration) and purchase and install all necessary ancillary equipment. Operating and maintenance costs would include rental and labor for exchange of the rental units (if applicable), labor and salt brine costs for onboard regeneration (if applicable), operating labor, electrical costs, and maintenance equipment costs.

Ion exchange would remove ammonia from the wastewater, thereby reducing total nitrogen in the effluent. (This compares to biological nitrification, which does not reduce total nitrogen but instead converts one form of nitrogen to another—relatively toxic ammonia to relatively nontoxic nitrate.) Ion exchange would not remove other (nonionic) forms of nitrogen, such as nitrate/nitrite and organic nitrogen. However, these forms are present at only low concentrations in AWT effluent. The average nitrate/nitrite concentration in AWT effluent is 3.32 mg/L, which is less than one-tenth the concentration of ammonia. There is little or no organic nitrogen in the AWT effluent as the concentration of total Kjeldahl nitrogen (which measures organic nitrogen plus ammonia) is almost the same as the concentration of ammonia.

Phosphorus Removal by Chemical Precipitation

Phosphorus is typically removed at sewage treatment plants by one of two methods: enhanced biological uptake or chemical precipitation. Since enhanced biological uptake is a complex process that would require significant modifications to the existing AWT, EPA instead evaluated chemical precipitation. Chemical precipitation of phosphorus is performed at sewage treatment plants by adding ferric chloride, ferrous chloride, or aluminum sulfate (alum) to the aeration tanks of the activated sludge plants. The precipitated iron or aluminum phosphate is removed with the biological sludge. One advantage of ferric or ferrous chloride over alum is that ferric or ferrous chloride typically achieves the same removal as alum using a lower dosage. On average, phosphorus precipitation at sewage treatment plants reduces total phosphorus levels to 0.8 mg/L in the effluent.

Cruise ships would need to purchase and install a chemical feed system to add ferric or ferrous chloride to the AWT bioreactors. Operating and maintenance costs for the chemical feed system would include operating labor, energy, chemicals, and maintenance equipment.

Metals Removal Technologies

Metals Removal by Ion Exchange

Ion exchange for metals removal from cruise ship effluent is a process in which effluent from the UV disinfection system would be passed through a cylindrical tank containing a chelating resin. Metal ions would become bound to the resin. When the resin is fully saturated with metal ions, it could be regenerated onboard with an acid solution. The resulting regeneration solution from metals removal would contain the target metals and have a pH less than two. Alternatively, the resin canister could be regenerated shore side by a waste management company. Theoretically, ion exchange could remove 100% of metals such as copper, nickel, zinc and mercury. However, wastes generated from resin regeneration onboard would have to be appropriately managed, including an assessment against the RCRA hazardous waste regulations at 40 CFR 262.11 (see Section 6 for further discussion). The costs and potential environmental concerns associated with management of these wastes would need to be considered as part of the assessment of this technology.

Cruise ships would need to either purchase and install the add-on ion exchange technology and all necessary ancillary equipment, or rent ion exchange canisters from a vendor (who would handle resin regeneration) and purchase and install all necessary ancillary equipment. Operating and maintenance costs would include rental and labor for exchange of the rental units (if applicable), labor and regeneration solution costs for onboard regeneration (if applicable), operating labor, electrical costs, and maintenance equipment costs.

Metals Removal by Reverse Osmosis

Reverse osmosis is a process in which dissolved ions would be removed from AWT effluent using pressure to force the water through a semipermeable membrane element, which would pass the water but reject most of the dissolved materials. This membrane separation process is expected to remove more than 90% of copper, nickel, zinc, and mercury from AWT effluent (FILMTEC, 1998). Reverse osmosis also would remove other metals and other analytes in cruise ship effluent, including other chlorinated solvents, phenol- and benzene-based organic compounds, and possibly pharmaceuticals and personal care products.

Reverse osmosis is expected to generate a concentrate stream that is approximately 15% of the total influent flow. This concentrate stream would have to be appropriately managed, including an assessment against the RCRA hazardous waste regulations at 40 CFR 262.11 (see Section 6 for further discussion). The costs and potential environmental concerns associated with management of this waste would need to be considered as part of the assessment of this technology.

Cruise ships would need to purchase and install the add-on reverse osmosis technology and all necessary ancillary equipment. Operating and maintenance would include operating labor, electricity, membrane replacement, and membrane cleaning chemicals.

Temperature Control

One method of reducing temperature would be to install a shell and tube heat exchanger that transfers heat from the AWT effluent to a recirculating cold water system. Shell and tube heat exchangers are simply designed, able to operate under varying heat loads, and easily serviced. The recirculating cold water that passes through the heat exchanger to reduce the effluent temperature could be provided by either the vessel's existing chilled water system or by a separate chilled water system designed specifically for heat removal from the final effluent.

Cruise ships would need to purchase and install the add-on heat exchanger, as well as a new chiller if the existing chiller does not provide a sufficient volume of cold water to cool the effluent. Operating and maintenance costs for the heat exchanger system would include operating labor (e.g., start-up and shut-down maintenance at the start and end of the Alaska cruise season), electricity, and maintenance equipment.

2.5 What action is the federal government taking to address sewage from cruise ships?

EPA is evaluating the performance of advanced sewage and graywater treatment systems.
EPA is evaluating the performance of various advanced sewage and graywater treatment systems as part of its effort to assess whether revised or additional standards for sewage and graywater discharges from large cruise ships operating in Alaska are warranted under Title XIV (see subsection 2.2.3). Some of the results of this intensive effort, including sampling four different Advanced Wastewater Treatment systems and a survey questionnaire for all cruise ships operating in Alaska in 2004, are summarized in this report. EPA anticipates making these full analyses publicly available in 2008.

Coast Guard has developed regulations implementing the monitoring requirements of Title XIV.
Under Title XIV, the Coast Guard has implemented an inspection regime that includes sampling of cruise ship sewage and graywater discharges in Alaskan waters. In July 2001, the Coast Guard published a final rule (33 CFR 159.301-321) that outlines its oversight of cruise ships sampling in Alaskan waters.

Coast Guard is conducting a review of its inspection and enforcement policies.
The Coast Guard has started a review of their inspection and enforcement policies and regulations for cruise ship environmental practices. This review includes a survey of inspectors from Coast Guard regions, focusing on MSDs, oil/water separators, and the effectiveness and feasibility of various inspection practices.

California National Marine Sanctuaries propose to prohibit cruise ship sewage discharges.
Under the National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.), the Monterey Bay, Gulf of the Farallones, and Cordell Bank National Marine Sanctuaries have proposed regulations to

prohibit the discharge of treated and untreated sewage from large vessels, including cruise ships (71 FR 59050, Oct. 6, 2006; 71 FR 59338, Oct. 6, 2006; 71 FR 59039, Oct. 6, 2006). NOAA is currently reviewing the comments on these proposed rules. The Channel Islands National Marine Sanctuary has published a notice of intent (72 FR 40775, July 25, 2007) to revise a proposed action concerning vessel discharges (71 FR 29096, Oct. 5, 2006). The proposed rule containing the revision, which will include a prohibition on treated and untreated sewage from cruise ships, will be published for public comment in the near future.

References

Alaska Department of Environmental Conservation (ADEC). 2000a (September 13). *Alaska Cruise Ship Initiative Interim Report; Memorandum to Governor Tony Knowles*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/interimrep.pdf)

Alaska Department of Environmental Conservation (ADEC). 2000b. *Alaska Cruise Ship Initiative Part 1 Final Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/finreportp10808.pdf)

Alaska Department of Environmental Conservation (ADEC). 2001. *Alaska Cruise Ship Initiative Part 2 Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/acsireport2.pdf)

Alaska Department of Environmental Conservation (ADEC). 2002. *The Impact of Cruise Ship Wastewater Discharge on Alaska Waters*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/impactofcruiseship.pdf)

Alaska Department of Environmental Conservation (ADEC). 2004. *Assessment of Cruise Ship and Ferry Wastewater Impacts in Alaska*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/assessreport04.htm)

Booth, P.M., Jr., Sellers, C.M., Jr., & Garrison, N.E. 1981. Effects of Intermittent Chlorination on Plasma Proteins of Rainbow Trout (*Salmo gairdneri*). *Bull. of Env. Contam. & Tox* 26(2): 163-170.

Choi, Charles. 2007 (March 25). Cruise Ships Face Tough New Waste Disposal Limits - Industry Says Its Self-Policing Negates Need for Crackdown. *New York Times*. (http://travel.nytimes.com/2007/03/25/travel/25heads.html?pagewanted=print)

Cruise Line International Association (CLIA). 2006. *CLIA Industry Standard: Cruise Industry Waste Management Practices and Procedures*. Fort Lauderdale, FLr. (www.cruising.org/industry/PDF/CLIAWasteManagementAttachment.pdf and www.cruising.org/industry/PDF/CLIAWasteManagement.pdf)

Extoxnet. 1996. *Pesticide Information Profiles: Simazine*. Oregon State University. (http://extoxnet.orst.edu/pips/simazine.htm)

FILMTEC, Dow Chemical Company. 1998 (April). *FILMTEC Membranes Fact Sheet: Estimated Percent Rejection of Various Solutes by FILMTEC Membranes*. Midland, MI. (http://www.h2ro.com/_FilmRemo.pdf)

Hydroxyl Systems, Inc. 2007. *Royal Caribbean Places $9.2 Million Hydroxyl CleanSea Environmental Technology Order*. Victoria, British Columbia. (www.hydroxyl.com/news/?p=15)

Metcalf & Eddy. 1991. *Wastewater Engineering: Treatment and Reuse*, Third Edition. New York, NY: McGraw Hill.

National Research Council (NRC): Committee on Wastewater Management for Coastal Urban Areas, Water Science and Technology Board, Commission on Engineering and Technical Systems. 1993. *Managing Wastewater in Coastal Urban Areas*. Washington, DC: National Academy Press. (http://www.nap.edu/catalog.php?record_id=2049#toc)

National Research Council (NRC): Committee on Oil in the Sea: Inputs, Fates, and Effects. 2003. *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: National Academy Press. (http://www.nap.edu/catalog.php?record_id=10388#toc)

Pruss, Annette. 1998. Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemiology* 27: 1-9.

Rees, G. 1993. Health Implications of Sewage in Coastal Waters - the British Case. *Marine Pollution Bulletin* 26(1): 14-19.

Sanders, J.G., & Ryther J.H. 1980. Impact of chlorine on the species composition of marine phytoplankton. In: R.L. Jolley, et al. (Eds.), *Water Chlorination: Environmental Impact and Health Effects* 3: 631. Ann Arbor, MI: Ann Arbor Science Publishers.

U.S. Environmental Protection Agency. 1983. *Health Effects Criteria for Marine Recreational Waters* (EPA-600/1-80-031). Research Triangle Park, NC. (http://www.epa.gov/nerlcwww/mrcprt1.pdf)

U.S. Environmental Protection Agency. 1984a. *Ambient water quality criteria for chlorine* (EPA 440/5-84-030). Washington, DC. (http://www.epa.gov/ost/pc/ambientwqc/chlorine1984.pdf)

U.S. Environmental Protection Agency. (1984b). *Health Effects Criteria for Fresh Recreational Waters* (EPA-600/1-84-004). Research Triangle Park, NC. (http://www.epa.gov/nerlcwww/frc.pdf)

U.S. Environmental Protection Agency. 1986. *Quality Criteria for Water* (EPA 440/5-86-001). Washington, DC. (http://www.epa.gov/waterscience/criteria/goldbook.pdf)

U.S. Environmental Protection Agency. 1989. *Ambient water quality criteria for ammonia (saltwater)*(EPA 440/5-88-004). Washington, DC. (http://www.epa.gov/waterscience/pc/ambientwqc/ammoniasalt1989.pdf)

U.S. Environmental Protection Agency. 2001. *Nutrient Criteria Technical Guidance Manual: Estuarine and Coastal Marine Waters* (EPA-822-B-01-003). Washington, DC. (http://www.epa.gov/waterscience/criteria/nutrient/guidance/marine/)

U.S. Environmental Protection Agency. 2002. *Cruise Ship Plume Tracking Survey Report* (EPA842-R-02-001). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/plumerpt2002/plumereport.pdf)

U.S. Environmental Protection Agency. 2004. *Survey Questionnaire to Determine the Effectiveness, Costs, and Impacts of Sewage and Graywater Treatment Devices for Large Cruise Ships Operating in Alaska* (EPA Form No. 7500-64). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/cruise_ship_survey.pdf)

U.S. Environmental Protection Agency. 2006a. *Sampling Episode Report for Holland America Veendam* (Sampling Episode 6503). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/Veendam/VeendamSER.pdf)

U.S. Environmental Protection Agency. 2006b. *Sampling Episode Report for Norwegian Star* (Sampling Episode 6504). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/FinalStar/FinalStarSERNCBI.pdf)

U.S. Environmental Protection Agency. 2006c. *Sampling Episode Report for Princess Cruise Lines – Island Princess* (Sampling Episode 6505). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/Island/IslandSER.pdf)

U.S. Environmental Protection Agency. 2006d. *Sampling Episode Report for Holland America Oosterdam* (Sampling Episode 6506). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/Oosterdam/OosterdamFinal.pdf)

U.S. Environmental Protection Agency. 2006e. *Sampling Episode Report for Nitrogen Compounds Characterization* (Sampling Episodes 6517 Through 6520). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/nitrogen/nitrogen_NCBI.pdf)

Vetrano, K.M. 1998. *Molecular Chlorine: Health and Environmental Effects.* TRC Environmental Corporation. Windsor, CT.

World Health Organization (WHO). 1986. Ammonia Environmental Health Criteria 54. Geneva, Switzerland. (http://www.inchem.org/documents/ehc/ehc/ehc54.htm)

Wu, R.S.S. 1999. Eutrophication, Water Borne Pathogens and Xenobiotic Compounds: Environmental Risks and Challenges. *Marine Pollution Bulletin* 39: 11-22.

Section 3: Graywater

Graywater generally means wastewater from sinks, baths, showers, laundry, and galleys. On cruise ships using Advanced Wastewater Treatment systems, one or more graywater sources are often treated with sewage (see Section 2 for more information). On other cruise ships, graywater generally is not treated.

This section discusses the current state of information about vessel graywater, the laws regulating graywater discharges from vessels, the potential environmental impacts of untreated cruise ship graywater discharges, and federal actions taken to address graywater from cruise ships. The types of equipment used to treat graywater generated on some cruise ships, and how well they remove various pollutants, are discussed in Section 2.

3.1 What is graywater and how much is generated on cruise ships?

Graywater generally means wastewater from sinks, baths, showers, laundry, and galleys (see Table 3-1). The source water for most graywater sources is potable water. Some common graywater sources and potential characteristics are listed in Table 3-2 below.

Table 3-1. Graywater Definitions

Source	Graywater Definition
Clean Water Act, 33 U.S.C. § 312(a)(11)	Galley, bath, and shower water
International Maritime Organization (IMO) Guidelines for Implementation of Annex V of MARPOL 73/78 (Sec. 1.7.8)	Drainage from dishwasher, shower, laundry, bath and washbasin drains and does not include drainage from toilets, urinals, hospitals, and animal spaces, as defined in regulation 1(3) of Annex IV, as well as drainage from cargo spaces
Title XIV – Certain Alaskan Cruise Ship Operations, 33 U.S.C. § 1901 Note (Sec. 1414(4))	Only galley, dishwasher, bath, and laundry waste water
Coast Guard Regulations, 33 CFR 151.05	Drainage from dishwasher, shower, laundry, bath, and washbasin drains and does not include drainage from toilets, urinals, hospitals, and cargo spaces

Table 3-2. Common Sources and Characteristics of Graywater

Water Source	Characteristics
Automatic Clothes Washer	bleach, foam, high pH, hot water, nitrate, oil and grease, oxygen demand, phosphate, salinity, soaps, sodium, suspended solids, turbidity
Automatic Dish Washer	bacteria, foam, food particles, high pH, hot water, odor, oil and grease, organic matter, oxygen demand, salinity, soaps, suspended solids, turbidity
Sinks, including kitchen	bacteria, food particles, hot water, odor, oil and grease, organic matter, oxygen demand, soaps, suspended solids, turbidity
Bathtub and Shower	bacteria, hair, hot water, odor, oil and grease, oxygen demand, soaps, suspended solids, turbidity

Source: ACSI, 2001

According to information gathered by EPA during ship visits and via responses to EPA's survey of cruise ships operating in Alaska in 2004, the following waste streams also may be sent to the graywater system on some cruise ships: wastewater from bar and pantry sinks, salon and day spa sinks and floor drains, interior deck drains, shop sinks and deck drains in non-engine rooms (e.g., print shops, photo processing shops, dry cleaning areas, and chemical storage areas); refrigerator and air conditioner condensate; wastewater from laundry floor drains in passenger and crew laundries; dry cleaning condensate; wastewater from dishwashers, food preparation, galley sinks, floor drains, and the food pulper; wastewater from garbage room floor drains and from sinks in restaurants and cafes; wastewater from whirlpools; and wastewater from medical facility sinks and medical floor drains. Some of these waste streams may not fall within the statutory definitions of graywater listed above.

Estimated graywater generation rates reported in response to EPA's 2004 cruise ship survey ranged from 36,000 to 249,000 gallons/day/vessel or 36 to 119 gallons/day/person. EPA is not able to independently confirm the accuracy of these estimated rates. Average graywater generation rates were 170,000 gallons/day/vessel and 67 gallons/day/person (see Figure 3-1). There appears to be no relationship between per capita graywater generation rates and number of persons onboard (see Figure 3-2). Estimated graywater generation rates reported in response to EPA's 2004 cruise ship survey indicate that approximately 52% of wastewater was from accommodations, 17% from laundries, and 31% from galleys.

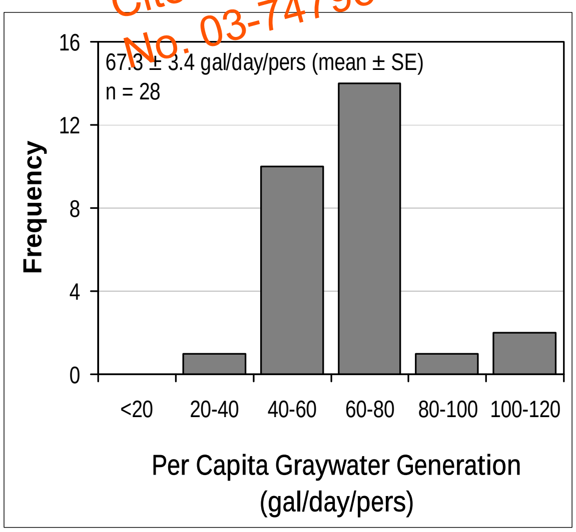


Figure 3-1. Per Capita Graywater Generation as Reported in EPA's 2004 Cruise Ship Survey

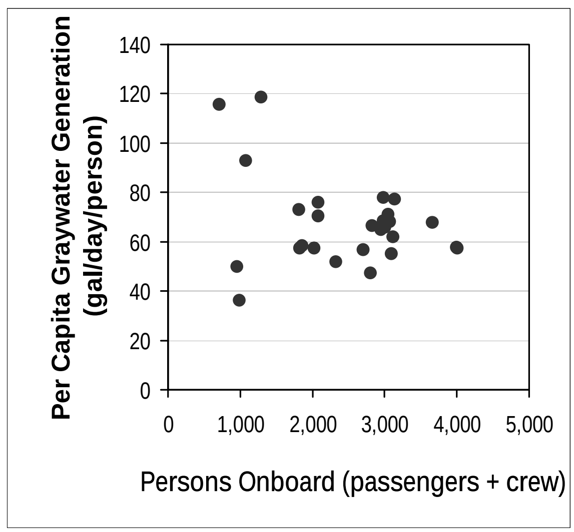


Figure 3-2. Graywater Generation by Persons Onboard as Reported in EPA's 2004 Cruise Ship Survey

During EPA's 2004 sampling of four ships with Advanced Wastewater Treatment systems (AWTs), graywater generation was measured on one ship at 45 gal/day/person (EPA, 2006a). On other ships, measurements were made of sewage plus graywater sources treated by the AWT. The Alaska Cruise Ship Initiative (ADEC, 2000) used a rule of thumb of 50 to 65 gallons of graywater generated per person per day. Residential graywater generation has been estimated at about 51 gallons per person per day (Mayer and DeOreo, 1998).

On ships where graywater is treated, treated graywater discharge rates are nearly equivalent to graywater generation rates. Differences between these two rates are attributed to the volume of wastewater treatment sludge, if any, that is removed during wastewater treatment (see subsection 2.3.3).

A typical graywater piping system may lead to several graywater holding tanks segregated by graywater source. On some ships, graywater sources may undergo limited treatment enroute to the holding tanks (e.g., gross particle filters or grease traps). Graywater from holding tanks can be sent to an AWT for treatment, discharged immediately upon generation, or diverted to longer-term storage in one or more double bottom holding tanks for controlled discharge.

Cruise vessel capacity to hold graywater varies significantly. According to responses to EPA's 2004 cruise ship survey, graywater holding capacity ranges from 5 to 90 hours, with an average holding capacity of 56 hours. When graywater is discharged untreated, motor-driven centrifugal pumps force the wastewater overboard approximately five meters below the ship's waterline via one or more discharge ports, approximately 140 mm in diameter.

3.2 What laws apply to graywater from cruise ships?

3.2.1 Clean Water Act

Graywater discharges from vessels generally are not regulated under the Clean Water Act, except for graywater from commercial vessels operating on the Great Lakes, which is discussed below. Clean Water Act regulations (40 CFR 122.3) exempt discharges incidental to the normal operation of a vessel, including "laundry, shower, and galley sink wastes," from permit requirements under the National Pollution Discharge Elimination System (NPDES). On September 18, 2006, however, a federal District Court in California vacated the NPDES exclusion for these discharges, effective on September 30, 2008. The decision has been appealed to the U.S. Court of Appeals for the Ninth Circuit, where it is pending.

Section 312 of the Clean Water Act (CWA; 33 U.S.C. § 1322) requires that vessels with installed toilet facilities be equipped with an operable marine sanitation device, certified by the Coast Guard to meet EPA performance standards, in order to operate on the navigable waters of the United States. CWA section 312 has limited applicability to graywater because the definition of sewage includes graywater with respect to commercial vessels on the Great Lakes (33 U.S.C. § 1322(a)(6)). For a full discussion of CWA section 312, see Section 2 (subsection 2.2.1).

3.2.2 Certain Alaskan Cruise Ship Operations

On December 12, 2000, Congress enacted an omnibus appropriation that included new statutory requirements for certain cruise ship discharges occurring in Alaska (Departments of Labor, Health and Human Services, and Education, and Related Agencies Appropriations Act, 2001, Pub. L. No. 106-554, 114 Stat. 2763, enacting into law Title XIV of Division B of H.R. 5666, 114 Stat. 2763A-315, and codified at 33 U.S.C. § 1901 Note). Title XIV sets discharge standards for sewage and graywater from certain cruise ships (those authorized to carry 500 or more passengers for hire) while operating in the Alexander Archipelago and the navigable waters of the United States in the State of Alaska and within the Kachemak Bay National Estuarine Research Reserve. For a full discussion of Title XIV, see Section 2 (subsection 2.2.3).

3.2.3 National Marine Sanctuaries Act

The National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.), as amended, authorizes the National Oceanic and Atmospheric Administration (NOAA) to designate as National Marine Sanctuaries areas of the marine environment that have special aesthetic, ecological, historical, or recreational qualities, and to provide comprehensive and coordinated conservation management for such areas. The National Marine Sanctuary Program manages 13 sanctuaries and the Papahānaumokuākea Marine National Monument. Designated sanctuaries are managed according to site-specific management plans developed by NOAA that typically prohibit the discharge or deposit of most material. Discharges of graywater and treated vessel sewage, however, are sometimes allowed provided they are authorized under the Clean Water Act. In some sanctuaries the discharge of graywater, as well as sewage, is prohibited in special zones to protect fragile habitat, such as coral. The Act also provides for civil penalties for violations of its requirements or the permits issued under it.

3.3 Characterization of untreated graywater

Except in Alaska, graywater from cruise ships currently is not required to be treated before discharge. However, Cruise Lines International Association (CLIA) members have agreed to incorporate various standards for waste stream management into their Safety Management Systems (see Section 1.3). For ships traveling regularly on itineraries beyond the territorial waters of coastal states, CLIA member lines have agreed to discharge graywater only while the ship is underway and proceeding at a speed of not less that six knots (for vessels operating under sail, or a combination of sail and motor propulsion, the speed shall not be less than four knots); that graywater will not be discharged in port and will not be discharged within four nautical miles from shore or such other distance as agreed to with authorities having jurisdiction or provided for by local law except in an emergency, or where geographically limited (CLIA, 2006).

While some cruise ships are using Advanced Wastewater Treatment systems (AWTs) to treat graywater (as well as sewage), detailed information on the effluent from AWTs can be found in Section 2 and will not be repeated here. The remainder of this subsection provides information on untreated graywater from two sources: EPA's 2004 sampling of cruise ships operating in Alaska and a voluntary sampling effort in 2000 and 2001 by the Alaska Cruise Ship Initiative.

Data Collection

EPA Sampling: EPA sampled wastewater in 2004 from four cruise ships that operated in Alaska to characterize graywater and sewage generated onboard and to evaluate the performance of the Zenon, Hamworthy, Scanship, and ROCHEM AWTs (see EPA, 2006 a-d). EPA analyzed individual graywater sources (accommodations, laundry, galley, and food pulper wastewater) on each ship for over 400 analytes, including pathogen indicators, suspended and dissolved solids, biochemical oxygen demand, oil and grease, dissolved and total metals, organics, and nutrients. In addition, laundry wastewater samples were analyzed for dioxins and furans, and galley wastewater samples were analyzed for organohalide and organophosphorus pesticides.

Alaska Cruise Ship Initiative (ACSI) Sampling: Concerns over cruise ship wastewater discharges in Alaska led to a voluntary sampling effort in 2000 by the Alaska Cruise Ship Initiative (ADEC, 2001). Twice during the 2000 cruise season, samples were collected from each sewage and graywater discharge port from each of the 21 large cruise ships operating in Alaska. Sampling was scheduled randomly at various ports of call on all major cruise routes in Alaska. Analytes included total suspended solids (TSS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pH, fecal coliform, total residual chlorine (TRC), free residual chlorine, and ammonia for all samples, and priority pollutants (metals, hydrocarbons, organochlorines) for one sample per ship. Voluntary sampling continued at the start of the 2001 cruise ship season through July 1, 2001, when Alaska state graywater and sewage discharge regulations (AS 46-03.460 - 46.03.490) came into effect. Additional sampling of untreated graywater was done under these regulations during the remainder of the 2001 cruise season. Samples collected during both the voluntary and compliance monitoring sampling programs characterized different types of wastewater depending on ship-specific discharge configurations. The ACSI sampling results presented in this section include only those sampling points designated as "Mixed Graywater." Mixed graywater samples were collected either as generated or following longer-term storage in double bottom holding tanks.

The results of these sampling efforts are discussed in greater detail below, but to summarize, the results of analyses of graywater demonstrated that the strength of the graywater, in terms of BOD, COD and TSS, is variable and that it can have high levels of fecal coliform bacteria (ADEC, 2001).

Pathogen Indicators

EPA analyzed untreated graywater sources for the pathogen indicators fecal coliform, enterococci, and *E. coli*. Table 3-3 presents the graywater sampling data for the individual graywater sources. All three pathogen indicators were detected in all four food pulper samples and in the majority of galley and accommodations wastewater samples.

EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated graywater, which resulted in an estimated fecal coliform concentration of 36,000,000 CFU/100mL. ACSI/ADEC results indicated 2,950,000 MPN/100mL fecal coliform for untreated mixed graywater (see Table 3-3). These fecal coliform concentrations are one to three orders of magnitude greater than typical fecal coliform concentrations in untreated domestic wastewater of 10,000 to 100,000 MPN/100 mL (Metcalf & Eddy, 1991).

Conventional Pollutants and Other Common Analytes

Table 3-4 shows EPA's and ACSI/ADEC's sampling results for some conventional pollutants and other common analytes in untreated graywater, as well as typical concentrations in untreated domestic wastewater. Key analytes commonly used to assess wastewater strength are biochemical oxygen demand, chemical oxygen demand, and total suspended solids. Food pulper wastewater is the highest strength graywater source, with key analyte concentrations more than an order of magnitude greater than those in other graywater sources. The remaining graywater sources in order of decreasing wastewater strength are galley wastewater, accommodations wastewater, and laundry wastewater. Average untreated graywater strength is comparable or higher in strength than untreated domestic wastewater.

Metals

EPA sampled for 54 total and dissolved metal analytes (26 of which are priority pollutants) and ACSI sampled for 13 priority pollutant total metal analytes in untreated graywater. Table 3-5 presents graywater sampling data for priority pollutant metals that were detected in greater than 10 percent of either the EPA or ACSI/ADEC samples (less frequent detection of analytes is considered not representative of the wastestream).

Table 3-3. Comparison of Untreated Graywater Concentrations to Untreated Domestic Wastewater—Pathogen Indicators

Analyte	Graywater Source	Units	Average Concentration[1]	Range	Number of Results ≤ 200	Number of Results 201 to ≤ 100,000	Number of Results 100,001 to ≤ 1,000,000	Number of Results >1,000,000
E. Coli	Accommodations	MPN/ 100 mL	83,500#	ND(1.00) - 1,050,000 (17 detects out of 21 samples)	6	7	7	1
	Laundry	MPN/ 100 mL	1,930*	ND(1.00) - 7,700 (5 detects out of 21 samples)	19	2	0	0
	Galley	MPN/ 100 mL	935,000#	ND(1.00) - >24,200,000 (21 detects out of 22 samples)	1	10	7	4
	Food Pulper	MPN/ 100 mL	336,000**	17,300 - 2,420,000 (4 detects out of 4 samples)	0	3	0	1
	Graywater[2]	MPN/ 100 mL	292,000#					
Enterococci	Accommodations	MPN/ 100 mL	532#	ND(1.00) - >2,420 (16 detects out of 21 samples)	11	10	0	0
	Laundry	MPN/ 100 mL	253#	ND(1.00) - >2,420 (7 detects out of 21 samples)	17	4	0	0
	Galley	MPN/ 100 mL	6,750**	95 – 51,700 (22 detects out of 22 samples)	3	19	0	0
	Food Pulper	MPN/ 100 mL	411,000**	10,400 – 1,600,000 (4 detects out of 4 samples)	0	3	0	1
	Graywater[2]	MPN/ 100 mL	8,920#					
Fecal Coliform	Accommodations	CFU/ 100 mL	36,700,000#	1,500 - 120,000,000 (18 detects out of 19 samples)	0	7	6	6
	Laundry	CFU/ 100 mL	7,940#	ND(2.00) - >60,000 (11 detects out of 19 samples)	11	8	0	0
	Galley	CFU/ 100 mL	29,100,000**	1,900 - 910,000,000 (19 detects out of 19 samples)	0	4	6	9
	Food Pulper	CFU/ 100 mL	87,400	29,000 - 170,000 (4 detects out of 4 samples)	0	2	2	0
	Graywater[2]	CFU/ 100 mL	36,000,000#					
	Graywater (ASCI / ADEC Data)	MPN/ 100 mL	2,950,000#[3]	ND(2.00) – 32,000,000 (134 detects out of 156 samples)	36	29	42	49

[1] Based on data collected by EPA in 2004 unless otherwise noted.

[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated graywater.
[3] Based on data collected by ACSI/ADEC in 2000 and 2001.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
** Average includes at least one result flagged by the laboratory as not diluted sufficiently; therefore this average represents a minimum value.
# Average includes at least one nondetect value (calculation uses detection limits for nondetected results) and at least one result flagged by the laboratory as not diluted sufficiently.
The “>” symbol indicates that the laboratory flagged the sample as not diluted sufficiently; therefore, this represents a minimum value for the sample.

Table 3-4. Comparison of Untreated Graywater Concentraions to Untreated Domestic Wastewater—Conventional Pollutants and Other Common Analytes

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]	Concentration in Untreated Domestic Wastewater[4]
Alkalinity	mg/L	48.1* (11 detects out of 12 samples)	71.6 (12 detects out of 12 samples)	57.7* (9 detects out of 12 samples)	ND(57.5) (0 detects out of 4 samples)	53.8* (32 detects out of 40 samples)	57.8 (4 detects out of 4 samples)	
Biochemical Oxygen Demand (5-Day)	mg/L	260 (11 detects out of 11 samples)	83.8 (11 detects out of 11 samples)	1,490 (11 detects out of 11 samples)	30,500 (4 detects out of 4 samples)	1,140 (37 detects out of 37 samples)	354 (42 detects out of 42 samples)	110 to 400
Chemical Oxygen Demand	mg/L	723 (12 detects out of 12 samples)	257 (12 detects out of 12 samples)	1,830 (12 detects out of 12 samples)	26,400 (4 detects out of 4 samples)	1,890 (40 detects out of 40 samples)	1,000 (41 detects out of 41 samples)	250 to 1,000
Chloride	mg/L	66.6 (12 detects out of 12 samples)	22.4 (12 detects out of 12 samples)	145 (12 detects out of 12 samples)	1,240 (4 detects out of 4 samples)	125 (40 detects out of 40 samples)	NC	
Conductivity	µS/cm	236 (43 detects out of 43 samples)	74.4 (43 detects out of 43 samples)	647 (48 detects out of 48 samples)	4,060 (7 detects out of 7 samples)	427 (141 detects out of 141 samples)	2,250 (21 detects out of 21 samples)	
Free Residual Chlorine	µg/L	NR	NR	NR	NR	NR	0.256* (6 detects out of 43 samples)	
Hardness	mg/L	38.2 (12 detects out of 12 samples)	14.1 (12 detects out of 12 samples)	65.1 (12 detects out of 12 samples)	449 (3 detects out of 3 samples)	54.5 (39 detects out of 39 samples)	NC	
Hexane Extractable Material	mg/L	37.6 (12 detects out of 12 samples)	13.4 (11 detects out of 11 samples)	172 (12 detects out of 12 samples)	1,960 (3 detects out of 3 samples)	149 (38 detects out of 38 samples)	78.0 Oil and Grease (4 detects out of 4 samples)	
pH		83.3% of pH samples are between 6.0 and 9.0 (35 of 42 samples)	81.8% of pH samples are between 6.0 and 9.0 (36 of 44 samples)	50.0% of pH samples are between 6.0 and 9.0 (24 of 48 samples)	0% of the pH samples are between 6.0 and 9.0 (0 of 8 samples)	66.9% of pH samples are between 6.0 and 9.0 (95 of 142 samples)	76.7% of pH samples are between 6.0 and 9.0 (33 out of 43	Between 6.0 and 9.0

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]	Concentration in Untreated Domestic Wastewater[4]
							samples)	
Salinity	ppt	1.72* (42 detects out of 43 samples)	1.26 (43 detects out of 43 samples)	2.56 (48 detects out of 48 samples)	6.05 (7 detects out of 7 samples)	2.08* (140 detects out of 141 samples)	NC	
Settable Residue	mg/L	4.43* (7 detects out of 11 samples)	0.492* (3 detects out of 11 samples)	18.7 (11 detects out of 11 samples)	728 (4 detects out of 4 samples)	25.6* (25 detects out of 37 samples)	1.10* (2 detects out of 4 samples)	
Silica Gel Treated Hexane Extractable Material	mg/L	ND(5.89) (0 detects out of 12 samples)	ND(5.37) (0 detects out of 11 samples)	8.39* (2 detects out of 12 samples)	821* (2 detects out of 3 samples)	36.6* (4 detects out of 38 samples)	NC	
Sulfate	mg/L	41.5 (12 detects out of 12 samples)	16.3 (12 detects out of 12 samples)	61.0 (12 detects out of 12 samples)	194 (4 detects out of 4 samples)	49.9 (40 detects out of 40 samples)	NC	
Temperature	°C	34.7 (42 detects out of 42 samples)	48.6 (44 detects out of 44 samples)	41.9 (48 detects out of 48 samples)	66.5 (8 detects out of 8 samples)	39.6 (142 detects out of 142 samples)	NC	
Total Dissolved Solids	mg/L	244 (12 detects out of 12 samples)	191 (12 detects out of 12 samples)	897 (12 detects out of 12 samples)	5,160 (3 detects out of 3 samples)	578 (39 detects out of 39 samples)	NC	
Total Organic Carbon	mg/L	78.9 (12 detects out of 12 samples)	60.2 (12 detects out of 12 samples)	358 (12 detects out of 12 samples)	21,300 (4 detects out of 4 samples)	535 (40 detects out of 40 samples)	481 (4 detects out of 4 samples)	
Total Residual Chlorine	mg/L	NR	NR	NR	NR	NR	0.372* (9 detects out of 43 samples)	
Total Suspended Solids	mg/L	207 (12 detects out of 12 samples)	37.1 (12 detects out of 12 samples)	877 (12 detects out of 12 samples)	16,500 (3 detects out of 3 samples)	704 (39 detects out of 39 samples)	318 (43 detects out of 43 samples)	100 to 350
Turbidity	NTU	186 (43 detects out of 43 samples)	20.9 (41 detects out of 41 samples)	408 (33 detects out of 33 samples)	NC	224 (117 detects out of 117 samples)		

[1] Based on data collected by EPA in 2004.
[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated graywater.

[3] Based on data collected by ACSI/ADEC in 2000 and 2001.
[4] Metcalf & Eddy, 1991.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
"NC" indicates that this information was not collected.
"NR" indicates that this information was not reported. Equipment used to measure free and total chlorine is not suitable for measuring low levels of chlorine and is subject to interferences; accordingly, field measurements collected for the sole purpose determining sample preservation requirements are not reported.

Table 3-5. Untreated Graywater Concentrations—Metals

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]
Antimony, Total	µg/L	ND(3.99) (0 detects out of 12 samples)	ND(3.99) (0 detects out of 12 samples)	ND(3.99) (0 detects out of 12 samples)	6.67* (3 detects out of 4 samples)	4.09* (3 detects out of 40 samples)	1.34* (4 detects out of 6 samples)
Arsenic, Total	µg/L	ND(2.16) (0 detects out of 12 samples)	ND(2.16) (0 detects out of 12 samples)	2.44* (3 detects out of 12 samples)	5.85* (1 detect out of 4 samples)	2.25* (4 detects out of 40 samples)	1.22 (6 detects out of 6 samples)
Beryllium, Total	µg/L	0.0688* (1 detect out of 12 samples)	ND(0.0620) (0 detects out of 12 samples)	0.116* (2 detects out of 12 samples)	ND(0.0448) (0 detects out of 4 samples)	0.0736* (3 detects out of 40 samples)	0.0907* (4 detects out of 6 samples)
Cadmium, Total	µg/L	0.463* (1 detect out of 12 samples)	0.270* (1 detects out of 12 samples)	0.391* (6 detects out of 12 samples)	1.29 (4 detects out of 4 samples)	0.452* (12 detects out of 40 samples)	0.541* (10 detects out of 30 samples)
Chromium, Total	µg/L	22.4* (11 detects out of 12 samples)	2.25* (10 detects out of 12 samples)	7.03* (10 detects out of 12 samples)	16.7 (4 detects out of 4 samples)	16.7* (35 detects out of 40 samples)	4.17* (8 detects out of 30 samples)
Chromium, Dissolved	µg/L	1.49* (9 detects out of 12 samples)	1.38* (6 detects out of 12 samples)	2.04* (10 detects out of 12 samples)	5.16 (3 detects out of 3 samples)	1.70* (28 detects out of 39 samples)	NC
Copper, Total	µg/L	677 (12 detects out of 12 samples)	278 (12 detects out of 12 samples)	383 (12 detects out of 12 samples)	208 (4 detects out of 4 samples)	510 (40 detects out of 40 samples)	483* (20 detects out of 30 samples)
Copper, Dissolved	µg/L	167 (12 detects out of 12 samples)	253 (12 detects out of 12 samples)	232 (12 detects out of 12 samples)	15.3 (3 detects out of 3 samples)	195 (39 detects out of 39 samples)	NC
Lead, Total	µg/L	14.8* (9 detects out of 12 samples)	5.77* (9 detects out of 12 samples)	21.2* (10 detects out of 12 samples)	14.1* (3 detects out of 4 samples)	12.3* (31 detects out of 40 samples)	19.3* (11 detects out of 30 samples)
Lead, Dissolved	µg/L	2.48* (5 detects out of 12 samples)	3.76* (8 detects out of 12 samples)	10.2* (7 detects out of 12 samples)	2.87* (1 detects out of 3 samples)	4.25* (21 detects out of 39 samples)	NC

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data) [1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data) [2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data) [3]
Mercury, Total[4]	µg/L	0.153* (8 detects out of 12 samples)	0.0518* (7 detects out of 12 samples)	0.0703* (6 detects out of 12 samples)	0.197* (2 detects out of 4 samples)	0.100* (23 detects out of 40 samples)	0.0733* (2 detects out of 24 samples)
Mercury, Dissolved[4]	µg/L	0.155* (5 detects out of 12 samples)	0.0895* (6 detects out of 12 samples)	0.108* (6 detects out of 12 samples)	0.143* (2 detects out of 3 samples)	0.122* (19 detects out of 39 samples)	NC
Nickel, Total	µg/L	34.0 (12 detects out of 12 samples)	6.19 (12 detects out of 12 samples)	29.2 (12 detects out of 12 samples)	22.4 (4 detects out of 4 samples)	29.7 (40 detects out of 40 samples)	48.7* (12 detects out of 30 samples)
Nickel, Dissolved	µg/L	17.2 (12 detects out of 12 samples)	4.85 (12 detects out of 12 samples)	26.4 (12 detects out of 12 samples)	31.1 (3 detects out of 3 samples)	18.2 (39 detects out of 39 samples)	NC
Selenium, Total	µg/L	1.07* (4 detects out of 12 samples)	1.26* (3 detects out of 12 samples)	4.93* (9 detects out of 12 samples)	26.9 (4 detects out of 4 samples)	3.37* (20 detects out of 40 samples)	4.45* (4 detects out of 6 samples)
Selenium, Dissolved	µg/L	1.05* (4 detects out of 12 samples)	1.02* (4 detects out of 12 samples)	4.74* (7 detects out of 12 samples)	22.1 (3 detects out of 3 samples)	3.04* (18 detects out of 39 samples)	NC
Silver, Total	µg/L	2.07* (1 detect out of 12 samples)	1.73* (6 detects out of 12 samples)	1.13* (4 detects out of 12 samples)	1.04* (1 detect out of 4 samples)	1.82* (12 detects out of 40 samples)	0.880* (13 detects out of 30 samples)
Thallium, Total	µg/L	1.13* (1 detects out of 12 samples)	ND(0.765) (0 detects out of 12 samples)	0.405* (2 detects out of 12 samples)	0.550* (3 detects out of 4 samples)	0.930* (6 detects out of 40 samples)	ND
Thallium, Dissolved	µg/L	ND(0.405) (0 detects out of 12 samples)	0.407* (1 detects out of 12 samples)	0.405* (4 detects out of 12 samples)	0.296* (1 detects out of 3 samples)	0.403* (6 detects out of 39 samples)	NC
Zinc, Total	µg/L	3,130 (12 detects out of 12 samples)	345 (12 detects out of 12 samples)	1,460 (12 detects out of 12 samples)	6,380 (4 detects out of 4 samples)	2,540 (40 detects out of 40 samples)	790* (19 detects out of 30 samples)
Zinc, Dissolved	µg/L	792 (12 detects out of 12 samples)	266 (12 detects out of 12 samples)	1,070 (12 detects out of 12 samples)	47,800 (3 detects out of 3 samples)	1,610 (39 detects out of 39 samples)	NC

[1] Based on data collected by EPA in 2004.
[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated graywater.
[3] Based on data collected by ACSI/ADEC in 2000 and 2001.
[4] Because it was not possible to incorporate "clean" sampling and analysis methodologies for mercury when sampling onboard ships, there is no way for EPA to determine whether mercury reported here is present in the graywater or if the mercury was the result of contamination from nearby metal or sources of airborne contamination.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
"NC" indicates that this information was not collected.
"ND" indicates that the analyte was not detected (number in parentheses is detection limit).

Food pulper wastewater contained the highest average concentration of 10 of the 21 metal analytes listed in Table 3-5. Six metal analytes were detected in accommodations wastewater at the highest average concentration. Galley and laundry wastewater contained the highest average concentration of only three and two metal analytes, respectively.

Total and dissolved copper, total and dissolved nickel, and total and dissolved zinc were detected in all EPA graywater samples. These six metal analytes also were detected at the highest average concentrations among the priority metal analytes. Total copper, total nickel, and total zinc were also the priority pollutant metal analytes detected at the highest average concentrations in ACSI/ADEC graywater samples.

Volatile and Semivolatile Organics

EPA tested for 84 volatile and semivolatile organics, of which approximately 85 percent are priority pollutants. ACSI/ADEC sampled for almost 140 priority pollutant and non priority pollutant volatile and semivolatile organic analytes. Table 3-6 presents untreated graywater sampling data for priority pollutant volatile and semivolatile organics that were detected in greater than 10 percent of either EPA or ACSI/ADEC samples (less frequent detection of analytes is considered not representative of the wastestream).

Analytes listed in Table 3-6 that were detected at the highest average concentration and/or frequency include plasticizers (phthalates), chlorine byproducts (e.g., chloroform and bromodichloromethane), and compounds naturally produced in foods (phenol).

Nutrients

Table 3-7 shows average nutrient concentrations in untreated graywater, as well as typical concentrations in untreated domestic wastewater. Food pulper wastewater contains the highest average concentration of nutrients.

Average nitrate/nitrite, total Kjeldahl nitrogen, and total phosphorus concentrations in untreated graywater are comparable to concentrations in untreated domestic wastewater. The average ammonia concentration in untreated graywater is much less than that in untreated domestic wastewater (because the presence of ammonia is indicative of human waste).

Table 3-6. Untreated Graywater Concentrations—Volatile and Semivolatile Organics

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]
1,2-Dichloroethane	µg/L	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	ND(7.37) (0 detects out of 40 samples)	0.426* (4 detects out of 24 samples)
2,4-Dichlorophenol	µg/L	ND(11.2) (0 detects out of 12 samples)	ND(10.1) (0 detects out of 12 samples)	ND(10.4) (0 detects out of 12 samples)	ND(80.2) (0 detects out of 4 samples)	ND(11.9) (0 detects out of 40 samples)	0.275 (6 detects out of 6 samples)
Bis(2-ethylhexyl) phthalate	µg/L	25.3* (11 detects out of 12 samples)	56.3 (12 detects out of 12 samples)	155* (11 detects out of 12 samples)	526* (2 detects out of 4 samples)	71.9* (36 detects out of 40 samples)	22.4* (21 detects out of 30 samples)
Bromodichloromethane	µg/L	ND(7.50) (0 detects out of 12 samples)	7.50* (1 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	7.37* (1 detects out of 40 samples)	3.92* (15 detects out of 30 samples)
Bromoform	µg/L	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	ND(7.37) (0 detects out of 40 samples)	1.97* (9 detects out of 30 samples)
Butyl benzyl phthalate	µg/L	ND(10.3) (0 detects out of 12 samples)	ND(10.0) (0 detects out of 12 samples)	ND(10.0) (0 detects out of 12 samples)	ND(80.2) (0 detects out of 4 samples)	ND(11.4) (0 detects out of 40 samples)	7.74* (6 detects out of 30 samples)
Chloroform	µg/L	7.53* (1 detect out of 12 samples)	48.6* (11 detects out of 12 samples)	7.99* (4 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	13.5* (16 detects out of 40 samples)	13.3* (20 detects out of 30 samples)
Dibromochloromethane	µg/L	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	ND(7.37) (0 detects out of 40 samples)	3.08* (11 detects out of 30 samples)
Diethyl phthalate	µg/L	14.1* (5 detects out of 12 samples)	10.6* (3 detects out of 12 samples)	11.1* (1 detect out of 12 samples)	ND(80.2) (0 detects out of 4 samples)	14.1* (9 detects out of 40 samples)	5.41* (18 detects out of 30 samples)
Di-n-butyl phthalate	µg/L	ND(10.3) (0 detects out of 12 samples)	ND(10.0) (0 detects out of 12 samples)	ND(10.0) (0 detects out of 12 samples)	ND(80.2) (0 detects out of 4 samples)	ND(11.4) (0 detects out of 40 samples)	2.96* (15 detects out of 30 samples)

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]
Di-n-octyl phthalate	µg/L	ND(10.3) (0 detects out of 12 samples)	ND(10.0) (0 detects out of 12 samples)	ND(10.0) (0 detects out of 12 samples)	ND(80.2) (0 detects out of 4 samples)	ND(11.4) (0 detects out of 40 samples)	0.688 (6 detects out of 6 samples)
Ethylbenzene	µg/L	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	ND(7.37) (0 detects out of 40 samples)	0.563* (10 detects out of 30 samples)
Methylene chloride	µg/L	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	ND(7.37) (0 detects out of 40 samples)	1.31* (4 detects out of 30 samples)
Phenol	µg/L	46.2* (9 detects out of 12 samples)	55.3* (11 detects out of 12 samples)	58.3 (12 detects out of 12 samples)	93.8* (2 detects out of 4 samples)	52.5* (34 detects out of 40 samples)	1.16* (5 detects out of 30 samples)
Tetrachloroethylene	µg/L	18.1* (1 detect out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(7.50) (0 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	11.4* (1 detect out of 40 samples)	10.7* (9 detects out of 30 samples)
Toluene	µg/L	28.0* (1 detects out of 12 samples)	ND(7.50) (0 detects out of 12 sample)	9.70* (5 detects out of 12 samples)	ND(5.24) (0 detects out of 4 samples)	21.3* (6 detects out of 40 samples)	0.589* (6 detects out of 30 samples)
Trichloroethene	µg/L	10.2* (1 detect out of 12 sample)	ND(7.50) (0 detects out of 12 sample)	ND(7.50) (0 detects out of 12 sample)	ND(5.24) (0 detects out of 4 sample)	8.40* (1 detect out of 40 samples)	3.12* (4 detects out of 30 samples)

[1] Based on data collected by EPA in 2004.
[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated graywater.
[3] Based on data collected by ACSI/ADEC in 2000 and 2001.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
"ND" indicates that the analyte was not detected (number in parentheses is detection limit).

Table 3-7. Comparison of Untreated Graywater Concetrations to Untreated Domestic Wastewater—Nutrients

Analyte	Unit	Average Concentration in Untreated Cruise Ship Accommodations Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Laundry Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Galley Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Food Pulper Wastewater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]	Concentration in Untreated Domestic Wastewater[4]
Ammonia - Nitrogen	mg-N /L	0.383* (6 detects out of 12 samples)	0.439* (6 detects out of 12 samples)	2.93* (8 detects out of 12 samples)	17.5* (3 detects out of 4 samples)	2.13* (23 detects out of 40 samples)	2.21* (28 detects out of 30 samples)	12 to 50
Nitrate/Nitrite	mg/L	0.0858* (9 detects out of 12 samples)	0.109 (12 detects out of 12 samples)	0.0477* (8 detects out of 12 samples)	0.335* (3 detects out of 4 samples)	0.0872* (32 detects out of 40 samples)	0.00900 (3 detects out of 3 samples)	0
Total Kjeldahl Nitrogen	mg/L	15.2 (12 detects out of 12 samples)	4.14* (11 detects out of 12 samples)	38.8 (12 detects out of 12 samples)	188 (4 detects out of 4 samples)	26.2* (39 detects out of 40 samples)	11.1 (4 detects out of 4 samples)	20 to 85
Total Phosphorus	mg/L	2.20 (12 detects out of 12 samples)	4.31 (12 detects out of 12 samples)	20.0 (12 detects out of 12 samples)	186 (4 detects out of 4 samples)	10.1 (40 detects out of 40 samples)	3.34 (4 detects out of 4 samples)	4 to 15

[1] Based on data collected by EPA in 2004.
[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated graywater.
[3] Based on data collected by ACSI/ADEC in 2000 and 2001.
[4] Metcalf & Eddy, 1991.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

3.4 What are the potential environmental impacts associated with untreated graywater from cruise ships?

In order to evaluate the potential environmental impacts of untreated graywater waste streams from cruise ships, EPA compared data from untreated graywater discussed in subsection 3.3 above to (1) current wastewater discharge standards for ships and land-based sewage treatment plants and (2) EPA's National Recommended Water Quality Criteria. Detailed information on treated graywater (that is, the effluent from Advanced Wastewater Treatment systems) can be found in Section 2, and will not be repeated here.

3.4.1 Comparison to wastewater discharge standards

Table 3-8 shows the comparison of average analyte concentrations from EPA and ACSI/ADEC untreated graywater sampling to:

- EPA's standards for discharges from Type II MSDs on vessels;
- EPA's standards for secondary treatment of sewage from land-based sewage treatment plants; and
- Alaska cruise ship discharge standards under "Certain Alaska Cruise Ship Operations" (also referred to as "Title XIV").

Untreated cruise ship graywater concentrations exceeded the EPA standards for discharges from Type II MSDs (for fecal coliform and total suspended solids). In addition, untreated graywater concentrations exceeded all wastewater discharge standards under Title XIV for continuous discharge from cruise ships in Alaska, and secondary treatment discharge standards from land-based sewage treatment plants. (Graywater is not required to meet any of the standards shown in Table 3-8, with the exception that continuous graywater discharges in Alaska waters must achieve the Title XIV continuous discharge standards.)

Table 3-8. Comparison of Untreated Cruise Ship Graywater to Wastewater Discharge Standards

Analyte	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[2]	Performance Standards for Type II MSDs (33 CFR Part 159 Subpart C)	Secondary Treatment Discharge Standards for Sewage from Land-based Sewage Treatment Plants (40 CFR 133.102)	Title XIV Standards for Continuous Discharge in Alaskan Waters (33 CFR Part 159 Subpart E)
Fecal coliform (fecal coliform/ 100 mL)	36,000,000*	2,950,000* MPN/ 100 mL	<200		<20[3]
Total residual chlorine (µg/L)	NR	372*			<10
Biochemical oxygen demand (5-day) (mg/L)	1,140	354		<45[4] <30[5]	<45[4] <30[5]

Total suspended solids (mg/L)	704	318	<150	<45[4] <30[5]	<45[4] <30[5]
pH	67% of pH samples between 6.0 and 9.0	77% of pH samples between 6.0 and 9.0		between 6.0 and 9.0	between 6.0 and 9.0

[1] Based on EPA sampling data from 2004.
[2] Based on data collected by ACSI/ADEC in 2000 and 2001.
[3] The geometric mean of the samples from the discharge during any 30-day period does not exceed 20 fecal coliform per 100 milliliters (ml) and not more than 10 percent of the samples exceed 40 coliform per 100 ml.
[4] The 7-day average shall not exceed this value.
[5] The 30-day average shall not exceed this value. In addition, the 30-day average percent removal shall not be less than 85 percent.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
"NR" indicated that this information was not reported; equipment used to measure free and total chlorine is not suitable for measuring low levels of chlorine and is subject to interferences. Accordingly, field measurements collected of the sole purpose determining simple preservation requirements are not provided.

3.4.2 Comparison to EPA's National Recommended Water Quality Criteria

EPA compared average untreated graywater concentrations from EPA's and ACSI/ADEC's sampling (discussed in subsection 3.3 above) to EPA's 2006 National Recommended Water Quality Criteria (NRWQC) for saltwater aquatic life and for human health (for the consumption of organisms only). Analytes that exceed the NRWQC are discussed in greater detail in the subsections below.

EPA's NRWQC are recommended concentrations of analytes in a waterbody that are intended to protect human health and aquatic organisms and their uses from unacceptable effects from exposures to these pollutants. The NRWQC are not directly comparable to analyte concentrations in a discharge because NRWQC not only have a concentration component, but also a duration and frequency component. However, comparison of cruise ship wastewater discharges to NRWQC provides a conservative screen of whether these discharges might cause, have the potential to cause, or contribute to non-attainment of the water quality standards in a given receiving water. If the concentration of a given analyte in cruise ship wastewater is less than the NRWQC, the wastewater should not cause, have the potential to cause, or contribute to non-attainment of a water quality standard based on that criterion. If the concentration of a particular analyte in cruise ship wastewater is greater than the NRWQC, additional analysis would determine whether the discharge would cause, have the potential to cause, or contribute to non-attainment of a water quality standard in a given receiving water.

Pathogen Indicators

Wastewater may contain many pathogens of concern to human health, including *Salmonella, shigella*, hepatitis A and E, and gastro-intestinal viruses (National Research Council, 1993). Pathogen contamination in swimming areas and shellfish beds poses potential risks to human health and the environment by increasing the rate of waterborne illnesses (Pruss, 1998; Rees, 1993; National Research Council, 1993). Shellfish feed by filtering particles from the water, concentrate bacteria and viruses from the water column, and pose the risk of disease in consumers when eaten raw (National Research Council, 1993; Wu, 1999).

The NRWQC for pathogen indicators references the bacteria standards in EPA's 1986 *Quality Criteria for Water*, commonly known as the Gold Book. The Gold Book standard for bacteria is described in terms of three different waterbody use criteria: freshwater bathing, marine water bathing, and shellfish harvesting waters. The marine water bathing and shellfish harvesting waterbody use criteria shown in Table 3-9 were used for comparison with cruise ship graywater concentrations.

Table 3-9. National Recommended Water Quality Criteria for Bacteria

Waterbody Use	Gold Book Standard for Bacteria
Marine Water Bathing	Based on a statistically sufficient number of samples (generally not less than five samples equally spaced over a 30-day period), the geometric mean of the enterococci densities should not exceed 35 per 100 ml; no sample should exceed a one-sided confidence limit (C.L.) using the following as guidance: 1) Designated bathing beach 75% C.L. 2) Moderate use for bathing 82% C.L. 3) Light use for bathing 90% C.L. 4) Infrequent use for bathing 95% C.L. based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.7 as the log standard deviation.
Shellfish Harvesting Waters	The median fecal coliform bacterial concentration should not exceed 14 MPN per 100 ml with not more than 10 percent of samples exceeding 43 MPN per 100ml for the taking of shellfish.

Pathogen indicator data from untreated graywater consistently exceed the NRWQC for marine water bathing and shellfish harvesting waters (see Table 3-10). Over 66% of EPA samples for enterococci exceeded the 35 MPN/100 mL standard for marine water bathing. Over 80 percent of ACSI/ADEC samples for fecal coliform exceeded the 43 MPN/100 mL standard for harvesting shellfish. Given the consistent exceedance of the NRWQC for bacteria, untreated graywater may cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

Table 3-10. EPA and ACSI Untreated Cruise Ship Graywater Pathogen Indicator Data

Analyte	Average Concentration (and Range) in Untreated Cruise Ship Graywater (EPA Data)[1]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[2]
Fecal coliform (fecal coliform/100 mL)	36,000,000 * (ND [2.00] to 455,000,000)	2,950,000* MPN/100 mL (ND [2.00] to 32,000,000)
Enterococci (MPN/100 mL)	8,920* (ND [1.00] to 1,600,000)	NC

[1] Based on EPA sampling data from 2004.
[2] Based on data collected by ACSI/ADEC in 2000 and 2001.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
"NC" indicates that this information was not collected.

Conventional Pollutants and other Common Analytes

Conventional pollutants and other common analytes that have a saltwater aquatic life or human health (for the consumption of organisms) narrative NRWQC include oil and grease, settleable residue, total suspended solids (TSS) (see Table 3-11), and temperature (see Tables 3-11 and 3-12). In addition, the NRWQC include a numeric standard for total residual chlorine (see Table 3-13).

Table 3-11. Narrative National Recommended Water Quality Criteria for Conventional Pollutants and Other Common Analytes

Analyte	Gold Book Standard
Oil and Grease	For aquatic life: (1) 0.01 of the lowest continuous flow 96-hour LC50 to several important freshwater and marine species, each having a demonstrated high susceptibility to oils and petrochemicals. (2) Levels of oils or petrochemicals in the sediment which cause deleterious effects to the biota should not be allowed. (3) Surface waters shall be virtually free from floating nonpetroleum oils of vegetable or animal origin, as well as petroleum-derived oils.
Settleable and Suspended Solids	Freshwater fish and other aquatic life: Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.
Temperature	Marine Aquatic Life: In order to assure protection of the characteristic indigenous marine community of a waterbody segment from adverse thermal effects, the maximum acceptable increase in the weekly average temperature resulting from artificial sources is 1°C (1.8 °F) during all seasons of the year, providing the summer maxima are not exceeded; and daily temperature cycles characteristic of the waterbody segment should not be altered in either amplitude or frequency. Summer thermal maxima, which define the upper thermal limits for the communities of the discharge area, should be established on a site-specific basis.

Oil and Grease

Annual worldwide estimates of petroleum input to the sea exceed 1.3 million metric tonnes (about 380 million gallons) (National Research Council, 2003). Levels of oil and grease of any kind can cause a variety of environmental impacts including the drowning of waterfowl because of loss of buoyancy, preventing fish respiration by coating their gills, asphyxiating benthic organisms from surface debris settling on the bottom, and reducing the natural aesthetics of waterbodies (EPA, 1986).

EPA does not have information on cruise ship graywater that would allow us to directly evaluate the narrative NRWQC for oil and grease. Hexane extractable material (HEM) was detected in 100 percent of EPA's untreated graywater samples (38 detects out of 38 samples) with detected amounts ranging between 5.6 and 5,010 mg/L. ACSI/ADEC also detected oil and grease in 100 percent of untreated graywater samples (4 detects out of 4 samples) with detected amounts ranging between 38 and 130 mg/L. However, EPA did not observe any floating oils in their untreated graywater samples, therefore it is unlikely that there would be floating oils in the receiving water (ACSI/ADEC did not provide a visual description of their samples to indicate if floating oils were observed)**.**

Settleable and Suspended Solids

Solids, either settleable or suspended, may harm marine organisms by reducing water clarity and available oxygen levels in the water column. In addition, solids can directly impact fish and other aquatic life by preventing the successful development of eggs and larva, blanketing benthic populations, and modifying the environment such that natural movements and migration patterns are altered (EPA, 1986).

EPA did not directly evaluate cruise ship graywater against the narrative NRWQC for settleable and suspended solids because the criterion is based on conditions in a specific waterbody. Total suspended solids were consistently detected by ACSI/ADEC in untreated graywater samples at levels ranging from 18 to 4,770 mg/L, with an average of 318 mg/L. Total suspended solids were consistently detected by EPA in untreated graywater samples at levels ranging from 24 to 29,400 mg/L, with an average of 704 mg/L. The detected values are substantially higher than the discharge standards for sewage from land-based sewage treatment plants (7-day average shall not exceed 45 mg/L). A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water.

Temperature

Temperature changes can directly affect aquatic organisms by altering their metabolism, ability to survive, and ability to reproduce effectively. Increases in temperature are frequently linked to acceleration in the biodegradation of organic material in a waterbody, which increases the demand for dissolved oxygen and can stress local aquatic communities.

EPA did not directly evaluate cruise ship graywater against the narrative NRWQC for temperature because the criterion is based on conditions in a specific waterbody. The average temperature from EPA's untreated graywater samples was 39.6 °C (temperature data were not available for ACSI/ADEC's untreated graywater samples). Local waterbody temperatures would be needed to determine if the average temperature from untreated graywater would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. Table 3-12 provides a few examples of the water temperatures observed in various coastal waters across the United States. The average temperature for untreated graywater effluent exceeds the temperatures presented in Table 3-12. A site-specific evaluation would determine if the cruise ship discharge volume is significant enough to alter the temperature of a given waterbody. However, considering the size of coastal waterbodies where cruise ships operate, it is unlikely that cruise ship effluent temperatures would cause an increase in waterbody temperature that would exceed the NRWQC.

Table 3-12. Seasonal Coastal Water Temperatures in °C Across the United States

Location	State	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Boston Harbor	MA	4.44	2.22	5.00	7.22	12.22	16.11	18.89	20.00	18.89	14.44	10.56	5.56
Baltimore	MD	4.44	2.78	6.11	10.56	16.11	21.11	25.00	26.11	25.00	18.89	12.22	6.11
Miami Beach	FL	21.67	22.78	23.89	25.56	26.67	28.89	30.00	30.00	28.89	28.33	24.44	22.78
Key West	FL	20.56	21.11	23.89	26.11	27.78	30.00	30.56	30.56	30.00	28.33	24.44	22.22
Seattle	WA	8.33	7.78	7.78	8.89	10.00	11.67	12.78	13.33	13.33	12.22	10.56	9.44
Los Angeles	CA	14.44	14.44	15.56	15.56	16.11	16.67	18.33	20.00	19.44	18.89	17.78	15.56
Galveston	TX	12.22	12.78	16.11	21.67	25.56	28.33	30.00	30.00	28.33	23.89	19.44	15.00
Juneau	AK	2.22	2.22	2.78	4.44	7.78	10.56	11.11	10.56	9.44	6.67	4.44	3.33
Honolulu	HI	24.44	24.44	24.44	24.44	25.56	26.11	26.67	26.67	27.22	27.22	26.11	25.00

Source: National Oceanographic Data Center Coast Water Temperature Guide (www.nodc.noaa.gov/dsdt/wtg12.html)

Total Residual Chlorine

Chlorine is extremely toxic to aquatic organisms. Chlorine concentrations as low as 3 µg/L can result in a high mortality rate for some species (EPA, 1984). In fish, exposure to low levels of total residual chlorine (<1,000 µg/L) can cause avoidance behavior, respiratory problems, and hemorrhaging (Vetrano, 1998). Fish may recover once removed from the chorine environment, but the severity of the reaction and chance of death increases as the concentration of total residual chlorine increases (Booth et al., 1981). Studies have shown that continuous chlorination can lead to a shift in the composition of phytoplankton communities, thus altering the benthic and fish communities that feed on them (Sanders and Ryther, 1980).

Total residual chlorine concentrations were not available for EPA's untreated graywater samples. The average concentration of total residual chlorine from ACSI/ADEC's untreated graywater sampling data exceeded the NRWQC for total residual chlorine (see Table 3-13). A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. The most likely source for total residual chlorine in untreated graywater is from the chlorination of the drinking water on the cruise ship.

Table 3-13. Comparison of Untreated Cruise Ship Graywater to Numeric National Recommended Water Quality Criteria for Total Residual Chlorine

Analyte	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[1]	NRWQC Criteria Maximum Concentration (CMC)	NRWQC Criterion Continuous Concentration (CCC)
Total Residual Chlorine (µg/L)	372*	13	7.5

[1] Based on data collected by ACSI/ADEC in 2000 and 2001.

* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Metals

In the aquatic environment, elevated concentrations of metals can be toxic to many species of algae, crustaceans, and fish. Exposure to metals at toxic levels can cause a variety of changes in biochemical, physiological, morphological, and behavioral pattern in aquatic organisms. One of the key factors in evaluating metal toxicity is the bioavailability of the metal in a waterbody. Some metals have a strong tendency to adsorb to suspended organic matter and clay minerals, or to precipitate out of solution, thus removing the metal from the water column. The tendency of a given metal to adsorb to suspended particles is typically controlled by the pH and salinity of the waterbody. If the metal is highly sorbed to particulate matter, then it is likely not in a form that organisms can process. Therefore, a high concentration of a metal measured in the total form may not be an accurate representation of the toxic potential to aquatic organisms. Accordingly, NRWQC for the protection of aquatic life for metals are typically expressed in the dissolved form. In contrast, human health criteria (for the consumption of organisms) for metals are commonly expressed in the total metal form. The use of total metals for human health criteria is because human exposure to pollutants is assumed to be through the consumption of organisms, where the digestive process is assumed to transform all forms of metals to the dissolved phase, thus increasing the amount of biologically available metals.

EPA detected in the untreated graywater samples several dissolved metals that are common components of ship piping—copper, nickel, and zinc—at levels approximately 2 to 63 times above NRWQC for aquatic life (see Table 3-14). Both EPA and ACSI/ADEC detected total arsenic in 10 percent or more of samples with average concentrations exceeding the NRWQC for human health (for the consumption of organisms) (see Table 3-14). EPA also detected total thallium in untreated graywater at levels exceeding the NRWQC for human health (for the consumption of organisms). A site-specific evaluation would determine if these untreated graywater concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. However, as discussed in section 3.4.3 below, these analytes would likely meet NRWQC after initial mixing (about 1 to 7 meters from the ship) even when a vessel is at rest.

Table 3-14. Comparison of Untreated Cruise Ship Graywater to National Recommended Water Quality Criteria for Metals

Analytes that Exceed One or More NRWQC[1]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[2]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[3]	NRWQC Criteria Maximum Concentration (CMC)	NRWQC Criterion Continuous Concentration (CCC)	NRWQC Human Health (for the Consumption of Organisms)
Arsenic (Total) (μg/L)	2.25*	1.22			0.14
Copper (Dissolved) (μg/L)	195	NC	4.8	3.1	
Nickel (Dissolved) (μg/L)	18.2	NC	74	8.2	
Thallium (Total) (μg/L)	0.930*	ND			0.47
Zinc (Dissolved) (μg/L)	1,610	NC	90	81	

[1] Analytes are not listed in this table if the number of detects was not considered representative of untreated cruise ship graywater (i.e., less than 10% of samples), if the data were not in the correct form for comparison with NRWQC, or if the average concentration was driven by detection limits.
[2] Based on EPA sampling data from 2004.
[3] Based on data collected by ACSI/ADEC in 2000 and 2001.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
"NC" indicates that this information was not collected.
"ND" indicates that the analyte was not detected.

Semivolatile and Volatile Organics

Table 3-15 presents the organic compounds detected in untreated graywater that exceed NRWQC. Note that EPA and ACSI/ADEC did not test graywater for all organic compounds that have a NRWQC. The magnitude of the exceedances of NRWQC for the semivolatile and volatile organic compounds discussed in this subsection ranged from 3.2 to 33 times the standard. A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. However, as discussed in section 3.4.3 below, these analytes would likely meet NRWQC after initial mixing (about 1 to 7 meters from the ship) even when a vessel is at rest.

Table 3-15. Comparison of Untreated Cruise Ship Graywater to National Recommended Water Quality Criteria for Semivolatile and Volatile Organics

Analytes that Exceed One or More NRWQC[1,2]	Average Concentration in Untreated Cruise Ship Graywater (EPA Data)[3]	Average Concentration in Untreated Cruise Ship Graywater (ACSI/ADEC Data)[4]	NRWQC Human Health (for the Consumption of Organisms)
Bis(2-ethylhexyl) phthalate (µg/L)	71.9*	22.4*	2.2
Tetrachloroethylene (µg/L)	11.4*	10.7*	3.3

[1] Analytes are not listed in this table if the number of detects was not considered representative of untreated cruise ship graywater (i.e., less than 10% of samples), if the data were not in the correct form for comparison with NRWQC, or if the average concentration was driven by detection limits.
[2] Untreated graywater data were not available for all analytes that have a NRWQC. Therefore this table may not include all analytes that exceed NRWQC.
[3] Based on EPA sampling data from 2004.
[4] Based on data collected by ACSI in 2000 and 2001.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Bis(2-ethylhexyl) phthalate is a manufactured chemical that is commonly added to plastics to make them flexible and can be found in a variety of common products such as wall coverings, tablecloths, floor tiles, furniture upholstery, and shower curtains. Tetrachloroethylene is widely used in dry cleaning and for metal-degreasing. The likely source of this tetrachloroethylene is the condensate from onboard dry cleaning operations. (Spent tetrachloroethylene from dry cleaning is not discharged with cruise ship wastewater and is handled as a separate stream for disposal.)

Nutrients

Untreated graywater contains nutrients, such as nitrogen and phosphorus, which are important elements for aquatic plant and algae growth. The influx of excess nutrients can negatively effect marine ecosystems, resulting in diebacks of corals and seagrasses, eutrophication (oxygen-depleted "dead" zones), and increases in harmful algal blooms that can alter the seasonal progression of an ecosystem and choke or poison other plants and wildlife (National Research Council, 1993).

Ammonia is the only nutrient for which there is a numeric saltwater or human health (for the consumption of organisms) NRWQC. In the aquatic environment, ammonia exists in the unionized (NH_3) and ionized (NH_4^+) form. Unionized ammonia is the more toxic form of the two, with several factors such as pH, temperature, and salinity determining the toxicity to aquatic organisms. Acute levels of NH_3 that are toxic to fish can cause a loss of equilibrium, hyperexcitability, and increased breathing, cardiac output, and oxygen uptake (WHO, 1986). Extreme concentrations can cause convulsions, coma, and even death.

The marine NRWQC references EPA's 1989 *Ambient Water Quality Criteria for Ammonia (Saltwater)* document, which includes a matrix table for ammonia standards based on the pH, temperature, and salinity of a waterbody. Table 3-16 presents the average concentration of ammonia in untreated graywater. Table 3-17 presents examples of the ammonia NRWQC calculated from pH, temperature, and salinity at some cruise ship ports of call in the United States.

Table 3-16. Ammonia Concentration in Untreated Graywater

Analyte	Average Concentration in EPA Graywater Sampling[1]	Average Concentration in ACSI Graywater Sampling[2]
Ammonia (NH3-N µg/L)	2,130*	2,210*

[1] Based on EPA sampling data from 2004.
[2] Based on data collected by ACSI in 2000 and 2001.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.

Table 3-17. Calculated Ammonia NRWQC for Some Cruise Ship Ports of Call in the United States

Location	State	pH	Average Temperature (°C)	Salinity (psu)	NRWQC Criteria Maximum Concentration (CMC) (NH3-N µg/L)[4]	NRWQC Criterion Continuous Concentration (CCC) (NH3-N µg/L)[4]
Galveston Bay[1]	TX	8.1	29.0	14.0	2,140	321
Honolulu Harbor[1]	HI	8.0	25.5	34.4	4,110	617
Los Angeles Harbor[1]	CA	8.1	17.4	32.6	7,110	1,110
Port of Miami[2]	FL	8.0	25.3	32.0	4,110	617
Monterey Harbor[1]	CA	8.1	15.3	32.9	6,860	1,070
New York Harbor[1]	NY	7.5	22.1	22.9	11,500	2,960
Southeast Alaska[3]	AK	7.8	12.5	20.0	15,600	2,340
Portland Harbor[1]	ME	7.8	19.4	29.6	9,040	1,400

[1] Data source: EPA's EMAP National Coastal Database (http://oaspub.epa.gov/coastal/coast.search)
[2] Data source: South Florida Water Management District Monitoring Stations (http://glades.sfwmd.gov/pls/dbhydro_pro_plsql/water_quality_interface.main_page)
[3] Data source: Draft State of Alaska Department of Environmental Conservation Large Commercial Passenger Vessel Wastewater Discharge General Permit No. 2007DB0002 (www.dec.state.ak.us/water/cruise_ships/pdfs/PN%20Version%20LPV%20WWGP%20-%20DRAFT.pdf)
[4] Ammonia standards were calculated based on pH, temperature, and salinity values for each waterbody using the matrix table provided in EPA's 1989 *Ambient water quality criteria for ammonia (saltwater)* document. In cases where measured values fell between column and row headings for pH and temperature the standard was approximated based on the closest value. In addition, the ammonia standards were converted from µg-NH_3/L to µg-NH_3-N/L by multiplying the standard by 0.822.

Average concentrations of ammonia in untreated graywater exceed most of the NRWQC Criteria Continuous Concentration and one of the NRWQC Criteria Maximum Concentration presented in Table 3-17**.** Although ammonia standards can vary from waterbody to waterbody, there is only a small range of pH, temperature, and salinity values that result in a chronic ammonia standard that untreated graywater concentrations will not exceed. This suggests that ammonia concentrations in untreated graywater at the end-of-pipe are likely to exceed chronic NRWQC regardless of the receiving water. A site-specific evaluation would determine if these discharge concentrations would cause, have the potential to cause, or contribute to non-attainment of water quality standards in a given receiving water. For additional discussion of the potential impacts of nutrients in cruise ship discharges, see Section 2.

3.4.3 Mixing and Dilution

Although average analyte concentrations in cruise ship untreated graywater exceed some NRWQC at the end-of-pipe, the mixing and dilution that occurs following discharge also is relevant to an evaluation of potential environmental impact.

Dilution at Rest

A Science Advisory Panel created by the Alaska Cruise Ship Initiative (ACSI) used the Cornell Mixing Zone Expert System (CORMIX) model to estimate dilution of effluent achieved when a vessel is at rest. Their modeling showed that a discharge rate of 50 m^3/hr yields a dilution factor of 36 at a distance of about 4.5 m from the ship, and a dilution factor of 50 at 7 m from the ship after 43 seconds (ADEC, 2002, Appendix 8, footnote 50).

The Alaska Department of Environmental Conservation (ADEC) modeled the dilution of large cruise ship effluent during stationary discharge under a very conservative scenario (a neap tide in Skagway Harbor), using the Visual Plumes model. Their modeling showed the dilution factors ranging from 5 to 60, which would occur between 1 and 7 meters from the ship (ADEC, 2004).

The initial dilution estimated by ACSI and ADEC for a vessel at rest would not likely be great enough for untreated graywater to meet all NRWQC, in particular fecal coliform and enterococci (see Tables 3-9 and 3-10). However, most of the other analytes that exceed NRWQC at the end-of-pipe would likely meet NRWQC after initial mixing when the vessel is at rest, based on the initial dilution factors discussed above. For example, metal exceedances at the end-of-pipe ranged from 2 to 63 times the lowest NRWQC (see Table 3-14), and ammonia was 7 times the lowest estimated NRWQC (see Tables 3-16 and 3-17).

It is important to note that the initial mixing estimates discussed above are based on ship and waterbody-specific input parameters such as discharge port size, effluent flow, waterbody temperature, and salinity. Therefore, they are not necessarily representative of the dilution factors that would be achieved by cruise ships in other ports of call in the United States. Site-specific and ship-specific calculations would be required to determine the dilution for ships in other locations.

Dilution Underway

For vessels underway, there is significant additional dilution due to movement of the vessel and mixing by ship propellers. In 2001, EPA conducted dye dispersion studies behind four large cruise ships while underway off the coast of Miami, Florida. The results of this study indicate that dilution of discharges behind cruise ships moving between 9.1 and 17.4 knots are diluted by a factor of between 200,000:1 and 640,000:1 immediately behind the boat (EPA, 2002). Based on these dilution factors, graywater would likely meet all NRWQC except for fecal coliform while underway.

3.4.4 Potential Treatment Technologies in Addition to AWTs

As part of its assessment of the cruise ship sewage and graywater discharge standards in Alaska, EPA evaluated upgrades to Advanced Wastewater Treatment systems (AWTs) and technologies that could be added on to AWTs that would improve the quality of the treated effluent in terms of nutrients, metals, and temperature. See Section 2 (subsection 2.4.4) for a discussion of these potential treatment technologies.

3.5 What action is the federal government taking to address graywater waste streams from cruise ships?

EPA is evaluating the performance of advanced sewage and graywater treatment systems.
EPA is evaluating the performance of various advanced sewage and graywater treatment systems as part of its effort to assess whether revised or additional standards for sewage and graywater discharges from large cruise ships operating in Alaska are warranted under Title XIV (see subsection 2.2.3). Some of the results of this intensive effort, including sampling four different Advanced Wastewater Treatment systems and a survey questionnaire for all cruise ships operating in Alaska in 2004, are summarized in this report. EPA anticipates making these full analyses publicly available in 2008.

EPA is developing a water permit program for pollutant discharges incidental to the normal operation of vessels.
Under a recent court decision, the existing EPA regulations that exclude discharges incidental to the normal operation of a vessel from Clean Water Act permitting will be vacated (revoked) as of September 30, 2008. The Agency is appealing that decision, but if left unchanged, this would mean that vessel owners or operators whose discharges previously have been excluded from such permitting by the regulation will require a permit beginning September 30, 2008. With the exception of commercial vessels on the Great Lakes (which are regulated under CWA section 312), such regulated discharges may include graywater. At the time this report went to press, EPA was in the process of developing a permitting framework.

Coast Guard has developed regulations implementing the monitoring requirements of Title XIV.
Under Title XIV, the Coast Guard has implemented an inspection regime that includes sampling of cruise ship sewage and graywater discharges in Alaskan waters. In July 2001, Coast Guard published a final rule (33 CFR 159.301-321) that outlines its oversight of cruise ships sampling in Alaskan waters.

Coast Guard is conducting a review of inspection and enforcement policies.
The Coast Guard has started a review of their inspection and enforcement policies and regulations for cruise ship environmental practices. This review includes a survey of inspectors from Coast Guard regions, focusing on MSDs, oil/water separators, and the effectiveness and feasibility of various inspection practices.

California National Marine Sanctuaries propose to prohibit cruise ship graywater discharges.
Under the National Marine Sanctuaries Act (16 U.S.C. § 1431 et seq.), the Monterey Bay, Gulf of the Farallones, and Cordell Bank National Marine Sanctuaries have proposed regulations to prohibit the discharge of treated and untreated graywater from large vessels, including cruise ships (71 FR 59050, Oct. 6, 2006; 71 FR 59338, Oct. 6, 2006; 71 FR 59039, Oct. 6, 2006). NOAA is currently reviewing the comments on these proposed rules. The Channel Islands National Marine Sanctuary has published a notice of intent (72 FR 40775, July 25, 2007) to revise a proposed action concerning vessel discharges (71 FR 29096, Oct. 5, 2006). The proposed rule containing the revision, which will include a prohibition on treated and untreated graywater from cruise ships, will be published for public comment in the near future.

References

Alaska Department of Environmental Conservation (ADEC). 2000. *Alaska Cruise Ship Initiative Part 1 Final Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/finreportp10808.pdf)

Alaska Department of Environmental Conservation (ADEC). 2001. *Alaska Cruise Ship Initiative Part 2 Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/acsireport2.pdf)

Alaska Department of Environmental Conservation (ADEC). 2002. *The Impact of Cruise Ship Wastewater Discharge on Alaska Waters*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/impactofcruiseship.pdf)

Alaska Department of Environmental Conservation (ADEC). 2004. *Assessment of Cruise Ship and Ferry Wastewater Impacts in Alaska*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/assessreport04.htm)

Booth, P.M., Jr., Sellers, C.M., Jr., & Garrison, N.E. 1981. Effects of Intermittent Chlorination on Plasma Proteins of Rainbow Trout (*Salmo gairdneri*). *Bull. of Env. Contam. & Tox* 26(2): 163-170.

Cruise Line International Association (CLIA). 2006. *CLIA Industry Standard: Cruise Industry Waste Management Practices and Procedures*. Fort Lauderdale, FL. (www.cruising.org/industry/PDF/CLIAWasteManagementAttachment.pdf and www.cruising.org/industry/PDF/CLIAWasteManagement.pdf)

Metcalf & Eddy. 1991. *Wastewater Engineering: Treatment and Reuse*, Third Edition. New York, NY: McGraw Hill.

Mayer, Peter W. and William B. DeOreo. 1998. *Residential End Uses of Water*. Aquacraft, Inc. Water Engineering and Management. American Water Works Association. (www.aquacraft.com/Publications/resident.htm)

National Research Council (NRC): Committee on Wastewater Management for Coastal Urban Areas, Water Science and Technology Board, Commission on Engineering and Technical Systems. 1993. *Managing Wastewater in Coastal Urban Areas*. Washington, DC: National Academy Press. (http://www.nap.edu/catalog.php?record_id=2049#toc)

National Research Council (NRC): Committee on Oil in the Sea: Inputs, Fates, and Effects. 2003. *Oil in the Sea III: Inputs, Fates, and Effects*. Washington, DC: National Academy Press. (http://www.nap.edu/catalog.php?record_id=10388#toc)

Pruss, Annette. 1998. Review of epidemiological studies on health effects from exposure to recreational water. *International Journal of Epidemiology* 27: 1-9.

Rees, G. 1993. Health Implications of Sewage in Coastal Waters - the British Case. *Marine Pollution Bulletin* 26(1): 14-19.

Sanders, J.G., & Ryther J.H. 1980. *Impact of chlorine on the species composition of marine phytoplankton*. In: R.L. Jolley, et al. (Eds.), *Water Chlorination: Environmental Impact and Health Effects*, 3: 631. Ann Arbor, MI: Ann Arbor Science Publishers.

U.S. Environmental Protection Agency. 1984. *Ambient water quality criteria for chlorine* (EPA 440/5-84-030). Washington, DC. (http://www.epa.gov/ost/pc/ambientwqc/chlorine1984.pdf)

U.S. Environmental Protection Agency. 1986. *Quality Criteria for Water* (EPA 440/5-86-001). Washington, DC. (http://www.epa.gov/waterscience/criteria/goldbook.pdf)

U.S. Environmental Protection Agency. 1989. *Ambient water quality criteria for ammonia (saltwater)*(EPA 440/5-88-004). Washington, DC. (http://www.epa.gov/waterscience/pc/ambientwqc/ammoniasalt1989.pdf)

U.S. Environmental Protection Agency. 2002. *Cruise Ship Plume Tracking Survey Report* (EPA842-R-02-001). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/plumerpt2002/plumereport.pdf)

U.S. Environmental Protection Agency. 2004. *Survey Questionnaire to Determine the Effectiveness, Costs, and Impacts of Sewage and Graywater Treatment Devices for Large Cruise Ships Operating in Alaska* (EPA Form No. 7500-64). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/cruise_ship_survey.pdf)

U.S. Environmental Protection Agency. 2006a. *Sampling Episode Report for Holland America Veendam* (Sampling Episode 6503). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/Veendam/VeendamSER.pdf)

U.S. Environmental Protection Agency. 2006b. *Sampling Episode Report for Norwegian Star* (Sampling Episode 6504). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/FinalStar/FinalStarSERNCBI.pdf)

U.S. Environmental Protection Agency. 2006c. *Sampling Episode Report for Princess Cruise Lines – Island Princess* (Sampling Episode 6505). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/Island/IslandSER.pdf)

U.S. Environmental Protection Agency. 2006d. *Sampling Episode Report for Holland America Oosterdam* (Sampling Episode 6506). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/Oosterdam/OosterdamFinal.pdf)

U.S. Environmental Protection Agency. 2006e. *Sampling Episode Report for Nitrogen Compounds Characterization* (Sampling Episodes 6517 Through 6520). Washington, DC. (http://www.epa.gov/owow/oceans/cruise_ships/nitrogen/nitrogen_NCBI.pdf)

Vetrano, K.M. 1998. *Molecular Chlorine: Health and Environmental Effects.* TRC Environmental Corporation. Windsor, CT.

World Health Organization (WHO). 1986. Ammonia Environmental Health Criteria 54. Geneva, Switzerland. (http://www.inchem.org/documents/ehc/ehc/ehc54.htm)

Wu, R.S.S. 1999. Eutrophication, Water Borne Pathogens and Xenobiotic Compounds: Environmental Risks and Challenges. *Marine Pollution Bulletin* 39: 11-22.

Section 4: Oily Bilge Water

Oily bilge water is the mixture of water, oily fluids, lubricants, cleaning fluids, and other similar wastes that accumulate in the lowest part of a vessel from a variety of different sources including the engines (and other parts of the propulsion system), piping, and other mechanical and operational sources. On most cruise ships, bilge water can be managed in one of two ways: (1) retained onboard in a holding tank and discharged later to a reception facility on shore, or (2) treated onboard with an Oily Water Separator (OWS).

This section discusses the current state of information about bilge water, the laws regulating bilge water discharges from vessels, the types of equipment used to treat bilge water generated on cruise ships, the potential environmental impacts of cruise ship bilge water, and federal actions taken to address bilge water from cruise ships.

4.1 What is bilge water and how much is generated on cruise ships?

Bilge water is the mixture of water, oily fluids, lubricants, cleaning fluids, and other similar wastes that accumulate in the lowest part of a vessel from a variety of different sources including the engines (and other parts of the propulsion system), piping, and other mechanical and operational sources. It is not uncommon on ships for oil to leak into the bilge from engine and machinery spaces or from fittings and engine maintenance activities. These leaks, along with onboard spills, wash waters generated during the daily operation of a vessel, and waste water from operational sources (e.g., water lubricated shaft seals, propulsion system cooling, evaporators, and other machinery), collect in the bilge. In addition to containing oil and grease, bilge water may contain solid wastes such as rags, metal shavings, paint, glass, and a variety of chemical substances (EPA, 1997). Bilge water may contain various oxygen-demanding substances, volatile organic compounds, semi-volatile organics, inorganic salts, and metals. Bilge water also may contain other contaminants such as soaps, detergents, dispersants, and degreasers used to clean the engine room. These cleaning agents create an emulsion and prevent separation of oil and water. Moreover, they are often incompatible with Oily Water Separators and Oil Content Monitors. Due to the various sources that contribute to the production of bilge water, the composition of bilge water varies from vessel to vessel, and from day to day. Other waste streams discussed in this report, such as graywater and sewage, are typically contained within their own systems and might only be present in bilge water as a result of leaks.

The amount of bilge water that accumulates on board can vary, and depends on a number of factors including the size of the ship, engine room design, preventative maintenance, and the age of the components. Accumulation of bilge water is ongoing and needs to be properly managed because it can cause damage to the propulsion systems and ancillary machinery on the vessel as well as present a fire hazard and impact the vessel's stability. Periodically, it is necessary to pump out the bilge spaces into a holding tank, which allows the vessel to maintain stability and eliminates potentially hazardous conditions from the accumulation of bilge water.

Large vessels such as cruise ships have several additional waste streams that contain sludge, waste oil, and oily water mixtures, including fuel oil sludge, lubricating waste oil, and cylinder oil, that can inadvertently find their way to the bilge. Sludge is produced by the constant purification of fuel. To prevent damage to the ship's engines, the fuel is purified by centrifuges virtually continuously. Oil purifiers remove the waste which typically drains into a sludge tank. Lubricating oil needed for the ship's engines are processed in the same fashion. Cylinder oil comes from the oil injected along the cylinder walls in the engine and contains contaminants from the combustion process. All of these waste oils are typically drained to a sludge tank. The production of sludge, unlike bilge water, remains fairly constant and is usually at least 1-2 percent of the heavy fuel oil consumed on board. Among the impurities separated out by the purifiers are water and oily water.

There are various management practices that can lead to cross contamination of the bilge water from the sludge tank. For example, if the same pumps and manifolds are used for transfers, it may leave residual sludge and oil in the pipes used for the bilge system. Also, if the oily water from the sludge tank is removed and decanted to the bilge water holding tank, it may also bring with it greater concentrations of oil.

ADEC (2000) reported that cruise ships operating in Southeast Alaska produced 1,300 to 5,300 gallons of oily bilge water every 24 hours. Table 4-1 shows the bilge water production and treatment capacities based on ship tonnage.

Table 4-1. Maximum Daily Volume of Bilge Water Production

Ship Tonnage (Gross Tons)	Passenger and Crew Capacity	Bilge Water Production (max. gallons/day)	Bilge Water Treatment Capacity (max. gallons/day)
22,000	1,100	1,000	5,000
46,000-48,000	1,500-2,160	3,000	4,000
50,700-55,400	1,850-2,380	5,000	5,000
76,000-78,000	2,700-3,200	2,640	6,400

Source: ADEC, 2000

4.2 What laws apply to bilge water from cruise ships?

4.2.1 International Convention for the Prevention of Pollution from Ships and Act to Prevent Pollution from Ships

The International Convention for the Prevention of Pollution from Ships (MARPOL)

The International Convention for the Prevention of Pollution from Ships, 1973, and Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships, together are referred to as MARPOL or the MARPOL Protocol. Six Annexes of the Convention cover various sources of pollution from ships and provide a framework for international objectives. However, these Annexes are only in force if ratified and implemented by the flag state. The vast majority of cruise lines operating in United States ports are foreign flag vessels. Cruise ships flagged under countries that are signatories to MARPOL are subject to its requirements, regardless of where they sail, and member nations are responsible for vessels registered under their respective nationalities.

MARPOL Annex I, *Regulations for the Prevention of Pollution by Oil,* addresses oil pollution and lists oil prevention requirements for machinery spaces on all ships covered by the Convention and provides requirements for cargo areas of oil tankers. The requirements of MARPOL Annex I cover all petroleum products, including crude oil, fuel oil, oily waste, oily mixtures located in the bilge, and petroleum products in cargo spaces of oil tankers. In 1983, the United States ratified Annex I of the International Convention for the Prevention of Pollution from Ships (MARPOL).

The Act to Prevent Pollution from Ships (APPS)

The Act to Prevent Pollution from Ships (APPS; 33 U.S.C. § 1901 et seq.) is the federal law implementing those provisions of MARPOL that have been ratified by the United States. With respect to implementation of Annex I, APPS applies to all U.S. flagged ships anywhere in the world, and to all foreign flagged vessels operating in the navigable waters of the United States (which extend seaward 3 nautical miles from shore for the purpose of this statute), or while at a port or terminal under the jurisdiction of the United States.

Applicable Coast Guard regulations

The Coast Guard generally has the primary responsibility to prescribe and enforce the regulations necessary to implement APPS in the United States. Because most cruise lines are foreign registered and because APPS only applies to foreign ships within the navigable waters, the APPS discharge regulations have limited applicability to cruise ship operations, especially since U.S. enforcement practices have led most cruise lines to implement policies restricting discharges of machinery space waste within three miles. However, the following Coast Guard regulations pertain to ship discharges of oil or oily mixtures into the sea[1]:

- Coast Guard regulations (33 CFR 151.10) provide that, when within 12 nautical miles of the nearest land, any discharge of oil or oily mixtures into the sea from a ship is prohibited except when all of the following conditions are satisfied:
  - (1) The oil or oily mixture does not originate from cargo pump room bilges;
  - (2) The oil or oily mixture is not mixed with oil cargo residues;
  - (3) The oil content of the effluent without dilution does not exceed 15 parts per million (ppm);
  - (4) The ship has in operation oily-water separating equipment, a bilge monitor, bilge alarm, or combination thereof, as required by Part 155 Subpart B; and
  - (5) The oily-water separating equipment is equipped with a 15 ppm bilge alarm; for U.S. inspected ships, approved under 46 CFR 162.050 and for U.S. uninspected ships and foreign ships, either approved under 46 CFR 162.050 or listed in the current International Maritime Organization (IMO) Marine

[1] Sections 151.09 through 151.25 of the Coast Guard regulations at Chapter 33 CFR do not apply to: 1) A warship, naval auxiliary, or other ship owned or operated by a country when engaged in noncommercial service; 2) A Canadian or U.S. ship being operated exclusively on the Great Lakes of North America or their connecting and tributary waters; and 3) A Canadian or U.S. ship being operated exclusively on the internal waters of the United States and Canada; or 4) Any other ship specifically excluded by MARPOL 73/78.

Environment Protection Committee (MEPC) Circular summary of MARPOL 73/78 approved equipment.

- Coast Guard regulations (33 CFR 151.10) provide that, when more than 12 nautical miles from the nearest land, any discharge of oil or oily mixtures into the sea from a ship is prohibited except when all of the following conditions are satisfied:
  - (1) The oil or oily mixture does not originate from cargo pump room bilges;
  - (2) The oil or oily mixture is not mixed with oil cargo residues;
  - (3) The ship is not within a special area;
  - (4) The ship is proceeding en route;
  - (5) The oil content of the effluent without dilution is less than 15 ppm; and
  - (6) The ship has in operation oily-water separating equipment, a bilge monitor, bilge alarm, or combination thereof, as required by Part 155 Subpart B.

  Further, Coast Guard regulations (33 CFR 151.10) provide that if the bilge water cannot be discharged in compliance with these standards, then it must be retained onboard or discharged to a designated reception facility. However, both MARPOL and the APPS regulations exempt emergency discharges needed to save the ship or save a life at sea. Emergency discharges or other exceptional discharges must nevertheless be accurately recorded in ship records and reported to the nearest port state or Coast Guard Captain of the port.

- In addition, Coast Guard regulations (33 CFR 151.25) provide that vessels of 400 gross tons and above shall fully maintain an Oil Record Book Part I (Machinery Space Operations) and vessels of 150 gross tons and above that carry 200 cubic meters or more of oil in bulk shall also maintain an Oil Record Book Part II (Cargo/Ballast Operations). The Oil Record Book is subject to routine inspection by the Coast Guard. (33 C.F.R. 151.23; 151.25(g)). In pertinent part, the APPS regulations require:

  (a) Each oil tanker of 150 gross tons and above, ship of 400 gross tons and above other than an oil tanker, and manned fixed or floating drilling rig or other platform shall maintain an Oil Record Book Part I (Machinery Space Operations). An oil tanker of 150 gross tons and above or a non oil tanker that carries 200 cubic meters or more of oil in bulk, shall also maintain an Oil Record Book Part II (Cargo/Ballast Operations).

  * * *

  (d) Entries shall be made in the Oil Record Book on each occasion, on a tank to tank basis if appropriate, whenever any of the following machinery space operations take place on any ship to which this section applies--

  (1) Ballasting or cleaning of fuel oil tanks;

  (2) Discharge of ballast containing an oily mixture or cleaning water from fuel oil tanks;

  (3) Disposal of oil residue; and

  (4) Discharge overboard or disposal otherwise of bilge water that has accumulated in machinery spaces.

  * * *

(g) In the event of an emergency, accidental or other exceptional discharge of oil or oily mixture, a statement shall be made in the Oil Record Book of the circumstances of, and the reasons for, the discharge.

(h) Each operation described in paragraphs (d), (e) and (f) of this section shall be fully recorded without delay in the Oil Record Book so that all the entries in the book appropriate to that operation are completed. Each completed operation shall be signed by the person or persons in charge of the operations concerned and each completed page shall be signed by the master or other person having charge of the ship.

(i) The Oil Record Book shall be kept in such a place as to be readily available for inspection at all reasonable times and shall be kept on board the ship.

(j) The master or other person having charge of a ship required to keep an Oil Record Book shall be responsible for the maintenance of such record.

MARPOL contains additional requirements on what information must be recorded in an Oil Record Book, including the details of overboard discharges of "bilge water which has accumulated in machinery spaces"[2] (MARPOL, Annex I, Appendix III(D)). MARPOL also requires the logging of any failure of the oil discharge monitoring and control equipment (Id. at Appendix III(F)). MARPOL also requires that any accidental or other "exceptional" discharge be recorded in the Oil Record Book (Id. at Appendix III(G)). In short, cruise ships visiting United States ports must maintain an accurate record of overboard discharges per this requirement.

[2] The MARPOL Protocol, Annex I, Appendix III, in pertinent part requires logging of the following information:

(D) Non-automatic discharge overboard or disposal otherwise of bilge water which has accumulated in machinery spaces

13. Quantity discharged or disposed of.
14. Time of discharge or disposal (start and stop).
15. Method of discharge or disposal:
    .1 through 15 ppm equipment (state position at start and end);
    .2 to reception facilities (identify port);
    .3 transfer to slop tank or holding tank (indicate tank(s); state quantity transferred and the total quantity retained in tank(s).

* * *

(F) Condition of oil discharge monitoring and control system

20. Time of system failure.
21. Time when system has been made operational.
22. Reasons for failure.

* * *

(G) Accidental or other exceptional discharges of oil

23. Time of occurrence.
24. Place or position of ship at time of occurrence.
25. Approximate quantity and type of oil.
25. Circumstances of discharge or escape, the reasons therefore and general remarks.

4.2.2 Oil Pollution Act and Clean Water Act

The Oil Pollution Act of 1990 (OPA; 33 U.S.C. § 2701 et seq.) is a comprehensive statute designed to expand oil spill prevention, preparedness, and response capabilities of the federal government and industry. It amends section 311 of the Clean Water Act (CWA; 33 U.S.C. § 1321) to clarify federal response authority, increase penalties for spills, establish Coast Guard response organizations (including elements of the National Strike Force, district response advisory staff, Coast Guard personnel, and equipment of ports within the district), require tank vessel and facility response plans, and provide for contingency planning in designated areas. CWA section 311, as amended by the Oil Pollution Act of 1990, applies to cruise ships and prohibits discharge of oil or hazardous substances in harmful quantities into or upon U.S. navigable waters, or into or upon the waters of the contiguous zone, or which may affect natural resources in the U.S. Exclusive Economic Zone (which extends 200 miles offshore).

EPA regulations (40 CFR 110.3) provide that for the purposes of section 311(b)(4) of the CWA, discharges of oil in quantities that the Administrator has determined may be harmful to the public health or welfare or the environment of the United States include discharges of oil that:

- violate applicable water quality standards, or
- cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines, or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

4.3 How do cruise ships manage bilge water?

In order to maintain vessel stability and eliminate potentially hazardous conditions from the accumulation of bilge waste, it is necessary to periodically pump out the bilge spaces into a holding tank. The bilge water then can be managed in one of two ways: (1) retained onboard in a holding tank and discharged later to a reception facility on shore; or (2) treated onboard with an Oily Water Separator (OWS). The treated bilge water then can be discharged overboard in accordance with applicable standards and regulations while the petroleum products extracted by the OWS (i.e., oily waste) are retained in a dedicated holding tank onboard (and later could be incinerated and/or offloaded in port). The international standard established by MARPOL Annex I, and implemented into United States law by APPS, is that machinery space waste including bilge water may be discharged overboard if it contains a concentration of 15 ppm oil or less. MARPOL and APPS also require that the discharge be made through 15 ppm equipment, namely an OWS and Oil Content Monitor.

The holding tank may contain other oily water mixtures including those resulting from the purification of fuel and lubricating oils. In addition to removing the waste from the bilge area, a holding tank can allow for some separation of the oil and water. Bilge water may be discharged overboard after processing by an Oily Water Separator and passing through a bilge alarm, more commonly known as an Oil Content Monitor that is designed to detect when the effluent exceeds an oil content of greater than 15 ppm. The required pollution prevention equipment also includes an automatic stopping device (typically a three-way solenoid valve) that when triggered by the

Oil Content Monitor, will automatically divert the oily water mixture back into a holding tank. APPS and MARPOL define machinery space waste as an oily water mixture.

All ships over 400 gross tons are required to have equipment installed onboard that limits the discharge of oil into the oceans to 15 ppm when a ship is en route and provided the ship is not in a special area (where all discharge of oil is prohibited). Such ship equipment allows for compliance with both international regulations (MARPOL) and Coast Guard regulations that require the oil content of the discharged effluent to be less than 15 ppm and that it not leave a visible sheen on the surface of the water. Regulations also require that all oil or oil residues that cannot be discharged in compliance with these regulations, be retained onboard or discharged to a reception facility.

Conventional bilge water systems use an OWS to remove oil to meet regulatory standards prior to discharge. These systems use the techniques of centrifugal force, coalescence, gravity, and other methods to isolate oil from water (Table 4-2 describes some OWS technologies). The management of bilge water by most vessels consists of the following steps:

1) Bilge water is pumped into a holding tank, which is usually of sufficient size to hold the water for several days;
2) Bilge water is processed by an OWS to extract oil and petroleum products from the bilge water. Different cruise ships may use different types of OWS (e.g., centrifugal, filtration, and gravity based systems);
3) The treated bilge water from the OWS is discharged overboard provided that the OWS is certified by the Coast Guard, using International Standards Organization 9377-2:2000; the discharge does not have an oil content of greater than 15 ppm; and the discharge does not leave a visible sheen on the surface of the water;
4) All oil or oil residues that cannot be discharged in compliance with the abovementioned requirements – generally the oily waste collected by the OWS – is retained in a holding tank until it can be incinerated onboard or offloaded to a land-based treatment facility (CELB, 2003).

Table 4-2. Oily Water Separator Technologies

Description/Capabilities of OWS Devices	Processing Capacity
– Removes oil and grease using naturally-occurring bacteria – Continuous monitoring of hydrocarbons in effluent	Up to 20,000 gallons of bilge water per week (2,880 gal/day)
– Designed to separate and to remove free and emulsified oil – System can treat bilge and sludge – Oil content meter (bilge alarm calibrated to measure 15 ppm oil content)	12 - 24 m^3/day (or 53 - 106 gal/day)
– Utilizes fluid velocity reduction, differential specific gravity, and coalescences to separate nonsoluble oil, solids, and entrained air from oily water – Provides efficient removal or reduction of oil content to 15 ppm or less	Up to 44 gallons per minute
– High-speed centrifugal separation system for treatment of large bilge water volumes at sea – Generally reduces oil content to below 5 ppm – Continuous operation (24 hours/day)	Approximately 400 - 1320 gallons per hour

Sources: Ensolve, 2006; Senitec, 2007; Coffin World Water Systems, 2006; Alfa Laval, 2006

All vessels are required to have a bilge alarm or bilge monitor integrated into the piping system to detect whether the treated bilge water that is being discharged from the oily water separator has turbidity levels calibrated to be equivalent to samples containing an oil content greater than 15 ppm. If the monitor senses that the oil in the bilge water exceeds 15 ppm, the system is required to stop the overboard discharge and divert the effluent back to a holding tank. Any bilge water found to contain oil or oil residues with an oil content greater than threshold levels must be retained onboard or discharged to a designated reception facility. According to CELB (2003), several cruise lines now often use two oily water separators to assure that effluent levels meet or exceed the 15 ppm limit.

Cruise Lines International Association (CLIA) member lines have agreed to incorporate various standards for waste stream management into their Safety Management Systems (see Section 1.3). For bilge water and oily water residues, CLIA member lines have agreed to meet or exceed the international requirements for removing oil from bilge and wastewater prior to discharge. More specifically, CLIA member lines have agreed that bilge and oily water residue are processed prior to discharge to remove oil residues, such that oil content of the effluent is less than 15 ppm as specified by MARPOL Annex I.

In accordance with MARPOL (73/78) Regulation 20 and U.S. regulations (33 CFR 151.25) as appropriate, CLIA member lines have agreed that every cruise ship of 400 gross tons and above shall be provided with an oil record book which shall be completed on each occasion whenever any of numerous specified operations take place on the ship. Those operations include the following (CLIA, 2006):

a. Ballasting or cleaning of fuel oil tanks;
b. Discharge of dirty ballast or cleaning water form the fuel oil tanks above;
c. Disposal of oily residues; and
d. Discharge of bilge water that accumulated in machinery spaces.

4.4 What are the potential environmental impacts associated with inadequately treated bilge water from cruise ships?

Cruise ships have the potential to discharge oil or oily water via inadequately separated oily bilge water as a result of a faulty or malfunctioning OWS, human error, malfunctioning bilge monitors, or a deliberate OWS by-pass. Exposure of marine organisms to petroleum hydrocarbons can result in mortality due to acute toxicity or physical smothering. Additionally, possible long-term impacts include: impaired survival or reproduction; chronic toxicity of persistent components; and habitat degradation (Peterson and Holland-Bartels, 2002). Oil, even in minute concentrations, can kill fish or have various sub-lethal chronic effect (CRS, 2007), as well as severely damage coral reefs. According to the Bluewater Network (2000), ingestion of oil can kill birds or lead to starvation, disease, and predation of these animals. A Canadian study has estimated that 300,000 seabirds are killed annually in Atlantic Canada from this type of routine discharge of oily vessel waste (Wiese and Robertson, 2004).

According to CELB (2003), any oils that remain on the surface can interfere with larvae development and marine birds; heavier oils can sink to the bottom of the ocean and contaminate the sediment, causing potential long-term impacts to benthic habitats. According to CELB (2003), diesel fuel is acutely toxic to fish, invertebrates, and seaweed, although in open water this fuel dilutes quite rapidly. CELB (2003) further states that spills can be particularly toxic to crabs and shellfish in shallow, confined near-shore areas because in these organisms oil bio-accumulates – often over a period of several weeks after exposure.

4.5 What action is the federal government taking to address bilge water from cruise ships?

EPA is developing a water permit program for pollutant discharges incidental to the normal operation of vessels. Under a recent court decision, the existing EPA regulations that exclude discharges incidental to the normal operation of a vessel from Clean Water Act permitting will be vacated (revoked) as of September 30, 2008. The Agency is appealing that decision, but if left unchanged, this would mean that vessel owners or operators whose discharges previously have been excluded from such permitting by the regulation will require a permit beginning September 30, 2008. Such regulated discharges may include bilge water. At the time this report went to press, EPA was in the process of developing a permitting framework.

The federal government's bilge water management efforts have focused on responding to oil spills and developing preventative programs. The Coast Guard is the primary federal agency responsible for monitoring and enforcing cruise ship discharges. In addition to monitoring and enforcing standards, the Coast Guard has been working with the IMO to develop new international performance standards for oil pollution prevention equipment.

The Coast Guard has a robust enforcement regime involving all vessels regarding violations of MARPOL Annex I. The Coast Guard conducts inspections of all cruise vessels operating in United States ports and waters quarterly and annually. These inspections typically include examination and testing of pollution prevention equipment and review of Oil Record Books. The Coast Guard works closely with the U.S. Department of Justice (DOJ). Through this cooperation, criminal enforcement actions have been taken for intentional discharges of oily bilge waste. The most common violations of bilge water quality and treatment requirements include the intentional falsification of Oil Record Books to conceal the deliberate bypassing of the OWS entirely or tampering with the monitoring equipment. Tampering has included disabling or modifying the Oil Content Monitor or flushing the device with freshwater to prevent sampling of the actual effluent. Inspections of vessels have found the following problems:

- Data records that are manipulated or data recorders that are disabled;
- Poorly maintained OWS equipment and related piping systems;
- Crew error or lack of crew training;
- Bilge alarms/monitors that are out of calibration due to poor maintenance (thereby allowing bilge water discharges that exceed 15 ppm of oil);
- Piping systems that are re-routed to bypass the bilge alarms/monitors; and,
- Improper use of oil inhibitors to degrade OWS efficiency and to conceal oil discharge sheens.

Additionally, deliberate discharges of untreated bilge water might be accompanied by efforts to deceive port state control officials by falsifying the Oil Record Book. Several port states (i.e., the country the cruise ship visits) have reacted by increasing their scrutiny of OWS systems and diligence for oil record book keeping (OECD, 2003). The U.S. is taking a lead in enforcement actions for such criminal violations. To date the U.S. has prosecuted over 75 cases involving intentional discharges of oily bilge waste from vessels in general, with over $150 million collected in criminal fines since 2000. Many of the major cruise ship companies calling on U.S. ports have been convicted of such violations, including, Royal Caribbean, Holland America, Carnival and Norwegian Cruise Line Limited. As a result of the prosecutions, all the companies have been at one time placed in probation with a requirement to implement Environmental Compliance Plans.

References

Alaska Department of Environmental Conservation (ADEC). 2000. *Alaska Cruise Ship Initiative Part 1 Final Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/finreportp10808.pdf)

Bluewater Network. (2000, March 17). Petition to Environmental Protection Agency Administrator Carol M. Browner. (www.epa.gov/owow/oceans/cruise_ships/petition.pdf)

Center for Environmental Leadership in Business (CELB). 2003. *A Shifting Tide: Environmental Challenges and Cruise Industry Responses.* Washington, DC. (www.celb.org/ImageCache/CELB/content/travel_2dleisure/cruise_5finterim_5fsummary_2epdf/v1/cruise_5finterim_5fsummary.pdf)

Congressional Research Service (CRS). 2007. *Cruise Ship Pollution: Background, Laws and Regulations, and Key Issues* (Order Code RL32450). Washington, DC. (www.ncseonline.org/NLE/CRSreports/07Jul/RL32450.pdf)

Cruise Line International Association (CLIA). 2006. *CLIA Industry Standard: Cruise Industry Waste Management Practices and Procedures*. Fort Lauderdale, FL. (www.cruising.org/industry/PDF/CLIAWasteManagementAttachment.pdf and www.cruising.org/industry/PDF/CLIAWasteManagement.pdf)

Organization for Economic Co-operation and Development (OECD). 2003. *Cost Savings Stemming from Non-Compliance with International Environmental Regulations in the Maritime Sector*. Paris, France. (www.oecd.org/dataoecd/4/26/2496757.pdf)

Peterson, Charles H. et al. 2002. Nearshore vertebrate predators: constraints to recovery from oil pollution. *Marine Ecology Progress Series* 241:235-236.

U.S. Environmental Protection Agency. 1997. *Profile of the Water Transportation Industry*. (EPA/310-R-97-003). Washington, D.C.: Author. (http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/watersct.pdf)

Wiese, F.K. & Robertson, G.J. 2004. Assessing impacts of chronic oil discharges at sea on seabirds: a general oiled seabird mortality model applied to Eastern Canada. *Journal of Wildlife Management* 68: 627–638.

Section 5: Solid Waste

Solid waste, as defined in section 1004(27) of the Resource Conservation and Recovery Act (RCRA), is the garbage, refuse, sludge, rubbish, trash, and other discarded materials resulting from industrial, commercial, and other operations, as well as that disposed of every day by individuals, businesses, and communities. Solid waste can be either non-hazardous or hazardous waste. On most cruise ships, solid waste is managed by utilizing a multifaceted strategy that includes source reduction, source segregation for waste streams, waste minimization, and recycling. According to ADEC (2001), 75 to 85 percent of trash is generally incinerated onboard, and the ash is typically discharged at sea; some solid waste is landed ashore for disposal or recycling (CRS, 2007).

This section discusses the current state of information about solid waste, the laws regulating solid waste from vessels, how solid waste is managed on cruise ships, the potential environmental impacts of cruise ship solid waste, and federal actions taken to address solid waste from cruise ships.

5.1 What is solid waste and how much is generated on cruise ships?

Solid waste is the garbage, refuse, sludge, rubbish, trash, and other discarded materials resulting from industrial, commercial, and other operations, as well as that disposed of every day by individuals, businesses, and communities. Solid waste can be either non-hazardous or hazardous waste. Non-hazardous waste, for example, may be in the form of trash and the waste associated with product packaging, cans, bottles, food waste, newspapers, product and machinery parts, disposable products, and recyclable products; this waste may be solid, liquid, semisolid, or gaseous material. This section discusses non-hazardous solid waste generated on cruise ships. Hazardous waste, however, is a type of solid waste or combination of solid wastes, which, because of its quantity, concentration or physical, chemical, or infectious characteristics may cause or significantly contribute to an increase in mortality or illness or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed or otherwise managed. Hazardous waste generally contains hazardous substances which can be liquids, solids, or contained gases and must be handled, tracked, treated, and disposed of separately from other types of solid waste. Hazardous waste generated on cruise ships is discussed separately in Section 6.

Solid waste generated onboard a cruise ship typically comprises the materials used for packaging products for transportation or storage, waste generated by passenger and crew activity, and food waste. More specifically, the types of solid waste generated on a ship can include food waste, glass, paper, wood, cardboard, incinerator ash, metal cans, and plastics. Table 5-1 identifies some types of common solid waste items, including specific examples, generated aboard cruise ships.

Table 5-1. Types and Specific Examples/Descriptions of Solid Waste Generated on Cruise Ships

Type of Solid Waste	Examples and Descriptions
Cardboard	Dunnage (lining and packing materials that float) and cardboard from all manner of packaging materials
Paper	Paper and packaging
Plastic	Synthetic ropes, fishing nets, plastic containers, plastic bags, biodegradable plastics, Poly-Ethylene Terephthalate (P.E.T.) plastics, and High Density Polyethylene (HDPE) plastics
Wood	Wood pallets and waste wood
Glass	Chipped or broken glasses, food and beverage jars, and bottles
Metal cans	Aluminum soft drink cans, tin cans from the galley, and steel cans from ship maintenance operations
Food waste	Wastes derived in whole or part from fruits, vegetables, meats, or other plant or animal material (includes food scraps, table refuse, galley refuse, food wrappers or packaging materials contaminated with food residue)
Incinerator ash	Ash generated from the incineration of packing materials, paper and cardboard wastes, etc.
Food wrappers and packaging	Paper and plastic wrapping/packaging materials with food residue

According to a 1999 Royal Caribbean Cruises Environmental Report, packaging materials from consumables and spare parts for a ship can generate up to 15 tons of waste in a single day. Table 5-2 presents the estimates of certain types of solid waste generated per week on an individual vessel in the Holland America Lines and Royal Caribbean Cruises fleets.

Table 5-2. Estimates of Solid Waste Generated Per Vessel per Week

	Holland America Lines	Royal Caribbean Cruises
Dunnage	30 cubic meters	60 cubic meters
Glass and Cans	6,000 lbs of glass 450 lbs of cans	5 cubic meters of glass 2.5 cubic meters of cans
Food Wastes	12 cubic meters	12 cubic meters

Sources: ADEC, 2002 and Royal Caribbean Cruises, 1999

The amount of solid waste generated by cruise ships varies from ship to ship, based on the size of the vessel, number of passengers and crew, and consumption of material. Compared to other types of vessels, cruise ships generate large volumes of solid waste. Environmental Resources Limited (1991) estimated that a cruise ship generates 70 times more solid waste per day than a typical cargo ship. It has been further estimated that 24% of the solid waste generated by vessels worldwide (by weight) comes from cruise ships (National Research Council, 1995).

With large cruise ships carrying several thousand passengers, the amount of waste generated in a given day can be considerable. One large cruise ship of 2,500 passengers and 800 crew (total 3,300 persons onboard) can generate 1 ton of garbage from normal operations in a day (National Research Council, 1995). On average, each cruise ship passenger generates at least two pounds of non-hazardous solid waste per day (CELB, 2003). In addition to that, each cruise ship passenger disposes of two bottles and two cans (both of which are recyclable materials) per day

(CELB, 2003). Table 5-3 presents various estimates of the amount of solid waste a passenger generates in a given day during a cruise.

Table 5-3. Estimates of Solid Waste Generated per Person per Day on a Cruise Ship

Source of Data	Trash Generated (lbs/person/day)
Environmental Resources Limited	7.7
Florida Caribbean Cruise Association	0.7
Holland America Line	1.8
Organization of Eastern Caribbean States (OECS) Waste Management Study	6.5
Seebacher	5.7

Source: Simmons & Associates, 1994

The newest addition in Royal Caribbean's Freedom family of ships, the *Liberty of the Seas*, is currently the largest cruise ship at 1,112 ft long and carries up to 3,634 passengers and 1,360 crew. Building even larger cruise ships is on the horizon with Royal Caribbean building Genesis class ships that will be almost 1,200 feet long (Bell, 2007). Over the past two decades, the average ship size has been increasing at the rate of roughly 90 ft every 5 years (Bell, 2007). As the size and number of passengers these cruise ships can carry increases, the volume of wastes generated – and discharged – will presumably increase as well.

5.2 What laws apply to solid waste from cruise ships?

5.2.1 International Convention for the Prevention of Pollution from Ships and Act to Prevent Pollution from Ships

The International Convention for the Prevention of Pollution from Ships

In 1987, the United States ratified Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL). MARPOL Annex V pertains to different types of garbage, including plastics, and specifies the distances from land and the manner in which they may be disposed. More specifically, the Annex prohibits the at-sea disposal of plastic wastes and regulates the distance from shore that ships may dispose of other items that constitute garbage.

Under Annex V, the term garbage includes "all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically except those substances which are defined or listed in other Annexes." The Annex also requires governments to ensure the provision of facilities at ports and terminals for the reception of garbage. Annex V sets more stringent discharge standards for specifically identified "special areas." The special areas are particular areas of water that have special significance and require more protective measures than other areas. The special areas identified by Annex V are the Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, Gulfs area, North Sea, Antarctic, and Wider Caribbean Region. In addition, the Annex requires some ships (i.e., depending on size and passenger load) to maintain Garbage Record Books, develop Garbage Management Plans, and display placards that outline the disposal requirements.

Act to Prevent Pollution from Ships

The Act to Prevent Pollution from Ships (APPS; 33 U.S.C. § 1901 et seq.) was amended by the Marine Plastic Pollution Research and Control Act of 1987, which implements the provisions of Annex V of MARPOL relating to garbage and plastics. APPS applies to all U.S. flagged ships anywhere in the world, and, with respect to Annex V, to all foreign flagged vessels operating in the navigable waters or exclusive economic zone of the United States or while at a port or terminal under the jurisdiction of the United States. APPS and its implementing regulations (33 CFR 151.51-77) prohibit the discharge of all garbage within three miles of shore; certain types of garbage from 3-25 miles offshore; and plastic anywhere. Vessels are also required to record each discharge or incineration of garbage in a Garbage Record Book.

Under APPS, the definition of "ship" includes fixed or floating platforms. There are separate garbage discharge provisions applicable to these units. For these platforms, and for any ship within 500 meters of these platforms, disposal of certain types of garbage is prohibited. Additionally, all manned, oceangoing U.S. flagged vessels of 12.2 meters or more in length that are engaged in commerce, and all manned, fixed, or floating platforms subject to the jurisdiction of the United States, are required to keep records of garbage discharges and disposals. The Coast Guard regularly inspects vessel discharge records and logbooks required by the MARPOL 73/78 Convention, and investigates all allegations of illegal discharges on the high seas or within United States waters. Receipts and record-keeping for Annex V waste streams from ships are addressed in MARPOL Annex V, Regulation 9.

Applicable Coast Guard Regulations

The Coast Guard generally has the primary responsibility to prescribe and enforce the regulations necessary to implement APPS in the United States. The following Coast Guard regulations pertain to the management of solid waste on ships:

- Every manned oceangoing ship of 400 gross tons and above and every ship certified to carry 15 passengers or more shall ensure that a written record is maintained on the ship for the following discharge or disposal operations:
  - discharge overboard,
  - discharge to another ship,
  - discharge to a reception facility, and
  - incineration on the ship (33 CFR 151.55).

- Each manned, oceangoing ship of 40 feet or more in length must have a garbage management plan in place and each person handling the garbage must follow the plan (33 CFR 151.57).

- Each ship of 26 feet or more must ensure that appropriate placards outlining disposal requirements are placed in prominent locations and in sufficient numbers for both passengers and crew (33 CFR 151.59).

- No person onboard any ship may discharge garbage into the navigable waters of the United States. Navigable waters means the waters of the United States, including the territorial seas (i.e., the belt of seas measured from the line of ordinary low water along that portion of the coast which is in direct contact with the open sea and the line marking the seaward limit of inland waters, and extending seaward a distance of three miles). No person onboard any ship may discharge into the sea, or into the navigable waters of the United States, plastic or garbage mixed with plastic, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags. All garbage containing plastics must be discharged ashore or incinerated (33 CFR 151.66 and 151.67).

- For vessels operating outside a special area, no person may discharge, into the sea, garbage that is separated from plastic, if the distance from nearest land is less than: (1) 25 nautical miles for dunnage, lining and packing materials that float; or (2) 12 nautical miles for victual wastes and all other garbage including paper products, rags, glass, metal, bottles, crockery and similar refuse, except that, such garbage may be discharged outside of three nautical miles from nearest land after it has been passed through a grinder or comminuter (i.e., pulverizer) (33 CFR 151.69).

Table 5-4 provides a summary of garbage discharge restrictions per 33 CFR Part 151 for vessels operating both in special areas and outside of special areas.

Table 5-4. Summary of Garbage Discharge Restrictions for Vessels

Garbage Type	All Vessels Except Fixed or Floating Platforms and Associated Vessels	
	Outside special areas (33 CFR 151.69)	**In special areas[2] (33 CFR 151.71)**
Plastics, including synthetic ropes and fishing nets and plastic bags	Disposal prohibited (33 CFR 151.67)	Disposal prohibited (33 CFR 151.67)
Dunnage, lining and packing materials that float	Disposal prohibited less than 25 miles from nearest land and in the navigable waters of the U.S.	Disposal prohibited (33 CFR 151.71)
Paper, rags, glass, metal bottles, crockery and similar refuse	Disposal prohibited less than 12 miles from nearest land and in the navigable waters of the U.S.	Disposal prohibited (33 CFR 151.71)
Paper, rags, glass, etc. comminuted or ground[1]	Disposal prohibited less than 3 miles from nearest land and in the navigable waters of the U.S.	Disposal prohibited (33 CFR 151.71)
Victual waste not comminuted or ground	Disposal prohibited less than 12 miles from nearest land and in the navigable waters of the U.S.	Disposal prohibited less than 12 miles from nearest land
Victual waste comminuted or ground[1]	Disposal prohibited less than 3 miles from nearest land and in the navigable waters of the U.S.	Disposal prohibited less than 12 miles from nearest land
Mixed garbage types[3]	See Note 3	See Note 3

Source: 33 CFR 151.51- 151.77 Appendix A
[1] Comminuted or ground garbage must be able to pass through a screen with a mesh size no larger than 25 mm (1 inch) (33 CFR 151.75).
[2] Special areas under Annex V are the Mediterranean, Baltic, Black, Red, and North Seas areas, the Gulfs area, the Antarctic area, and the Wider Caribbean region, including the Gulf of Mexico and the Caribbean Sea (33 CFR 151.53).
[3] When garbage is mixed with other substances having different disposal or discharge requirements, the more stringent disposal restrictions shall apply.

- The regulations applicable to port reception facilities for garbage are published at 33 CFR Part 158. Under those regulations, the Coast Guard administers the reception facility "Certificate of Adequacy" (COA) program for certification, including periodic inspection, of the port reception facilities to which those regulations apply. All port facilities and terminals under the jurisdiction of the United States, including commercial fishing facilities, mineral and oil shore bases, and recreational boating facilities, must have a garbage reception facility which meets the regulatory requirements for adequacy. 33 CFR 158.133(c). These regulations apply to U.S. ports and terminals that receive garbage from cruise ships. Though only a subset of those ports require a COA, (see 33 CFR 158.135(c) for COA criteria with respect to Annex V wastes), Coast Guard field units regularly inspect all port reception facilities for adequacy, regardless of the requirement for a COA, and investigate all allegations of inadequate reception facilities.

5.2.2 Clean Water Act

As a general matter, the Clean Water Act (CWA; 33 U.S.C. § 1251 et seq.) prohibits any person from discharging any pollutant from any point source into waters of the United States, which includes the territorial seas (i.e., the belt of seas measured from the line of ordinary low water along that portion of the coast which is in direct contact with the open sea and the line marking the seaward limit of inland waters, and extending seaward a distance of three miles), except in compliance with a National Pollutant Discharge Elimination System (NPDES) permit or as otherwise authorized under the Act. The term "point source" is defined to include a "vessel or other floating craft." The term "pollutant" does not include sewage from vessels (within the meaning of CWA section 312). Outside the territorial seas, i.e., in the contiguous zone or the ocean, the addition of any pollutant from a "vessel or other floating craft" is not a "discharge of pollutants," and therefore does not require an NPDES permit (CWA section 502(12)(b)). The addition of any pollutant to the waters of the contiguous zone or ocean from any point source *other* than a "vessel or other floating craft" is a "discharge of pollutants," and therefore does require an NPDES permit. However, EPA has interpreted this permitting requirement to apply to certain discharges from a vessel that operates in a capacity other than as a means of transportation such as when used as an energy or mining facility, a storage facility or a seafood processing facility, or when secured to the bed of the ocean, contiguous zone or waters of the United States for the purpose of mineral or oil exploration or development (40 CFR 122.3(a)).

In addition, EPA regulations (40 CFR 122.3(a)) have excluded discharges incidental to the normal operation of a vessel (for example, effluent from properly functioning marine engines, laundry, shower, and galley sink wastes) from the requirement of an NPDES permit.[2] This regulatory exclusion does not apply to discharges of rubbish, trash, garbage, or other such materials discharged overboard a vessel.

5.2.3 National Marine Sanctuaries Act

The National Marine Sanctuaries Act (NMSA; 16 U.S.C. § 1431 et seq.), as amended, authorizes the National Oceanic and Atmospheric Administration (NOAA) to designate as National Marine Sanctuaries areas of the marine environment that have special aesthetic, ecological, historical, or recreational qualities, and to provide comprehensive and coordinated conservation management for such areas. The National Marine Sanctuary Program manages 13 sanctuaries and the Papahānaumokuākea Marine National Monument. Designated sanctuaries are managed according to site-specific management plans developed by NOAA that typically prohibit the

[2] On September 18, 2006, the United States District Court for the Northern District of California upheld a challenge to EPA's denial of a petition to withdraw a long-standing regulation that excluded discharges incidental to vessel operations from the NPDES program. The Court's order vacates, as of September 30, 2008, the exemption for discharges incidental to the normal operation of a vessel contained in 40 CFR 122.3(a). Nothing in the decision, however, affects the prohibition on the unpermitted discharge of rubbish, trash, garbage, or other such materials discharged overboard. EPA has since appealed the District Court's order to the U.S. Court of Appeals for the Ninth Circuit.

discharge or deposit of most material. Under NOAA's implementing regulations for the NMSA, it is illegal to discharge solid waste into most national marine sanctuaries.

5.2.4 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA; 42 U.S.C. § 6901 et seq.) is the federal law that, among other things, defines and regulates solid waste and hazardous waste. RCRA is designed to minimize the hazards of waste disposal, conserve resources through waste recycling, recovery, and reduction, and ensure waste management practices that are protective of human health and the environment. In order to achieve these goals, RCRA established a Solid Waste Program (RCRA Subtitle D) and a Hazardous Waste Program (RCRA Subtitle C).[3]

RCRA Subtitle D encourages environmentally-sound solid waste management practices that maximize reuse and recycling efforts, and establishes regulations that specify how solid waste disposal facilities should be designed and operated.

5.2.5 Marine Protection, Research, and Sanctuaries Act

The Marine Protection, Research, and Sanctuaries Act (MPRSA, 33 U.S.C. § 1401 et seq.) (also called the Ocean Dumping Act) prohibits (1) the transportation of any material from the United States for the purpose of disposal in ocean waters without a permit; (2) the transportation of any material by U.S. agencies or by U.S. flagged vessels or aircraft for the purpose of disposal in ocean waters without a permit; and (3) any person from dumping, without a permit, any material transported from a location outside the United States into the U.S. territorial seas or into the contiguous zone, to the extent it may affect the territorial seas or the territory of the United States. This Report does not address the transportation of materials that would require an ocean dumping permit under the MPRSA.

5.3 How do cruise ships manage solid waste?

The management of shipboard-generated waste is a challenge not only for cruise ships at sea, but also for other commercial vessels, military ships, fishing vessels, and recreational boats. Most cruise ship trash is treated onboard (incinerated, pulped, or ground for discharge overboard) (CRS, 2007). According to ADEC (2001), 75 to 85 percent of trash is generally incinerated onboard, and the ash is typically discharged at sea; some solid waste is landed ashore for disposal or recycling (CRS, 2007). CELB (2003) states that Royal Caribbean’s Vision-class ships sort, crush, and offload about 450 pounds (204kgs) of aluminum cans for recycling per weeklong trip.

Food wastes and hazardous wastes generated on cruise ships are often separated from other solid wastes and processed separately. Food waste is often pulped or compressed, and then incinerated. According to ADEC (2000), the food liquids (1,300 to 2,600 gallons per day)

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[3] In states with RCRA programs authorized by EPA, the authorized state RCRA program operates in lieu of the federal RCRA program. Some states have authorized RCRA programs that are more stringent than the federal RCRA program.

removed during dehydration are recycled through a pulping/compression process several times, and eventually end up in the graywater holding tanks; the remaining compressed, dehydrated food waste is incinerated. Hazardous wastes are separated from other solid wastes because onboard incinerators do not operate at the temperatures necessary to properly destroy hazardous substances. Therefore, proper waste identification and segregation of hazardous waste prior to burning is critical. As a result, waste segregation, as well as crew and passenger training, and compliance with appropriate waste handling procedures is a fundamental aspect of vessel waste management and safe discharges. Upon arriving in port, the solid waste generator (the cruise ship) offloads any remaining solid waste in accordance with applicable state solid waste management requirements.[4] Examples of Royal Caribbean Cruise's waste management practices are presented in the Table 5-5.

Table 5-5. Waste Management Practices by Royal Caribbean Cruises

Type of Waste	Management Practice
Cardboard	Packing materials are collected onboard and incinerated or offloaded for recycling or disposal.
Paper	Paper wastes are collected onboard and incinerated or offloaded for recycling or disposal.
Plastic	Plastic wastes are collected onboard and incinerated or offloaded for recycling or disposal.
Glass	Glass is collected, crushed onboard, stored, and offloaded for recycling.
Metal Cans	Cans are collected and sorted onboard to separate the aluminum cans that have a high market recycling value. Cans are crushed on board, stored, and offloaded for recycling.
Food Waste	Wet food waste is processed through giant grinders (called pulpers) that reduce the size of the food particles, which allows for more efficient removal of water by extractors. Removing excess water allows the food to be burned and managed more easily. The water removed in the process is ultimately discharged as gray water.

Source: RCC, 1999

Cruise Lines International Association (CLIA) member lines have agreed to incorporate various standards for waste stream management into their Safety Management Systems (see Section 1.3). CLIA member lines have stated that the industry is attempting to improve solid waste management both through reduction and proper waste disposal. CLIA member lines have committed to eliminate, to the maximum extent possible, the disposal of MARPOL Annex V wastes into the marine environment. Annex V ship wastes are to be minimized through purchasing practices, reuse and recycling programs, landing ashore and onboard incineration in approved shipboard incinerators. Glass, aluminum, other metals, paper, wood and cardboard are, in most cases, recycled. Wood and cardboard may be incinerated when appropriate. Any Annex V waste that is discharged at sea is to be done in strict accordance with MARPOL and any other prevailing requirements. By adopting a multifaceted strategy that includes waste minimization, source reduction and recycling, the total waste from the industry has been reduced by nearly 50% over the last ten years (CLIA, 2006).

Source segregation for waste streams is critical for onboard waste management and CLIA member lines endorse the following (CLIA, 2006):

- source reduction,
- minimization,

[4] RCRA Subtitle D established regulations addressing how solid waste disposal facilities should be designed and operated.

- recycling,
- collection,
- processing, and
- discharge ashore.

According to CLIA (2006), this focuses the use of incinerators of CLIA member lines primarily for food waste, contaminated cardboard, some plastics, trash, and wood. With this approach, incinerator ash is not normally a hazardous waste (CLIA, 2006), as the abovementioned waste management strategies call for the removal of items that would cause the ash to be hazardous. Further, those items separated out from the wastestream would then be handled according to accepted hazardous waste protocols (see Section 6 for the hazardous waste discussion).

CLIA member lines have stated that incinerator ash will be tested at least once quarterly for the first year of operation to establish a baseline and that testing may then be conducted once a year. The member lines have further stated that a recognized test procedure will be used to demonstrate that ash is not a hazardous waste. Proper hazardous waste management procedures are to be instituted onboard each ship to assure that waste products which would result in a hazardous ash, are not introduced into the incinerator. Non-hazardous incinerator ash is disposed of at sea in accordance with MARPOL Annex V. If any ash is identified as being hazardous, it is to be disposed of ashore in accordance with RCRA. (CLIA, 2006.)

5.4 What are the potential environmental impacts associated with solid waste from cruise ships?

Waste products in the past were made from natural materials and were mostly biodegradable. Now, much of the non-hazardous waste generated on cruise ships is either not easily biodegradable or does not biodegrade at all (see Table 5-6) (CELB, 2003).

Table 5-6. Amount of Time for Objects to Dissolve at Sea

Object	Time to Dissolve
Cotton cloth	1-5 months
Rope	3-14 months
Woolen cloth	1 year
Painted wood	13 years
Tin can	100 years
Aluminum can	200-500 years
Plastic bottle	450 years

Source: Hellenic Marine Environment Protection Association (HELMEPA) (IMO, 2007)

Solid waste that enters the ocean directly or indirectly may become marine debris, and can then pose a threat to marine organisms, humans, coastal communities, and commercial industries. Marine debris may accumulate on beaches, on the surface of waters, and in the benthos. The potential environmental and physical effects of marine debris include (National Research Council, 1995):

- aesthetic degradation of surface waters and beach areas;
- physical injuries to humans and life-threatening interference with their activities;
- ecological damage caused by the interference of plastics with gas exchange between overlying waters and those in the benthos;
- alterations in the composition of ecosystems caused by debris that provides habitats for opportunistic organisms;
- entanglements of birds, fish, turtles, and cetaceans in lost or discarded nets, fishing gear, and packing materials; and
- ingestion of plastic particles by marine animals.

With regard to marine debris causing adverse impacts to human health, beach users can be injured by broken glass, cans, needles, or other litter washed ashore. Such debris may cause significant adverse economic impact in coastal communities. An informal survey conducted in 1993 for the Center for Marine Conservation revealed annual costs for beach cleanup ranging from $24,240 per mile in Virginia Beach to $119,530 per mile in Atlantic City, New Jersey (National Research Council, 1995). In addition, marine debris can pose navigational hazards to vessels, requiring time and money for repairs.

Food waste can contribute to increases in biological oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC) if discharged overboard.

5.5 What action is the federal government taking to address solid waste from cruise ships?

The Interagency Marine Debris Coordinating Committee, a federal group chaired by EPA and NOAA, is looking into ways to reduce the impact and sources of marine debris (any abandoned or uncontrolled solid material that is introduced into the ocean and coastal environment), including debris from vessels such as cruise ships. The group will provide recommendations for research priorities, educational programs, monitoring techniques, and federal agency action in a Report to Congress in 2008 as required by section 5(c) of the Marine Debris Research, Prevention, and Reduction Act (Pub. L. 109-449).

According to the IMO (2007), the U.N. General Assembly invited IMO to review MARPOL Annex V, in consultation with relevant organizations and bodies, to assess the Annex's effectiveness in addressing sea-based sources of marine debris. The U.S. Government is part of the IMO working group and the U.S. delegation assigned to the working group assembled the appropriate federal agencies. Comprehensive review of MARPOL Annex V began in February 2006.

The Coast Guard implements ongoing inspection and compliance programs to insure the adequacy of port reception facilities. In 2006 alone, the Coast Guard conducted over 14,000 facility inspections (up from approximately 3,500 in calendar year 2000), including inspections of MARPOL Annex V port reception facilities for compliance and adequacy. During the period from 2002 to 2006, vessel arrivals at U.S. ports nearly doubled which in turn increased pressure on the capacities of U.S. ports. In meeting this increased compliance and inspection challenge, the Coast Guard issued or responded to and investigated 7,424 facility deficiencies in calendar year 2006, including reception facility deficiencies (up from 2,587 in calendar year 2000). From the time period between 2002 and 2006, the Coast Guard has documented a 26% reduction in the number of pollution incidents reported at facilities, which demonstrates the Coast Guard's continuing commitment to vigorous implementation of the pollution prevention and environmental stewardship missions which have been entrusted to the Coast Guard by Congress. This includes the administration of the COA program and insuring the adequacy of all U.S. port reception facilities for Annex V wastes from vessels.

The United States (as a party to MARPOL), with active Coast Guard engagement, participates in international work groups in efforts to standardize both Advance Notice Forms generated by vessels with respect to their reception facility needs for all wastes and a standard receipt form for such wastes. Addressing this standardization issue has been an ongoing effort by the MEPC of the IMO (since at least October 2004) to improve the performance of port reception facilities for solid waste management. The Coast Guard itself has focused on ways to address standardized reporting, including updates to implementing regulations as well as the Coast Guard instructions that provide guidance to its field units. Implementation of standardized receipts, as proposed by the IMO with Coast Guard concurrence, will enhance the capacity of Coast Guard inspectors to confirm both allegations of illegal discharges and reports of inadequate reception facilities (approximately 80 reports of inadequacies have been received and investigated so far in 2007). Coast Guard inspectors will be able to compare Advance Notice records with reception facility receipts (which are required to be kept with the vessel garbage log book for a period of two years under Section 4.2 of the Appendix to MARPOL Annex V, 2006 Consolidated Edition). Presently, reports of inadequate reception facilities are available through the International Maritime Organization's Global Integrated Shipping Information System public website at http://gisis.imo.org/Public/.

References

Alaska Department of Environmental Conservation (ADEC). 2000. *Alaska Cruise Ship Initiative Part 1 Final Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/finreportp10808.pdf)

Alaska Department of Environmental Conservation (ADEC). 2001. *Alaska Cruise Ship Initiative Part 2 Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/acsireport2.pdf)

Alaska Department of Environmental Conservation (ADEC). 2002. *The Impact of Cruise Ship Wastewater Discharge on Alaska Waters*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/impactofcruiseship.pdf)

Bell, Tom. 2007 (September 28). Experts: Mega-berth needed for cruise ships. *Portland Press Herald*. (www.pressherald.mainetoday.com/story_pf.php?id=137059&ac=PHnws)

Bluewater Network. 2000 (March 17). Petition to Environmental Protection Agency Administrator Carol M. Browner. (www.epa.gov/owow/oceans/cruise_ships/petition.pdf)

Center for Environmental Leadership in Business (CELB). 2003. *A Shifting Tide: Environmental Challenges and Cruise Industry Responses.* Washington, DC. (www.celb.org/ImageCache/CELB/content/travel_2dleisure/cruise_5finterim_5fsummary_2epdf/v1/cruise_5finterim_5fsummary.pdf)

Cruise Line International Association (CLIA). 2006. *CLIA Industry Standard: Cruise Industry Waste Management Practices and Procedures*. Fort Lauderdale, FL. (www.cruising.org/industry/PDF/CLIAWasteManagementAttachment.pdf and www.cruising.org/industry/PDF/CLIAWasteManagement.pdf)

Congressional Research Service (CRS). 2007. *Cruise Ship Pollution: Background, Laws and Regulations, and Key Issues* (Order Code RL32450). Washington, DC. (www.ncseonline.org/NLE/CRSreports/07Jul/RL32450.pdf)

International Maritime Organization (IMO). 2007. *Prevention of Pollution by Garbage from Ships*. London, England. (www.imo.org/Environment/mainframe.asp?topic_id=297)

Royal Caribbean Cruises Ltd. 1999. *Environmental Report.*

Simmons & Associates. 1994. *The Impact of Tourism on the Marine Environment of the Caribbean: With Special Reference to Cruise and Other Types of Marine-based Tourism*. Caribbean Tourism Organization, Barbados.

Section 6: Hazardous Waste

Hazardous waste is a subset of "solid waste," and is a waste that contains hazardous constituents that can be liquid, solid, semisolid, or contained gas. On most cruise ships, the hazardous waste generated onboard is stored onboard until the wastes can be offloaded for recycling or disposal. Hazardous waste that is offloaded for disposal is handled in accordance with RCRA requirements, and must be sent to a licensed hazardous waste Treatment, Storage, and Disposal Facility (TSDF).

This section discusses the current state of information about hazardous waste, the laws regulating hazardous waste from vessels, how hazardous waste is managed on cruise ships, the potential environmental impacts of cruise ship hazardous waste, and federal actions taken to address hazardous waste from cruise ships.

6.1 What is hazardous waste and how much is generated on cruise ships?

Under federal law, "hazardous waste" is a subset of "solid waste." The regulations implementing the Resource Conservation Recovery Act (RCRA) establish the criteria for defining "hazardous waste" with two basic approaches: a solid waste is a hazardous waste if it is either a waste that appears on one of the four hazardous waste lists (i.e., F-List, K-List, P-List, or U-List); or the solid waste exhibits at least one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity). Once a waste is identified as a hazardous waste, any person who generates or manages the hazardous waste must comply with all applicable state and federal regulations regarding its management. Hazardous wastes need to be stored, treated, and disposed in a manner so as to minimize the risks to human health and the environment.

The universe of hazardous waste is diverse – it is a waste that contains hazardous constituents that can be liquid, solid, semisolid, or contained gas. Daily cruise ship activities that produce hazardous wastes include photo processing, dry cleaning, and equipment cleaning. These resulting wastes contain a wide range of substances such as hydrocarbons, chlorinated hydrocarbons, heavy metals, paint waste, solvents, fluorescent and mercury vapor light bulbs, various types of batteries, and unused or outdated pharmaceuticals. Table 6-1 identifies different types of wastes generated on cruise ships that are, or may be, hazardous. This is only a list of typical wastes, and ultimately it is the responsibility of the person generating the waste (i.e., ship owner and/or operator) to make this determination and to comply with all applicable environmental requirements.

Table 6-1. Types of Potentially Hazardous Waste Generated Aboard Cruise Ships

Waste Type	Description
Photo Processing Waste (including X-ray development fluid waste)	Spent fixer, spent cartridges, expired film, and silver flake. The fixer removes unexposed silver compounds from the film during the developing process. Though silver-bearing waste is typically hazardous waste under RCRA due to silver content, RCRA regulations at 40 CFR 266.70, which apply to materials recycled to recover economically significant amounts of certain precious metals, including silver, do not include all of the requirements applicable to other types of hazardous wastes generally.

Waste Type	Description
Dry Cleaning Wastes	Dry cleaning units produce a small volume of waste from the bottoms of the internal recovery stills and filter media. This waste comprises dirt, oils, filter material, and spent solvent. The spent solvent is a chlorinated solvent called perchlorethylene (perc) and must be managed as a hazardous waste.
Print Shop Wastes	Printing solvents, inks, and cleaners may contain hydrocarbons, chlorinated hydrocarbons, and heavy metals.
Photocopying and Laser Printer Cartridges	Spent or discarded cartridges, inks, and toner materials are not typically defined as hazardous under the federal RCRA program, but may be hazardous waste under some authorized state programs.
Used Cleaners, Solvents, Paints, and Thinners	Degreasing materials are a common element of maintenance onboard vessels; tetrachloroethylene is used for metal-degreasing.
Used or Outdated Pharmaceuticals	Cruise ships have pharmaceuticals based on the ship's itinerary and the demographics of the passenger base. Inventory that is discarded because it is off specification or has exceeded shelf life may qualify as hazardous waste.
Incinerator Ash	Incinerator ash may contain constituents, such as heavy metals, in concentrations that would classify the ash as hazardous waste under RCRA.
Fluorescent/Mercury Vapor Bulbs	These bulbs contain small amounts of mercury, and therefore lamps containing these types of bulbs might qualify as RCRA hazardous waste when discarded. To promote the safe recycling and disposal of certain used lamps, EPA classifies these lamps as Universal Waste (40 CFR 273.3). For more information, see www.epa.gov/epaoswer/hazwaste/id/univwast/lamps/lamps.htm.
Batteries	Large batteries are used on tenders and standby generators; small batteries are used in flashlights and cameras. Other equipment on board may also require batteries. Four types of batteries typically used onboard cruise ships are: • Lead-acid – Batteries that are wet, rechargeable, and usually six-celled typically contain a sponge lead anode, a lead dioxide cathode, and a sulfuric acid electrolyte that is corrosive. • Nickel Cadmium (Nicad) – Batteries that are usually rechargeable and contain wet or dry potassium hydroxide as an electrolyte. The potassium hydroxide is corrosive; cadmium is a characteristic hazardous waste. • Lithium – Batteries used for flashlights and portable electronic equipment. Some spent lithium batteries, specifically, lithium metal-sulfide batteries, may constitute hazardous wastes based on the "reactivity" criterion (D003). • Alkaline – Batteries used for flashlights and other personal equipment. Though spent alkaline batteries are not considered hazardous waste under federal regulations, some alkaline batteries might be defined as hazardous waste under some authorized states' more stringent (or broader in scope) hazardous waste regulations (e.g., some states include tests, such as bioassay tests, to define hazardous waste, and some alkaline batteries may fail this test).
Spent Explosives	Explosives are used occasionally in small quantities for celebratory (e.g., theatrical productions, parties, etc.) and/or emergency purposes (e.g., lifeboat flares). Discarded explosives are managed as hazardous waste (ADEC, 2002).

Sources: ADEC, 2000 and ADEC, 2002

Limited information is available on the amount of hazardous waste that a cruise ship might generate. Table 6-2 presents estimates of the hazardous waste generated in one week by the Holland America Lines fleet which consists of 11 vessels.

Table 6-2. Estimates of Hazardous Waste Generated Onboard Holland America Lines Fleet Per Week

Waste Type	Amount Generated by the Fleet (11 Vessels)
Photo wastes	2262 gallons/week
Discarded and expired chemicals	1735 lbs/week
Medical Waste	45 lbs/week
Batteries	75 lbs/week
Fluorescent Lights	153 lbs/week
Explosives	6 lbs/week
Spent paints and thinners	213 gallons/week

Source: The information above is the hazardous waste production per week by Holland America Lines Fleet, as reported in their 2000 Environmental Report (ADEC, 2002).

6.2 What laws apply to hazardous waste on cruise ships?

6.2.1 Clean Water Act

As explained in Section 5 on solid waste, the Clean Water Act (CWA; 33 U.S.C. § 1251 et seq.) prohibits any person from discharging any pollutant from any point source into waters of the United States, except in compliance with a National Pollutant Discharge Elimination System (NPDES) permit or otherwise authorized under the Act. The term "point source" is defined to include a "vessel or other floating craft." Under Clean Water Act section 502(12)(b), the requirement for an NPDES permit applies to the addition of any pollutant from any point source "other than a vessel or other floating craft" in the contiguous zone or the ocean, i.e., outside the territorial seas. Whether a discharge is authorized under an NPDES permit affects applicability of the Resource Conservation and Recovery Act (RCRA); dissolved and solid materials in industrial discharges which are point sources subject to NPDES permits are not "solid waste" under the RCRA statute and thus not "hazardous waste." This only applies to materials once they have been discharged. Prior to being discharged pursuant to an NPDES permit, wastes remain subject to RCRA if they are hazardous wastes.

Section 311 of the CWA also prohibits the discharge of oil or hazardous substances into or upon the navigable waters of the United States, adjoining shorelines, or into or upon the waters of the contiguous zone, or in connection with activities under the Outer Continental Shelf Lands Act or the Deepwater Port Act, or which may affect natural resources belonging to, appertaining to, or under the exclusive management authority of the United States in such quantities as may be harmful, as determined by the President. In Executive Order Number 11735, the President delegated to EPA the authority to determine these quantities. EPA has identified the quantities that may be harmful for hazardous substances in regulations at 40 CFR 117 and for oil in regulations at 40 CFR 110. Section 311(b)(5) of the CWA also requires the person in charge of a vessel or an onshore facility or an offshore facility to, as soon as he has knowledge of any discharge of oil or a hazardous substance in violation of Section 311, immediately notify the National Response Center of the discharge.

6.2.2 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) imposes management requirements on generators, transporters, and persons who treat or dispose of hazardous waste. Cruise ships regularly use chemicals for operations ranging from routine maintenance such as cleaning and painting, to passenger services such as dry cleaning, beauty parlors, and photography labs. Thus, cruise ships or passenger service facilities within cruise ships may be subject to RCRA requirements. Issues the cruise ship industry may face relating to RCRA include ensuring the hazardous waste identification is made at the point at which a hazardous waste is considered generated; ensuring that parties are properly identified as generators, storers, treaters, or disposers; and determining the applicability of RCRA requirements to these parties.

RCRA (42 U.S.C. §§ 6901 et seq.) is the federal law that, among other things, defines and regulates solid waste and hazardous waste. RCRA is designed to minimize the hazards of waste disposal, conserve resources through waste recycling, recovery, and reduction, and ensure waste management practices that are protective of human health and the environment. In order to achieve these goals, RCRA established a Solid Waste Program (RCRA Subtitle D) and a Hazardous Waste Program (RCRA Subtitle C).[5] Subtitle C of RCRA establishes a hazardous waste management system that controls hazardous waste from the point of generation until ultimate disposal, also referred to as a "cradle-to-grave" program. As part of this program, RCRA Subtitle C regulates hazardous waste generators. The owner or operator of a cruise ship may be a "generator" and/or a "transporter" of hazardous waste. EPA regulation (40 CFR 260.10) defines a generator to mean any person, by site, whose act or process produces hazardous waste, or whose act first causes a hazardous waste to become subject to regulation. EPA regulation (40 CFR 260.10) defines a transporter to mean a person engaged in the transportation of hazardous waste by air, rail, highway, or water.

As stated previously, the RCRA regulations contain criteria for identifying whether or not a solid waste is a hazardous waste (40 CFR 261, Subparts C and D). There are two basic ways a waste is defined as hazardous under RCRA: it is either a waste that appears on one of the four hazardous waste lists (i.e., F-List, K-List, P-List, or U-List); or the waste exhibits at least one of four hazardous characteristics (ignitability, corrosivity, reactivity, or toxicity). EPA's RCRA regulations at 40 CFR 262.11 require that any person who produces or generates a waste must determine if that waste is hazardous. Once a waste is identified as a hazardous waste, any person who generates or manages the hazardous waste must comply with all applicable federal regulations regarding its handling and management.

Hazardous waste generators are regulated based on the amount of hazardous waste produced each month. Table 6-3 shows that generators are divided into three categories: large quantity generators (LQGs); small quantity generators (SQGs); and conditionally exempt small quantity generators (CESQGs). LQGs are facilities that generate greater than or equal to 1,000 kg of hazardous waste per month, greater than 1 kg of acutely hazardous waste per month (i.e., any waste denoted with the hazard code "H" and all P-listed wastes), or greater than 100 kg of acute

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[5] In states with RCRA programs authorized by EPA, the authorized state RCRA program operates in lieu of the federal RCRA program. Some states have authorized RCRA programs that are more stringent than the federal RCRA program.

spill residue or soil per month (i.e., soil, waste, or debris resulting from the cleanup of an acute hazardous waste spill). SQGs are facilities that generate between 100 kg and 1,000 kg of hazardous waste per month. CESQGs are facilities that generate ≤100 kg of hazardous waste per month; ≤100 kg of acute spill residue or soil per month; or ≤1 kg of acutely hazardous waste per month.

Generator status is determined on a monthly basis, so it is possible for a generator's (e.g., a cruise ship) status to change from one month to the next, depending upon waste generation during that period. If a generator's status does change, the generator is required to comply with the applicable regulatory requirements for that class of generators for the hazardous waste generated in that particular month. For example, if a generator has reached LQG status in a particular month, then biennial reporting is required, and all of the other regulatory requirements applicable to large quantity generators will apply to the waste generated in that month. Accurate counting of the waste is critical, because the regulations are specific to each generator type. EPA regulations (40 CFR 261.5(c) and (d)) specify the types of hazardous wastes that must be included in a generator's monthly count. EPA regulation (40 CFR 262.34) specifies the threshold quantities for LQGs and SQGs and includes limits on the amount of time hazardous waste may be accumulated on site before being sent offsite for further management (e.g., treatment, recycling, disposal, etc.). EPA regulation (40 CFR 261.5) also specifies threshold quantities for CESQGs, as shown in Table 6-3. There is no accumulation time limit for CESQGs. According to the Congressional Research Service (CRS, 2007), the generator classification assigned to individual cruise ships is often unclear. However, once a cruise ship has determined its appropriate generator classification, the cruise ship must follow the appropriate accumulation requirements.

Table 6-3. Classification System and Accumulation Limits for Hazardous Waste Generators

Classification of Generator	Amount of Hazardous Waste Generated Per Month	Amount of Acutely Hazardous Waste Generated Per Month	Amount of Acute Spill Residue Generated Per Month	On-site Accumulation Time	On-site Quantity Limit
Large Quantity Generators	≥ 1000 kg	> 1 kg	> 100 kg	≤ 90 days on site	No Limit
Small Quantity Generators	100 kg < 1000 kg	N/A	N/A	≤ 180 day on site or ≤ 270 if shipped 200 miles or more	6,000 kg
Conditionally Exempt Small Quantity Generators	≤ 100 kg	≤ 1 kg	≤ 100 kg	N/A	1,000 kg 1kg acute 100 kg residue

Source: EPA, 2005

Any individual cruise ship that is identified as a large or small generator (i.e., LQG or SQG) is required to have a "Cruise Ship Identification Number" to identify both the type and quantity of hazardous waste onboard (40 CFR 262.12); comply with the manifest system (40 CFR 262, Subpart B); handle wastes properly before shipment (40 CFR 262, Subpart C); and comply with record-keeping and reporting requirements (40 CFR 262, Subpart D). The identification number is used to identify a generator and to track waste activities, as well as to provide increased coordination between the USCG, EPA, and states. The number remains with a vessel, and is used on all hazardous waste manifests, regardless of where the waste is off-loaded in the United States. Upon off-loading hazardous waste, the cruise ship must comply with that particular off-loading state's RCRA requirements, whether or not that state assigned the ID number.

The Hazardous Waste Manifest System is a set of forms, reports, and procedures designed to track hazardous waste from the time it leaves the generator where it was produced, until it reaches the off-site waste facility that will store, treat, or dispose of the hazardous waste (for more information on the Hazardous Waste Manifest System, see http://www.epa.gov/epaoswer/hazwaste/gener/manifest/). The system enables waste generators to verify that their waste has been properly delivered, and that no waste has been lost or unaccounted for in the process (40 CFR 262, Subpart B).

EPA's RCRA regulations (40 CFR 273) also specify that a number of the hazardous wastes generated aboard cruise ships may be treated as Universal Wastes under the Universal Waste Program. The Universal Waste Program was developed under RCRA to streamline collection requirements for certain widely-generated hazardous wastes to promote waste recycling, and to ease the regulatory burden associated with handling, transportation, and collection. Waste considered to be "widely-generated" includes batteries, pesticides, mercury-containing equipment, and lamps with hazardous components (e.g., fluorescent, metal halide, and high pressure sodium). The Universal Waste Rule allows a facility (e.g., a cruise ship) additional time for these wastes to accumulate for recycling or disposal and thereby streamlines requirements related to hazardous waste notification, labeling, marking, employee training, responses to releases, offsite shipments, tracking, exports, and transportation.

6.2.3 The Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; U.S.C. § 9601 et seq.) regulates the release of "hazardous substances" of which RCRA hazardous wastes are a sub-set. CERCLA provides that any person in charge of a vessel or an offshore or an onshore facility shall, as soon as he has knowledge of any release (other than a "federally permitted release") of a hazardous substance from such vessel or facility in quantities equal to or greater than those determined pursuant to CERCLA section 9602, immediately notify the National Response Center of such release. The National Response Center conveys the notification expeditiously to all appropriate government agencies. While the universe of CERCLA hazardous substances is larger than RCRA hazardous wastes (see 40 CFR 302.4 for the complete list of CERCLA hazardous substances), all RCRA hazardous wastes are by definition CERCLA hazardous substances. Therefore, in addition to the RCRA "cradle-to-grave" requirements summarized elsewhere in this section, releases of RCRA hazardous waste in amounts above the regulatory threshold are subject to reporting as a CERCLA hazardous substance unless excepted as a federally permitted release.

6.3 How do cruise ships manage hazardous waste?

Hazardous waste generated onboard cruise ships are stored onboard until the wastes can be offloaded for recycling or disposal. Hazardous waste that is offloaded for disposal is handled in accordance with RCRA requirements, and must be sent to a licensed hazardous waste Treatment, Storage, and Disposal Facility (TSDF). RCRA establishes waste treatment standards for TSDFs that make the hazardous waste safe for land disposal.

Cruise Lines International Association (CLIA) member lines have adopted programs of waste minimization, waste reuse and recycling, and waste stream management. In the development of industry practices and procedures for waste management, member lines of CLIA have agreed to incorporate various standards for waste stream management into their Safety Management Systems (see Section 1.3). CLIA member lines have stated that hazardous wastes and waste streams onboard cruise vessels will be identified and segregated for individual handling and management in accordance with appropriate laws and regulations. They have further stated that hazardous wastes will not be discharged overboard, nor be commingled or mixed with other waste streams. With regard to hazardous waste collection and storage onboard ships, CLIA member lines have stated that specific procedures for hazardous waste collection, storage and crew training will be addressed in each ship's Safety Management System or equivalent onboard instruction in the case of U.S. registry vessels.

CLIA members have endorsed the following when treating hazardous waste (CLIA, 2006):

Photo Processing, Including X-Ray Development Fluid Waste -- Eliminate the discharge of silver from these sources into the marine environment through the use of best available technology that will reduce the silver content of the waste stream below levels specified by prevailing regulations and land the remaining effluent ashore as industrial waste or by treating all photo processing and x-ray development fluid waste (treated or untreated) as a hazardous waste and landing ashore in accordance with RCRA requirements.

Dry-cleaning Waste Fluids and Contaminated Materials -- Prevent the discharge of chlorinated dry-cleaning fluids, sludge, contaminated filter materials and other dry-cleaning waste byproducts into the marine environment by treating perchloroethylene (perc) and other chlorinated dry-cleaning fluids, contaminated sludge and filter materials as a hazardous waste and landing ashore in accordance with RCRA requirements.

Print Shop Waste Fluids -- Prevent the discharge of hazardous wastes from printing materials (inks) and cleaning chemicals into the marine environment by utilizing, whenever possible, printing methods and printing process chemicals that produce both less volume of waste and less hazardous waste products; training shipboard printers in ways to minimize printing waste generated; and using, whenever possible, alternative printing inks such as soy based, non-chlorinated hydrocarbon based ink products. All print shop waste including waste solvents, cleaners, and cleaning cloths will be treated as hazardous waste, if such waste contains chemical components that may be considered as hazardous by regulatory definitions, and that all other waste may be treated as non-hazardous.

Photo Copying and Laser Printer Cartridges -- Initiate procedures so as to maximize the return of photocopying and laser printer cartridges for recycling, and in any event, bring these cartridges ashore; use only inks, toners and printing/copying cartridges that contain non-hazardous chemical components, and none of these cartridges or their components should be disposed of by discharge into the marine environment. In recognition of the member lines' goal of waste minimization, they have further agreed these cartridges should, whenever possible, be returned to the manufacturer for credit, recycling, or for refilling.

Unused and Outdated Pharmaceuticals -- Ensure that unused and/or outdated pharmaceuticals are effectively and safely disposed in accordance with legal and environmental requirements by establishing a reverse distribution system for returning unexpired, unopened non-narcotic pharmaceuticals to the original vendor; appropriately destroying narcotic pharmaceuticals onboard ship in a manner that is witnessed and recorded; landing listed pharmaceuticals in accordance with local regulations (listed pharmaceuticals are a hazardous waste having chemical compositions which prevent them from being incinerated or disposed of through the ship's sewer system. Listing of such pharmaceuticals may vary from state to state); and disposing of other non-narcotic and non-listed pharmaceuticals through onboard incineration or landing ashore.

Fluorescent and Mercury Vapor Lamp Bulbs -- Prevent the release of mercury into the environment from spent fluorescent and mercury vapor lamps by assuring proper recycling or by using other acceptable disposal methods (disposal of the glass tubes can be accomplished by (1) processing with shipboard lamp crusher units that filter and adsorb the mercury vapor through H.E.P.A. and activated carbon or (2) by keeping the glass tubes intact for recycling ashore. The intact lamps or crushed bulbs are classified as "Universal Waste" when they are shipped to a properly permitted recycling facility; as such, testing is not required. The filters are disposed of as a hazardous waste in accordance with applicable US EPA or other prevailing laws and regulations).

Batteries -- Prevent the discharge of spent batteries into the marine environment by isolating discarded batteries from the refuse waste stream to prevent potentially toxic materials from inappropriate disposal. The wet-cell battery-recycling program is kept separate from the dry battery collection process. Unless recycled or reclaimed, batteries are disposed of as hazardous waste.

Incinerator Ash -- Reduce the production of incinerator ash by minimizing the generation of waste and maximizing recycling opportunities; prevent the discharge of incinerator ash containing hazardous components through a program of waste segregation and periodic ash testing.

It is possible that during waste management and waste segregation, hazardous waste may be incinerated with solid wastes, resulting in hazardous ash; however, the discharge of incinerator ash containing hazardous components can be prevented through a program of waste segregation and periodic ash testing. According to CLIA (2006), incinerator ash is not normally hazardous because the hazardous waste is separated out from other solid wastes. Proper waste management is necessary to ensure that hazardous materials are not introduced into the incinerator.

According to CLIA (2006), this focuses the use of incinerators of CLIA member lines primarily for food waste, contaminated cardboard, some plastics, trash, and wood. With this approach, incinerator ash is not normally a hazardous waste (CLIA, 2006), as the abovementioned waste management strategies call for the removal of items that would cause the ash to be hazardous. Further, those items separated out from the waste stream would then be handled according to accepted hazardous waste protocols.

Member lines have agreed that incinerator ash will be tested at least once quarterly for the first year of operation to establish a baseline and that testing may then be conducted once a year. The member lines have further agreed that a recognized test procedure will be used to demonstrate that ash is not a hazardous waste. Proper hazardous waste management procedures are to be instituted onboard each ship to assure that waste products which would result in a hazardous ash are not introduced into the incinerator. Non-hazardous incinerator ash is disposed of at sea in accordance with MARPOL Annex V. If any ash is identified as being hazardous, it is to be disposed of ashore in accordance with RCRA. (CLIA, 2006.)

The cruise ship industry is also researching and, in some cases, installing new technologies and design features to minimize hazardous waste generation (ADEC, 2000):

- Effective and efficient digital photo technology to reduce hazardous waste stream generation during photo processing.
- Alternative dry cleaning processes such as CO_2 and wet (i.e., a water-based alternative to dry cleaning) processes.
- Use of non-toxic printing ink and non-chlorinated solvents and other non-hazardous products to eliminate hazardous wastes in print shops.

6.4 What are the potential environmental impacts associated with hazardous waste from cruise ships?

Although the quantities of hazardous waste generated on cruise ships are small, their toxicity to sensitive marine organisms can be significant (CRS, 2007). When hazardous waste generated aboard cruise ships is properly identified, stored, and treated and/or disposed onshore, the risk posed to the environment is normally minimized. Hazardous wastes should be properly stored and segregated from other wastes where required by law (e.g., incompatible hazardous wastes cannot be stored together) and where necessary to ensure proper management. To ensure hazardous waste is handled and disposed of properly, adequate operational procedures and employee training and, in some instances, passenger training (e.g., clear demarcation of the proper locations for the onboard discard of materials that may be hazardous) is necessary.

After three years of sampling and analysis, ADEC (2002) determined that sewage and graywater waste streams are not used for hazardous waste disposal and that cruise ships screen for hazardous waste prior to incineration. However, there are a number of possible hazardous waste streams produced on cruise ships, including perchloroethylene, silver, mercury, hydrocarbons, heavy metals, and corrosives that could enter the environment and cause harm if not appropriately managed as required under RCRA.

6.5 What action is the federal government taking to address hazardous waste from cruise ships?

EPA has brought multiple enforcement actions against cruise ship operators for illegal discharges of hazardous substances and other pollutants to ensure that cruise ships comply with these requirements through environmental management systems developed as conditions of probation in criminal plea agreements.

EPA and states have worked together to develop a system whereby an EPA hazardous waste identification (ID) number is assigned to every cruise ship (EPA, 2001). Previously, cruise ships were receiving different numbers from a variety of states upon off-loading hazardous waste. As a result, cruise ships were receiving multiple identification numbers and creating multiple copies of hazardous waste management records. Implementation of this 2001 policy has enabled individual cruise ships to be assigned a single EPA hazardous waste identification number for the purposes of identification as a generator of hazardous waste under the Resource Conservation and Recovery Act.

Under the 2001 policy, the following procedures apply (EPA, 2001):

a) A cruise ship determines its American-based home port state (the state in which it has corporate offices or its main port of call).

b) After determining the home port state, the cruise line notifies the selected state or corresponding EPA regional office of its hazardous waste activities.

c) The cruise ship identifies its hazardous waste generator size in accordance with 40 CFR 261.5(c).

d) The home port state or EPA regional office issues a hazardous waste identification number for the cruise ship. The number reflects the home port state initials and ten alphanumeric characters.

After the identification number is assigned, that number remains with the ship, and is used for all hazardous waste manifests, regardless of where the waste is off-loaded in the United States. The assignment of the EPA ID number does not affect the applicability of state-specific RCRA requirements; cruise ships must still comply with each state's RCRA requirements when off-loading hazardous waste, regardless of which state assigned the ID number. The ship must provide records to the relevant individual off-loading state as required by that state's laws.

References

Alaska Department of Environmental Conservation (ADEC). 2000. *Alaska Cruise Ship Initiative Part 1 Final Report*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/finreportp10808.pdf)

Alaska Department of Environmental Conservation (ADEC). 2002. *The Impact of Cruise Ship Wastewater Discharge on Alaska Waters*. Juneau, AK. (www.dec.state.ak.us/water/cruise_ships/pdfs/impactofcruiseship.pdf)

Cruise Line International Association (CLIA). 2006. *CLIA Industry Standard: Cruise Industry Waste Management Practices and Procedures*. Fort Lauderdale, FL. (www.cruising.org/industry/PDF/CLIAWasteManagementAttachment.pdf and www.cruising.org/industry/PDF/CLIAWasteManagement.pdf)

Congressional Research Service (CRS). 2007. *Cruise Ship Pollution: Background, Laws and Regulations, and Key Issues* (Order Code RL32450). Washington, DC. (www.ncseonline.org/NLE/CRSreports/07Jul/RL32450.pdf)

U.S. Environmental Protection Agency. 2001. *Memorandum: Cruise Ship Identification Numbers and State Required Annual Reporting Components*. Washington, DC. (www.epa.gov/osw/meeting/pdf02/cruise.pdf)

U.S. Environmental Protection Agency. 2005. *Introduction to Generators (40 CFR Part 262)* (EPA530-K-05-011). Washington, DC. (http://www.epa.gov/epaoswer/hotline/training/gen05.pdf)

December 2007
EPA842-R-07-005