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Cruise Ship Discharge Assessment Report

Section 3: Graywater

December 29, 2008

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Graywater generally means wastewater from sinks, baths, showers, laundry, and galleys. On cruise ships using Advanced Wastewater Treatment systems (AWTs), 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. The conclusion of this section lists a wide range of options and alternatives that could be considered when addressing graywater from cruise ships.

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 Guidelines for Implementation of Annex V of MARPOL (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 implementing MARPOL and the Act to Prevent Pollution from Ships, 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 do not fall within the statutory definitions of graywater listed above and thus would not be considered graywater for purposes of compliance with these statutes. The United States has successfully prosecuted violations of the Clean Water Act (CWA) for unpermitted discharges of hazardous materials from cruise ship dry cleaning operations, photographic chemicals from photographic processing equipment, solvents from print shop operations, as well as other chemicals, pollutants and waste streams, through the graywater system.

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. Graywater generation rates generally are not measured, and EPA is not able to independently confirm the accuracy of these estimated rates. It is not clear why reported rates would vary this much. 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.

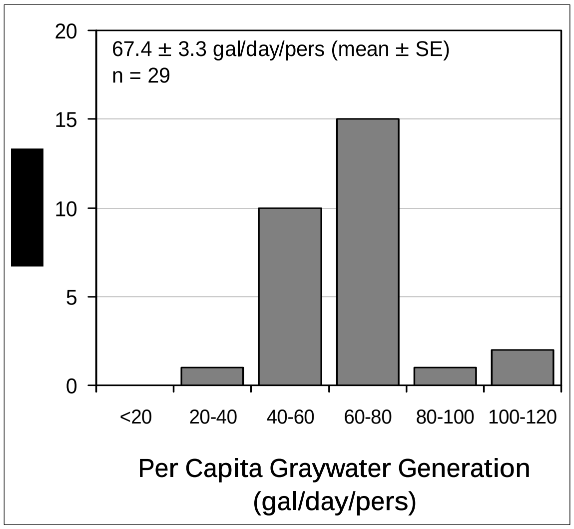

Figure 3-1. Per Capita Graywater Generation as Reported in EPA's 2004 Cruise Ship Survey

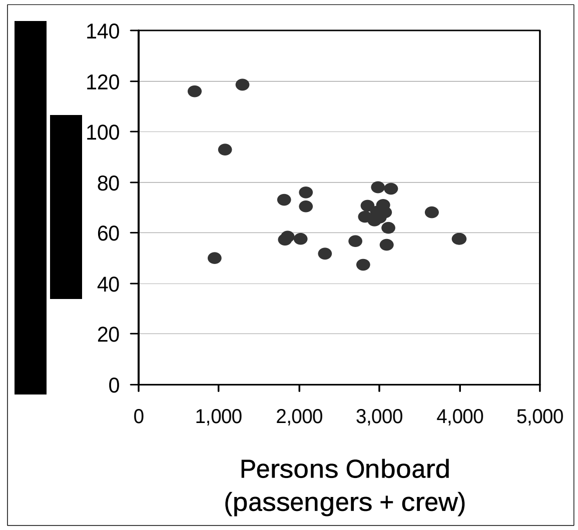

Figure 3-2. Graywater Generation by Persons Onboard as Reported in EPA's 2004 Cruise Ship Survey

During EPA’s 2004 sampling of four ships with AWTs, graywater generation was measured on one ship at 45 gallons/day/person (EPA, 2006a). On other ships, measurements were made of sewage plus graywater sources treated by the AWTs. 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 AWTs 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 federal laws apply to graywater from cruise ships?

3.2.1 Clean Water Act

Graywater discharges from commercial vessels operating in the Great Lakes are regulated under section 312 of the Clean Water Act (CWA), as discussed below. Graywater discharges from vessels operating elsewhere historically have been excluded from CWA permitting requirements through regulations at 40 CFR 122.3(a). However, as explained in section 1.1, a court order vacated that exclusion as of December 19, 2008, and as a result, except for the Great Lakes, graywater discharges into waters of the U.S. from cruise ships 79 feet or longer in length are subject to NPDES permitting.

As noted in Section 2, CWA section 312 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. Marine sanitation devices primarily treat vessel sewage. CWA section 312 also applies to graywater from a limited set of vessels because the statutory 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 (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 (together referred to as “sites”). Designated sites are managed according to site-specific management plans developed by NOAA that typically prohibit by regulation the discharge or deposit of most material. Discharges of graywater and treated vessel sewage, however, are sometimes allowed provided they are authorized under the CWA. In some sanctuaries the discharge of graywater, as well as sewage, is prohibited in special zones to protect fragile habitat, such as coral. NMSA 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. For ships traveling regularly on itineraries beyond the territorial waters of coastal states, Cruise Lines International Association (CLIA) environmental standards provide that the discharge of graywater should occur 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 should not be discharged in port and should 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 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 (ACSI).

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 ACSI (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, biochemical oxygen demand, chemical oxygen demand, pH, fecal coliform, total residual chlorine, 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 biological oxygen demand, chemical oxygen demand and total suspended solids, 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/Alaska Department of Environmental Conservation (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% of either the EPA or ACSI/ADEC samples (less frequent detection of analytes is considered not representative of the waste stream). Copper, nickel, and zinc, which showed the highest concentrations, are common components of ship piping.

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)	0.432* (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% 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% of either EPA or ACSI/ADEC samples (less frequent detection of analytes is considered not representative of the waste stream).

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)	0.100 (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 (NRWQC). 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. Also relevant to an evaluation of potential environmental impact is the mixing and dilution that occurs following discharge; this is discussed in subsection 3.4.3 below.

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 Alaskan 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% 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.
^ The minimum detection limit for total residual chlorine reported by most analytical labs is 100 µg/l.
"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 solely for 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), and for pathogen indicators, compared these effluent concentrations to criteria for the protection of human health from incidental ingestion during recreational activities (e.g., swimming and surfing) and to criteria for consumption of shellfish. 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 for a number of reasons. First, NRWQC not only have a concentration component, but also a duration and frequency component. Second, it is not always necessary to meet all water quality criteria within the discharge pipe to protect the integrity of a waterbody (EPA, 1991). Sometimes it is appropriate to allow for ambient concentrations above the criteria in small areas near outfalls. These are called mixing zones. To ensure mixing zones do not impair the integrity of the waterbody, it should be determined that the mixing zone will not cause lethality to passing organisms and, considering likely pathways of exposure, that there are not significant human health risks. Third, under EPA's regulations (40 CFR 122.44(d)(1)(ii)), when determining whether a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a state water quality standard, the permitting authority shall use procedures which account for, where appropriate, the dilution of the effluent in the receiving water.

Nevertheless, 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. It should be noted that such an analysis may be more difficult for mobile sources such as vessels, but in general, greater mixing and dilution would be expected for mobile sources.

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% of samples exceeding 43 MPN per 100 ml for the taking of shellfish.

Pathogen indicator data from untreated graywater consistently exceed the NRWQC for marine water bathing and shellfish harvesting waters (see Tables 3-3 and 3-10). Over 66% of EPA samples for enterococci exceeded the 35 MPN/100 mL standard for marine water bathing. Over 80% 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; 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.

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 (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% 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% 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% 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, such as flushing and the factors that influence flushing. 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 chlorine 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)[2]	NRWQC Criterion Continuous Concentration (CCC)[2]
Total Residual Chlorine (µg/l)	372*^	13	7.5

[1] Based on data collected by ACSI/ADEC in 2000 and 2001.
[2] The National Recommended Water Quality Criteria for chlorine in marine waters are expressed as chlorine-produced oxidants as measure by total residual chlorine.
* Average includes at least one nondetect value; this calculation uses detection limits for nondetected results.
^ The minimum detection limit for total residual chlorine reported by most analytical labs is 100 µg/l.

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 patterns 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% 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 on Mixing and Dilution 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.

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^+) forms. 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 (NH_3-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) (NH_3-N µg/l)[4]	NRWQC Criterion Continuous Concentration (CCC) (NH_3-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. However, as discussed in section 3.4.3 below, ammonia in untreated graywater would likely meet NRWQC after initial mixing (about 1 to 7 meters from the ship) even when a vessel is at rest. 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 ACSI used the Cornell Mixing Zone Expert System 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 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). This dilution factor may not necessarily apply to situations where the discharge port faces a dock, pilings, or other another obstruction.

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 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 AWTs and a survey questionnaire for all cruise ships operating in Alaska in 2004, are summarized in this Assessment Report. EPA anticipates making these full analyses publicly available in 2009. As part of this effort, EPA in conjunction with the ADEC conducted a scientific survey in July 2008 using EPA's Ocean Survey Vessel *Bold* to (1) measure the dilution of AWT discharges from stationary cruise ships, and (2) evaluate the potential environmental impact of nutrients in AWT discharges. EPA anticipates making the results of these studies publicly available in 2009.

EPA is developing a water permit program for pollutant discharges incidental to the normal operation of vessels.
Under a U.S. District Court decision, the existing EPA regulations that exclude discharges incidental to the normal operation of a vessel from CWA permitting were vacated (revoked) as of December 19, 2008. The District Court's decision to vacate that exclusion was recently upheld by the Ninth Circuit Court of Appeals. *NW. Envt'l Advocates et al. v. EPA*, 537 F.3d 1006 (9th Cir. 2008). Thus, as explained in section 1.1, as of December 19, 2008, discharges incidental to the normal operation of vessels into waters of the U.S. from cruise ships 79 feet or more in length are subject to National Pollutant Discharge Elimination System permitting.

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 proposed rule (73 CFR 16580, March 28, 2008) to revise a proposed action concerning vessel discharges (71 FR 29096, Oct. 5, 2006). The proposed rule containing the revision includes a prohibition on treated and untreated graywater from cruise ships. NOAA is currently reviewing the comments on this proposed rule.

National Park Service manages cruise ship waste streams in Glacier Bay National Park. The National Park Service (NPS) manages cruise ship waste streams indirectly in Glacier Bay National Park through competitively awarded concession contracts. The NPS has jurisdiction over the submerged lands and marine waters of Glacier Bay National Park up to 3 miles from the mean high tide line and including all of Glacier Bay proper. Glacier Bay is a well known, very popular attraction for the cruise ship industry in Alaska. Recent environmental reviews and decisions allow up to two cruise ship entries per day into Glacier Bay proper during the primary visitor season. Cruise ship operations in the park are authorized under concession contracts, which are awarded under a competitive solicitation and prospectus process. Impact on park resources is a general standard selection criterion for park concessions. The NPS uses waste stream management as one of a number of selection criteria in this regard. In the past, cruise ship operators have usually proposed to minimize the impact of waste streams by committing to a no-discharge policy while in the park (even if legal under applicable law) for sewage, graywater, ballast water, bilge water, cooling water, hazardous waste, and solid waste. If awarded a contract, companies must comply with their proposal. Typically cruise ships operate in the park for 8-10 hours and then depart. They do not dock or transfer any wastes to shore while in the park.

3.6 Possible Options and Alternatives to Address Graywater from Cruise Ships

Based on the public comments received on the draft of this report as well as other information gathered, listed below are a wide range of options and alternatives that address graywater from cruise ships. Identification of any particular option does not imply any EPA recommendation or preference for future action, or that EPA has determined that any of these options are necessary or feasible, or that EPA believes a change to the status quo is warranted, or that EPA or any other entity has the legal authority to implement that option.

Prevention & Reduction

- Establish standards or best management practices for design, operation, maintenance and/or training that will decrease or eliminate the contaminants and/or volume of untreated graywater and/or treated graywater effluent.

Control: Discharge Standards

- Establish and/or revise standards for the discharge of graywater, for example,
  - to require attainment of national federal water quality criteria at point of discharge.
  - to require attainment of national federal water quality criteria at the edge of a mixing zone.
  - to require attainment of applicable state water quality standards.
  - to require attainment of secondary treatment standards for publicly owned treatment works.
  - to require the reduction attainable through application of the best available technology economically achievable.
  - to require technology that would eliminate remaining pollutants of concern (i.e., reduce to level below concern).
  - to require use of Advanced Wastewater Treatment systems.
  - to apply Title XIV standards (which apply in certain Alaskan waters) nationwide.
  - to address additional parameters, e.g., additional pathogen indicators.
  - to account for potential bioaccumulation.
  - to require period sampling and testing.
  - to require more stringent standards in areas frequented by multiple cruise ships.
  - to define which waste streams/pollutants may be sent to the graywater system.

Control: Geographic Restrictions on Discharge

- Restrict discharge of untreated or all graywater, for example,
  - no discharge out to a certain distance (e.g., 3 miles from shore, 12 miles from shore, 12 nautical miles from the 20-meter contour line).
  - no discharge in or within a certain distance (e.g., 0.5 nautical miles, 4 nautical miles) of sensitive areas (e.g., shellfish, ports, coral reefs, bathing beaches, water bodies with restricted circulation, flushing or inflow, marine protected areas, breeding grounds, near large population centers).
  - no discharge in any U.S. waters.
  - require shore-side discharge.
  - withhold discharge when a system upset occurs.

Enforcement & Compliance Assurance: Monitoring

- Require sampling and testing of untreated and/or treated graywater to ensure that it meets applicable standards
    - by government agencies with enforcement authority.
    - by third-parties.
    - by cruise lines.
- Require onboard observers to monitor all sampling, monitoring, and other effluent-related requirements/to oversee discharging practices, equipment operation and maintenance, and the completion and submittal of accurate logbooks.
- Require rapid testing methods for pathogen indicators.

Enforcement & Compliance Assurance: Reporting

- Require certain reporting by cruise ship operators, for example,
    - immediate notification to appropriate agencies in the event of an treatment system malfunction or upset.
    - disclosure of implementation or non-implementation of pollution reduction and prevention practices, including but not limited to treatment systems, in all advertisements in the U.S.
    - advance notification from ships planning to discharge in U.S. waters.
    - notification to appropriate agencies of all discharges of untreated graywater or treated graywater effluent in U.S. waters.
    - notification of discharges in state waters to appropriate state agencies.
- Require electronic transponders to signal land-based authorities when a discharge line is opened or closed.

Enforcement & Compliance Assurance: Inspections & Enforcement

- Penalties for failure to meet treated or untreated graywater standards.
- Increase inspections and inspection requirements.
- Establish a funding mechanism based on the polluter-pays model that will provide revenues to develop and implement a comprehensive regulatory scheme.
- Impose uniform requirements on all ships as a condition of port entry and within waters under the jurisdiction of the U.S. consistent with international law, regardless of flag state.
- Prohibit or otherwise restrict noncompliant vessels (and sister ships, depending on the degree of involvement by parent companies) from operating in sensitive areas of the marine environment under U.S. jurisdiction.

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