Grey Water from Passenger Vessels in Alaska

2000-2019

An overview of grey water management for passenger vessels in Alaska, as well as summaries of requirements and sample data results

Produced for Ocean Conservancy

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Introduction

The grey water of a ship is wastewater generated by human activities. It excludes sewage, the drainage from toilets and urinals. The most common sources of grey water are showers, laundry, dishwashers, bath and washbasin drains. However, in practice, the term "grey water" can be used as a catch-all for any wastewater on a ship that is not sewage (also known as blackwater), ballast, or bilge water. Definitions of grey water vary by ship and nation.

Grey water can contain high levels of bacteria, nutrients, and harmful substances that may impair human and environmental health. Data reported by ships in Alaska show that the volume of grey water is much larger than treated sewage—the volume is often 8 to 12 times greater. With its greater volume and high values of pollutants and bacteria, it is concerning that grey water is not regulated internationally or even nationally in many parts of the world.

However, Alaska does regulate grey water. A large number of Alaskans live in small coastal communities and depend on clean water for sustenance as well as economic activity. Recreation is also a common use of nearshore waters. To address public concern over water quality as rapid growth in the size and number of ships made their environmental impact more apparent, both the US government and State of Alaska created regulations for passenger vessel sewage and grey water discharges at the start of the century. Since this time, grey water and sewage samplings have been conducted on passenger vessels in Alaskan waters.

This report reviews the contents and volumes of grey water, and its management and discharge requirements in Alaska, followed by a summary of water sample results from 19 years of Alaska Department of Environmental Conservation (ADEC) data. It provides lessons learned from ADEC's years of vessel sampling, recommends needed research moving forward, and offers recommendations on to how to improve grey water management in Alaska and internationally.

Historical Context of Alaska Passenger Vessel Regulatory Measures

In the 1990s, Alaska experienced a notable increase in the size and number of cruise ships plying its waters. From 1993-1997, the number of cruise ship visitors to the state increased 60 percent, and from 1997-2002, it increased another 85 percent. Several notable pollution violations only exacerbated already intensifying public concern about increasing cruise ship traffic and their wastewater management practices. To address this concern, in 1999 ADEC gathered a variety of community, government, and industry stakeholders (later to be named the Alaska Cruise Ship Initiative) for public discussions around cruise ship waste practices. Voluntary sampling completed in 2000 identified various concerns with improperly functioning marine sanitation devices and alarming levels of fecal coliform bacteria in sampled wastewater (Morehouse & Koch 2003). Soon thereafter, to address these concerns, both federal and state legislation established new wastewater regulation in Alaskan waters.

Federal Requirements for Passenger Vessels Operating in Alaskan Waters

In 2000, federal legislation regulating large cruise ship wastewater in Alaskan waters was enacted as part of the Consolidated Appropriations Act of 2001, P.L. 106-554. Title XIV of Appendix D of that Act— "Certain Alaskan Cruise Ship Operations"—prohibited discharge of untreated sewage in Alaskan waters, as well as areas within the Alexander Archipelago more than three nautical miles (nm) from shore. It also created requirements for the treatment of grey water within one nm of shore or at speeds of six knots or less. The United States Coast Guard (USCG) implemented the requirements per regulations (33 CFR 159 subpart E).

Title XIV tasked the Environmental Protection Agency (EPA) with creating minimum effluent quality regulations that would be consistent with State of Alaska water quality standards, and allowed the State of Alaska to impose additional requirements and permits. However, EPA did not create final Alaska minimum effluent regulations cited in the law. Instead, the interim limits established under the law are based on EPA secondary standards and the State of Alaska water quality standards that were in place at the time. EPA established nationwide standards for grey water from passenger vessels in 2008.

State of Alaska Requirements for Passenger Vessels

The ADEC's Commercial Passenger Vessel Environmental Compliance (CPVEC) Program was established in July 2001 by Alaska Statutes 46.03.460 - AS 46.03.490. State law set effluent limits and required sampling on the discharge of both sewage and grey water from large commercial passenger vessels, also known as cruise ships. Additional laws were established soon after for small commercial passenger vessels and state ferries with overnight cabins (over 50 lower berths). For these small ships, effluent limits were established for bacteria and solids. These effluent limits were replaced with Best Management Practices plans (BMP) that document treatment or other measures taken to reduce potential impact on human health and the environment. The plans are approved by ADEC and require sampling and other measures.

In August 2006, Alaska voters approved a ballot measure that added new requirements to the CPVEC Program. Operators of large commercial passenger vessels (cruise ships) were required to obtain a wastewater discharge permit for the discharge of any treated sewage or treated grey water into marine waters of the state. The new law required that cruise ship wastewater effluent meet Alaska Water Quality Standards at the point of discharge. The law also required vessel tracking, Ocean Rangers onboard vessels, and passenger fees and taxes. This law was then modified in 2013 to allow ADEC to issue a general permit to cruise ships with effluent limits or standards that are less stringent than the water quality standards at the point of discharge if the department allows a mixing zone.

Table 1 Alaska Large Cruise Ship Grey Water Effluent Limits

Parameter	MSD II [1]	Coast Guard continuous compliance	Alaska 2014 GP
Fecal Coliform monthly geometric mean and daily maximum	200	20 & 40 [2]	14 & 40
Total Suspended Solids (mg/L) monthly average and daily maximum	150	150	30 & 150
pH daily minimum and maximum		6.0-9.0	6.0-9.0
Chlorine (µg/L)		10	10
Biochemical Oxygen Demand (BOD_5 mg/L) monthly average and daily maximum		30 & 45	30 & 60

[1] *MSD II certification standards, also federal limits for more than 1nm and 6 knots speed*

[2] *Not more than 10% can exceed 40 FC/100 ml*

Differences between ADEC and USCG Alaska (in charge of implementing federal regulation) requirements for wastewater are as follows:

- State requires approval under a permit for large cruise ships; USCG approves ships for continuous discharge.
- USCG continuous discharge is less than 6 knots and within one nm; ADEC less than six knots only.
- USCG applies to 500 passengers or more; ADEC 50 passengers or more (250 for large cruise ships requirements).
- USCG requires samples to demonstrate compliance before discharging in Alaska, ADEC only requires this for small passenger vessels.
- ADEC compliance sampling must be in Alaska and while discharging; USCG allows sampling while recirculating to a holding tank.
- ADEC requires regular sampling for small cruise ships and ferries; USCG does not.

EPA Grey Water Vessel Requirements

In 2008, the EPA issued a Vessel General Permit (VGP) regarding discharge. The VGP covered a range of discharge (grey water, ballast, and many other wastewaters) and vessel types. Grey water discharge requirements are listed in Table 2. Treatment was required for many passenger vessels—specific requirements are in Table 3. The 2018 Vessel Incidental Discharge Act will replace the revised 2013 VGP with new national standards (although they are still under development by the EPA) —the VGP requirements are remaining in place until those standards are in place. The new national standards will replace any state grey water requirements in the United States, with the exception of Alaska requirements on passenger vessels.

Table 2 EPA 2013 Vessel General Permit Grey Water Discharge Requirements

Location	All Ships	Ships with holding capacity	Over 400 gross tons, travel outside 1nm, and holding capacity
In Port	Minimize discharge	Onshore discharge if available or treatment, otherwise minimize	No discharge unless treated
Conservation waters	Minimize production	No discharge	No discharge
Impaired waters	Minimize production and discharge	No discharge	No discharge
Within 1nm of shore	Minimize	Onshore discharge if available or treatment, otherwise minimize	No discharge unless treated
1nm to 3nm			All large cruise ships and medium cruise ships built after 2008 must treat, large ferries must discharge while over 6 knots in speed

Note- grey water must be treated by a Marine Sanitation Device or held when operating on the Great Lakes.

Table 3 EPA 2013 VGP Treated Grey Water Effluent Limits for Specific Passenger Vessels

	500 or more	100 to 499	Large Ferries
Fecal Coliform monthly geometric mean and daily maximum	20 and 40 [1]	Same if ship constructed after Dec 19, 2008	Same if docked and grey water holding capacity is available
Total Suspended Solids (mg/L) monthly and weekly averages	30 & 45 [2]		
pH daily minimum and maximum	6.0-9.0		
Chlorine (µg/L)	10		
Biochemical Oxygen Demand (BOD_5 mg/L) monthly and weekly average	30 & 45 [2]		

[1] Not more than 10% can exceed 40 FC/100 ml
[2] 30-day average removal of 85% is also required

Definitions and Sources of Grey Water

As stated above, grey water is defined by the International Convention for the Prevention of Pollution from Ships (MARPOL) as drainage sourced from showers, laundry, dishwasher, and bath and washbasins. The definition excludes sewage, which is drainage from toilets and urinals, as well as drainage from hospitals and animal spaces.

Definitions of grey water vary in the United States. Definitions for grey water do not reflect all sources that passenger vessels may label as grey water sources. Grey water is often used as a catch-all for wastewater that is not sewage, bilgewater, or ballast water. It can mix with any of the other wastewaters. Waters similar to grey water but not included in any definition are water from pools, spas, and fountains on passenger vessels. Some ships have mixed these sources with grey water based on information obtained by ADEC.

Some grey water definitions do include sources considered sewage or animal wastes, and may exclude wastewater from medical facilities. The US EPA VGP requires grey water mixed with sewage to meet all VGP sewage and grey water requirements. Grey water discharged from commercial vessels in the Great Lakes is defined as sewage under 33 U.S.C. 1322 and must meet federal requirements for sewage.

Table 4 Grey Water Legal Definitions

	Bath	Laundry	Galley	Dish-water	Shop sinks	Drinking fountains	Interior deck drains	Stored GW
US Title XIV	Y	Y	Y	Y	N			
US EPA 2013 VGP	Y	Y	Y	Y	N	Y		
EPA 2018 (proposed)	Y	Y		Y				
US Clean Water Act	Y		Y					
US Vessels of the Armed Forces	Y	Y	Y		Y	Y	Y	
Alaska Law	Y	Y	Y					N*
Alaska 2014 GP	Y	Y	Y	Y				Y
IMO MEPC.295(71)	Y	Y		Y				
Canada	Y	Y	Y	Y	N			

Green is included, orange is not included, red is specifically excluded from definitions. Bath is showers and bath sinks (washbasins). Dishwater in green striped likely meets galley water definition.
** Defined as "other wastewater" if stored after treatment. Same requirements as sewage and grey water.*
Appendix A contains the text and citations of definitions from the table above.

Grey Water Sources in Alaska Sample Results

Accommodations grey water, bath grey water

Showers, washroom sinks, bath and head floor drains, and other non-sewage sources are included in the bath or accommodations grey water. This wastewater may contain small amounts of human waste, personal health care products, and cleaning products.

Domestic grey water includes accommodation sources as well as galleys and laundry, but some ships define it as wastewater from passenger cabins and heads excluding sewage from toilets and urinals.

Galley grey water

Galley grey water is from galley sinks, dishwashers, and drains. MARPOL Annex V excludes food waste from grey water, but it will enter grey water from sink and dishwasher sources unless carefully removed or screened. It may include water drained from food waste or waters used to transport food waste. Other galley-related wastewater could include icemaker drains, drink dispensing drains, appliance drains, and condensate from refrigeration.

Galley grey water is different from other sources of grey water in the high amount of nutrients that may be present and is a source for grease and oils. In Alaska most operating Advanced Water Treatment System (AWTS) units do not process galley grey water or only process some types. This water, or the portions with potential for high nutrients, will be stored in tanks for discharge offshore. Initial tank and influent sampling in Alaska of grey water with dairy products had extremely high levels of Biochemical Oxygen Demand (BOD).

Bars, lounges, café

Grey water from bars and other beverage-serving areas is normally categorized as galley water. This water may contain alcohol, small amounts of food waste, dairy products, and cleaners.

Laundry
Laundry grey water is from washing of clothes. It contains cleaning and other chemicals that could interfere with biological processes and can create foaming in the treatment process. It is often excluded from AWTS treatment influent and is stored for offshore discharge. The *Carnival Spirit* used a reverse osmosis AWTS to treat laundry grey water—this is the only laundry-sourced grey water included in grey water AWTS sampling.


Figure 1 Laundry Grey Water Tank with Foam

Alaska sampling results show high bacteria levels in some laundry grey water samples. Dry cleaning chemicals were also found to be present in early sampling, and the EPA 2004 ship surveys documented dry cleaning condensate as part of the laundry grey water on some ships (EPA, 2008). Tetrachloroethene, a chemical used in dry cleaning (also known as perc), is occasionally be observed in sample results from small cruise ships. Laundry wastewater can also contain plastics in the form of fibers, a potential source of plastic pollution that can interfere with wastewater treatment filtration.

Drain water
Internal drains from passenger cabin floors (near showers and sinks) may be included with accommodation grey water. Other drains may be in laundry rooms, galley spaces, dining spaces, passageways, and other public or crew spaces. Ship surveys completed for EPA and ADEC identified condensate drainage from air conditioning and refrigeration systems as a possible source of metals in grey water. Drain water may also contain cleaners, small debris such as paints and plastics, and other potential pollutants.

External deck drain water is not included in definitions of grey water, but it is possible externally sourced water may enter internal drains on some ships. This may occur in entryways and partially enclosed public areas.

The method of discharge of drainage water from plants and landscaping on large cruise ships was unclear from ADEC reporting. Large water fountains and similar features that can be present on large cruise ships are also a potential source.

Shop sinks and cleaning sinks
These sources are specifically excluded from the Alaska federal definition of grey water, however, some ships include them in grey water. Ships reported these only include some but not all shop sinks, such as those used by crew for handwashing. Some shop sinks included were from the engine rooms. At least one ship included chemical storage area sinks. Some sinks were reported to have been disconnected from the grey water system such as those used for photo processing after the sampling projects in Alaska began.

Salons and day spas
Large passenger vessels have dedicated areas for hair care, cosmetic services, and relaxation services. These facilities will have sinks for washing, and floor drains. Wastewater from these areas may contain personal care products and disinfection chemicals such as barbercide.

Drinking fountains
Drinking fountains are included only in the US Armed Forces Vessel definition of grey water, but should be considered grey water due to the similarity with other grey water sources.

Pools and spas
Pool and spa waters are not included in legal definitions of grey water but have been a source of grey water in Alaska on large passenger vessels. Pool and spa waters share similarities with other sources of grey water such as showers and bathtubs. The EPA defines pool and spa waters as a separate type of discharge. Pool and spa waters can contain human waste and high levels of disinfectants. If "shocked" with high levels of disinfectant due to human waste, this can damage wastewater treatment systems or impair biological processes.

Medical spaces sources
Surveys completed for EPA and ADEC identified medical sinks and floor drains for medical spaces on a small number of ships. Hospital wastewater is excluded from the grey water definition in MEPC.219(63). On smaller passenger and other vessels, medical spaces may be temporary and shared for other purposes.

Potable water
Drinking water has been added to grey water to clean and flush out equipment. Volumes could be relatively large, e.g. several cubic meters. One ship reported adding potable water prior to sampling to reduce ammonia levels in the effluent.

Ballast Water
Sampling plans documented shared tanks, pipes, and pumps for the ballast water and (usually treated) grey water systems. Grey water or treated effluent could be used as ballast. It is possible with shared equipment that water types could mix, and some ballast water could be present in pipes or tanks.

Boiler water
One ship identified boiler drain water as the possible reason for high levels of metals in its initial grey water samples. The boiler water was added to the grey water instead of the bilge because it would be treated by an AWTS.

Technical water
Grey water can be treated and reused on a ship e.g., for toilet flush water. Some large cruise ships operating in Alaska have used reverse osmosis AWTS grey water effluent as technical water for cleaning windows and other items.

Bilge water
Bilge water was not reported in Alaska as a source of grey water. It was, however, documented by the US Department of Justice (DOJ) in an oily water discharge settlement with Princess Cruise Lines on a large cruise ship outside of Alaska. The DOJ press release of December 1, 2016, said the following: "Graywater [sic] tanks overflowed into the bilges on a routine basis and were pumped back into the graywater system and then improperly discharged overboard when they were required to be treated as oil contaminated bilge waste. The overflows took place when internal floats in the graywater collection tanks got stuck due to large amounts of fat, grease and food particles from the galley that drained into the graywater system. Graywater tanks overflowed at least once a month and, at times, as frequently as once per week. Princess had no

written procedures or training for how internal graywater spills were supposed to be cleaned up and the problem remained uncorrected for many years."

Several of the potential sources of grey water can also be sources of bilge water or stored for discharge separately. ADEC expressed concern that restrictions on a grey water definition would incentivize the practice of adding grey water to bilge water, or discharged separately and untreated. For some wastewater types, grey water treatment can remove solids and disinfect, while bilge water treatment may be focused on oily waste. The impact on bilge water and other wastewaters should be evaluated in any future rules for grey water.

Grey Water Discharge Treatment Options in Alaska

Grey water treatment and handling by passenger vessels and ferries in Alaska is documented in Vessel Specific Sampling Plans (VSSP) and BMP plans submitted by the vessel operator and approved by ADEC. Summaries of information are posted online by ADEC each year. ADEC provides annual reports of the treatment systems used by each ship regulated by the state and notes which ships are approved for discharge. All passenger vessels carrying more than 50 overnight passengers (by lower berth) are regulated in Alaska. A summary of treatment used by each ship until 2019 is included in Appendix B.

Discharge Options with Potential for No Onboard Treatment

Direct overboard

Direct overboard indicates a ship that does not provide any treatment of grey water and discharges it directly overboard. That said, sinks and showers may have strainers and drain traps that catch larger objects. This approach is most often found on small cruise ships and occasionally on large cruise ships, yet is more common on ships built more than 20 years ago. Sample data is limited, and these overboard discharge ports are difficult to sample. Some discharge ports are consolidated, while those on other ships may have separate discharge for each cabin or sink. To reduce environmental and human impacts near shore, some direct discharges may be minimized. For example, laundry machines may have power cut off, or crew and passengers are asked to avoid showers while in port.

Figure 2 Direct Grey Water Overboard Discharge Port

Holding tanks

Holding tanks may be used to store grey water and sewage for discharge to onshore treatment or for discharge outside of state and federal waters. These can be classified as Type III Marine Sanitation Devices in the United States. Holding tanks are used exclusively on Alaska state-owned ferries designed for day use only and on some smaller craft without a sewage treatment plant. Passenger vessels with AWTS will hold some grey water that could interfere with treatment systems, such as laundry or galley sources. These ships can also hold treated grey water while offshore where discharge is not allowed or ship policies restrict discharge. Holding tanks have also been installed on some small cruise ships that travel in Glacier Bay to avoid discharges in the national park or wilderness areas. Stored wastewater may be pumped onshore by truck or a dedicated connection at a dock.

In Southeast Alaska, large cruise ships can offload grey water directly at the dock in Juneau. This includes grey water that is not typically treated by the AWTS including galley grey water. The grey water is pumped into the municipal sewage systems where it is sampled and the volume is measured. The cost to discharge is based on the volume and measured levels of nutrients and solids in the grey water. Discharge in other communities is restricted by infrastructure and capacity.

Occasional tank cleaning and disinfection

Small cruise ships with limited space and small holding tanks may open the tanks for disinfection and clean out of grey water and sewage tanks to remove any solids or grease. Some small cruise ships have implemented this as part of their Alaska BMP to reduce bacteria levels. Pipes may also be flushed occasionally. Chemicals can be added to the tank to neutralize the chorine prior to discharge.

Figure 3 Tank Top With Bolts to Allow Opening

Treatment of Grey Water by Passenger Vessels in Alaska

Treatment by AWTS mixed with sewage

Large cruise ships that discharge in Alaska must use AWTS. These systems use additional treatment steps compared with traditional US certified marine sanitation devices (MSD). MSD units in use at the time of adoption of the federal and state standards used maceration and chlorination, and some used aeration to treat wastewater. AWTS typically includes filtration steps, biological treatment, and disinfection without using chlorine. Systems used successfully in Alaska often have a pre-treatment step with solids and other materials removed, along with separation of sludge and biomass of sewage after biological treatment. Most AWTS systems have been designed to treat either grey water or a mix of sewage and grey water.

Figure 4 AWTS Membrane Bioreactors

Table 5 Comparison of AWTS with Traditional MSD II Systems

	AWTS	**US MSD II (non-AWTS)**
Standards	Performance-based with testing onboard with installed system	Certification of system design with test unit
Type of wastewater	Sewage and grey water	Sewage
Required for discharge on	Ships carrying more than 250 passengers (by lower berth) in Alaska	Ships over 65 feet in length discharging sewage
Typical design* (note newer MSD designs are built to meet MARPOL standards and may act more as AWTS)	Mechanical and biological treatment, Ultra Violet (UV) or ozone disinfection. Separation of solids and sludge	Grinding and chlorine disinfection in many with possible aeration, some have biological treatment and filtration, some have UV

	AWTS	US MSD II (non-AWTS)
Effluent limits on solids and nutrients	US Secondary Treatment effluent limit for nutrients and solids, includes 85% removal of solids and BOD, daily (60 mg/L BOD and 150 mg/L Total Suspended Solids (TSS) and 30-day average limits (30 mg/L for BOD and TSS)	150 mg/L Total Suspended Solids
Bacteria limits	Based on human consumption and recreation guidance. Alaska limits to 14 fecal coliform units/100 ml monthly geometric mean, and 40 fc/100 ml for daily maximum	200 fecal coliform/100ml
Other limits	pH 6-9, Total Residual Chlorine is effectively limited to .1 mg/L. Alaska has stationary limits for ammonia and dissolved copper	None
Chlorine	Cannot be added to disinfect, Total Residual limit is effectively 0.1 mg/L	Often used as method to disinfect, no limit

Treatment with dedicated AWTS

Several Princess Cruises ships operated with "split" treatment, with some of the AWTS membrane bioreactors treating grey water only and one unit treating mixed sewage and grey water. Treated grey water can be discharged continuously, while mixed wastewater will be discharged underway where Alaska General Permit ammonia limits are higher.

The *Carnival Spirit* used a dedicated low-pressure reverse osmosis AWTS when sampled in Alaska. This system treated accommodation grey water, laundry wastewater, and occasionally swimming pool water. The treatment system used a vibrating filter to remove items like lint from laundry wastewater and used Ultraviolet (UV) to disinfect.

Several large cruise ships have used dedicated grey water treatment systems to produce water for washing or flush water for toilets. These recycling systems were sampled, but not as part of the Alaska or EPA sampling as they were not discharging in Alaska.

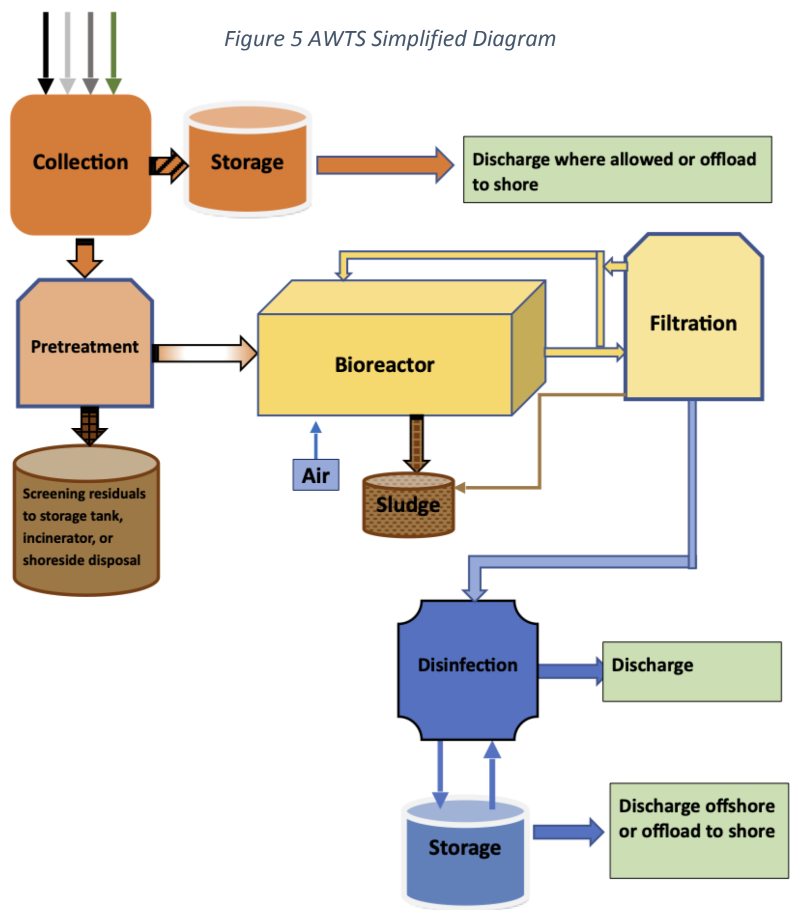


Figure 5 AWTS Simplified Diagram

Treatment of grey water using the MSD II sewage treatment system

State ferries and many large and small cruise ships treat some or all grey water with the treatment system used for sewage. Grey water can be used as "dilution" for the sewage, especially on ships that use low volume vacuum toilets. Sewage treatment systems will disinfect, remove some or most solids, and in newer systems provide biological treatment to remove nutrients.

Figure 6 MSD I Prior to Removal From State

Grey water can interfere with sewage treatment systems. Laundry water can add chemicals or foaming to interfere with biological or physical treatment. Cleaning chemicals and chlorine can damage filtration membranes or the biological process. Galley grey water can add grease and high levels of nutrients, and can clog or overwhelm a sewage treatment system. Adding grey water also increases the volume of water to be treated, and may not have been anticipated when the sewage treatment system was selected or installed.

Chlorine injection

Chlorine can be injected with small pumps into grey water holding tanks, which disinfects grey water prior to discharge. Holding time and dosage need to be adjusted for complete disinfection while minimizing discharged chlorine. Disinfection will not be complete if solids are present;
bacteria may be able to survive inside of the solids or semi-solids. Neutralization of chlorine may occur before discharge with chemicals added. These systems were added by several ships operating in Alaska to reduce bacteria levels.

Figure 7 Chlorine Dosage Pumps

Other treatment systems

Other methods of treatment are available but have not been part of the ADEC sampling program. These include technologies such as electrolysis and evaporation. These may be used on vessels outside the scope of the sampling program.

Grey Water Volumes

The amount of grey water generated on passenger vessels is typically much larger than sewage. Information from ADEC permit documents and other sources suggest that for large cruise ships, grey water is about 8 to 10 times the volume of sewage. These ships have extensive water conservation measures for both sewage and grey water. Small cruise ships and ferries average 4.5 times more grey water than sewage, a lower ratio since many of the ships sampled do not have vacuum toilets to reduce sewage volumes.

EPA used the value of 45 gallons per person per day (170 liters) in the VGP as a typical amount of grey water. This value may not be representative of a typical passenger vessel and does not match average values from large passenger ship surveys conducted by EPA and ADEC. The value used by EPA was from one ship (*Veendam*) monitored for one week in 2004, with values used from only five days (EPA, 2006). Four ships were monitored but some did not have all sources monitored, and for one ship, negative flows were measured from tanks. Sewage was measured as 28% of total flow, which is very high compared with typical large cruise ships. The value previously used by EPA is from limited data and does not match other estimates on volumes for this ship provided to ADEC.

The uncertainty of the representativeness of the average amount on the aforementioned ship must be viewed along with the higher amounts reported on EPA and ADEC ship surveys and by large cruise ships in certified permit applications. EPA reported in 2008 that, based on available information, "There appears to be no relationship between per capita graywater generation rates and number of persons onboard." Additional sources of information should be evaluated when determining grey water volumes. A comprehensive long-term evaluation of grey water amounts is needed for passenger vessels and other vessel types to determine environmental impact.

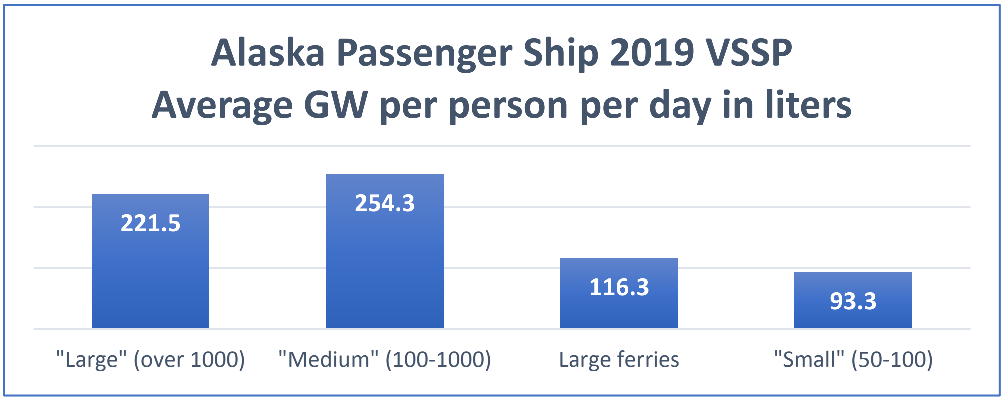
This report uses information submitted to ADEC to estimate ship grey water volumes. Passenger ships discharging grey water in Alaska are required to estimate generated amounts in the annual VSSPs. Surveys were conducted by EPA in 2004 and ADEC in 2012 with large cruise ship operators to gather wastewater information for permit development (EPA, 2011 & ADEC, 2013). EPA classified large cruise ships as 500 passengers or more while ADEC used 250 or more lower berths. These surveys were certified by the operators to be accurate to the best of their knowledge.

GW in liters per person per day	Min	Max	Average
EPA 2004 measurement (*Veendam*)	164	171	**170**
EPA 2004 Survey	136	450	**246**
ADEC SAP 2012	154	345	**251**

The EPA 2004 ship survey average was 65 gallons (246 liters) per person per day, compared with the 45 gallons (170 liters) per person per day used by EPA in the VGP. The survey showed variation for each ship. Variation may be due to ship age, size, and water conservation equipment used. The ADEC Science Advisory Panel 2012 survey average-per-person result was similar at 251 liters per day of grey water.

ADEC VSSP information from 2019 includes estimates of daily wastewater generation from cruise ships and ferries authorized to discharge in Alaska. "Medium"-sized cruise ships included several that are advertised as luxury cruise ships. Luxury cruise ships often have a higher ratio of crew to passengers, which may explain the higher rate of wastewater generation per passenger. Large ferry volumes are lower, likely because of limited cabin utilization, and many passengers on shorter voyages. Laundry facilities may be more limited on ferries and very small cruise ships. Small cruise ships with 50 to 100 passengers reported much lower average grey water generation. With limited information and direct discharge on some ships it is possible the estimates are very different than the actual grey water generation.

Figure 8 Grey Water Averages Per Person from 2019 VSSPs



Data from the VSSPs and the ADEC survey on estimated generation by type is included in Appendix C.

Grey water by source and sewage volumes
ADEC and EPA evaluated grey water into general categories of laundry, galley, accommodations, and "other". The ratio from each source varies from ship to ship and by ship size. Sewage has a higher ratio on small ships and ferries as most of these do not use vacuum toilets, and consequently have large amounts of flush-water that may be seawater.

Figure 9 Average Grey Water Volumes Generated per Day

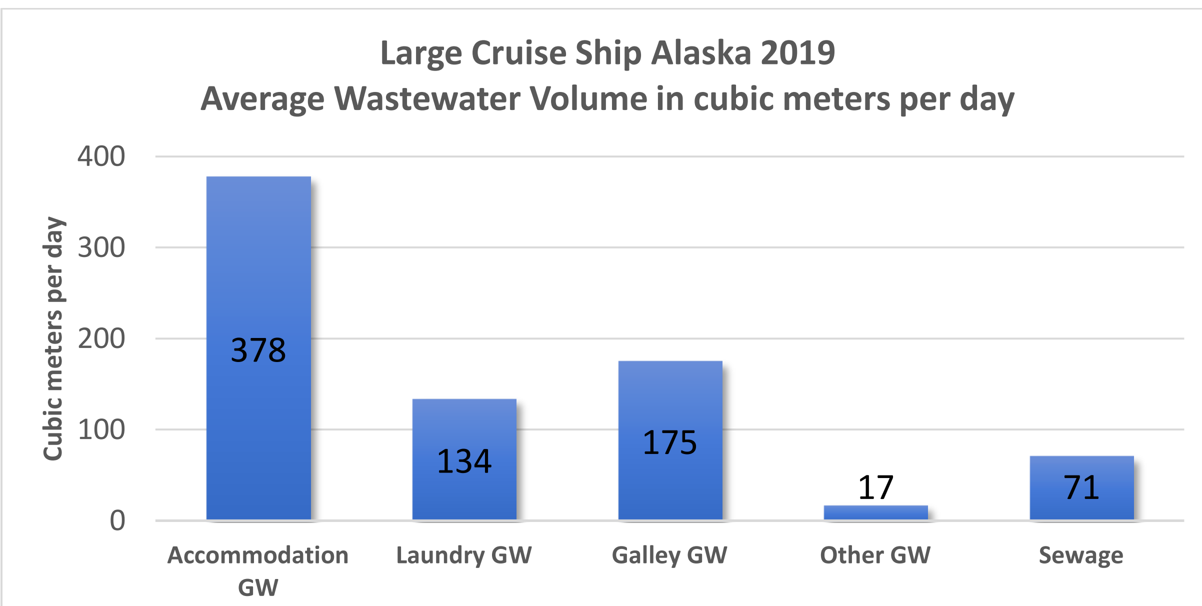
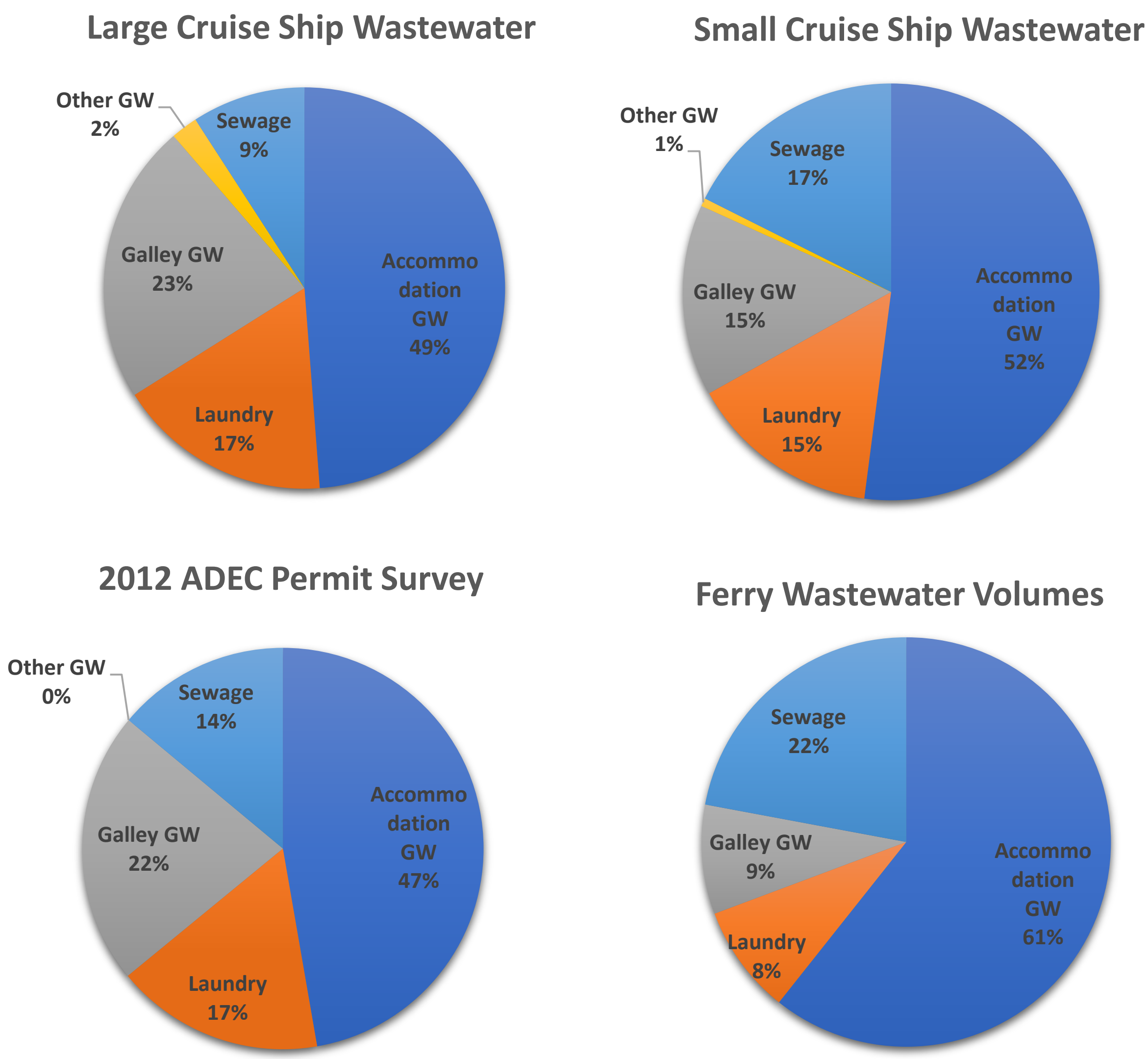


Figure 10 Wastewater Generation Ratios from 2019 Alaska Vessel Specific Sampling Plans



Volumes must be evaluated with sample results to determine the load of pollutants. For example, accommodations grey water may be about half of all grey water and sewage generated per day but will have much lower nutrient loads compared with galley grey water. For this reason, the accommodations grey water is often mixed with sewage to help dilute the organic and solids loading in the sewage.

Discharge monitoring reports (DMR) are monthly summaries of discharge amounts and sample results submitted to ADEC for all ships operating under the 2014 large cruise ship wastewater general permit. Although the wastewater amounts for many ships are estimates, the DMR must be signed and certified as accurate to the knowledge of the ship operator. A DMR does not separate the amounts of grey water from sewage treated and discharged, but sewage should be a small fraction (~10%) based on permit Notice of Intent (NOI) information. Table 6 lists 2018 information for each month on discharges in cubic meters compared with estimated production from NOI and VSSP estimates of daily production. Only ships discharging in Alaska submit DMRs.

Table 6 Large Cruise Ship Reported 2018 Alaska Discharges

2018 DMR Reported Volumes in cubic meters

			Reported Alaska Discharge Totals									Estimated Produced		Discharged		
Ship Name	Effluent	Days in AK	April	May	June	July	August	September	October	Total	Average per day	Est per day	Est Total	% produced	Shoreside discharge cubic m3	Shoreside discharge % prod
Disney Wonder	Mixed BW&GW	65	-	2,292	6,037	4,007	6,261	1,592	-	20,189	310.60	750	48,750	41%	0	0%
Eurodam	Mixed BW&GW	64	-	2,688	1,668	1,545	1,235	1,668	-	8,804	137.56	1040	66,560	13%	0	0%
Nieuw Amsterdam	Mixed BW&GW	83	-	1,808	1,632	1,710	1,819	1,376	-	8,345	100.54	835	69,305	12%	0	0%
Volendam	Mixed BW&GW	88	-	4,180	6,992	6,642	6,800	5,715	-	30,329	344.65	535	47,080	64%	0	0%
Zaandam	Mixed BW&GW	95	-	4,275	4,332	3,180	5,080	4,488	-	21,355	224.79	535	50,825	42%	0	0%
Coral Princess	Mixed BW&GW	87	-	574	3,072	2,560	2,480	1,616	-	10,302	118.41	960	83,520	12%	6,088	7%
Emerald Princess	Mixed BW&GW	48	-	38	1,035	915	658	264	-	2,910	60.63	987	47,376	6%	10,352	22%
Golden Princess	Mixed BW&GW	61	-	1,470	1,470	3,124	7,199	2,250	-	15,513	254.31	1025	62,525	25%	9,849	16%
Grand Princess	Mixed BW&GW	55	-	3,674	3,492	3,504	2,784	2,416	-	15,870	288.55	987	54,285	29%	0	0%
Island Princess	Mixed BW&GW	87	-	-	2,162	3,650	3,125	1,834	-	10,771	123.80	960	83,520	13%	7,654	9%
Ruby Princess	Mixed BW&GW	77	342	6,390	2,508	4,505	2,574	1,524	-	17,843	231.73	1050	80,850	22%	6,485	8%
Star Princess	Mixed BW&GW	104	-	7,372	4,224	6,380	6,480	4,665	-	29,121	280.01	990	102,960	28%	7,064	7%
Seabourn Sojourn	Mixed BW&GW	92	-	19	2,180	3,048	3,080	2,992	321	11,640	126.52	255	23,460	50%	0	0%
Norwegian Bliss	Mixed BW&GW	57	-	-	15,061	14,692	9,793	9,953	-	49,499	868.40	1445	82,365	60%	0	0%
Norwegian Jewel	Mixed BW&GW	87	-	5,985	13,537	12,894	13,834	9,438	-	55,688	640.09	1220	106,140	52%	0	0%
Norwegian Pearl	Mixed BW&GW	91	-	11,092	9,965	10,151	10,282	10,024	2,591	54,105	594.56	1120	101,920	53%	0	0%
Oceania Regatta	Mixed BW&GW	55	-	186	474	700	1,160	1,586	-	4,106	74.65	345	18,975	22%	0	0%
Seven Seas Mariner	Mixed BW&GW	46	-	742	697	742	966	409	-	3,556	77.30	350	16,100	22%	0	0%
	Totals	**1342**	342	52,785	80,538	83,949	85,610	63,810	2,912	**369,946**		**15,389**	**1,146,516**	**32%**	**47,493**	**4%**

Note- Ships with split greywater and mixed discharges did not differentiate between the amount of each.
Note- The same amounts were reported for the Golden Princess in May and June, the same amounts are unlikely based on days in Alaska

Source: Discharge Monitoring Reports, ADEC 2018. GW represents grey water, and sewage is BW for blackwater.

DMR data from 2018 suggest that only a fraction of the amount of produced wastewater is discharged or offloaded in Alaska. For some ships this may in part be explained by not discharging while in port and in Glacier Bay National Park and other locations. There may not be sufficient time in Alaskan waters to discharge all stored wastewaters from the treatment system, requiring storage of the excess grey water and/or effluent. Stored wastewater may be discharged outside of state waters offshore with or without treatment where allowed.

Discharge logs (record books) are submitted monthly by large cruise ships to ADEC. Small cruise ships and ferries must have discharge information available for ADEC. Much of the records are estimated and handwritten. Several attempts were made by ADEC to review and create a database of discharges. The attempts demonstrated this was time consuming, and the data had errors that made the analysis difficult. Errors were found in locations, discharge calculations, vessel minimum speed, and what was discharged. Errors were found in both electronic records and handwritten logs. The discharge logs were designed to be used for compliance, not data collection. Several operators removed discharge information from outside of state waters prior to submitting to ADEC.

The 2010 ADEC General Permit added a requirement that if flow meters are installed the flow data must be reported. Several ships were found by Ocean Rangers to have disconnected or disabled flow meters by the time the permit came into effect.

It was suggested by Ocean Rangers to review water production and loading data, which is water produced or loaded as an indicator at grey water generation. Some ships kept very detailed records of water production. As long as it is not discharged directly, drinking water and technical water (water used for non-drinking uses such as flushing and cleaning) should be a guide to grey water generation. Estimates of condensate and other inputs should be added. Water used for boilers and swimming pools would need to be subtracted.

Sampling

Passenger vessel treated sewage and grey water have been sampled each year in Alaska since 2000. Most of the sampling is of water being discharged from the ship into surrounding waters. Initial sampling from 2001 to 2004 also focused on influent into storage or collection tanks and treatment systems to identify sources of bacteria, nutrients, and pollutants.

Sample data in this report were collected by ADEC. This report also includes data obtained by the USCG and EPA, both of which worked in conjunction with ADEC. Data in this report have been included in annual ADEC sampling summaries as well as ADEC and EPA reports. This report includes a review of 19 years of ADEC sample data. EPA reports on Alaska passenger vessel grey water data included only a few years and were limited to large cruise ships.

Only passenger vessel sample data submitted to ADEC are included in this report. Vessel operators may conduct additional sampling beyond regulatory requirements. These samples are only included if directly submitted to ADEC and certified as meeting all regulatory sampling requirements.

Grey water in the sample data used for this report includes all sources identified in the Grey Water Sources section of this report. "Mixed wastewater" is grey water mixed with other wastewaters; for this report it is a mix of grey water and sewage. Wastewater is abbreviated as WW in some tables, GW for grey water, and sewage as BW for blackwater.

Some mixed sewage and grey water samples were reported to ADEC as grey water due to the initial EPA VGP definition. This report uses the information in the field notes by the samplers to identify the type of wastewater in these samples.

All sample events included in this report, with the exception of some EPA-collected composite samples and Whole Effluent Toxicity (WET) samples, are collected as "grab" (single collection time) samples. ADEC required discharging while sampling for all large cruise ships starting in 2008. USCG allows "recirculation" samples, which are effluent samples taken while effluent is diverted to a holding tank. USCG also requires sampling prior to arrival in Alaska that is not included in this report. Only samples collected while discharging in Alaska from large cruise ships are included in the ADEC sample results from 2008 to 2019. Some small cruise ship samples after 2008 were taken while the ship was not discharging. ADEC allowed limited discharges on small cruise ships while sampling even if their BMP allowed underway discharge only.

Samples are divided in ADEC reports by the purpose of the sample. General Permit samples are taken to measure compliance with permit limits. USCG continuous compliance samples are a short list of conventional samples (BOD, TSS, fecal coliform, chlorine, and pH) to demonstrate an AWTS is operational. "Conventional" samples measure indicator parameters and those with effluent limits such as BOD, TSS, fecal coliform, chlorine. Conventional samples may include conductivity, some dissolved metals, and ammonia as required by ADEC. "Priority" or "twice a year" sample events include a full list of parameters including priority pollutants (volatile organic compounds, base/neutrals and acids, metals), nutrients, and other parameters such as hardness as well as conventional parameters. "USCG" labeled samples are USCG random unannounced sample events using the continuous compliance parameter list.

Sampling Frequency

ADEC specifies sampling frequency for large cruise ships in wastewater permits with any ship-specific requirements in ship permit discharge authorizations. Small cruise ships and ferry sampling has been determined each year for each ship based on internal guidelines. USCG sampling frequency is determined by the Sector Juneau Captain of the Port and has remained largely the same since 2002.

Wastewater sampling frequency should be based on the risk of harm to human health and the marine environment. It must also account for performance variability of sewage treatment plants. In Alaska, concern over passenger vessel traffic in sensitive and nearshore waters used for fisheries and recreation prompted a robust data collection program. Highly variable results from treated wastewater originating from passenger vessels have identified frequent sampling as a key regulatory strategy for mitigating risk posed by wastewater discharges.

Table 7 Compliance Monitoring Requirements

	State of Alaska	US Coast Guard Alaska
Large passenger vessels	Twice a month	Twice a month
Small and medium passenger vessels	Varies by size and time in state, but generally twice a year	None
Large ferry	Quarterly when discharging	None

Factors that determined sampling frequency required by the State of Alaska include:

- Overall amount of discharged pollutants.
- Variability of results based on past data and similar treatment systems.
- Impact of pollutants- toxicity and other impacts.
- Receiving waters- sensitive areas, human use, existing impairments.
- Cost and logistics- including the availability of analysis in remote areas.

A long-term goal was to reduce frequency over time to the minimum needed; exceedances of standards often suspended reduction goals. ADEC reduced requirements for AWTS sampling for passenger ships that had previously sampled prior to 2014 for nutrients, most metals, and priority pollutants.

Table 8 Sample Frequency Requirements- ADEC Only

ADEC Sampling 2018	Conv	Conv+AC	Conv II	Nutrients	Prior-ity	WET	Rec
Large cruise ships stationary discharge		2/month					2/year
Large cruise ships underway only discharge	2/month						
New large cruise ships or not previously sampled for all current requirements	see above	see above	2/year		2/year	1/month	2/year
Large ferries	1/quarter		1/year	1/2 years	1/year		
Small cruise ships with over 100 passengers	2/year		1/year		1/year		
Small cruise ships under 100 passengers	1/year		1/year		1/ 2 years		
New small cruise ships	3/year		1/year	1/year	1/year		

Conv= Fecal coliform, TSS, BOD, chlorine, pH, temperature
Conv+AC= Conventional plus ammonia, dissolved copper, hardness, conductivity
Conv II= Ammonia, COD, settleable solids, conductivity, oil and grease, hardness, alkalinity
Nutrients= Phosphorus, nitrate/nitrite, total kjeldahl nitrogen, ammonia, total organic carbon
Priority= Metals, VOCs, BNAs
WET= Whole Effluent Toxicity (stationary only), Rec= Receiving water sampling
Note- USCG requires 2x per month BOD while Alaska requires 2x year for some large cruise ships
USCG also requires nutrients, conv II, and priority twice a year

Parameters Sampled

The parameters measured at each sample have varied by type of sample, type of ship, and requirements made by USCG, EPA, and ADEC. Sample parameter selection for ADEC was initially based on the 2001 Alaska Cruise Ship Initiative Science Advisory Panel recommendations and updated with input from experts, or to address information needed for permit development. For example, ADEC sampled briefly for pesticides but determined they should not be commonly found in passenger vessel effluent. Some of the pesticides sampled were banned for sale in the United States.

Not Required
EPA sampling, large ship
Large ships only
Small ships only
Large and small ships

Table 9 Parameters Measured By Year and Ship Type

Parameter	2000	2001	2002	2003	2004	2005-2007	2008-2014	2014-2016	2017-2019
Flow								2015 small	
Temperature									
Fecal coliform									
E Coli								VGP	
Total residual & free chlorine, pH									
TSS, BOD, COD									
Conductivity			Small BW						
Settleable solids									
Oil and grease			Small BW						
Alkalinity			Small BW						
Hardness								2013	
Ammonia									
Total Organic Carbon									
Phosphorus			Small BW						
Total Kjeldahl Nitrogen (TKN)			Small BW						
Total Nitrogen							2010 only		
Nitrate as N							2010-2011	2013-2014	
Nitrite							2012-2014		
Total Nitrate-Nitrite						large to 2009	2012 large	2015	
Total and dissolved metals		GW only							
Base, Neutral, Acids		GW only							
Volatile Organic Chemicals		GW only							
Cyanide									
Pesticides									
Polychlorinated biphenyls (PCBs)									
Whole Effluent Toxicity					2002-2006				Stationary

What was sampled	2000	2001	2002	2003	2004	2005-2013	2014-2019
Effluent							
Receiving Waters							Stationary
Influent							
Biosludge and screenings							

Note, EPA in 2004 was only four ships, used expanded metals list
Nutrient sampling frequency for small ships reduced in 2016

Physical Measurements

Temperature, conductivity, and pH are measured with electronic meters according to requirements in the Quality Assurance Project Plan (QAPP). Temperature and pH measurements are conducted as field tests along with chlorine within 15 minutes of the sample.

Temperature
Temperature is measured at each sample event. Temperature can be used as an indicator of seawater intrusion and retention time in tanks. There is not a permit limit for temperature. Alaska has water quality standards for temperature, but grey water should not significantly raise ambient water temperature of cold harbor water. Some small cruise ships report temperature in Fahrenheit and this has been converted in the ADEC sample data.

pH
High or low pH values can interfere with biological processes and harm marine life. The EPA set a secondary treatment standard of 6.0 to 9.0 for discharge. Previous Alaska discharge permits had limits of 6.5 to 8.5 based on water quality standards—these limits were changed in 2014 to better match federal limits. Measurement of pH can also be used as an indicator of failures in biological or chemical processes in wastewater treatment. It can also be an indicator of wastewater source, for example grey water or sewage.

Conductivity
Conductivity can be measured as an indicator for salinity and other dissolved solids to determine seawater dilution or intrusion. It may also indicate problems with the treatment system if compared with prior results. Conductivity was initially added to determine how much seawater was used on ships with seawater toilet flushing. It was added to additional large cruise ship sample events in the 2014 General Permit after a review of twice-a-year sampling showed seawater intrusion detected in sample results prior to identification by ship crew, Ocean Rangers, or samplers. Besides seawater, conductivity may come from other dissolved solids.

Flow
Flow is reported in sample field notes, often calculated based on estimates by the ship's crew. This is a recent addition to sampling requirements; previously sample reports were required to include copies of the most recent discharge log entries only. Flow rate was needed for receiving water sampling added in the 2014 General Permit, but was also added for future permit development. Errors were identified in flow rates in the sample reports—there most common appeared to be conversion errors. Flow rate reporting requirements included units in the general permit that are not used on most ships requiring conversion.

Chlorine
Chlorine is measured both as free and total residual. Most samples were tested with a field test kit. Chlorine is toxic to marine life; as a disinfectant it will damage cells and disrupt biological activity.

High levels of chlorine with organic material can create hazardous disinfection by-products. The Alaska large cruise ship permit and the USCG Alaska continuous compliance program for large cruise ships use the state water quality chronic criteria of chlorine as a limit (0.0075 mg/L). The compliance limit is 0.1 mg/L in the General Permit due to the sensitivity of the test methods used.

Bacteria and Viruses
Bacteria are measured for the presence of harmful bacteria and viruses in effluent and wastewater. There are several types of indicator bacteria that have been tested in cruise ship effluent and wastewater. Fecal coliform has been tested in almost every sample result obtained from passenger vessels in Alaska.

Holding time is a major logistical challenge for collecting representative bacteria samples from passenger vessels. This limited sampling times for those ships discharging only while underway, and limited the locations where sample collection could occur. Many Alaskan ports did not have labs available to analyze bacteria, and flying samples from remote communities is difficult given infrequent flights and potentially hazardous weather.

Chlorine must be neutralized when the sample is collected, or the measured bacteria results will be lower than the discharged amount. This is critical given the potential holding time of several hours.

Fecal coliform

Fecal coliform is the measurement required by ADEC and the USCG for bacteria in passenger vessel effluent and grey water. Note thermotolerant coliform is another name for fecal coliform to reflect that not all fecal coliform bacteria are associated with feces. However, fecal coliform is the name used in this report to match sample reports and ADEC and EPA reports.

E. coli

E. coli is a required sampling parameter by the 2013 EPA Vessel General Permit along with fecal coliform for large cruise ships and medium cruise ships discharging grey water near shore.

Enterococci

Enterococci are another indicator of disease-causing bacteria found in wastewater. EPA has included Enterococci in some vessel sampling surveys. ADEC and USCG did not include Enterococci in the passenger vessel sampling programs, but ADEC includes it in beach water quality sampling.

Viruses

Virus outbreaks occur on cruise ships even with widespread measures on ships to reduce virus transmission. The US Centers for Disease Control (CDC) maintains a list of outbreaks and provides reporting on all ships in the US above a 3% infection rate by crew or passengers (CDC, 2020). Ocean Rangers regularly reported illness by isolated individuals or below the reporting threshold, as might occur in any large concentration of people. Norovirus was the most frequently reported illness, but other viruses have been reported. Virus outbreaks including Covid-19 have occurred on cruise ships. No sampling for viruses was conducted by the State of Alaska or USCG in Alaska.

A 2007 Washington State Department of Health assessment raised concerns with passenger vessel wastewater discharges containing viruses (Washington Dept of Health, 2007). It included recommendations to limit discharges near shellfish used for human consumption. Washington has established no-discharge zones for vessel sewage. UV light in AWTS treatment of wastewater or chlorine should inactivate viruses, but sampling to confirm was not conducted in Alaska.

Solids

Total suspended solids (TSS)

This measurement of particles suspended in the wastewater will indicate the performance of solids treatment in wastewater. High TSS can interfere with disinfection. US EPA standards reflect a technology limit to minimize the discharge of particles in wastewater. MSD II certification standards and the initial Alaska requirements denoted a 200 mg/L TSS limit.

Settleable solids
These are solids that can settle out of the water within one hour and include larger particles. The USCG requires that large cruise ships sample settleable solids twice a year, and less frequent sampling is required by Alaska for cruise ships and ferries. This parameter was added in 2001 to the "conventional pollutants" sample list at the advice of the 2001 Science Advisory Panel. Settleable solids can be used as an indicator for sewage treatment plant failures. AWTS generally report non-detect levels of settleable solids, which are observed in results from other MSD II sewage treatment plants.

Nutrients and Related Indicators

Biochemical oxygen demand (BOD)
BOD is an indicator of the organic matter present in wastewater by measuring the oxygen demand for biological processes to break down organic matter. High BOD levels can lower oxygen levels in surrounding waters. Low oxygen levels are toxic to most marine life.

Chemical oxygen demand (COD)
US EPA defines COD as "A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater; the amount of oxygen consumed from a chemical oxidant in a specific test." COD has been used as a quality check of BOD analysis on some cruise ship samples by sampling contractors. Limits were not established in Alaska for COD.

This measurement along with BOD will indicate the potential impact of nutrients from treated wastewater. Wastewater with high BOD and COD can remove dissolved oxygen needed by marine life from water. COD is a parameter with limits in the IMO MARPOL guidelines for effluent standards for sewage treatment plants. The MEPC.227(64) type approval standard for COD is no more than 125 mg/l when accounting for dilution. This standard may be revised in the future.

Total Nitrogen and Total Phosphorus
Nitrogen and phosphorus are included in the parameter list to monitor nutrients. Nutrients can cause biological activity in waters and lower oxygen levels, causing harm to marine life. Total nitrogen was only briefly reported in Alaska, but total nitrogen can be calculated from adding the reported Total Kjeldahl Nitrogen (TKN) and nitrate-nitrate in the sample results. TKN includes ammonia and organic nitrogen. Monitoring for ammonia, TKN, and nitrate-nitrite can provide information on the biological treatment of wastewater. Biological treatment and filtration will reduce nutrient releases into the environment.

Alaska did not set nitrogen and phosphorus limits for ships as most Alaska marine waters are not nutrient impaired. There is an ammonia limit in Alaska on large passenger vessels because it can be toxic to marine life, and relatively high values had been measured. Some waterbodies worldwide are impaired with high levels of nutrients. The International Maritime Organization (IMO) placed sewage treatment certification limits for sewage wastewater from passenger vessels under MARPOL Annex IV discharging in special areas such as the Baltic Sea.

Ammonia
Ammonia was identified as a parameter of concern by ADEC in the 2008 large cruise ship wastewater general permit, based on the toxicity of ammonia to aquatic life. Ammonia toxicity depends on the concentration as well as ambient pH, temperature, and salinity.

Ammonia is present in sewage on ships from human waste such as urine. Ammonia is also produced by biological processes from organic matter such as food waste in grey water. Ammonia may also be present in some cleaning products.

Total organic carbon (TOC)
TOC is a measure of the organic load of the effluent. It provides information on the organic loading being released into receiving waters and on the treatment process. TOC is only measured in Alaska passenger vessels when sampling for nutrients.

Alkalinity
Compounds in water can neutralize acids, measured as alkalinity. Alkalinity is needed for some biological processes that are present in wastewater treatment. Nitrification can lower alkalinity.

Total Hardness
Total hardness was added in 2013 to nutrient samples to provide additional information on the wastewater treatment process. It is a measure of calcium ions in water.

Metals

The list of metals included in the sampling requirements includes many metals known to be toxic to marine life. EPA 2004 sampling included additional metals such as aluminum and iron not required by ADEC or USCG for passenger vessels. Metals are measured as both dissolved and total recoverable.

ADEC identified dissolved copper, dissolved nickel, and dissolved zinc as parameters of concern from passenger vessel and implemented limits in the 2008 large cruise ship wastewater General Permit. The 2014 General Permit includes limits on dissolved copper for some ships but removed nickel and zinc limits.

There is a potential quality assurance issue where sample results for dissolved metals may be higher than total recoverable on samples mainly from large passenger vessels. The cause of this is not known, although method error when measuring at very low levels may be a component of the difference for some results. This topic was identified by ADEC as a topic for future work in QAPP meetings. Contamination is a concern when sampling for metals, especially when measuring at very low levels. The QAPPs include elements to test for and reduce the possibility of metal contamination.

In 2010, a change was made to the procedure for filtration of dissolved metals to require that it occurs within 15 minutes of sample collection. ADEC allowed an exemption prior to 2010 to allow samples to be filtered in the lab away from potential contamination while ADEC sought guidance from EPA on the test method. There was a concern regarding contamination in location in the engine room where metals are present and metal work like grinding could contaminate the area. Samples taken after the start of the 2010 cruise ship season in Alaska were filtered in the field; however efforts were made to reduce the potential for contamination during collection and filtration.

Total Mercury
Mercury results are presented with other metals. Only total mercury is tested for the ADEC and USCG. Mercury is highly toxic and is not detected in most samples. Sources of mercury onboard ships are unknown—mercury should not be present in any wastewater.

Base/Neutrals and Acids (BNAs, also referred to as semi volatile organic compounds--SVOCs)

- *3/4 Methylphenol.* Found in creosote and coal tar. International Labor Organization (ILO) lists 4-Methylphenol as toxic or fatal to humans and harmful to aquatic life with an occupational exposure limit of 5 ppm.
- *Benzoic acid.* A preservative, found in food and health care products.
- *Benzyl alcohol.* Sources include fruit, solvents, and health care products. ILO lists it as harmful to aquatic life with an occupational exposure limit of 5 ppm.
- *Bis(2-ethylhexyl) phthalate.* Found in plastics, personal care products, laundry detergent, and other products. Plasticizer for Polyvinyl Chloride (PVC) which is used in pipes on some ships.
- *Diethyl phthalate.* A substance found in some plastics. ILO lists it as potentially harmful to the environment.
- *Phenol.* Phenol can be a byproduct of metabolism and found in human waste, it is also used in plastics and may be in paint removers. ILO lists it as corrosive and harmful to aquatic life with an occupational exposure limit of 5 ppm.

Volatile Organic Compounds (VOCs)

- *Acetone.* Acetone can be a metabolic product in human waste and is used in solvents. It is relatively common in sample results.
- *Benzene.* A hydrocarbon occasionally found in treated wastewater samples. ILO lists it as carcinogenic and harmful to aquatic life with long lasting effects and with an occupational exposure limit of 0.5 ppm.
- *Bromoform.* Bromoform is present in many small cruise ship and ferry samples. The likely source is as a chlorination byproduct. Bromoform is an irritant. ILO lists it as harmful to aquatic life with an occupational exposure limit of 0.5 ppm.
- *Carbon tetrachloride.* Present in some phased-out refrigerants and fire extinguishers and used as a solvent. ILO lists it as toxic and a marine pollutant with an occupational exposure limit of 5 ppm.
- *Chloroform.* This may be present as a chlorination byproduct in many small cruise ship and ferry samples which use chlorine as a disinfectant. Chloroform is an irritant and an anesthetic. ILO lists an occupational exposure limit of 10 ppm.
- *m,p-Xylenes.* Used in some solvents. ILO lists m xylene and p xylene as toxic to aquatic organisms.
- *Toluene.* A solvent found in paint thinners, glues, and hydrocarbons. ILO lists it as an irritant with an occupational exposure limit of 20 ppm.
- *Tetrachloroethane.* Solvent and refrigerant.
- *Tetrachloroethylene (tetrachloroethene).* Solvent used in dry cleaning.

Whole Effluent Toxicity (WET)

WET is a biological test to determine potential toxicity of the wastewater effluent. It exposes aquatic organisms in a lab to different levels of diluted effluent and monitors factors such as survival, growth, and reproduction. This test may capture toxicity by substances not sampled for or the combined effects of substances in the effluent.

The methods used for WET are developed by the EPA. Guidelines for shipboard sampling and species used were further developed by ADEC and the State of Washington. WET sampling involves obtaining large amounts of effluent to test. ADEC prefers to use species that are found in receiving waters, but the species used may be from other states on the west coast of North America. WET sampling was completed by ADEC from 2002 to 2006, and is an ADEC permit requirement for stationary discharge after 2015 for new large cruise ships.

Cyanide

Cyanide has been used as a fumigation insecticide on ships. Testing for cyanide was limited to large cruise ships in the year 2000. The ADEC Assessment of Cruise Ships and Ferry Wastewater Impacts recommended resuming cyanide testing in 2004 due to high concentrations in some samples. However, this was not added to the sampling requirements.

Pesticides

Sampling for pesticides was conducted in 2000 and 2003. Results are not included in this report, but can be found in ADEC reporting summaries. No pesticides were reported as present in 2003 (ADEC, 2004). Sources of agricultural pesticides are not likely to be present unless from food—some pesticides may be used for rodent or insect control.

Plastics

Sampling was not directly conducted to determine if plastics or microplastics were present. The priority sampling may detect some components of plastics if they dissolve in wastewater. A treatment system with good filtration such as most AWTS units will remove most particles including plastics. Sources of plastics include the following: fibers from laundry, food packaging, microbeads in personal hygiene products, and in mixed wastewater, anything plastic flushed from a toilet. Ocean Rangers reported occasional plastic bags and other plastic items in ground food waste. Maceration, if part of the treatment system, can grind plastics into small particles.

Parameter	Method
pH	EPA 150.1
Conductivity	SM 2510B
Fecal coliform (2000-2004)	SM 9221E
Fecal coliform (2005-2019)	SM 9222D
E coli	SM 9223B
Chlorine	SM 4500-Cl
BOD	EPA 405.1
COD	EPA 410.4
TSS	EPA 160.2
Settleable solids	SM 2540F
Hexane extractable material	EPA 1664B
Phosphorus	EPA 365.1
Total Kjeldahl Nitrogen	EPA 351.2
Ammonia	EPA 350.1
Total Organic Carbon	SM 5310B
Alkalinity	SM 2320B
Hardness	SM 2340B
Nitrate	EPA 300.0
Nitrate plus nitrite	EPA 350.1
Dissolved metals	EPA 200.8
Total recoverable metals	EPA 200.8
Mercury	EPA 245.1
VOCs	EPA 624
BNA	EPA 625
Cyanide	EPA 335.2
PCBs	EPA 608
Pesticides	8081A

Table 10 Testing Methods

Pharmaceutical Products

Direct sampling was not conducted in Alaska for pharmaceutical products.

Methods

Testing methods and tested parameters are listed in the ship operator QAPP available from ADEC and updated at least every five years. Table 10 includes selected methods.

Representative Sampling

Representative sampling is a critical element in evaluating the impact of wastewater to human health and the environment. Effluent quality will vary depending on treatment. This may be influenced by changes to influent sources, loading of pollutants, and volume over time. Water conservation measures used on ships reduces flow compared with shoreside treatment. This would dilute high pollutant loads and can cause rapid changes in influent. Space and weight limitations prevent the retention of large amounts of water to even out changes during the day and in passenger loading compared with shoreside treatment.

Sampling on a ship presents logistical challenges not present in a shoreside treatment facility. Holding times are limited, and a ship must be near a laboratory or able to transfer samples within the method holding time. Holding time for bacteria limited many underway sample events to early morning and may not be representative of discharge at other times.

More information and an expanded list of representative sampling and quality assurance elements are in Appendix D. This appendix also identifies some causes of sampling failures.

Vessel Specific Sampling Plan (VSSP)

Each ship is required by ADEC and USCG to provide a VSSP) prior to sampling. A VSSP must provide information needed to understand the sampling, the treatment process, and how a sample would be representative of discharged wastewater. The VSSP also documents sample port location, equipment used to treat wastewater, and any ship-specific sampling information. It is a critical element of representative sampling.

Initial VSSPs contained inaccuracies and did not contain needed information. ADEC staff and the USCG worked with vessel operators to improve the VSSP to include important information and fix errors. Ocean Ranger reporting identified numerous errors or undocumented changes in VSSP documents. Operators are required to submit revised VSSPs as errors were identified or to document changes. See Appendix E.

Quality Assurance

Quality assurance of samples is another critical element of a successful sampling program. Incorrect sample collection, laboratory errors, and incorrect procedures could produce incorrect results. The ADEC and USCG cruise ship monitoring programs are compliance programs placing emphasis on quality assurance and representative sampling.

ADEC and USCG personnel regularly audit sample events, inspect ships, and verify documentation related to wastewater. Inspections are a critical part of monitoring for compliance, and identifying quality assurance issues in sample collection. Third party auditors are required by USCG to audit sample events for large cruise ships. Ships using third party samplers were observed to have a lower rate of quality assurance issues.

Quality Assurance Project Plans (QAPP)

A QAPP documents sampling procedures, methods, and actions to be taken to verify sample results are accurate and representative. A QAPP for passenger sampling is required by State of Alaska and USCG regulations. The Northwest Cruise Association (later Cruise Lines International Association) submitted a QAPP each year to be used by large cruise ships. This QAPP as approved by USCG and ADEC is available online from ADEC. Small cruises lines often used company-specific QAPPs based on state-provided generic plans and only need ADEC approval. The small cruise ship plans allowed for crew sampling. State ferries often used the large cruise ship QAPP but developed a separate QAPP in 2018. QAPPs shared many of the same elements and generally did not differ on analytical methods.

Duplicate sampling and replicate sampling

Blind duplicates or replicates are used to check laboratory analysis, with the ship name not being provided to the laboratory. Duplicate sampling results are compared by a third-party auditor and reviewed by ADEC staff.

Data Review by ADEC

ADEC reviewed all sample results as they were submitted and at the end of the season. Results were compared with compliance limits, previous results for the ship, and other ships with the same treatment equipment. Quality assurance reviews were carried out by an ADEC chemist and staff looking at duplicates, audits, and sample values. Sample reports were checked to verify if complete and if photos matched sample ports identified in the VSSP. Indicators such as temperature, pH, salinity, alkalinity, and other parameters were checked for large changes that could indicate seawater intrusion or a change of sources sampled. Sewage and grey water would have different physical characteristics that can indicate the presence of these sources when compared with previous results for each ship.

Results

Sample results from available grey water data are from original sample reports, EPA sampling reports, or ADEC annual datasets and reports. The results include updated information not found in earlier ADEC permit development and EPA reports. A comparison over time is included for several parameters. Most ADEC sample reports provide information for a single year at a time. Data are grouped in this section by parameter measured.

Sample results evaluated are as follows:

- ADEC/USCG AWTS effluent sample results 2008-2019.
- ADEC/USCG AWTS priority pollutant and metals sample results 2001-2019.
- ADEC small commercial passenger vessel and ferry sample results 2001-2019.
- ADEC WET 2001-2019.
- EPA 2000-2004 influent and treatment related sampling.
- USCG random unannounced sampling.

USCG continuous compliance samples taken outside of Alaska were not included in the data review, and EPA-treated effluent results were not evaluated as there was sufficient ADEC sample data, including sampling in 2004 and any samples taken outside of Alaska to meet EPA VGP requirements. Samplings for pesticides and PCBs are also not included. Some results initially showed high levels, but the sources were not determined, quality assurance questions were raised in ADEC reports, and the sampling was not repeated.

Not all 2019 data were available at the time of this report from ADEC. These include most priority pollutant data, large ship total recoverable metals, large ship oil and grease, large ship carbon, large ship alkalinity, and some flow estimates. ADEC was still reviewing quality assurance on this sample data. Cancellation due to COVID-19 restrictions resulted in no commercial passenger vessels expected to be sampled in 2020. State ferries collected only four samples in 2020; COVID-19 restrictions, budget cuts, and mechanical breakdowns caused a substantial reduction in voyages and passengers carried.

Temperature

Temperature varies by many factors. Wastewater stored in tanks and from AWTS effluent is much warmer than receiving waters. AWTS data from 2008 to 2018 averaged 29 °C. Small cruise ship wastewater is not as warm on average (20 °C). Ferry-mixed sewage and grey water averages about 15 °C. The ferry temperature is lower due to use of seawater for flushing and in the treatment process.

pH

Most sample pH results were within a range of 6 to 9 Standard Units (SU). Exceedances of effluent limits or outside the water quality criteria for Alaska were observed. These were sometimes associated with high BOD or ammonia levels. Exceedances of ADEC General Permit limits were rare with AWTS treatment—only nine exceedances out of nearly 2500 results. For small cruise ships there was more variability in pH from grey water compared with treated sewage or mixed wastewater.

Specific Conductance

Specific conductance is higher on ships that use seawater for flush water or as part of the treatment process. Ferries had a higher average than Juneau harbor. High results on AWTS ships were usually the result of a valve failure of the discharge system allowing seawater intrusion into the sample port.

Table 11 Specific Conductance By Ship and Treatment Type

Specific conductance (priority samples)	**µmhos/cm**		
	# samples	**Average**	**Std Dev**
Harbor Seawater (Juneau 2016)	24	27,623	4,839
AWTS GW (2002-2019)	97	914	1,772
Large ship GW non-AWTS (2000-2001)	140	3,100	6,213
AWTS mixed WW (2002-2019)	660	1,935	4,502
Large sewage and mixed WW non-AWTS (2000-2002)	10	19,507	13,295
Small GW chlorine treated (2001-2019)	78	1,268	1,743
Small GW untreated (2001-2019)	113	508	865
Small BW (2001-2019)	239	24,701	12,403
Small mixed (2001-2019)	79	15,441	13,848
Ferry mixed (2001-2019)	160	29,274	8,364

Chlorine (free and total)

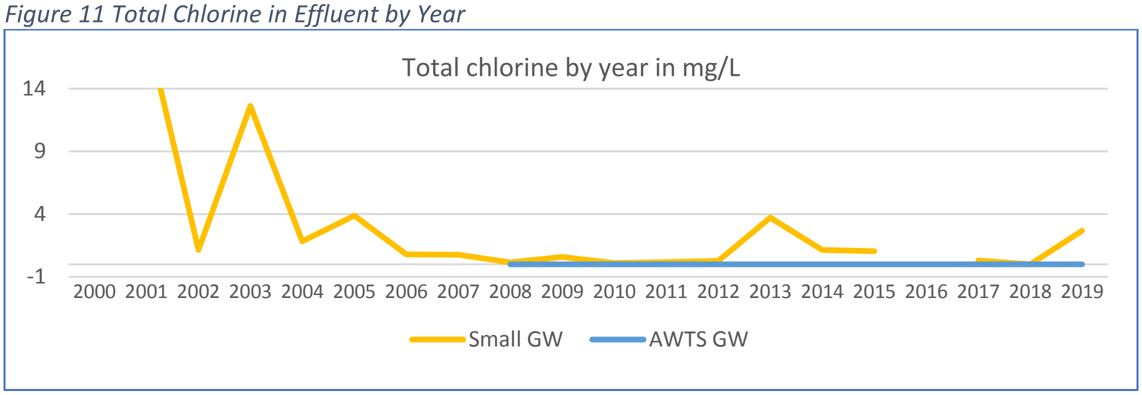
Chlorine is a concern due to the toxicity on marine life and the formation of hazardous chlorine byproducts. Chlorine is used to disinfect wastewater in many traditional sewage treatment devices, so the levels of chlorine and the reaction time are critical to disinfect wastewater. Several small ships add chlorine to tanks to disinfect grey water. Chlorine can be neutralized with substances such as ascorbic acid or sodium bisulfate prior to discharge.

Table 12 Chlorine Averages by Ship and Treatment Type

Chlorine	Total chlorine (mg/L)			Free chlorine (mg/L)		
	# samples	Average	Std Dev	# samples	Average	Std Dev
AWTS GW (2008-2019)	438	0	0	438	0	0.01
Large ship GW non-AWTS (2000-2001)	100	2.2	9.4	50	0.9	4.3
AWTS mixed WW (2008-2019)	2038	0	0.02	2023	0	0.01
Large sewage and mixed WW non-AWTS (2000-2002)	125	3.6	13	15	1	2
Small GW (2001-2019)	240	4.3	24.9	225	3.2	18.7
Small GW chlorine treated (2001-2019)	84	8.6	35.6	81	6.0	26.2
Small GW untreated (2001-2019)	153	2.0	16	141	1.6	12.7
Small BW (2001-2019)	247	3.8	11.5	245	2.1	8.7
Small mixed (2001-2019)	109	3.4	10.7	103	1	7
Ferry mixed (2001-2019)	178	3.4	5.7	177	1.9	3.5

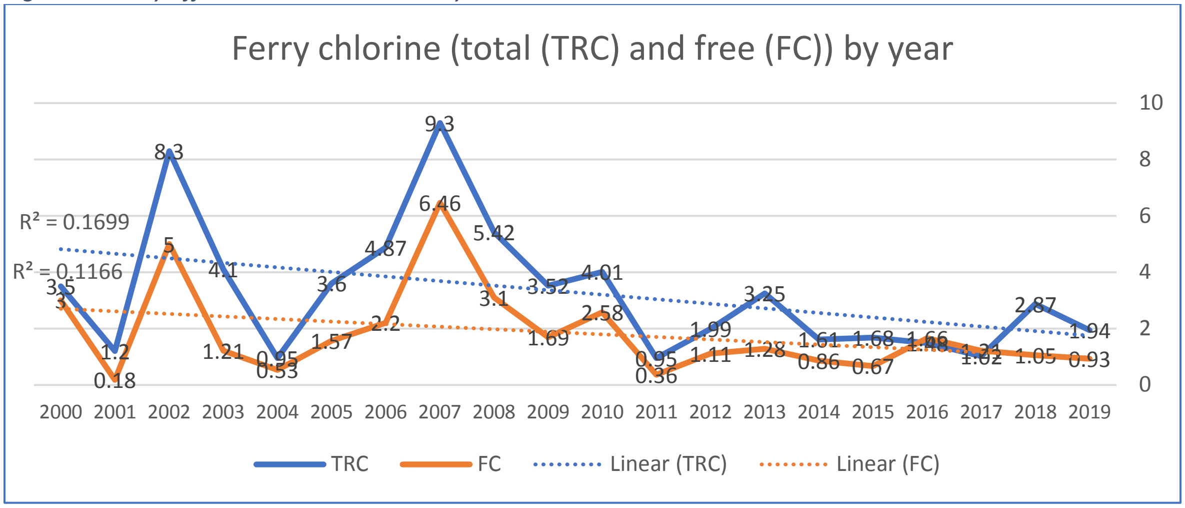
AWTS treatment has dramatically reduced chlorine levels in treated sewage and grey water. Chlorine is not used to disinfect, so any present is from cleaning chemicals or drinking water. The chlorine levels measured on small cruise ship grey water is also lower after the implementation of regulations requiring BMPs in 2004.

Figure 11 Total Chlorine in Effluent by Year



Ferry chlorine levels are lower due to implementation of de-chlorination chemicals added to the effluent and increased monitoring of chlorine and adjustments by crew.

Figure 12 Ferry Effluent Chlorine Results by Year



Bacteria

ADEC and USCG have required fecal coliform as a passenger vessel sampling requirement in Alaska. Most bacteria data is of fecal coliform, but US EPA also requires *E. Coli* to be included, and has sampled for other types of bacteria. Initial sampling by ADEC, USCG, and EPA showed high levels of bacteria from grey water and sewage treatment plant effluent. The results led to the development of federal and state wastewater requirements, and vessel operators to install AWTS on large passenger vessels. Sample results of fecal coliform and *E Coli* have demonstrated a substantial reduction by the use of AWTS to treat sewage and grey water.

For samples with fecal coliform results that were listed as "too numerous to count" (TNTC), the result of 2,400 was substituted for AWTS units, and 240,000 was used for non-AWTS systems. This was based on the average dilutions used. Samplers used multiple dilutions chosen based on past ship sample results. AWTS are expected to have a lower value so different dilutions are often used compared with general MSD II. These substituted values are likely a minimum of what the actual value would have been.

Fecal coliform

Table 13 Fecal Coliform Results from Discharged Wastewaters

Fecal coliform of discharges (FCU/100ml)	Geomean	Average	# samples
AWTS GW (2008-2019)	1.23	8	434
Large ship GW non-AWTS (2000-2001)	2,622	1,972,835	144
AWTS mixed BW and GW (2008-2019)	1.4	7	2039
Large ship BW and GW mixed non-AWTS (2000-2002)	2,736	1,985,672	104
Large ship BW only non-AWTS (2000-2002)	2,355	1,941,013	96
Small BW (2001-2019)	1,926	2,024,870	245
Small mixed BW and GW (2001-2019)	16,295	4,144,352	112
Ferry mixed BW and GW (2001-2019)	179.3	1,888,836	179
Small GW chlorine treated (2001-2019)	69.5	71,222	86
Small GW untreated (2001-2019)	818.3	447,003	150
Small ship galley water (ADEC)	119	30,817	19
Small ship grey water with galley water (ADEC)	387	318,827	174

Fecal coliform of discharges (FCU/100ml)	Geomean	Average	# samples
Small ship accommodation grey water (ADEC)	193	60,560	63

Table 14 Untreated Fecal Coliform Results by Type of Influent

Fecal coliform of influent (FCU/100ml)	Geomean	Average	# samples
Domestic (onshore) raw sewage (EPA, 2011)		10,000 to 100,000	NA
Mixed sewage and grey water (EPA 2004)	43,132,467	104,135,500	20
Mixed or unknown large ship grey water sources (ADEC)	21,619	2,562,940	93
Accommodations grey water (EPA 2004)	1,131,760	19,197,865	17
Accommodations large grey water (ADEC 2000-2002)	3,627	680,360	41
Galley large ship grey water (ADEC 2000-2002)	2,994	1,274,509	50
Galley grey water (EPA 2004)	804,581	38,523,060	15
Food pulper wastewater (EPA 2004)		116,500	3
Laundry wastewater (EPA 2004)	185	7,150	12
Laundry large (ADEC 2000-2002)	112	249,854	21

Fecal Coliform Changes over Time

Large cruise ship fecal coliform results improved with the introduction of AWTS treatment. Most AWTS samples do not detect this group of bacteria. Small cruise ship and ferry-treated sewage and sewage mixed with grey water treated by a MSD have shown some improvements. This has been the primary focus on improvements by ship operators. Small cruise ship grey water is either untreated grey water or treatment with chlorine only, and does not show an overall improvement trend.

Table 15 Fecal Geometric Mean by Year in FCU/100ml

	Ferries Mixed	Small Mixed	Small BW	Small GW	AWTS GW	AWTS Mixed
2000	5.0		15.8			
2001	762.9	1,320,771	4,731	84.7		
2002	438.0	27,749	9,556	382.3		
2003	14,416.9	168,566	1,364	48.1		
2004	1,308.1	73,9857	11,611	1,089.5		
2005	370	2,066,613	10,030	1,084.3		
2006	598.8		84,859	1,167.4		
2007	69.5	386,226	3647	116.8		
2008	149.5	8,088	639.7	227.3	1.3	1.24
2009	109.2	240,000	73.6	1,029.6	1	1.16
2010	192.4		190.1	264.0	1.27	1.53
2011	27.0	25,430	74.2	10.0	1	1.5
2012	33.0	6,057	48.5	1,306.8	1.49	1.52
2013	47.4	3,917	3244	2,134.9	1.23	1.52
2014	874.6	2,968	4737	111.7	1.13	1.37
2015	43.2	6,570	1349	174.7	1.39	1.59
2016	134.1	2,733	2.0		1.16	1.41
2017	59.5	13,167	4976	4,981.1	1.08	1.34
2018	13.1	5,592	178.3	19,6225	1.56	1.3
2019	31	411.7	24.2	382.8	1.07	1.5

Figure 13 Fecal Coliform Effluent Geometric Mean by Year

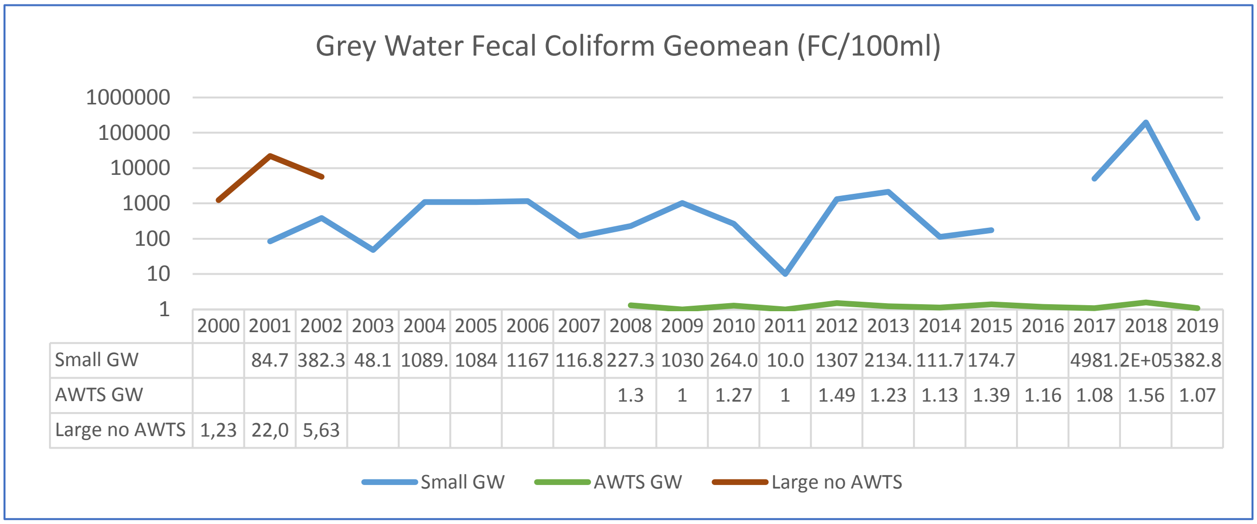
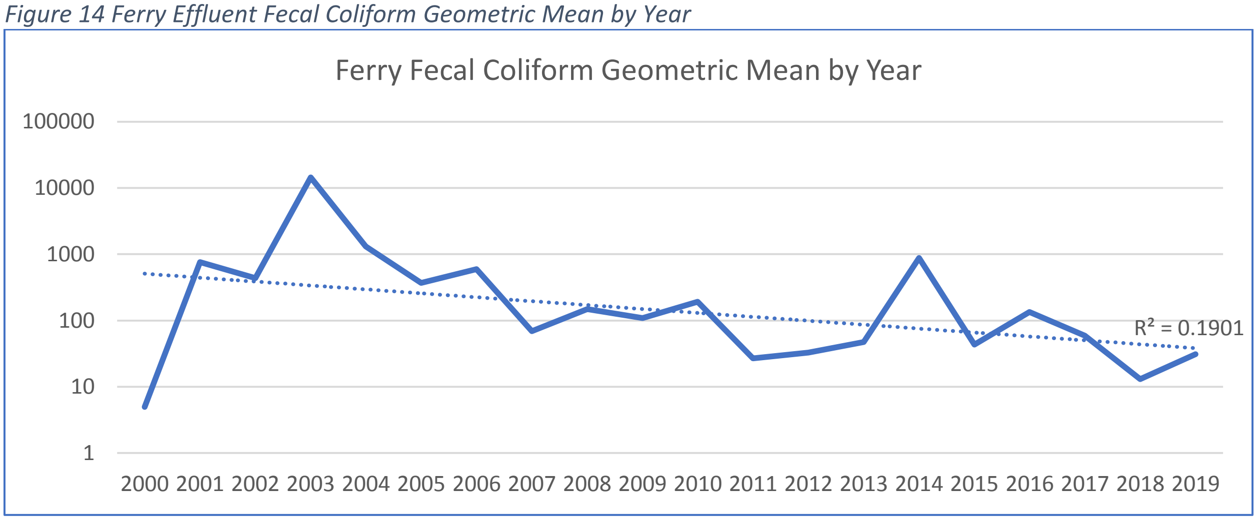


Figure 14 Ferry Effluent Fecal Coliform Geometric Mean by Year



Wastewater held in tanks

Initial sampling of holding tanks showed higher levels of bacteria in sewage even in treated sewage. This led to an ADEC requirement that stored treated wastewater must be sampled if discharged separately from directly discharged effluent from the treatment system. Grey water in tanks had lower bacteria levels on average, which may be from substances such as laundry chemicals that would be toxic to bacteria. Other sources of grey water may have rapid growth of bacteria if stored in tanks, particularly if food waste is present.

Table 16 Wastewater Sampling of Holding Tanks 2000-2002

Wastewater type	# samples	Geomean	Average
Blackwater in tanks	9	1,025,411	7,233,333
Blackwater not from tanks	97	1577	1,296,563
Grey water in tanks	154	2,939	1,526,913
Grey water not from tanks	88	5,061	1,644,429

E. coli

Only data directly reported to ADEC is presented here. Additional sample data for ships is available in annual reporting by ships accessed at the EPA 2013 VGP eNOI Vessel Search System.

EPA also collected data in 2009 with sampling in Alaska of non-passenger small vessels—this is included in the tables below as a comparison. Results are in the same range as untreated grey water sampled by EPA in 2004.

Table 17 E coli Sample Results

E. coli results summary	# samples	Geomean	Max
AWTS Mixed (2015-2019)	189	1.59	>2400
AWTS GW (2015-2019)	47	1.32	47
EPA 2004 Galley	15	193,869	12,200,000
EPA 2004 Laundry	12	4	7,700
EPA 2004 Accommodations GW	17	14,660	535,000
EPA 2004 Mixed Influent	20	8,240,496	87,600,000
EPA 2009 Grey Water Under 79 ft	8	110,000*	660,000

* Average

Enterococci

The only passenger vessel sample data available from ADEC for *Enterococci* was from EPA 2004 sampling. Results are similar to other bacteria testing with highest levels from mixed grey water and sewage and galley wastewaters.

Table 18 EPA Enterococci Results

Enterococci results summary	# samples	Geomean	Max
EPA 2004 Galley	15	8,938	1,600,000
EPA 2004 Laundry	12	9	1,210
EPA 2004 Accommodations GW	17	308	1,800
EPA 2004 Mixed Influent	20	1,587,222	36,500,000
EPA 2009 Grey Water Under 79 ft	8	40,000*	240,000

* Average

Non-cruise ship bacteria results

EPA sampled for grey water bacteria on eight small vessels (under 79 feet) in 2009. The selected vessels included five tugboats, a recreational boat, a shrimper, and a water taxi. Average bacteria levels are lower than some grey water sources on passenger vessels sampled in Alaska. These discharges are direct with likely no holding time for bacteria levels to increase.

Table 19 2009 EPA Small Vessels Grey Water Bacteria

Parameter	Units	Samples	Detected	Maximum	Average
Fecal coliform	CFU/100ml	8	7	570,000	200,000
E. Coli	MPN/100ml	8	7	660,000	110,000
Enterococci	MPN 100ml	8	7	240,000	40,000

Oxygen Demand

Grey water contains higher BOD and COD on average than untreated shoreside domestic sewage as reported by EPA. AWTS-treated wastewater has significantly reduced BOD and COD compared with untreated grey water and treatment by traditional sewage treatment plants. These treatment systems are required to meet US EPA secondary treatment standards that include 85% reduction of BOD and relatively low daily and monthly limits. BOD results for small passenger vessels remain high on average.

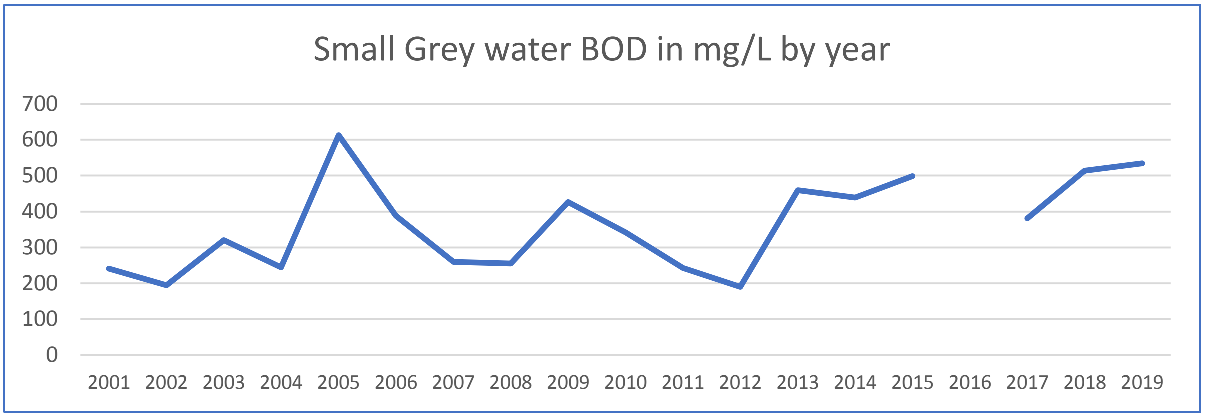
Table 20 BOD and COD by Ship Type and Treatment

Oxygen Demand	BOD 5 Day (mg/L)			COD (mg/L)		
	# samples	Average	Std Dev	# samples	Average	Std Dev
Domestic Sewage (EPA)		**110 to 400**			**200 to 780**	
AWTS GW (2008-2019)	434	7.4	27.2	95	37.5	37.3
Large ship GW non-AWTS (2000-2001)	252	835	2,560	254	1,819	5,897
AWTS mixed WW (2008-2019)	1989	6.95	15.4	657	72.7	105.2
Large sewage and mixed WW non-AWTS (2000-2002)	66	234	301	66	471	988
Small GW (2001-2019)	240	339	459	221	763	2,223
Small galley only GW (2001-2019)	18	549	816	16	515	595
Small BW (2001-2019)	247	199	485	236	898	925
Small mixed (2001-2019)	109	410	501	90	913	775
Ferry mixed (2001-2019)	173	112	85	165	787	1,161

Table 21 BOD and COD from Untreated Sources

Oxygen Demand by untreated source (EPA 2004)	BOD 5 Day (mg/L)			COD (mg/L)		
	# samples	Average	Std Dev	# samples	Average	Std Dev
Domestic Sewage (EPA)		**110 to 400**			**200 to 780**	
EPA Mixed BW & GW Influent	19	649.4	265	20	1,293	768
EPA Accommodations GW	16	177.4	93.2	17	434.9	404
EPA Galley GW	16	9,078	16,947	17	7,678	13,848
EPA Laundry	12	90.3	26.2	13	261.5	115
EPA Food Pulper	4	30,490	24,770	4	26,413	20120

Figure 15 Small Cruise Ship BOD Average by Year



BOD from Dairy Products

Several ships identified dairy products as the possible source for extremely high BOD levels. Dairy products contain a high concentration of carbohydrates and fats, resulting in high levels of BOD and nutrients (EPA, 1974).

	BOD	Units
Whole milk	103,900	mg/kg
Light creamer	243,900	mg/kg

Source: Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Dairy Product Processing May 1974, US EPA Washington DC 20460

BOD and Nutrients in Food Waste

Food waste and galley wastewater containing food waste contain high levels of nutrients and solids. This has been observed in galley water results from ADEC sampling. EPA in 2004 sampled water directly from the galley before mixture with other wastewater. The highest levels of BOD were from the food pulper wastewater.

Table 22 EPA 2004 Grey Water Sample Data, Food Pulper Wastewater

Vessel	BOD	COD	TSS	*E. coli*	*Enterococci*	Fecal coliform	Hexane Extractable Material	Total Organic Carbon	Total Phos-phorus	Settable Residue
Units	mg/L	mg/l	mg/L	MPN/100ml		CFU/100ml	mg/l	mg/l	mg/l	ml/l
1	50,200	25,300		100,000	1,600,000	100,000		77500	371	1000
2	17,300	51,400	19,800	1,220,000	19,600	79,500	5,010	5370	46	900
3	52,300	26,800	29,400	24,200	24,200	170,000	688	1560	308	1000
4	2,160	2,150	242				0	848	17.7	10
Average	30,490	26,413	16,481	448,067	547,933	116,500	1,899	21,320	185.7	727.5
Geomean				143,458	91,214	110,562				

No results

Some bacteria results are averaged on same day

Non-detects set to zero or ND

Composite sampling, grab for pathogens

Nutrients

Nutrients such as phosphorus and nitrogen are present at high levels in galley grey water and sewage. Treatment methods used in Alaska other than AWTS do not appear to be effective at reducing the environmental impact of nutrients into nearshore waters. Some ships avoid discharging grey water and treated sewage when near shore to reduce the impact.

Table 23 Phosphorus and Organic Carbon by Ship Type and Source

	Phosphorus (mg/L)			Total Organic Carbon (mg/L)		
	# samples	Average	Std Dev	# samples	Average	Std Dev
AWTS GW (2002-2019)	95	0.5	1.2	95	9.2	8.1
Large ship GW non-AWTS (2000-2001)	59	8.8	10.3	59	585.3	953.1
AWTS mixed WW (2002-2019)	655	5.1	6.9	614	25.8	54.9
Large sewage and mixed WW non-AWTS (2000-2002)	4	4.0	2	4	123.5	72
EPA galley GW (2004)	17	64.9	105.5	17	333	18,640
Small GW (2001-2019)	180	4.6	12.2	178	292	1,286
Small galley only GW (2001-2019)	14	12.6	22.6	15	171	352.2
Small BW (2001-2019)	186	8.4	10.9	185	127.2	355.5
Small mixed (2001-2019)	66	9.7	13.9	60	156.2	190.1
Ferry mixed (2001-2019)	144	2.9	2.9	144	83.7	117.2

Total nitrogen is not a reported parameter. It can be calculated by adding the measured components of total nitrogen (TKN and nitrate-nitrite).

Table 24 Total Nitrogen Components by Ship Type and Source

	TKN (mg/L)			Nitrate/Nitrite (mg/L)		
	# samples	Average	Std Dev	# samples	Average	Std Dev
AWTS GW (2002-2019)	95	3.2	4.9	66	1.9	4.8
Large ship GW non-AWTS (2000-2001)	58	32.0	63.8	23	0.1	0.1
AWTS mixed WW (2002-2019)	647	38.6	42	538	6.2	18.9
Large sewage and mixed WW non-AWTS (2000-2002)	4	22.9	11	4	1.3	1
Small GW (2001-2019)	180	23.4	88.3	178	1.5	16.2
EPA galley influent GW (2004)	17	75.9	87.1	17	0.1	0.2
Small galley only GW (2001-2019)	15	50.3	161.1	15	0.3	0.9
Small BW (2001-2019)	185	82.4	142.7	182	31.8	240.7
Small mixed (2001-2019)	66	58.7	55	62	0.5	1.4
Ferry mixed (2001-2019)	146	23.1	26.1	128	1	2.8

Ammonia

Ammonia is sampled both as a component of total nitrogen and because of its potential toxicity to marine life. Ammonia became a parameter of concern in the ADEC General Permit because of sample results much higher than water quality criteria. The water quality criteria vary by temperature, salinity, and pH. The value of 1 mg/L as the chronic water quality limit before accounting for mixing zone was established in the ADEC General Permit.

Table 25 Ammonia by Source and Ship Type

Ammonia in mg/L by source and treatment	# samples	Average	Std Dev
Domestic Sewage (EPA)		**12 to 50**	
AWTS GW (2008-2019)	423	2.3	9.3
Large ship GW non-AWTS (2000-2001)	157	3.6	9.1
AWTS Mixed WW (2008-2019)	1576	35	31
Large sewage and mixed WW non-AWTS (2000-2002)	60	115.6	153

Ammonia in mg/L by source and treatment	# samples	Average	Std Dev
EPA galley influent GW (2004)	17	7.6	15
EPA accommodation influent GW (2004)	17	0.2	0.3
EPA laundry influent GW (2004)	13	0.7	1.5
EPA BW and GW influent (2004)	20	40.3	44
Small ship grey water (2001-2019)	225	11.4	60
Small galley only GW (2001-2019)	17	35.6	121
Small BW (2001-2019)	228	58.5	119.3
Small mixed (2001-2019)	89	37	38.4
Ferry mixed (2001-2019)	163	10.5	11.4

On passenger vessels the lowest amount of ammonia is usually found in accommodation and laundry grey water. High levels have been reported in holding tanks with mixed sewage and grey water. Human waste and biological treatment of wastewater are likely the largest sources of ammonia.

Some large cruise ships have reduced ammonia results by discharging only treated accommodations grey water while stationary. This is done to meet ADEC stationary discharge limits. Mixed sewage and accommodation grey water are treated by these ships but discharged only while underway where ADEC limits are higher. Galley and laundry grey water on large cruise ships in Alaska is often either discharged offshore or to onshore treatment facilities.

Ammonia can interfere with the process of disinfection by chlorine. A study completed for ADEC on chlorine decay from small cruise ships listed this as a possible reason for poor MSD performance on disinfections (ADEC, 2006). It is difficult to determine if the poor performance in non-AWTS is due in part to ammonia, or due to high amounts of solids and other process failures.

Solids

TSS is a parameter measured as an indicator for solids treatment. It is measured at almost every sample event. Settleable solids are not monitored as frequently but can be a very useful indicator of treatment by filtration, separation, or grinding of solids.

AWTS systems remove most TSS and settleable solids. These systems must meet EPA secondary treatment standards that require the removal of 85% of solids. Pre-screening prior to AWTS treatment removes solids such as toilet paper. These solids are dried and usually incinerated onboard. Nearly all AWTS sample results are below the daily maximum limit of 150 mg/L.

Small passenger vessels often have only basic screening for large solids. These ships grind solids to assist with the disinfection process and eliminate the potential for discharge of floating or large solids. It is possible for this process to break down. On ferries, for example, the grinding equipment has been replaced due to damage by hard solids.

Large cruise ships before the installation of AWTS units had relatively high levels of TSS and settleable solids—higher than the averages for small passenger vessels. This indicated that the original treatment systems installed at the time were not successfully at treating for solids.

Figure 16 Total Suspended Solids Grey Water Compare of AWTS with Small Passenger Ships

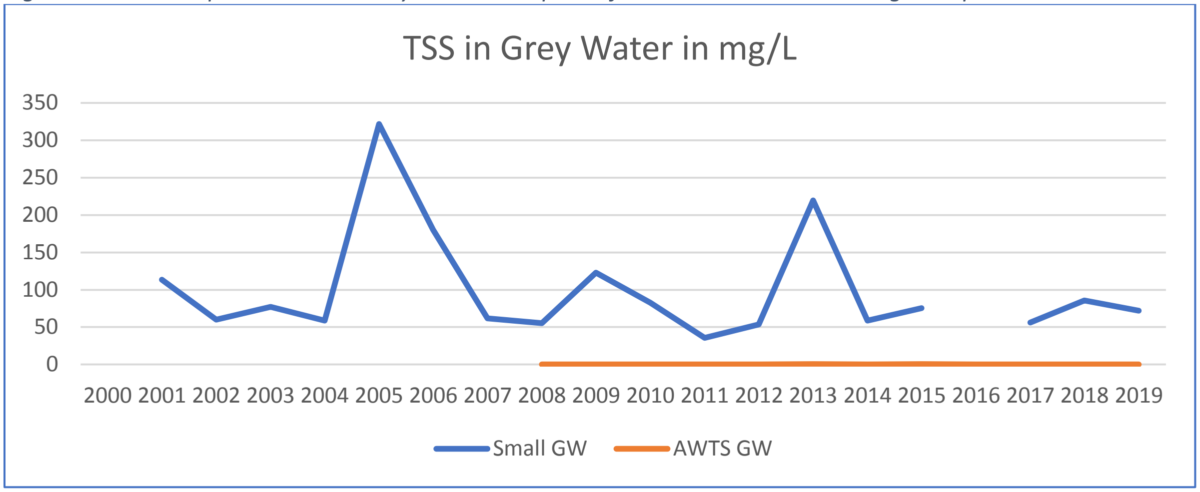


Table 26 Solids by Ship and Treatment type

Solids by Ship or Treatment Type	Suspended solids			Settleable solids		
	# samples	Average	Std Dev	# samples	Average	Std Dev
Domestic Wastewater (EPA)		**120 to 360**				
AWTS GW (2008-2019)	435	0.17	1.7	95	0	0
Large ship GW non-AWTS (2000-2001)	251	649.5	2730	58	0.47	70.1
AWTS Mixed WW (2008-2019)	1990	2.7	10.5	647	0.07	0.9
Large sewage and mixed WW non-AWTS (2000-2002)	66	471	533	4	2	3.8
Small BW (2001-2019)	249	235.2	717.3	77	8.0	22.2
Small mixed (2001-2019)	109	237.8	409.6	230	3.7	14.3
Small GW (2001-2019)	244	110	255.9	190	3.12	30.3
Ferry mixed (2001-2019)	174	83.1	86.8	153	1.5	6.9

Table 27 Solids by Wastewater Source

Solids by Source EPA 2004	Suspended solids			Settleable solids		
	# samples	Average	Std Dev	# samples	Average	Std Dev
EPA BW & GW Influent	20	686.1	352.9	19	36.3	28.2
Accommodations influent GW	17	108.2	95	16	1.6	3.7
Galley influent GW	16	3,961	8,306	16	204	381
Laundry influent	13	45.8	20.4	12	1.1	2.2
Food Pulper wastewater	3	16,481	14,860	4	728	481
Small GW galley only (2001-2019)	18	170.5	301.5	16	1.4	2.66
Small GW accommodations ADEC (2001-2019)	63	95.7	215.5	44	0.66	1.85

Oil and Grease

Low levels of oil and grease are reported in AWTS effluent samples from both grey water and sewage. On small passenger vessels and large passenger vessels without AWTS treatment the levels are lower in sewage compared with grey water and mixed grey water and sewage. The highest observed levels are from galley sources. EPA 2004 food pulper wastewater sampling had an average of nearly 1,900 mg/L.

Oil and grease may interfere with wastewater treatment. Some ships have separated the food waste sources and/or galley grey water to improve treatment of other wastewaters. Grease traps are often used to remove galley related greases and fats.

Table 28 Oil and Grease Results

Hexane Extractable Material	mg/L		
	# samples	Average	Std Dev
AWTS GW (2008-2018)	89	3	8.7
Large ship GW non-AWTS (2000-2001)	84	260.6	889
AWTS mixed WW (2008-2018)	610	0.5	2.2
Large sewage and mixed WW non-AWTS (2000-2002)	4	35.5	43
Small GW (2001-2019)	188	26.8	48.8
Small galley only GW (2001-2019)	16	86.4	105.7
EPA galley GW influent (2004)	16	516.6	1,211
Small BW (2001-2019)	201	8.1	14.1
Small mixed (2001-2019)	78	45.9	101.9
Ferry mixed (2001-2019)	150	19.4	91.6

Metals

ADEC identified copper, nickel, and zinc as parameters of concern due to higher levels relative to water quality standards for dissolved metals. High levels of other metals are occasionally seen on passenger vessels.

For the metals data summarized non-detects were set to zero as the method detection limit was at relatively low levels. Results until 2008 and those after 2008 were compared in the tables below. 2009 was the first year that ships had experience operating in Alaska under both the first ADEC General Permit and the first US EPA VGP, which were issued in 2008.

Metal results have on average been reduced for most metals, as shown comparing data from 2000 to 2008 and after. There has also been a reduction in the percentage of samples with detected results after 2008. There are likely multiple causes for the reduction in metals amounts that have occurred over time.

Changes that may be linked to metals results include:

- 2008 Alaska General Permit with associated limits and source reduction plans.
- EPA 2008 VGP.
- Operators inventoried chemicals used onboard for VGP and ADEC source reduction plans.
- Ocean Rangers fully implemented in 2008 with about 92% coverage of time in Alaska.
- Photo waste and other shop sinks disconnected from drains, regularly checked by Ocean Rangers.
- Lead and mercury have been removed from materials and products over time.
- Several ships had substantial pipe replacements during overhaul, often replacing with plastic.
- Change in ship composition (average ship age) and operations as a result of the 2008 recession. .
- Filtration of sampled metals moved from lab to onboard within 15 minutes in 2010.

Table 29 AWTS Metals Comparison 2002-2008 to 2009-2018

Parameter (µg/L)	AWTS 2009-2018		AWTS 2002-2008		Change	
	% detect	Average	% detect	Average	% detect	Average
Antimony, total	7.7%	0.13	39.7%	0.16	-80.7%	-21%
Antimony, dissolved	14.6%	0.24	37.9%	0.15	-61.5%	54%
Arsenic, total	44.8%	1.73	66.7%	2.40	-32.8%	-28%
Arsenic, dissolved	43.0%	1.62	65.5%	2.08	-34.4%	-22%
Chromium, total	45.8%	1.01	53.4%	2.64	-14.3%	-62%
Chromium, dissolved	48.6%	1.09	66.5%	2.75	-26.8%	-60%
Copper, total	98.3%	17.01	97.7%	22.12	0.6%	-23%
Copper, dissolved	96.5%	10.94	96.6%	17.42	0.0%	-37%
Lead, total	9.2%	0.87	51.1%	1.82	-82.1%	-52%
Lead, dissolved	7.2%	0.11	48.9%	0.81	-85.3%	-86%
Mercury	0.5%	0.002	5.8%	0.02	-91.4%	-92%
Nickel, total	97.5%	12.37	97.1%	13.04	0.4%	-5%
Nickel, dissolved	97.3%	12.19	97.1%	12.69	0.2%	-4%
Selenium, total	62.6%	5.85	50.0%	4.35	25.2%	35%
Selenium, dissolved	62.0%	5.98	47.1%	4.15	31.5%	44%
Silver, total	0.7%	0.02	25.9%	0.21	-97.1%	-90%
Silver, dissolved	0.2%	0	16.1%	0.12	-98.5%	-100%
Thallium, total	3.5%	0.04	13.2%	0.17	-73.8%	-75%
Thallium, dissolved	7.9%	0.18	20.7%	0.34	-61.8%	-47%
Zinc, total	98.5%	80.9	97.6%	96.24	0.9%	-16%
Zinc, dissolved	99.0%	77.8	100.0%	103.89	-1.0%	-25%

Table 30 Small Cruise Ship Metals Comparison 2002-2008 to 2009-2018

Parameter (µg/L)	AWTS 2009-2018		Small 2009-2018		Difference	
	% detect	Average	% detect	Average	% detect	Average
Antimony, total	7.7%	0.13	4.9%	0.07	56.8%	79%
Antimony, dissolved	14.6%	0.24	14.7%	0.24	-0.6%	0%
Arsenic, total	44.8%	1.73	69.2%	24.93	-35.3%	-93%
Arsenic, dissolved	43.0%	1.62	65.7%	21.13	-34.6%	-92%
Chromium, total	45.8%	1.01	51.7%	4.64	-11.5%	-78%
Chromium, dissolved	48.6%	1.09	42.7%	2.14	14.0%	-49%
Copper, total	98.3%	17.01	97.2%	175.83	1.1%	-90%
Copper, dissolved	96.5%	10.94	95.1%	106.36	1.5%	-90%
Lead, total	9.2%	0.87	49.7%	2.64	-81.5%	-67%
Lead, dissolved	7.2%	0.11	18.2%	0.53	-60.6%	-79%
Mercury	0.5%	0.002	4.2%	0.02	-88.3%	-90%
Nickel, total	97.5%	12.37	82.5%	11.55	18.2%	7%
Nickel, dissolved	97.3%	12.19	76.2%	10.84	27.6%	12%
Selenium, total	62.6%	5.85	69.2%	73.22	-9.5%	-92%
Selenium, dissolved	62.0%	5.98	62.9%	60.35	-1.5%	-90%
Silver, total	0.7%	0.02	2.8%	0.03	-73.5%	-30%
Silver, dissolved	0.2%	0	0.7%	0	-64.7%	0%
Thallium, total	3.5%	0.04	2.1%	0.14	65.2%	-70%
Thallium, dissolved	7.9%	0.18	6.3%	0.13	25.5%	36%
Zinc, total	98.5%	80.9	97.9%	342.13	0.6%	-76%
Zinc, dissolved	99.0%	77.8	96.5%	239.33	2.6%	-67%

Table 31 Small Passenger Vessel Metals, Mixed Grey Water and Sewage

Parameter (µg/L)	Small 2009-2018		Small 2001-2008		Difference	
	% detect	Average	% detect	Average	% detect	Average
Antimony, total	4.9%	0.07	29.8%	0.26	-83.6%	-73%
Antimony, dissolved	14.7%	0.24	31.4%	0.31	-53.3%	-23%
Arsenic, total	69.2%	24.93	86.5%	28.15	-20.0%	-11%
Arsenic, dissolved	65.7%	21.13	87.2%	27.12	-24.6%	-22%
Chromium, total	51.7%	4.64	86.6%	13.74	-40.3%	-66%
Chromium, dissolved	42.7%	2.14	82.3%	12.93	-48.1%	-83%
Copper, total	97.2%	175.83	100%	251.92	-2.8%	-30%
Copper, dissolved	95.1%	106.36	96.5%	51.74	-1.4%	106%
Lead, total	49.7%	2.64	95.1%	19.11	-47.8%	-86%
Lead, dissolved	18.2%	0.53	68.1%	2.75	-73.3%	-81%
Mercury	4.2%	0.02	8.0%	0.03	-47.4%	-33%
Nickel, total	82.5%	11.55	98.6%	25.36	-16.3%	-54%
Nickel, dissolved	76.2%	10.84	98.6%	19.77	-22.7%	-45%
Selenium, total	69.2%	73.22	79.6%	80.29	-13.0%	-9%
Selenium, dissolved	62.9%	60.35	73.8%	83.54	-14.7%	-28%
Silver, total	2.8%	0.03	36.4%	0.56	-92.3%	-95%
Silver, dissolved	0.7%	0	25.9%	0.34	-97.3%	-100%
Thallium, total	2.1%	0.14	10.6%	0.19	-80.3%	-26%
Thallium, dissolved	6.3%	0.13	16.4%	0.14	-61.7%	-7%
Zinc, total	97.9%	342.13	100%	470.39	-2.1%	-27%
Zinc, dissolved	96.5%	239.33	97.9%	163.36	-1.4%	47%

Table 32 Large Passenger Vessel No AWTS 2000-2002

Parameter (µg/L)	Large no AWTS GW		Large no AWTS BW	
	% detect	Average	% detect	Average
Antimony, total	34.9%	0.3	0.0%	0
Antimony, dissolved	78.3%	0.9	100.0%	25
Arsenic, total	51.2%	5.4	8.7%	3
Arsenic, dissolved	95.7%	10.2	100.0%	36.4
Chromium, total	72.1%	8.1	39.1%	6.4
Chromium, dissolved	100.0%	6.5	100.0%	9.8
Copper, total	100.0%	386	100%	838
Copper, dissolved	100.0%	67.8	100.0%	11.7
Lead, total	79.1%	21.8	30.4%	5.2
Lead, dissolved	91.3%	6.2	0.0%	0
Mercury	7.1%	0.03	30.4%	0.13
Nickel, total	76.7%	38.4	26.1%	15.2
Nickel, dissolved	100.0%	18.3	100.0%	23.4
Selenium, total	51.2%	12.4	8.7%	11.3
Selenium, dissolved	100%	23.3	100%	150
Silver, total	53.5%	0.89	39.1%	0.5
Silver, dissolved	39.1%	0.34	50.0%	3.4
Thallium, total	14.3%	0.04	0.0%	0
Thallium, dissolved	36.4%	0.2	0.0%	0
Zinc, total	97.3%	898	100%	496
Zinc, dissolved	100.0%	367	50.0%	17.2

Table 33 Small Passenger Vessel by Wastewater and Ship Type

Parameter (μg/L)	Small GW only		Small Mixed BW&GW		Ferries	
	% detect	Average	% detect	Average	% detect	Average
Antimony, total	21.2%	0.2	15.7%	0.2	13.8%	0.1
Antimony, dissolved	36.9%	0.4	23.5%	0.4	14.9%	0.1
Arsenic, total	53.7%	1.9	76.5%	17.6	85.1%	37
Arsenic, dissolved	52.2%	3.1	76.5%	17.3	82.8%	29.7
Chromium, total	76.1%	4	66.7%	11.7	60.9%	8.4
Chromium, dissolved	66.7%	3.2	66.7%	4.9	55.2%	5.7
Copper, total	100.0%	184.2	94%	210	100.0%	231
Copper, dissolved	98.5%	63.8	90.2%	50	98.9%	96.3
Lead, total	94.0%	17.6	72.5%	8.3	58.6%	10
Lead, dissolved	65.7%	2.1	39.2%	1.4	27.6%	1
Mercury	6.2%	0.01	4.0%	0	3.5%	0
Nickel, total	91.0%	10.9	88.2%	12.1	90.8%	17.6
Nickel, dissolved	89.6%	12.8	82.4%	9.1	83.9%	16.4
Selenium, total	64.2%	6.6	72.5%	51.4	79.3%	114
Selenium, dissolved	44.8%	9.7	66.7%	53.2	77.0%	94
Silver, total	23.1%	9.7	5.9%	0.1	13.8%	0.2
Silver, dissolved	10.8%	0.2	5.9%	0.1	9.2%	0.1
Thallium, total	12.1%	0.3	3.9%	0.1	5.7%	0
Thallium, dissolved	18.2%	0.2	5.9%	0	6.9%	0.1
Zinc, total	100.0%	470	98%	772	97.6%	127
Zinc, dissolved	98.5%	199	98.0%	334	94.3%	0.85

Cyanide

Cyanide was only briefly included in sampling lists. ADEC and EPA identified some relatively high individual sample results with no known source. ADEC in 2004 identified cyanide as a parameter to measure in the future but the parameter was dropped from the sampling requirements.

EPA 2004 cyanide sample data was not included. The data in the sampling reports did not use consistent units. Some results reported by EPA may include conversion errors.

Table 34 Total Cyanide Results

	Total Cyanide (μg/L)			
Cyanide by Ship Type and Source	# samples	% Detect	Average	Max
Large ship GW non-AWTS (2000-2001)	19	5.3%	0	0.02
Large sewage and mixed WW non-AWTS (2000-2002)	21	33.3%	11.5	73

Priority Pollutants

Priority pollutants include some substances that are toxic to marine life or that could harm human health. Sample results reported occasional high levels of priority pollutants although the majority of parameters are not detected in grey water from passenger vessels in Alaska. The tables below provide information on the frequency of detection of selected priority parameters and the maximum level reported by ship type.

Table 35 Selected Priority Pollutants % Detection and Maximum Large Cruise Ships in μg/L

	AWTS GW		AWTS Mixed		Large GW no AWTS		Large BW no AWTS	
Parameter (μg/L)	%	Max	%	Max	%	Max	%	Max
1,2,4-trichlorobenzene	0%	0	0.4%	0.65	4.6%	8.8	0%	0
1,2,4-trimethylbenzene	2.5%	2.5	0.8%	1.7	13.6%	8.8	0%	0
1,4-dichlorobenzene	0%	0	2.2%	7.1	3.1%	11	9.8%	350
2,4-dichlorophenol	0%	0	3.4%	4.8	0%	0	0%	0
2-butanone (methyl ethyl ketone)	0%	0	7.7%	98	10.8%	390	0%	0
2-Methylphenol	0%	0	0.2%	1.1	0.0%	0	0%	0
3/4-Methylphenol	15%	24	6.3%	860	81.8%	160	50%	21
4-isopropyltoulene	1.3%	1.7	0.2%	1.4	45.5%	16	0%	0
4-methyl-2-pentanone	0%	0	2.0%	8.2	13.6%	8.5	0%	0
Acrylonitrile	1.3%	1.1	0.2%	17	3.1%	1	0%	0
Benzene	0%	0	0%	0	0%	0	0%	0
Bis(2-ethylhexyl) phthalate	1.3%	8.7	4.8%	13	60%	120	26.2%	11
Carbon disulfide	1.3%	0.6	0.8%	4.8	13.6%	4.8	3.3%	8.1
Carbon tetrachloride	0%	0	0%	0	6.2%	1.8	18%	27
Diethyl phthalate	7.5%	19	4%	15	58.5%	28	9.8%	5.8
Dimethyl phthalate	1.3%	0.94	0.8%	9.4	3.1%	2.3	0%	0
Di-n-butyl phthalate	5%	16	6.3%	17	41.5%	34	21.3%	9.8
Ethylbenzene	3.8%	2.4	0.6%	1.1	23.1%	24	9.8%	3.6
m&p Xylene	5.0%	13	2.6%	11	72.7%	52	100%	1.6
Naphthalene	0%	0	0.8%	4.3	4.6%	42	0%	0
o-Xylene	3.8%	2.8	1.2%	2.5	59.1%	15	50%	0.84
Phenol	6.3%	12	6.7%	23	13.8%	4.3	9.8%	250
Styrene	2.5%	0.93	0%	0	4.5%	0.55	0%	0
Tetrachloroethane	0%	0	1.8%	29	33.8%	740	3.3%	33
Toluene	10%	6.1	7.1%	23	24.6%	93	4.9%	2.2
Trichloroethene	0%	0	0.4%	2.1	9.2%	9	0%	1.3

Table 36 Selected Priority Pollutants % Detection and Maximum Small Passenger Vessels in μg/L

	Small ship GW		Small & ferries mixed WW		Small BW	
Parameter (μg/L)	%	Max	%	Max	%	Max
1,2,4-trichlorobenzene	1.4%	1.3	0%	0	6.2%	5
1,2,4-trimethylbenzene	7.1%	15	1.5%	1.1	0.0%	0
1,4-dichlorobenzene	1%	0.27	1.5%	2	2.5%	62
2,4-dichlorophenol	1.4%	34	0.7%	1.1	1.2%	0.5
2-butanone (methyl ethyl ketone)	12.9%	46	8%	14	6.2%	26
2-Methylphenol	1.4%	0	2.9%	530	4.9%	800
3/4-Methylphenol	31.4%	360	34.3%	4400	34.6%	3000
4-isopropyltoulene	4.3%	1.8	2.2%	4.1	3.7%	3.3
4-methyl-2-pentanone	0%	0	0%	0	0.0%	0
Acrylonitrile	1.4%	9.1	0%	0	0.0%	0
Benzene	0.0%	0	2.9%	2.6	2.5%	0.51
Bis(2-ethylhexyl) phthalate	61.4%	120	27.7%	390	16.0%	63
Carbon disulfide	4.3%	6.2	13.1%	8.1	13.6%	220
Carbon tetrachloride	4.3%	9.9	0%	0	7.4%	240
Diethyl phthalate	40%	130	19.7%	35	8.6%	17
Dimethyl phthalate	0%	0	0%	0	0.0%	0
Di-n-butyl phthalate	10%	8.9	9.5%	17	7.4%	11
Ethylbenzene	5.7%	64	7.3%	11	8.6%	8.2
m&p Xylene	10%	37	13.1%	28	13.6%	32

	Small ship GW		Small & ferries mixed WW		Small BW	
Parameter (µg/L)	%	Max	%	Max	%	Max
Naphthalene	1.4%	1.5	2.2%	46	0.0%	0
o-Xylene	7.1%	15	5.8%	14	8.6%	10
Phenol	12.9%	150	21.2%	200	35.8%	2000
Styrene	2.9%	32	0.7%	0.16	0.0%	0
Tetrachloroethane	4.3%	1100	2.2%	3.8	1.2%	5.8
Toluene	14.3%	73	10.9%	21	7.4%	2.2
Trichloroethene	1.4%	17	2.2%	8.5	2.5%	19

Table 37 Selected Toxic Priority Pollutants Before and After 2008 in AWTS Effluent in µg/L

	AWTS 2008-2018		AWTS 01-07		Change	
Parameter (µg/L)	%	Max	%	Max	%	Max
1,2,4-trichlorobenzene	0.5%	0.65	0%	0	100%	0.65
1,2,4-trimethylbenzene	0.0%	0	3.3%	1.7	-100%	-1.7
1,4-dichlorobenzene	1.4%	1.2	4.9%	7.1	-72%	-5.9
2,4-dichlorophenol	1.4%	2.5	9.8%	4.8	-86%	-2.3
2-butanone (methyl ethyl ketone)	4%	98	17.9%	87	-76%	11
2-Methylphenol	0%	0	0.8%	1.1	-100%	-1.1
3/4-Methylphenol	4.6%	79	13.8%	860	-67%	-781
4-isopropyltoulene	0%	0	0.8%	1.4	-100%	-1.4
4-methyl-2-pentanone	0%	0	8.1%	8.2	-100%	-8.2
Acrylonitrile	0.3%	17	0%	0	30%	17
Benzene	0%	0	0%	0	0%	0
Bis(2-ethylhexyl) phthalate	4.3%	8.8	6.5%	13	-34%	-4.2
Carbon disulfide	0.3%	1	2.4%	4.8	-89%	-3.8
Carbon tetrachloride	0%	0	0%	0	0%	0
Diethyl phthalate	2.4%	14	9%	15	-73%	-1
Dimethyl phthalate	0%	0	3.3%	9.4	-100%	-9.4
Di-n-butyl phthalate	4.3%	17	12.2%	3.4	-65%	13.6
Ethylbenzene	0%	0	2.4%	1.1	-100%	-1.1
m&p Xylene	1.1%	11	7.3%	5.3	-85%	5.7
Naphthalene	0%	0	3.3%	4.3	-100%	-4.3
o-Xylene	0%	0	4.9%	2.5	-100%	-2.5
Phenol	11.1%	57	18.7%	630	-41%	-573
Styrene	0%	0	0%	0	0%	0
Tetrachloroethane	0%	0	7.3%	29	-100%	-29
Toluene	4.3%	13	15.4%	23	-72%	-10
Trichloroethene	0%	0	1.6%	2.1	-100%	-2.1
	370 samples		123 samples			

Bis(2-ethylhexyl) phthalate
EPA 2004 sampling reported relatively high levels in wastewater treatment screenings and some levels in food waste.

Tetrachloroethane
This refers to solvent and refrigerant, found in 2004 EPA sample data and 2000-2001 ADEC data. It was not detected in AWTS samples after 2008.

Tetrachloroethylene (tetrachloroethene)
This is the solvent used in dry cleaning, not detected in AWTS samples after 2004. Tetrachlorethylene was reported in one recent small passenger vessel sample event, but not often detected as many do not have dry cleaning onboard.

Chlorine Byproducts and Compounds from Biological Reactions

Chlorine byproducts can form when there is chlorine used to disinfect and organic material in the wastewater. AWTS-treated effluent has lower levels of these compounds due to not using chlorine as a disinfectant.

Table 38 Selected Priority Pollutants % Detection and Maximum Large Cruise Ships in ug/L

	AWTS GW		AWTS Mixed		Large GW no AWTS		Large BW no AWTS	
Parameter (µg/L)	%	Max	%	Max	%	Max	%	Max
3/4-Methylphenol	15.0%	24	6.3%	860	81.8%	160	50%	21
Acetone	22.5%	410	29.5%	430	90.9%	970	100%	22
Benzoic Acid	11.3%	54	6.1%	360	86.4%	900	50%	250
Benzyl Alcohol	11.3%	300	3.2%	48	81.8%	46	50%	3.7
Bromodichloromethane	7.5%	2.2	0.4%	19	55.4%	27	55.7%	190
Bromoform	5%	2.8	1%	21	35.4%	36	54.1%	440
Bromomethane	0%	0	1%	35	55.4%	27	1.6%	7
Chloroethane	0%	0	0%	0	7.7%	41	0%	0
Chloroform	31.3%	28	19.6%	83	80%	780	73.8%	1500
Chloromethane	0%	0	1.6%	31	9.2%	160	16.4%	240
Dibromochloroethane	5%	2.2	0.4%	24	35.4%	64	52.5%	270
Methylene chloride	1.3%	0.6	1.8%	12	18.5%	67	13.1%	42

Table 39 Selected Priority Pollutants % Detection and Maximum Small Passenger Vessels in ug/L

	AWTS GW		Small ship GW		Small & ferries mixed WW		Small BW	
Parameter (µg/L)	%	Max	%	Max	%	Max	%	Max
3/4-Methylphenol	15.0%	24	31.4%	360	34.3%	4400	34.6%	3000
Acetone	22.5%	410	32.9%	400	27.7%	200	28.4%	2100
Benzoic Acid	11.3%	54	35.7%	820	55.5%	2800	40.7%	7700
Benzyl Alcohol	11.3%	300	38.6%	320	16.8%	280	14.8%	570
Bromodichloromethane	7.5%	2.2	40%	26	39.4%	92	28.4%	1700
Bromoform	5%	2.8	22.9%	38	75.2%	460	44.4%	1000
Bromomethane	0%	0	0%	0	6.6%	14	3.7%	11
Chloroethane	0%	0	10%	21	2.9%	66	0.0%	0
Chloroform	31.3%	28	81.4%	2400	48.9%	100	34.6%	1800
Chloromethane	0%	0	12.9%	28	19%	560	12.3%	2100
Dibromochloroethane	5%	2.2	25.7%	41	56.9%	160	39.5%	130
Methylene chloride	1.3%	0.6	11.4%	7.8	13.1%	17	7.4%	150

Whole Effluent Toxicity (WET)

Non-AWTS grey water results showed toxicity to marine life. The suspected cause was high levels of chlorine found in several samples. Laundry chemicals were also pointed to as a possible toxin. In some AWTS samples, ammonia was suspected of causing some level of toxicity for a small number of samples.

ADEC stopped WET sampling after 2006 and resumed it for large cruise ships with stationary discharge in 2017. All data after 2017 is from AWTS effluent. Summary tables of WET results are found in Appendix F.

EPA Small Vessel Grey Water Sampling (2009)

EPA sampled grey water and other wastewaters on vessels with lengths under 79 feet (24.1 meters) (EPA, 2010). Eight vessels were sampled: one water taxi, one fishing boat (shrimper), a recreational boat, and five tug boats. This is a small dataset, but results contribute to limited vessel grey water data. The discharges were mostly directly overboard and intermittent. With direct discharges there would not be much time to for bacteria growth or biological conversion of nutrients. The samples show relatively high levels of BOD but low levels of ammonia.

Table 40 EPA Small Vessels Grey Water Bacteria

Parameter	Units	Samples	Detected	Maximum	Average
Fecal coliform	CFU/100ml	8	7	570,000	200,000
E. Coli	MPN/100ml	8	7	660,000	110,000
Enterococci	MPN 100ml	8	7	240,000	40,000

Table 41 EPA Small Vessels Grey Water Conventional Parameters

Parameter	Units	Samples	Detected	Average	Maximum
Temperature	C	8	8	36	27
pH	SU	8	8	7.4	8.7
Salinity	ppt	6	6	0.4	0.25
Conductivity	mS/cm	7	7	0.43	0.79
Dissolved oxygen	mg/L	7	7	7.4	10
Total residual chlorine	mg/L	8	6	0.12	0.11
Turbidity	NTU	8	8	74	110
Total suspended solids	mg/L	8	8	52	81
Biochemical oxygen demand	mg/L	8	8	430	1,200
Chemical oxygen demand	mg/L	8	8	1,000	4,000
Total organic carbon	mg/L	7	7	140	440
Sulfide	mg/L	8	5	0.017	0.73
Ammonia	mg/L	8	8	1.3	4.5
Nitrate/Nitrite	mg/L	8	7	1.6	2.4
Total Kjeldahl Nitrogen	mg/L	8	8	10	45
Total Phosphorus	mg/L	8	8	1.4	3.4
Hexane extractable material	mg/L	8	8	39	100
Silica treated HEM	mg/L	8	6	8.1	35

Conductivity is reported in different units than ADEC and USCG
Note- The reported average result for total chlorine was higher than the maximum

Table 42 EPA Small Vessels Selected Metals

Parameter	Units	Samples	Detected	Average	Maximum
Arsenic, dissolved	µg/L	8	2	1.9	4.5
Arsenic, total	µg/L	8	2	2	2.9
Chromium, dissolved	µg/L	8	2	1.4	2.2
Chromium, total	µg/L	8	4	2.5	4.9
Copper, dissolved	µg/L	8	8	55	280
Copper, total	µg/L	8	8	100	440
Lead, dissolved	µg/L	8	4	2.5	6.0
Lead, total	µg/L	8	5	7.6	43
Nickel, dissolved	µg/L	8	4	5.5	9.8
Nickel, total	µg/L	8	4	5.9	10
Zinc, dissolved	µg/L	8	8	400	1,500
Zinc, total	µg/L	8	8	890	3,500

Discussion

Sampling Documents Relatively High Results for Bacteria, Solids, and Nutrients

Grey water results show a need for treatment of grey water on ships. High levels of bacteria, solids, nutrients, and metals are common. Table 43 provides examples of high levels of selected parameters for untreated or partially treated grey water compared with typical home sewage. Results also show occasional detections of toxic substances, heavy metals, and substances found in plastics. The results support the need for performance monitoring of sewage and grey water treatment, especially on passenger vessels. There is a high level of variability in the results in non-AWTS wastewater treatment.

Table 43 Untreated Grey Water Compared with Domestic Sewage

Grey water compared with sewage	Fecal coliform FCU/100ml	TSS mg/L	BOD mg/L	COD mg/L	Phosphorus mg/L
Raw domestic (home) sewage and GW*	10,000 to 100,000	120 to 360	110 to 400	200 to 780	4 to 8
Galley grey water (EPA 2004)	804,581	3,961	9,078	7,678	65
Accommodations GW (EPA 2004)	1,131,760	108	177	435	2
Laundry grey water (EPA 2004)	185	46	90	262	7
Food pulper wastewater (EPA 2004)	110,562	16,481	30,490	26,413	186
Small cruise ship GW (ADEC 2001-2019)	331	110	339	763	5
Large ship GW non-AWTS (ADEC 2000-2001)	2,622	650	835	1,819	9

* From EPA, 2009 — Same range or higher than domestic sewage (highlighted)

Fecal coliform results are geometric mean, other results are averages. ADEC results include some treated grey water samples.

The results included in this report should not be automatically viewed as typical of treated or untreated grey water. The ships sampled are under regulatory requirements to reduce the environmental and human health impacts of discharged grey water. Large cruise ships, ferries, and many small cruise ships have installed or modified treatment equipment to improve effluent performance. Most of the sample events are known in advance, providing time to check equipment. These ships are under regular performance sampling, and subject to inspections and potential compliance actions by state and federal agencies.

Definition

Grey water does not have a consistent definition. It has become a catch-all on some ships for any wastewater that does not meet other definitions such as sewage and bilge water. A worldwide consistent definition is needed that identifies all sources which will be considered grey water on a vessel. The definition should clearly specify what is included in grey water. A potential definition could focus on the concept of grey water rather than specific sources, e.g. human-activity related wastewater aboard a vessel, other than sewage.

Treatment

Non-AWTS sewage treatment plants (MSD I and II) overall did not perform well at treating either sewage or grey water to the standards for which they were certified. Mixing grey water and sewage may cause additional problems with these treatment systems if they were not designed to handle the increased volumes, solids and nutrient loading, oil and grease, and laundry chemicals.

AWTS systems are very effective at treatment of grey water. Most fecal coliform results are below the detection limit. Solids and nutrients are removed at a high rate. Since 2008, the State of Alaska has focused on parameters most AWTS were not designed to treat in wastewater, such as metals and ammonia.

It is important to note that the presence of an AWTS on a ship does not automatically mean that wastewater is treated to the Alaska standards for grey water and sewage. The AWTS must be maintained and monitored to continue good results. In Alaska some AWTS systems have been shut off due to damage or operational issues. Some AWTS are not used or sampled in Alaskan waters because of company policies against discharges near shore. Ship surveys and Ocean Ranger information indicated some ships operate portions of the AWTS seasonally. There is no requirement to treat grey water outside of areas regulating it, such as in Alaska.

Grey Water Volumes

Much of the grey water generated by ships with AWTS in Alaska appears to be stored for offshore or shoreside discharge. This includes ships that do not discharge in state waters and most galley and laundry grey water. These are separated on many ships as they might interfere with the treatment system. Chemicals in laundry water may disrupt biological treatment, and fine fibers and other materials may damage filtration systems. Galley grey water introduces additional solids and nutrients to the wastewater, and oil and grease from food residues may interfere with filtration and biological treatment.

There is a need for long-term and recent data on typical grey water generation for different ship types. The data from the EPA and ADEC surveys is outdated and the estimates provided by ship operators in ADEC permit and VSSP submittals are often based on estimates.

IMO Grey Water Recommendations

The IMO needs to address and regulate grey water discharges. Other discharges are regulated under MARPOL, including sewage, ballast water, and exhaust gas cleaners. Grey water should be regulated based on the high levels of bacteria and nutrients as well as the potentially toxic substances detected in Alaska passenger vessel sampling. Initial work should include the following:

- Testing of grey water in different parts of the world and on different ships.
- Collection of volume information on multiple ship types.
- Evaluation of the sources of grey water on different types of ships.
- Evaluation of the potential for toxic materials to enter grey water.
- Not allowing food waste in galley grey water.
- Elimination of direct grey water discharges in new build ships, inclusion of holding tanks in new construction for grey water.
- Evaluation of grey water as a potential cause of performance failure for sewage treatment plants.
- Continuation of work to implement performance testing in Annex IV on sewage as a possible guide towards future grey water requirements.
- Evaluation of the impact on chlorine disinfection and the generation of chlorine disinfectant byproducts for systems that may use chlorine to disinfect.
- Coordination with the other Annexes as needed, such as with ballast water, solid wastes, and sewage. Passenger vessels in Alaska have used treated grey water as ballast water. Food wastes may be present in grey water. Miscellaneous wastewaters not clearly identified in Annexes could be added to grey water, or if grey water is regulated, they may be diverted to bilges or sewage.

Alaska Recommendations

The State of Alaska will update the large cruise ship discharge general permit in the future. During that time the ADEC process should include a review of sample, receiving water, and compliance data. The following items should be addressed in the next permit:

- Investigate sampling for hydrocarbons found in fuel and other possible hydrocarbon indicators such as vanadium in grey water. Discharge of bilge water through grey water systems was reported in the recent Princess Cruises settlement (DOJ, 2016). Ocean Rangers were tasked with checking large cruise ships in Alaska for illegal discharge of oily water. With the program potentially unfunded, unannounced sample events or continuous monitoring must be considered. Monitoring for hydrocarbons is already required for bilge and exhaust gas cleaning system discharges for these ships.
- Check for direct discharges of grey water on large cruise ships such as those reported in 2017 Ocean Ranger reports. A ship was built as recently as 2007 with direct grey water overboard discharges of dishwasher, sink, and floor drain water.
- Reinstate the requirement for sampling twice a year for priority pollutants, metals, and nutrients for large cruise ships. This matches USCG requirements. Occasional results for toxic substances and high metals and the recent DOJ settlement demonstrate the continued need to monitor for parameters that have a high potential for environmental harm.
- Establish effluent limits for toxics and heavy metals in the General Permit. Mercury, silver, and substances such as dry-cleaning chemicals should not be present in grey water or sewage.
- Complete cyanide monitoring and testing. The presence of cyanide in early 2000s was not explained. Cyanide should be tested to see if it is still present and sources identified if present. ADEC reports stated monitoring would resume in 2004 due to initial sample results, but this was not completed.
- For small cruise ships and ferries, ADEC should investigate the impact of chlorine byproducts at high levels on the environment and human contact (recreation). ADEC should also encourage the elimination of direct untreated grey water discharges. They should investigate treatment options that could be installed on these connections or for grey water in general, such as installation of holding tanks. Effluent limits should be established for any new ships built for operation in Alaska and evaluated for existing ships. ADEC should continue to seek disinfection without discharge of high levels of chlorine.

General Grey Water Recommendations

A variety of actions need to be taken to better address grey water impacts on the marine environment. The following are broader considerations to be considered at both the operational and regulatory level:

- Performance monitoring is needed for any grey water or sewage treatment system. Non-AWTS sewage treatment plant sample results show many systems do not meet the standards for which they were certified. Certified MSD II treatment systems have not performed in Alaska to the levels they were certified to meet. Treatment system performance must be monitored over time under real-world conditions. Monitoring should include unannounced sample events to be representative of typical performance.

- Chlorine disinfection produces byproducts that may be harmful. Use of chlorine as a disinfectant should be discouraged, especially when there is a high organic load in the wastewater. Treatment without using chlorine is beneficial in reducing or eliminating discharges of these substances. Excess chlorine is toxic to marine life.
- Food waste and wastewater related to food waste should not be included in grey water. Wastewater related to food waste samples from EPA show high amounts of nutrients and solids. Oils and grease can foul treatment systems.
- Indicators could also be used to observe treatment systems. Regular or continuous monitoring is needed to monitor for changes in the treatment system performance and in changes in influent.
- Any changes in grey water requirements should examine sources, pipe and storage cross-connections, and their impact on other wastewater and ballast water. Grey water can be used as ballast, and pipes and pumps can be shared as well as tanks switching between uses as needed. If grey water is defined to exclude some items, they may be discharged directly or to the bilge rather than handled as grey water.

Conclusion

Sampling in Alaska has shown that untreated grey water contains high levels of bacteria, nutrients, solids, and pollutants at levels as high as or higher than raw sewage. With the larger amounts compared with sewage, regulation and monitoring is needed to prevent the discharge of untreated grey water. Federal and state work in Alaska on passenger vessels has demonstrated grey water can be treated to levels safe for human contact and for reductions to the impact on the environment. Performance monitoring through sampling of grey water and sewage discharges in Alaska can be used as a model for future requirements on grey water.

Acronyms and Abbreviations

ADEC	Alaska Department of Environmental Conservation
AMHS	Alaska Marine Highway System
AS	Alaska Statute
AWTS	Advanced Wastewater Treatment System
BMP	Best Management Practices Plans
BNA	Base, Neutral, Acids
BOD	Biochemical oxygen demand
BW	Blackwater (sewage)
CDC	US Centers for Disease Control
CFR	US Code of Federal Regulations
COD	Chemical oxygen demand
CPVEC	Alaska Commercial Passenger Vessel Environmental Compliance
eNOI	Electronic Notice of Intent
EPA	US Environmental Protection Agency
GP	Alaska Large Commercial Passenger Vessel Wastewater General Permit
GW	Grey water (graywater in United States)
ILO	International Labor Organization
IMO	International Maritime Organization
MARPOL	International Convention for the Prevention of Pollution from Ships
MSD	Marine Sanitation Device
ND	Non-detect
NOI	Notice of Intent
SM	Standard Method
STP	Sewage Treatment Plant
TKN	Total Kjeldahl nitrogen
TNTC	Too numerous to count
TR	Total Recoverable (metals), Total Residual (chlorine)
TSS	Total suspended solids
US	United States
USC	US Code
USCG	US Coast Guard
VOC	Volatile organic chemicals
VGP	US EPA Vessel General Permit
WET	Whole effluent toxicity
WW	Wastewater

Abbreviations

Cl	chlorine
cm3	cubic meters
FCU	fecal coliform units
mg/L	milligrams per liter
nm	nautical mile
SU	standard units (pH)
µg/L	micrograms per liter

Definitions

Advanced Wastewater Treatment System
A sewage or grey water treatment system designed to meet the federal performance requirements of P.L. 106-554, 33 U.S.C. 1901 including EPA-defined secondary treatment which does not use chlorine for disinfection. Systems typically include filtration, biological treatment, and UV disinfection.

Blackwater
Sewage or wastewater with human body wastes including from medical facilities.

Commercial Passenger Vessel
A vessel that carries paying passengers. In Alaska the legal definition includes a vessel of more than 50 overnight lower berths.

Effluent
Treated and discharged wastewater, can be grey water, blackwater, or mixed wastewater.

Ferry
For this report a ferry is a vessel operated by the Alaska Marine Highway, a state agency transporting passengers for hire among ports in Alaska, Canada, and Washington state.

Geometric mean (Geomean)
Differs from arithmetic mean by being the nth root of the product of n numbers. Used for bacteria to normalize the mean. Non-detect are set to 1 in order to calculate a geometric mean.

Grey water (graywater in United States)
Wastewater from human habitation on a ship not including sewage. Includes bath, galley, and laundry waters. See grey water definition section for more specific information.

Influent
Wastewater prior to treatment or direct discharge if untreated.

Large cruise ship
Alaska definition is used in this report: a large cruise ship has 250 or more lower berths. USCG and US EPA define as 500 or more passengers.

Lower berths
Bed or berth that excludes top bunks and temporary beds such as convertible beds.

Marine Sanitation Device (MSD)
A sewage treatment plant as defined by US EPA and USCG. Sampling is from Type II MSDs, with one exception of a Type I in older samples from the ferry *Taku*. A Type III MSD is actually a holding tank, and is named as holding tank in this report.

Ocean Ranger
Marine engineer or graduate from maritime academy with experience in marine safety and environmental protection deployed on large cruise ships to monitor for federal and state requirements.

Quality Assurance Project Plan
A plan that addresses sampling methods, procedures, and quality control of the sampling and analysis of sampled wastewater and effluent.

Receiving water
Body of water into which wastewaters are discharged.

Sewage
Blackwater or wastewater, typically from toilets and urinals, with human body wastes including waste from medical facilities.

Sewage Treatment Plant
A shipboard sewage treatment plant as defined by MARPOL Annex IV.

Small cruise ship
Alaska defines a small cruise ship as an overnight passenger vessel with between 50 and 249 lower berths.

Vessel Specific Sampling Plan
A plan for each vessel sampling documenting how sample is taken, addressing sample repressiveness, and providing wastewater treatment information for regulators.

Water Quality Criteria
Criteria established to protect uses of the water. Chronic is long term, acute are short term for criteria.

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Appendix A Grey Water Legal Citations

Alaska Statute (AS) 46.03.490.6

(6) graywater means galley, dishwasher, bath, and laundry wastewater;

(10) other wastewater means graywater or sewage that is stored in or transferred to a ballast tank or other holding area on the vessel that may not be customarily used for storing graywater or sewage;

Note- the wastewater general permit for large cruise ships includes graywater stored as "other wastewater".

US 2000 Title XIV, (also known as "Murkowski Bill") and 33 CFR 159.305
33 USCA § 1901 NOTE, Sec 1414: Definitions

(4) GRAYWATER.--The term "graywater" means only galley, dishwasher, bath, and laundry wastewater. The term does not include other wastes or waste streams.

US Clean Water Act Section 312(a), 33 U.S.C. 1322(a)

(11) "graywater" means galley, bath, and shower water;

Note- GW on the Great Lakes under the same section is considered sewage.

US 33 CFR 151.05 (USCG Subchapter O- Pollution)

Graywater means drainage from dishwater, shower, laundry, bath, and washbasin drains. It does not include drainage from toilets, urinals, hospitals, animal spaces, and cargo spaces.

US 40 CFR 1700.4 - Discharges requiring control. (US Armed Forces)

Graywater: galley, bath, and shower water, as well as wastewater from lavatory sinks, laundry, interior deck drains, water fountains, and shop sinks.

US EPA 2013 Vessel General Permit for Discharges Incidental to the Normal Operation of Vessels (VGP)

"Graywater" means galley, bath, and shower water, as well as wastewater from lavatory sinks, laundry, and water fountains. [*modified from 40 CFR 1700.4 but removed shop sinks*]

Note- Mixed sewage and graywater are subject to the VGP and other federal sewage requirements.

MEPC.295(73) (Annex V 2017 Guidelines) 1.6.3

Grey water means drainage from dishwater, shower, laundry, bath and washbasin drains. It does not include drainage from toilets, urinals, hospitals, and animal spaces, as defined in regulation 1.3 of MARPOL Annex IV (sewage), and it does not include drainage from cargo spaces. Grey water is not considered garbage in the context of Annex V.

Note- the dishwater definition includes pre-cleaned dishes and utensils so that the operation of automatic dishwashers is not interfered with.

Canada Vessel Pollution and Dangerous Chemicals Regulations

Greywater means drainage from sinks, laundry machines, bath tubs, shower-stalls or dishwashers. It does not include sewage, or drainage from machinery spaces or workshop areas. (eaux grises)

Appendix B Ship Treatment and Information

Small Cruise Ship and Ferry Wastewater Treatment Information 2019

2019 Small[1] Commercial Passenger Vessels Wastewater Treatment

Operator	Vessel Name	Passenger Capacity	Crew Capacity	Total Passengers and Crew	Planned Alaska Voyages	Blackwater Treatment System (MSD II and STP)	MSD II Units	GW Treatment	Discharging in Alaska	
									BW	GW
Alaska Marine Highway	*Columbia*	625	66	691	Apr-Oct	Omnipure 15MX (15MXMP after 2009)	4	MSD II	Yes- Mixed	
Alaska Marine Highway	*Kennicott*	748	42	790	Year Rd.	Orca II 500	3	MSD II	Yes-Mixed	
Alaska Marine Highway	*Malaspina*	500	50	550	Jan-April	Omnipure 15MX (15MXMP after 2008)	3	MSD II	Yes-Mixed	
Alaska Marine Highway	*Matanuska*	498	50	548	Year Rd.	Omnipure 15MX (15MXMP after 2009)	3	MSD II	Yes-Mixed	
Alaska Dream Cruises	*Admiralty Dream*	66	21	87	18	Omnipure 12M	1	None, can be stored	Yes	Yes
Alaska Dream Cruises	*Chichagof Dream*	78	27	105	18	Orca II A-500 MSD	1	MSD II, laundry GW can be stored	Yes- Mixed	
American Cruise Lines	*American Constellation*	173	46	219	13	Marine Fast Model D-9S	1	MSD II	Yes- Mixed	
Hapag-Lloyd	*Bremen*	155	94	249	1	Hamworthy RT 80	1	Unkown, stored	No	
Lindblad/Nat. Geographic	*National Geographic Orion*	102	69	171	6	Triton MSTP7	1	Stored, grease trap for galley	No	
Lindblad/Nat. Geographic	*National Geographic Quest*	100	52	152	16	Gertsen & Olufsen Bioreactor BR37000	1	MSD II, laundry GW stored	Yes-Mixed	
Lindblad/Nat. Geographic	*National Geographic Sea Bird*	62	28	90	18	Omnipure 12MX	1	Chlorine injection into tank, galley is direct overboard	Yes	Yes
Lindblad/Nat. Geographic	*National Geographic Sea Lion*	62	28	90	16	Omnipure 12M	1	Chlorine injection into tank, galley is direct overboard	Yes	Yes
Lindblad/Nat. Geographic	*National Geographic Venture*	108	56	164	18	Gertsen & Olufsen Bioreactor BR37000	1	MSD II, laundry GW stored	Yes-Mixed	
Silver Expeditions	*Silver Explorer*	150	130	280	5	AquaMaster Unex Bio 200 E	1	MSD II, some stored, some chlorinated, grease trap for galley	Yes- Mixed	
Un-Cruise Adventures	*Safari Endeavor*	86	35	121	17	Omnipure 12M5508	2	None, can be stored	Yes	Yes
Un-Cruise Adventures	*S.S. Legacy*	92	34	126	15	Red Fox RF-2000-FP	1	Some crew GW with MSD, other is directly discharged	Yes	Yes
Un-Cruise Adventures	*Wilderness Adventurer*	76	24	100	24	Omnipure 12MX	1	MSD II	Yes-Mixed	
Un-Cruise Adventures	*Wilderness Discoverer*	78	24	102	18	HeadHunter TW-HMX-6004LP-A	2	Most by MSD II, galley sink and dishwasher can be stored	Yes-Mixed	
Un-Cruise Adventures	*Wilderness Explorer*	74	29	103	19	Red Fox RF-2000-FP	1	None, direct discharge	Yes	Yes
Windstar	*Star Legend*	212	155	367	12	Rochem Biofiltration 18/27-10	1	MSD II and stored	Yes- Mixed	

[1]A small vessel has overnight accommodations for 50 to 249 passengers.

Note- storage may be only while in port, or up to several days

2000-2018 Previous or Changed Small Commercial Passenger Vessels Wastewater Treatment

Operator	Vessel Name	Passenger Capacity	Crew Capacity	Passengers and Crew		Blackwater Treatment System	II Units	GW Treatment	Was Approved for	
									BW	GW
Alaska Marine Highway	*Taku (2011-2016)*	370	42	412		Omnipure 15MXP	3	MSD II	Yes-Mixed	
Alaska Marine Highway	*Taku (2000-2011)*	370	42	412		Effluent Technology (MSD I)MK1-001-TU	3	MSD I	Yes-Mixed	
Alaska Dream Cruises	*Baranof Dream*	49	21	70		Omnipure 12M812-27	1	None	Yes	Yes
American Cruise Lines	*American Spirit*	98	38	136		Orca IIA-165	1	MSD II	Yes-Mixed	
Cruise West	*Spirit of 98*	96	26	122		See 2019 SS Legacy- same ship	1	None	Yes	Yes
Cruise West	*Spirit of Alaska*	78	21	99		Omnipure 12M812-27	1	None	Yes	Yes
Cruise West	*Spirit of Columbia*	78	21	99		Omnipure 12M/PM	1	None	Yes	Yes
Cruise West	*Spirit of Discovery*	84	21	105		Red Fox	1	None	Yes	Yes
Cruise West	*Spirit of Endeavour*	102	28	130		See 2019 Safari Endeavor	2	None	Yes	Yes
Cruise West	*Spirit of Glacier Bay*	102	37	139		Orca Type II A-500 MSD	1	MSD II, none for laundry	Yes	Yes
Cruise West	*Spirit of Oceanus*	114	63	177		Hamworthy ST8	1	Some with MSD II	Yes	Yes
Cruise West	*Spirit of Yorktown*	138	37	175		Omnipure 12 MX 824-27	1	Chlorine injection	Yes	Yes
Discovery Shipping	*World Discoverer*	170	90	260		Unex Bio-200E	1	Chlorine injection	Yes	Yes
Glacier Bay	*Wilderness Discoverer*	87	23	110		Omnipure 12 MX Type II E/M	1	MSD II	Yes-Mixed	
ISP	*Clipper Odyssey*	128	76	204		Consillium Marine Neptunatic MSD	1	Chlorine injection	Yes	Yes
Majestic America	*Empress of the North*	235	85	320		Orca Type II	2	MSD II	Yes-Mixed	
Majestic America	*Contessa*	48	18	66		Ominpure Model 8MC	1	MSD II	Yes-Mixed	
Noble Caledonia	*Caledonian Sky*	116	73	189		Hamworthy Super Trident ST6A	2	Grease traps	Yes	Yes
V Ships	*Orion II*	110	68	178		Hamworthy Super Trident ST6A	2	Some with chlorine, grease traps for galley	Yes	Yes
Silver Expeditions	*Silver Discoverer*	128	72	200		Hamman WasserTechnik Model HI Type	1	Chlorine injection	Yes	Yes

Large Cruise Ship and Ferry Wastewater Treatment Information 2019

2001-2019 Large[1] Commercial Passenger Vessels with AWTS and sampling

Operator	Vessel Name	Passenger Capacity	Crew Capacity	Total Passengers and Crew	AWTS	AWTS Units	GW sampling details
Carnival Cruise Lines	*Carnival Spirit*	2125	934	3059	Rochem RO LPRO 160-10 for GW, Rochem BioFilt B2098 for sewage	2	Accommodation and laundry GW, sometimes pool water
Celebrity Cruises	*Celebrity Infinity*	2454	1001	3455	Hydroxyl Cleansea 900		All GW mixed with sewage
Celebrity Cruises	*Celebrity Mercury*	1870	909	2779	Biopure MSD (4 units) then treated by Rochem RO 192-10 with carbon and UV	2	GW mixed with sewage prior to treatment, no information if any excluded
Celebrity Cruises	*Celebrity Millennium*	2449	1000	3449	Hydroxyl CB-100 MSD	1	All GW mixed with sewage, galley GW has grease traps
Celebrity Cruises	*Celebrity Summit*	2449	960	3409	Lazarus System	1	Only sewage treated
Cunard	*Queen Elizabeth*	2081	1000	3081	Hamworthy 320 MBR	2	Accommodation GW mixed with sewage
Disney	*Disney Wonder*	2834	920	3754	Hamworthy MBR	2	All GW mixed with sewage
Holland America	*Eurodam*	2106	929	3035	Hamworthy 360N MBR	2	Accommodation GW mixed with sewage
Holland America	*Maasdam*	1380	580	1960	Zenon AWTS	2	All GW mixed with sewage
Holland America	*Nieuw Amsterdam*	2106	929	3035	Hamworthy 360N MBR	2	Accommodation GW mixed with sewage
Holland America	*Noordam*	1918	800	2718	Rochem RO LPRO 120-10 for GW, Rochem BioFilt 16/18 for sewage (3)	5	Rochem uses mixed WW
Holland America	*Oosterdam*	1848	800	2648	Rochem RO LPRO 120-10 for GW, Rochem BioFilt 16/18 for sewage (3)	5	Rochem uses mixed WW
Holland America	*Ryndam*	1260	602	1862	Zenon AWTS	2	All GW mixed with sewage
Holland America	*Statendam*	1260	588	1848	Zenon AWTS	2	All GW mixed with sewage
Holland America	*Veendam*	1266	602	1868	Zenon AWTS	2	All GW mixed with sewage
Holland America	*Volendam*	1440	647	2087	Zenon AWTS	2	All GW mixed with sewage
Holland America	*Westerdam*	1848	800	2648	Rochem BioFilt 16/18 (3 units) for BW, OVIVO GW Treatment Plant	4	Some GW mixed with BW for Rochem system, GW only in OVIVO
Holland America	*Zaandam*	1440	647	2087	Zenon AWTS	2	All GW mixed with sewage
Holland America	*Zuiderdam*	1848	800	2648	Rochem BioFilt 16/18	2	"some" GW mixed with sewage
Norwegian Cruise Line	*Norwegian Bliss*	3500	1706	5206	Scanship AWP 60 Type II AWTS	1	All GW mixed with sewage, galley GW has grease and sediment traps and solids are settled
Norwegian Cruise Line	*Norwegian Dream*	1748	700	2448	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Jewel*	2376	1100	3476	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Joy*	3500	1706	5206	Scanship AWP 60 Type II AWTS	1	All GW mixed with sewage, galley GW has grease and sediment traps and solids are settled
Norwegian Cruise Line	*Norwegian Pearl*	2394	1100	3494	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Sky*	1986	950	2936	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Spirit*	2635	965	3600	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Star*	2348	1100	3448	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Sun*	1936	950	2886	Scanship AWP	1	All GW mixed with sewage
Norwegian Cruise Line	*Norwegian Wind*	2100	700	2800	Scanship AWP	1	All GW mixed with sewage
Oceania	*Regatta*	777	373	1150	Triton Water MBR MSTP8-MF AWTS	2	All GW mixed with sewage
Ponant	*L'Austral*	264	136	400	Rochem Bio-filt AWTS	1	All GW but galley mixed with sewage
Ponant	*Le Soleal*	264	136	400	Rochem Bio-filt AWTS	1	All GW but galley mixed with sewage
Princess Cruise Line	*Coral Princess*	1986	900	2886	Hamworthy MBR AWTS	2	Accommodation GW mixed with sewage
Princess Cruise Line	*Crown Princess*	3080	1190	4270	Hamworthy MBR AWTS	3	Accommodation and laundry GW, split system with 1 MBR treating mixed WW
Princess Cruise Line	*Dawn Princess*	1998	847	2845	Hamworthy MBR AWTS	3	Accommodation GW mixed with sewage
Princess Cruise Line	*Diamond Princess*	2678	1238	3916	Hamworthy MBR AWTS	3	Accommodation GW mixed with sewage
Princess Cruise Line	*Emerald Princess*	3084	1201	4285	DeNora Ozone AWWTP	1	Accommodation and laundry water, sewage with MSD offshore
Princess Cruise Line	*Golden Princess*	2606	1060	3666	Hamworthy MBR AWTS	3	Accommodation and laundry GW, split system with 1 MBR treating mixed WW
Princess Cruise Line	*Grand Princess*	2606	1100	3706	Hamworthy MBR 16 AWTS	3	Accommodation and laundry GW, split system with 1 MBR treating mixed WW
Princess Cruise Line	*Island Princess*	2390	900	3290	Hamworthy MBR AWTS	2	Accommodation GW mixed with sewage
Princess Cruise Line	*Pacific Princess*	670	373	1043	Hamworthy MBR AWTS	2	Accommodation GW treated with one MBR, other MBR is mixed GW and BW
Princess Cruise Line	*Regal Princess*	1596	660	2256	Hamworthy MBR AWTS	2	Accommodation GW mixed with sewage
Princess Cruise Line	*Royal Princess (2019)*	3560	1378	4938	Hamworthy MBR AWTS	2	Accommodation GW treated with one MBR, other MBR is mixed GW and BW
Princess Cruise Line	*Royal Princess (2010)*	676	373	1049	Hamworthy MBR	2	Accommodation GW mixed with sewage
Princess Cruise Line	*Ruby Princess*	3599	1201	4800	Hamworthy MBR 16 AWTS	3	Accommodation and laundry GW, split system with 1 MBR treating mixed WW
Princess Cruise Line	*Sapphire Princess*	2678	1238	3916	Hamworthy MBR AWTS	3	Accommodation and laundry GW, split system with 1 MBR treating mixed WW
Princess Cruise Line	*Sea Princess*	2016	854	2870	Hamworthy MBR AWTS	2	Accommodation GW mixed with sewage
Princess Cruise Line	*Star Princess*	2600	1150	3750	Hamworthy MBR AWTS	3	Accommodation and laundry GW, split system with 1 MBR treating mixed WW
Princess Cruise Line	*Sun Princess*	1974	924	2898	Hamworthy MBR AWTS	3	Accommodation GW mixed with sewage
Regent Seven Seas	*Seven Seas Mariner*	769	431	1200	Hamworthy MBR 240C AWTS	2	All GW mixed with sewage
Regent Seven Seas	*Seven Seas Navigator*	544	350	894	Scanship Mussel FA 25	1	All GW mixed with sewage
Royal Caribbean Cruises	*Ovation of the Seas*	4180	1551	5731	Scanship AWP 60 Type II AWTS	2	All GW mixed with sewage, galley GW has grease traps
Royal Caribbean Cruises	*Serenade of the Seas*	2100	850	2950	Scanship Mussel FA 40	1	All GW mixed with sewage
Silver Seas	*Silver Shadow*	382	305	687	Marisan 250 AWWTP	1	BW treated by BioPure MSD, then mixed with all GW for Marisan treatment
Seabourn	*Sojourn*	450	338	788	Hamworthy MBR 140 AWTS	2	All GW mixed with sewage
Viking	*Viking Orion*	930	499	1429	Scanship AWP-25 1165	1	All GW mixed with sewage

[1]A large vessel has overnight accommodations for 250 or more passengers.

Note- ships may not have same systems installed as when sampled

2000-2003 Large non-AWTS Commercial Passenger Vessels Wastewater Treatment

Operator	Vessel Name	Passenger Capacity	Crew Capacity	Total Passengers and Crew	Blackwater Treatment System (MSD II) Manufacturer	MSD II Units	GW Treatment
Celebrity Cruises	*Celebrity Infinity*	2454	1001	3455	Unknown		Unknown
Celebrity Cruises	*Celebrity Mercury*	1870	908	2778	Trident	4	Rochem RO
Crystal	*Crystal Harmony*	960	550	1510	Triton	2	None
Holland America	*Nieuw Amsterdam*	Unknown	Unknown	Unknown	Unknown	4	Unknown
Holland America	*Ryndam*	1629	602		Unknown		Unknown
Holland America	*Statendam*	1629	602	2231	Triton	3	Zenon
Holland America	*Veendam*	1264	588	1852	Hamworthy Trident MSD	3	Unknown
Holland America	*Volendam*	1440	618	2058	Trident ST40X	4	Unknown
Holland America	*Westerdam*	1700	630	2330	Hamworthy Trident MSD	4	Unknown
Norwegian Cruise Line	*Norwegian Sky*	2000	800	2800	Trident MSD	3	None
Norwegian Cruise Line	*Norwegian Wind*	1748	617	2365	"None"	0	Triton MSD
Princess Cruise Line	*Dawn Princess*	2020	900	2920	Hamworthy Trident MSD	3	Chlorination
Princess Cruise Line	*Ocean Princess*	2020	900	2920	Trident MSD	5	Chlorination
Princess Cruise Line	*Regal Princess*	1596	696	2292	Hamworthy Trident MSD	4	Chlorination
Princess Cruise Line	*Sea Princess*	1950	900	2850	Hamworthy Trident MSD	5	Chlorination
Princess Cruise Line	*Sky Princess*	1308	560	1868	Hamworthy Trident MSD	4	Unknown
Princess Cruise Line	*Star Princess*	2600	1150	3750	Hamworthy Trident MSD	2	Chlorination
Princess Cruise Line	*Sun Princess*	2020	900	2920	Trident	4	Chlorination
Regent Seven Seas	*Seven Seas Navigator*	490	321	811	Unknown		Unknown
Royal Caribbean Cruises	*Vision of the Seas*	2220	775	2995	Unknown	2	Unknown
	Universe Explorer	734	365	1099	Omnipure 15MXPM	6	Omnipure MSD

Appendix C Grey Water Volumes

Grey Water Generation Estimates from 2012 ADEC SAP Survey

Ship Name	Year	GW Treatment	Passengers	Crew	Total	Total GW per day	Laundry GW	Galley GW	Accommo-dation GW	Other GW	BW	Reported water use/person	Calculated GW/person
						cubic meters/day						liters	
Carnival Spirit	2012	AWTS	2125	934	3059	1020	120	250	650	0	90	280	333.44
Disney Wonder	2012	AWTS	2834	920	3754	710	200	260	250	0	40	200	189.13
Coral Princess	2012	AWTS	2400	900	3300	910	160	250	500	0	200	290	275.76
Diamond Princess	2012	AWTS	2670	1238	3908	1010	160	250	600	0	220	310	258.44
Golden Princess	2012	AWTS	2600	1060	3660	1125	220	230	675	0	240	310	307.38
Island Princess	2012	AWTS	2400	900	3300	910	160	250	500	0	200	310	275.76
Sapphire Princess	2012	AWTS	2678	1238	3916	1010	160	250	600	0	220	310	257.92
Sea Princess	2012	AWTS	2270	910	3180	760	180	200	380	0	80	310	238.99
Statendam	2012	AWTS	1266	588	1854	470	100	75	295	0	40	314	253.51
Volendam	2012	AWTS	1440	647	2087	474	75	39	360	0	30	314	227.12
Westerdam	2012	AWTS	1848	800	2648	407.5	77.5	130	200	0	120	314	153.89
Zaandam	2012	AWTS	1140	647	1787	465	100	40	325	0	40	314	260.21
Regatta	2012	AWTS	777	373	1150	235	65	70	100	0	15	300	204.35
Norwegian Pearl	2012	AWTS	2990	1100	4090	880	180	335	365	0	160	285	215.16
Norwegian Star	2012	AWTS	2889	1100	3989	860	100	400	360	0	150	285	215.59
Seven Seas Navigator	2012	AWTS	540	350	890	230	53	23	154	0	20	320	258.43
Silver Shadow	2012	AWTS	435	305	740	255	55	110	90	0	25	338	344.59
Min			435	305	740	230	53	23	90	0	15	200	153.89
Max			2990	1238	4090	1125	220	400	675	0	240	338	344.59
Average			1959	824.1	2783	690.1	127.38	186	376.70588	0	111.2	300.24	251.16

Grey Water Estimates from 2019 Vessel Specific Sampling Plans

Over 1000 passengers

Ship Name	VSSP Year	GW Treatment	Passengers	Crew	Total	Total GW per day	Laundry GW	Galley GW	Accommo-dation GW	Other GW	BW	Reported water use/person	Calculated GW/person
						cubic meters/day						liters/day	
Golden Princess	2019	AWTS	3100	1060	4160	815	200	210	405	0	210	277	195.91
Coral Princess	2019	AWTS	2390	900	3290	910	160	250	500	0	50	240	276.60
Grand Princess	2019	AWTS	3100	1100	4200	897	100	310	487	0	90	230	213.57
Island Princess	2019	AWTS	2390	900	3290	910	160	250	500	0	50	250	276.60
Ruby Princess	2019	AWTS	3599	1201	4800	970	130	300	540	0	80	230	202.08
Star Princess	2019	AWTS	3100	1150	4250	910	200	260	450	0	80	290	214.12
Royal Princess	2019	AWTS	4222	1378	5600	910	160	250	500	0	100	178	162.5
Sun Princess	2019	AWTS	2250	924	3174	650	100	250	300	0	60	280	204.79
Ovation of the Seas	2019	AWTS	5011	1551	6562	1070	170	270	260	370	100	180	163.06
Queen Elizabeth	2019	AWTS	2175	1000	3175	555	170	115	270	0	80	200	174.80
Celebrity Millennium	2019	AWTS	2593	1001	3594	620	120	250	200	50	40	180	172.51
Disney Wonder	2019	AWTS	2834	920	3754	710	200	210	300	0	40	750	189.13
Norwegian Bliss	2019	AWTS	4992	1706	6698	1365	265	300	800	0	80	255	203.79
Norwegian Jewel	2019	AWTS	2889	1100	3989	1100	150	350	600	0	120	285	275.76
Norwegian Joy	2019	AWTS	5909	1800	7709	1365	265	300	800	0	163	255	177.07
Eurodam	2019	AWTS	2106	929	3035	952	200	120	632	0	88	195	313.67
Maasdam	2019	AWTS	1258	580	1838	550	120	100	330	0	100	322	299.24
Nieuw Amsterdam	2019	AWTS	2106	929	3035	775	200	125	450	0	60	314	255.35
Volendam	2019	AWTS	1440	647	2087	495	100	80	315	0	40	314	237.18
Min			1258	580	1838	495	100	80	200	0	40	178	162.5
Max			5909	1800	7709	1365	265	350	800	370	210	750	313.67
Average			3024	1093	4118	869.9	166.84	226.32	454.68	22.11	85.84	275.0	221.46

250 or more passengers (ADEC large cruise ship definition)

Ship Name	VSSP Year	GW Treatment	Passengers	Crew	Total	Total GW per day	Laundry GW	Galley GW	Accommodation GW	Other GW	BW	Reported water use/person	Calculated GW/person
						cubic meters/day						liters/day	
Golden Princess	2019	AWTS	3100	1060	4160	815	200	210	405	0	210	277	195.91
Coral Princess	2019	AWTS	2390	900	3290	910	160	250	500	0	50	240	276.60
Grand Princess	2019	AWTS	3100	1100	4200	897	100	310	487	0	90	230	213.57
Island Princess	2019	AWTS	2390	900	3290	910	160	250	500	0	50	250	276.60
Ruby Princess	2019	AWTS	3599	1201	4800	970	130	300	540	0	80	230	202.08
Star Princess	2019	AWTS	3100	1150	4250	910	200	260	450	0	80	290	214.12
Royal Princess	2019	AWTS	4222	1378	5600	910	160	250	500	0	100	178	162.5
Sun Princess	2019	AWTS	2250	924	3174	650	100	250	300	0	60	280	204.79
Ovation of the Seas	2019	AWTS	5011	1551	6562	1070	170	270	260	370	100	180	163.06
Queen Elizabeth	2019	AWTS	2175	1000	3175	555	170	115	270	0	80	200	174.80
Celebrity Millennium	2019	AWTS	2593	1001	3594	620	120	250	200	50	40	180	172.51
Disney Wonder	2019	AWTS	2834	920	3754	710	200	210	300	0	40	200	189.13
Eurodam	2019	AWTS	2106	929	3035	952	200	120	632	0	88	195	313.67
Maasdam	2019	AWTS	1258	580	1838	550	120	100	330	0	100	322	299.24
Nieuw Amsterdam	2019	AWTS	2106	929	3035	775	200	125	450	0	60	314	255.35
Volendam	2019	AWTS	1440	647	2087	495	100	80	315	0	40	314	237.18
Le Soleal	2019	AWTS	250	150	400	95	30	30	35	0	3	160	237.5
Norwegian Bliss	2019	AWTS	4992	1706	6698	1365	265	300	800	0	80	255	203.79
Norwegian Jewel	2019	AWTS	2889	1100	3989	1100	150	350	600	0	120	285	275.76
Norwegian Joy	2019	AWTS	5909	1800	7709	1365	265	300	800	0	163	255	177.07
Regatta	2019	AWTS	777	373	1150	330	40	120	170	0	15	300	286.96
Seabourn Sojourn	2019	AWTS	462	338	800	240	100	50	90	0	15	300	300
Seven Seas Mariner	2019	AWTS	769	431	1200	333	95	105	133	0	17	320	277.5
Viking Orion	2019	AWTS	954	499	1453	470	120	100	250	0	50	220	323.47
Silver Muse	2019	AWTS	596	417	1013	300	70	100	130	0	40	350	296.15
Min			250	150	400	95	30	30	35	0	3	160	162.5
Max			5909	1800	7709	1365	265	350	800	370	210	350	323.47
Average			2451	919.4	3370	731.9	145	192.2	377.88	16.8	70.84	253.0	237.17

100 to 1000 passengers

Ship Name	VSSP Year	GW Treatment	Passengers	Crew	Total	Total GW per day	Laundry GW	Galley GW	Accommodation GW	Other GW	BW	Reported water use/person	Calculated GW/person
						cubic meters/day						liters	
Star Legend	2019	Rochem biofilt, some not treated	212	155	367	131	30	34	67	0	8	335	356.95
Silver Explorer	2019	Some disinfected by MSD	150	130	280	80	10	15	50	5	5.5	305	285.71
American Constellation	2019	MSD II	173	46	219	32.97	2.27	6.09	24.61	0	1.3	151.42	150.55
National Geographic Quest	2019	MSD II for some	100	52	152	22.940	2.12	3.79	17.03	0	1.9	166.56	150.92
National Geographic Venture	2019	MSD II for some	108	56	164	22.940	2.12	3.79	17.03	0	1.9	166.56	139.88
National Geographic Orion	2019	MSD II for some	102	69	171	42	11	6	25.00	0	2.0	200	245.61
Le Soleal	2019	AWTS	250	150	400	95	30	30	35	0	3	160	237.5
Regatta	2019	AWTS	777	373	1150	330	40	120	170	0	15	300	286.96
Seabourn Sojourn	2019	AWTS	462	338	800	240	100	50	90	0	15	300	300
Seven Seas Mariner	2019	AWTS	769	431	1200	333	95	105	133	0	17	320	277.5
Viking Orion	2019	AWTS	954	499	1453	470	120	100	250	0	50	220	323.47
Silver Muse	2019	AWTS	596	417	1013	300	70	100	130	0	40	350	296.15
Min			100	46	152	22.94	2.1198	3.7854	17.034	0	1.325	151.42	139.88
Max			954	499	1453	470	120	120	250	5	50	350	356.95
Average			387.8	226.3	614.1	175.0	42.709	47.805	84.06	0.417	13.38	247.9	254.27

50 to 100 passengers

Ship Name	VSSP Year	GW Treatment	Passengers	Crew	Total	Total GW per day	Laundry GW	Galley GW	Accommodation GW	Other GW	BW	Reported water use/person	Calculated GW/person
						cubic meters/day						liters/day	
Admiralty Dream	2019	None	66	21	87	8.52	0.28	3.29	4.94	0	1.6	94.64	97.90
Chichagof Dream	2019	None	91	27	118	9.71	0.28	3.75	5.68	0	1.9	132.49	82.28
Sea Bird	2019	Chlorine injection	66	30	96	7.78	1.51	1.89	4.38	0	11.6	98.42	81.07
Sea Lion	2019	Chlorine injection	66	30	96	7.78	1.51	1.89	4.38	0	11.6	98.42	81.07
Safari Endeavor	2019	None	86	35	121	14.76	1.89	4.92	7.95	0	4.5	105.99	122.01
SS Legacy	2019	None	92	34	126	19.46	0.98	6.93	11.55	0	14.2	132.49	154.42
Wilderness Adventurer	2019	MSD II	76	24	100	5.30	0.57	1.70	3.03	0	4.5	94.64	53.00
Wilderness Discoverer	2019	MSD II for some	78	27	105	6.06	0.57	1.89	3.22	0.379	2.5	56.78	57.68
Wilderness Explorer	2019	MSD II for some	74	29	103	11.36	0.76	3.79	6.81	0	7.6	113.56	110.25
Min			66	21	87	5.30	0.28	1.70	3.03	0	1.647	56.78	53.00
Max			92	35	126	19.46	1.89	6.93	11.55	0.379	14.2	132.49	154.42
Average			77.22	28.56	105.8	10.08	0.93	3.34	5.77	0.042	6.667	103.05	93.30

Large ferries

Ship Name	VSSP Year	GW Treatment	Passengers	Crew	Total	Total GW per day	Laundry GW	Galley GW	Accommodation GW	Other GW	BW	Reported water use/person	Calculated GW/person
						cubic meters/day						liters/day	
Columbia	2019	MSD II	499	63	562	62.28	7.57	7.57	47.14	0	17.1	113.56	110.81
Kennicott	2019	MSD II	450	55	505	57.66	5.68	5.68	46.30	0	16.8	113.56	114.18
Malaspina	2019	MSD II	450	47	497	57.16	5.68	5.68	45.80	0	16.7	113.56	115.01
Matanuska	2019	MSD II	450	48	498	62.28	7.57	7.57	47.14	0	17.1	113.56	125.06
Min			450	47	497	57.16	5.68	5.68	45.80	0	16.66	113.56	110.81
Max			499	63	562	62.28	7.57	7.57	47.136	0	17.14	113.56	125.06
Average			462.3	53.25	515.5	59.84	6.62	6.62	46.59	0	16.94	113.56	116.26

Large Cruise Ship Reported 2018 Alaska Discharges

2018 DMR Reported Volumes in cubic meters

Ship Name	Effluent	Days in AK	Reported Alaska Discharge Totals: April	May	June	July	August	September	October	Total	Average per day	Estimated Produced: Est per day	Est Total	Discharged: % produced	Shoreside discharge: cubic m3	% prod
Disney Wonder	Mixed BW&GW	65	-	2,292	6,037	4,007	6,261	1,592	-	20,189	310.60	750	48,750	41%	0	0%
Eurodam	Mixed BW&GW	64	-	2,688	1,668	1,545	1,235	1,668	-	8,804	137.56	1040	66,560	13%	0	0%
Nieuw Amsterdam	Mixed BW&GW	83	-	1,808	1,632	1,710	1,819	1,376	-	8,345	100.54	835	69,305	12%	0	0%
Volendam	Mixed BW&GW	88	-	4,180	6,992	6,642	6,800	5,715	-	30,329	344.65	535	47,080	64%	0	0%
Zaandam	Mixed BW&GW	95	-	4,275	4,332	3,180	5,080	4,488	-	21,355	224.79	535	50,825	42%	0	0%
Coral Princess	Mixed BW&GW	87	-	574	3,072	2,560	2,480	1,616	-	10,302	118.41	960	83,520	12%	6,088	7%
Emerald Princess	Mixed BW&GW	48	-	38	1,035	915	658	264	-	2,910	60.63	987	47,376	6%	10,352	22%
Golden Princess	Mixed BW&GW	61	-	1,470	1,470	3,124	7,199	2,250	-	15,513	254.31	1025	62,525	25%	9,849	16%
Grand Princess	Mixed BW&GW	55	-	3,674	3,492	3,504	2,784	2,416	-	15,870	288.55	987	54,285	29%	0	0%
Island Princess	Mixed BW&GW	87	-	-	2,162	3,650	3,125	1,834	-	10,771	123.80	960	83,520	13%	7,654	9%
Ruby Princess	Mixed BW&GW	77	342	6,390	2,508	4,505	2,574	1,524	-	17,843	231.73	1050	80,850	22%	6,485	8%
Star Princess	Mixed BW&GW	104	-	7,372	4,224	6,380	6,480	4,665	-	29,121	280.01	990	102,960	28%	7,064	7%
Seabourn Sojourn	Mixed BW&GW	92	-	19	2,180	3,048	3,080	2,992	321	11,640	126.52	255	23,460	50%	0	0%
Norwegian Bliss	Mixed BW&GW	57	-	-	15,061	14,692	9,793	9,953	-	49,499	868.40	1445	82,365	60%	0	0%
Norwegian Jewel	Mixed BW&GW	87	-	5,985	13,537	12,894	13,834	9,438	-	55,688	640.09	1220	106,140	52%	0	0%
Norwegian Pearl	Mixed BW&GW	91	-	11,092	9,965	10,151	10,282	10,024	2,591	54,105	594.56	1120	101,920	53%	0	0%
Oceania Regatta	Mixed BW&GW	55	-	186	474	700	1,160	1,586	-	4,106	74.65	345	18,975	22%	0	0%
Seven Seas Mariner	Mixed BW&GW	46	-	742	697	742	966	409	-	3,556	77.30	350	16,100	22%	0	0%
	Totals	**1342**	342	52,785	80,538	83,949	85,610	63,810	2,912	**369,946**		**15,389**	**1,146,516**	**32%**	**47,493**	**4%**

Note- Ships with split greywater and mixed discharges did not differentiate between the amount of each.

Note- The same amounts were reported for the Golden Princess in May and June, the same amounts are unlikely based on days in Alaska

Source: Discharge Monitoring Reports, ADEC 2018

Appendix D Representative Sampling and Quality Assurance

Representative sampling is a critical element in evaluating the impact of wastewater to human health and the environment. Effluent quality will vary over time. This may be influenced by influent which can produce changes in sources, loading of pollutants, and volume.

Water conservation (i.e. reduction) measures reduce flow compared with shoreside treatment that would dilute high pollutant loads and can cause rapid changes in influent flow. Space and weight limitations prevent the retention of large amounts of water to even out changes during the day and in passenger loading compared with municipal or shoreside treatment.

Quality assurance of the samples is critical. Incorrect sample collection, laboratory errors, and incorrect procedures could produce incorrect results. ADEC and USCG cruise ship monitoring programs are compliance programs and place considerable emphasis on quality assurance and representative sampling.

Quality Assurance Project Plans
QAPP document sampling procedures, methods, and actions to be taken to verify sample results are accurate and representative. A QAPP for passenger vessel sampling is required by State of Alaska and USCG regulations. Large cruise ship QAPPs are submitted each year by the Northwest Cruise Association (later Cruise Lines International Association) and are reviewed and approved by both USCG and ADEC. The latest QAPP is available online from ADEC. Small cruise lines often use company specific QAPPs based on state provided generic plans and need only ADEC approval. The small cruise ship plans do not have USCG required elements and allow for crew sampling. State ferries often used the large cruise ship QAPP, but developed a separate QAPP in 2018. QAPPs share many of the same elements, and generally do not differ by analytical methods.

ADEC reviews the large-ship sampling program each year (for small ships this is usually every three years) and submits a list of any updates or changes needed. Meetings with the primary sampling contractor used by large cruise ships occur nearly every year for discussion of quality assurance, the QAPP, and potential improvements in sampling.

Vessel Specific Sampling Plans
Each ship is required by ADEC and USCG to provide a vessel-specific sampling plan (VSSP) prior to sampling. The VSSP is reviewed and approved by ADEC if it meets all requirements. A VSSP must provide information needed to understand how the sample will be taken, information about the treatment process, and how a sample would be representative of discharged wastewater. The VSSP documents sample port locations, equipment used to treat wastewater, and any ship-specific sampling information.

Initial VSSPs were often incorrect or did not contain needed information. ADEC and USCG staff worked with vessel operators to improve the VSSP to include important information and fix errors. Ocean Rangers reported numerous errors in VSSP documents; operators also identified errors and are required to submit revised VSSPs as items are identified.

Duplicate and replicate sampling
Blind duplicates are collected at a defined percentage of sample events and used to check laboratory analysis with no ship name provided to the laboratory. Duplicate sampling results are compared by a third-party auditor and reviewed by ADEC staff.

One potential source of variation between the sample analysis and duplicate analysis identified in audits occurred when duplicates were taken immediately before or after the sample event. A duplicate sample collected even a few minutes after the sample event may reveal differences due to changes in inputs, flow, or other variations. Collecting a larger sample volume and splitting into replicates could eliminate this, but mixing and transferring samples could also introduce contamination.

Blanks
Field and laboratory (or method) blanks are used as a quality control measure. These are bottles filled with "clean" water to compare with the sampled effluent. They are used to identify contamination in the sample collection process or transportation of the sample. Analysis of the blanks is included in the submitted reports for each sample event.

Notes and checklists
Field notes are required in the QAPPs and document what was sampled, when the sample was taken, location, field instrument calibration, and any field results (temperature, chlorine, and pH). Sampling and data review checklists are used by samplers to confirm actions taken. Sampling checklists and field notes are included in sample reports provided to ADEC and USCG. Deviations from QAPPs or sampling plans are required to be documented, and ADEC reviews the reported deviations. Corrective actions or resampling may be required by ADEC or USCG depending on the potential impact to sample representativeness. Photographs of the sample port as well as copies of vessel discharge logs are required for most samples to verify sample collection and discharge status.

Chain of custody
Chain of custody is an essential part of the quality assurance process. A chain of custody form is used at each sample event to document each time custody of the sample changes. It also documents time and date and who conducted the sampling. A copy of the chain of custody document is provided with sample reports submitted to USCG and ADEC.

Audits
Audits of laboratories in Alaska are conducted by ADEC chemists. ADEC did not conduct audits of out-of-state laboratories. Almost all samples included in this report were collected in Alaska with the possible exception of some 2000 to 2002 samples where collection location was not identified. USCG also conducts audits of laboratories, and shares information on any out-of-state audits with ADEC. Third-party audits for examination of sample collection, data review, and laboratory procedures are required for large cruise ship sampling.

Approval of samplers and laboratories
USCG maintains a list of sampling laboratories approved by USCG headquarters that are acceptable for use in sample collection from large cruise ships. They will also accept additional laboratories for one-time use if approved by Sector Juneau.

ADEC requires laboratories be certified to analyze drinking water by the State of Alaska, or to be National Environmental Laboratory Accreditation Program (NELAC) certified. ADEC has generally accepted USCG-approved laboratories for out-of-state vessel sampling.

ADEC regulations require ADEC approval of those conducting sampling each year. Sampling contractors or vessel operators must submit a list of samplers with their experience and training.

ADEC occasionally identified quality assurance issues with crew or samplers regarding sample collection and preservation, often by new or inadequately trained samplers.

Difficulties experienced in obtaining representative sampling

Sampling on a ship presents logistical challenges not present in a municipal treatment facility with a similar population. A ship must be near a laboratory at the time the sample is taken or be able to transport samples to a lab within the allowed holding time for analysis to occur.

Time of sample collection

Bacteria holding times of only a few hours limit many sample events to early morning prior to arrival in a port. Samples taken from 3:00 to 6:00 AM are likely not representative of peak flow or nutrient loading for some treatment systems.

Location of sampling

Location of the sample event may be limited to communities with labs or near airports with short flights to Juneau. Airport security restrictions, closure of labs, and unwillingness of some community-owned labs to process samples gradually restricted the ability to conduct bacteria analysis. Most of the sampling after 2008 in Alaska occurred near Juneau or between Juneau and Skagway. Laboratory availability in much of the Arctic and Aleutian Islands, as well as in other regions in Alaska, is limited. Laboratory infrastructure is needed in communities in these regions to address increase of cruises in the Arctic and remote areas of Alaska.

Direct discharges overboard

Some small ships, and occasionally large ships will have direct overboard connections for wastewater. These may be connected to a sink, shower, dishwasher, drain, or several of these devices. Sampling was typically conducted by a bucket on a rope, but many of the devices connected were only occasionally used. Vessel crew would use the sources to replicate a typical discharge, but it was challenging to verify if discharge was representative of typical use. ADEC reduced the requirement of sampling of direct discharges, since these were untreated wastewater, hence existing data on untreated discharges could be used to evaluate impact of discharges.

Recirculation sampling

USCG allows samples to be collected without discharging. This is done while effluent is pumped into a holding tank or recirculated back into the treatment system. Almost all ADEC required sampling must be collected while discharging, with a few exceptions. While samples identified as recirculation samples were not included in the results in this report, some sample reports were not clear on discharge status and may have been taken while in recirculation mode. On several samples over the effluent limits, ADEC was told at the time of the sample the ship was discharging, but when results were obtained, the ship reported it as a recirculation sample.

Samples cancelled or rescheduled due to no discharges

ADEC permits require sampling to occur only while discharging overboard. Vessels with systems upsets, or concerns about system performance, will stop discharging immediately. Sampling was mainly restricted to systems believed to be operating well. Sampling may not be representative of overall system performance, by not including times when systems were not operating at full performance. Several ships did not discharge in Alaska for an entire season or more, limiting sample data for these ships.

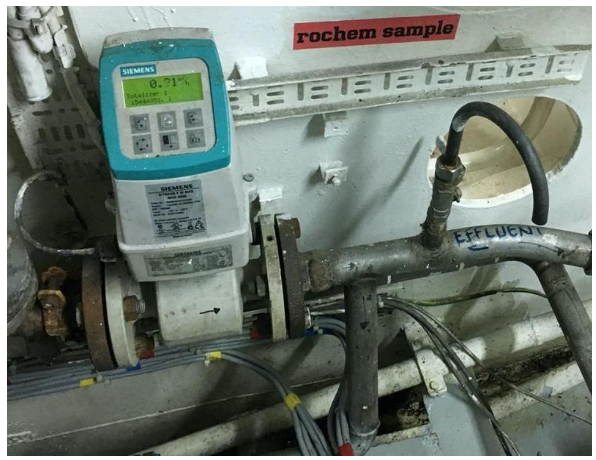
Insufficient sample volume

Some sample events, on both large and small cruise ships, were cancelled because the sampler could not obtain sufficient sample volume. On several ships this was due to an undersized sampling port that slowed flow. Other causes were reported, such as insufficient volume due to passengers being ashore. This occurred even on large ships that discharged hundreds of cubic meters a day. These low-flow events were likely not representative of typical higher-flow discharges.

Examples of failures in representative sampling

Note that many of the items below do not represent an intentional effort to deceive regulators or influence sample results. Several noted items were identified to inspectors and documented by crew.

Failure to properly disinfect sample port
The sample port must be disinfected to reduce the potential of bacterial contamination. Use of chlorine products to disinfect could raise the sampled chlorine level. High temperature or corrosive chemicals could leach metals. The most common disinfection method appears to have been the use of rubbing alcohol.



Wrong wastewater type, or wrong sample port sampled
Sampling the wrong sample port occurred on several ships, only to be identified several samples later by a sampler, from ADEC or USCG or an Ocean Ranger. This is less likely if the sample port was clearly labeled and identified in the sampling plan correctly. Photos of the sample port were added to sampling reports to better identify these errors.

Holding time or temperature failure
Bacteria will continue to increase in number over time and at warm temperatures. Several samples were identified with this as a potential cause for high values of bacteria. Improvements in quality assurance early in the sampling program led to lack of analysis by labs if holding time or temperature criteria are not met.

Volatiles escaping
Samplers must make sure the sample bottles are full or volatiles will enter the air in the bottle and will be lost when the bottle is opened. A loose cap can also allow volatiles to escape.

Failure to flush sample port and line
The sample line must be flushed before the sample is taken. At a minimum, the volume of the line between the discharge pipe and the sample port needs to be drained and flushed. If a sample port is directly off the lower part of a pipe or is a branch that is not used except for sampling, then material and bacteria can build up over time. In some cases, sample ports have been completely blocked by solids or corrosion.

Crew choosing sample collection time and delays in sampling
This situation was reported several times by Ocean Rangers. ADEC staff referred to these occurrences as “wait for it” sampling. Crew were reported to be watching electronic monitors such as turbidity, pH, or dissolved oxygen and then instructing samplers to take the sample when levels on the meters were within a specific range. Crew would also ask for sampling to be stopped for the same reasons. Sampling times were also sometimes delayed at the dock, with long waits for security clearance or other reasons.

Source switching or adding clean water
Switching influent type or adding water is a possible way to modify sample results. Water can be added to the treatment system as part of the regular treatment system operation, such as in cleaning or to dilute high levels of nutrients for better system performance. Several instances of drinking water being added before sampling were documented by ADEC and USCG—some up to several tons. Indicators can be neutral pH, very low nutrients, almost no ammonia, and low hardness or alkalinity. Low levels of metals may be present. On small cruise ships and ferries with seawater toilet flushing large amounts of seawater were added. Additional seawater could be added as dilution or if needed by the treatment system to generate chlorine. Ferries may store seawater if needed to add while transiting waters with low salinity to allow for adequate chlorine generation by the sewage treatment plant (STP).

Leaking discharge ports with seawater intrusion
Seawater intrusion into the discharge line and sample caused ADEC to add conductivity as a regular sample parameter. Other indicators of seawater intrusion are pH, temperature, nutrients, hardness, fecal coliform, and alkalinity. Samplers sometimes noted the smell of seawater in the sample. Seawater is much cooler than effluent in most Alaskan ports, with glacier runoff significantly cooling harbor water. Some vessels identified seawater intrusion in samples with fecal exceedances after thoroughly checking the treatment system for failure. ADEC used sample results taken by students of bacteria in waters around Juneau to compare, where a fecal coliform level seemed to match several of the seawater intrusion events. Causes of seawater intrusion are mainly from discharge ports not being fully closed or leaking due to corrosion, obstruction, or mechanical failure.

Bypasses
“Magic pipes” or bypasses can divert wastewater and effluent, or provide an alternative source of water. Samples could be switched with “clean” water.

System operation changes
The parts of the treatment system or additional treatment elements used in Alaska may be shut off at other times or when not needed. Operations may change depending on local rules.

Methods used to address representative sampling

ADEC and USCG personnel regularly audit sample events, inspect ships, and verify documentation related to wastewater. Inspections are a critical part of monitoring for compliance, and identify non-compliance as well as quality assurance issues in sample collection. Third party auditors are required by USCG to audit sample events for large cruise ships.

Third party sampling
USCG requires third party sampling on cruise ships with over 500 overnight passengers as part of the continuous compliance program for grey water and sewage. Third party samplers are trained in sample collection. Contractors for the cruise lines provide sampling and laboratory services.

Unannounced sampling
USCG requires some samples for large ships to be unannounced and not included in regular sampling schedules. Unannounced sampling for underway-only sampling is difficult, since ship security requires notification of who comes onboard and the samplers with their gear are immediately recognized by crew.

Random sampling
USCG typically conducts a small number of random sample events on large cruise ships to verify compliance and to compare results against regular sample events. This sampling appeared to be an effective compliance tool, with little notice to the ships that a sample would be collected. Several random sample events resulted in compliance actions by ADEC. ADEC also had authority to collect random samples, but this does not appear to have occurred after 2004. A possible reason may be that USCG rules require the ship to pay for the random sample collection and analysis, while ADEC pays for any ADEC collected samples. Ocean Rangers had sample collection kits for the first few years of the Ocean Ranger program, but these were never used.

Composite sampling
Almost all sample data in this report was collected as a grab sample at a single sampling event. Composite sampling is conducted over time, with multiple samples taken for mixing prior to analysis. This can even out variability and capture peaks in concentrations. Some 2004 EPA samples were composite, and WET sample collection is composite.

Continuous monitoring
ADEC and USCG do not require continuous monitoring, but this has been used in other sampling programs as a way to capture information on spikes in concentration and variability. Continuous monitoring is used on some treatment systems as an indicator of performance, and is required on some ships for other wastewaters such as the oil content of bilgewater. Continuous monitoring was not adopted in the state general permits in part because of other ways to verify treatment of wastewater such as daily inspections by Ocean Rangers. Many large cruise ships regularly monitor effluent with onboard labs or with field equipment that measures indicative parameters. These ships compare third-party sampling with results obtained onboard.

Data review
ADEC reviews sample results as they came in and at the end of the season. Results are compared with compliance limits, previous results for the ship, and other ships with the same treatment equipment. Quality assurance reviews are carried out by an ADEC chemist and staff looking at duplicates, audits, and sample values. Some sample reports are checked to verify if complete and if photos matched VSSP sample ports. Indicators such as temperature, pH, salinity, alkalinity, and other parameters are checked for large changes that could indicate seawater intrusion or a change of sources sampled. Blackwater and grey water can have different physical characteristics; pH and other indicators can be used to indicate the presence of these sources compared with previous results for each ship.

Appendix E Vessel Specific Sampling Plan

Example is derived from the Alaska DEC 2019 Large Cruise Ship VSSP, with most empty rows in tables removed.

Vessel Name:
IMO Number:
The sampler will use the VSSP as a guide to identify the specific onboard location(s) and sources to be sampled. To satisfy the VSSP requirement, you may fill in the blanks in this form starting on page 2 or you may submit an existing up to date VSSP if it contains the components listed in 18 AAC 69.030(b).

Please note that ADEC will not approve sampling locations that are more than 50 feet from the overboard discharge port. Samples taken in 2003 indicated that samples taken directly after the ultraviolet disinfection unit were not of the same quality as samples taken at the overboard discharge pipe.

Vessel Name: ______________________________

(Note: Include all units. Examples: cubic meters, gallons, cubic meters per second.)

Year ship joined fleet	
Gross tonnage	
Maximum passenger capacity	
Crew capacity	

Treatment equipment

MSD system (USCG type)	
Number of MSD units	
Other wastewater treatment units not listed above (list types & capacity)	

Generated Volumes

		Amount	Units
Blackwater generation per day			
Graywater generation per day (list units of measurement)	Accommodations		
	Galley		
	Laundry		
	Other		
Daily water use/individual			
Seawater usage per day			
Peak water use per hour			
Hours of peak water use			

Discharge Ports

List all discharge ports which discharge graywater, blackwater or other wastewater

Discharge port designation (name)	Wastewater types discharged	Diameter (list units)	Location	Vertical Distance from water line	Average Flow Rate

Discharge Pumps

Complete one line for each discharge pump (even if you have multiple discharge pumps per discharge port)

Discharge port designation (name)	Pump manufacturer and model	Maximum flow rate	Units

Collection Tanks

List all of the vessel tanks which are involved with collection of wastewater prior to treatment

Tank name/number	Type of wastewater stored	Location	Volume (with units of measurement)

Intermediate Tanks

List all of the tanks which are involved with wastewater treatment

Tank name/number	Type of wastewater stored	Location	Volume (with units of measurement)

Holding Tanks

List all of the tanks which are involved with collection of wastewater for storage

Tank name/number	Type of wastewater stored	Location	Volume (with units of measurement)

Wastewater Treatment

Provide a description and capacity of the wastewater treatment system(s) on this vessel:

Discharges

Provide the individual vessel rules or procedures for discharging wastewater.

Wastewater Sampling Port with suggested Locations and Timing

Describe the vessel's sample port location(s), where the sampling should occur (in port or underway) and the time of day that the sampling should take place. The owner/operator needs to explain why these selected sampling sites and times give the most representative sample. The sample selection should be adequately mixed and homogenous. All samples need to be taken from wastewater as it is discharging overboard, unless deemed impractical by ADEC.

Sample Port / Valve: [all vessels]

Sample Valve Identification [notation used in WW Discharge Logbook]	
Sample Valve Location	

Photo of Sample Valve: *<Insert Vessel Photo of Sample valve + caption>*

Sample Suggested Timing:

Discharge Regime	Sample Time Range (AK time)	Misc.
Continuous		
Underway		
Stationary		

Flushing sample valve / sample Line:

Sample valve directly attached to discharge line (Y/N)	
Length of sample line from discharge pipe to sample valve / line diameter [ft/m]	
Required minimum flushing volume [US gallons / Liters]	

►***Duration time of the Sampling Event not to exceed 30 minutes. If exceeded; a concise deviation report to be provided; including steps taken to avoid re-occurrence.***

Description of the standards the owner or operator will use to determine a deviation from the plan.

Attach a sketch of vessel with treatment system, tanks, discharge pumps, discharge lines, sampling locations, and overboard ports.
Attach a sketch of vessel with treatment system, tanks, discharge pumps, discharge lines, sampling locations, and overboard ports.
Receiving Water Sampling (for ships authorized for discharge into a mixing zone while under 6 knots under the 2014 General Permit (2013-DB0004))

Discharge Port Location:

(Provide external location information for the sampler to establish the discharge location)

Discharge port designation (name)	Wastewater types discharged	Side (port or starboard)	Reference Location used for sampler to determine port location (visible mark, or bow waterline for example)	Horizontal Distance from reference location

Discharge Port Location Sketch or Photo:

Describe how the receiving water sample will be representative when compared to the onboard sampling.

For intermittent and not continuous discharge, describe how the sampler will determine discharge status at time of receiving water sample event.

Wastewater Sampling Tables

Note: Full list of sample parameters will appear in the approved Quality Assurance Project Plan.

Cruise ships operating under a DEC discharge permit must obtain the required number and types of samples as listed in the permit. Cruise ships sampling for USCG continuous compliance must follow the USCG requirements for sampling.

Dates of sampling can be submitted separately by an operator or sampling contractor. Notification to DEC and USCG must be made 36 hours prior to a sample being taken.

Wastewater Type	Sample type	Sample Location	Representative times for Sampling
	Grab		
	Grab		
	Grab		

Appendix F WET Effluent Summaries

Grey Water WET 2002-2006 Summary

WET Testing- GW Only 2002-2006				Mysid Acute NOEC	Top-smelt Acute NOEC	Bivalve Larva Norm-ality NOEC	Bivalve Larva Survival NOEC	Echino-derm Fertili-zation NOEC	Kelp Germ-ination NOEC	Kelp growth NOEC
Ship	WW Type	Year	Treatment							
Dawn Princess	GW in tanks	2002	Chlorine	5%	5%	0.5%		0.5%		
Yorktown Clipper	GW	2002	Chlorine	0.5%	0.5%	0.5%		0.5%		
Spirit of Columbia	GW	2003	None	12.5%	25%	6.25%	25%	<1.5%		
Carnival Spirit	GW	2003	AWTS	>50%	50%	25%	50%			
Spirit of Alaska	GW	2004	None	12.5%	6.25%			3.125%		
Sea Lion	GW	2005	Chlorine	12.5%	25%	6.25%	50%	3.125%	3.125%	3.125%

Not tested or failed QA

NOEC- no observable effect concentration.

Grey Water Mixed with Sewage WET 2002-2006

WET Testing- Mixed WW 2002-2006				Mysid Acute NOEC	Top-smelt Acute NOEC	Bivalve Larva Normality NOEC	Bivalve Larva Survival NOEC	Echino-derm Ferti-lization NOEC	Kelp Germ-ination NOEC	Kelp growth NOEC
Ship	WW Type	Year	Treatment							
Celebrity Mercury	Mixed WW	2002	AWTS	50%	50%	50%		50%		
Volendam	Mixed WW	2002	AWTS	50%	5%	5%		5%		
Kennicott	Mixed WW	2002	MSD II	5%	5%	5%		0.5%		
Spirit of Oceanus	Mixed WW	2003	MSD II	25%	12.5%	<1.5%	12.5%	<1.5%		
Norwegian Wind	Mixed WW	2003	AWTS	>50%	12.5%	6.25%	50%	25%		
Ryndam	Mixed WW	2003	AWTS	>50%	50%	12.50%	50%	50%		
Sun Princess	Mixed WW	2003	AWTS	12.5%	12.5%	<1.5%	50%	<1.5%		
Kennicott	Mixed WW	2004	MSD II	50%	50%	25%	50%	12.5%		
Veendam	Mixed WW	2004	AWTS	50%	50%					
Coral Princess	Mixed WW	2004	AWTS	50%	25%	3.125%	12.5%	25%		
Malaspina	Mixed WW	2005	MSD II	12.5%	12.5%	3.125%	3.125%	<1.56%	1.56%	<1.56%
Ryndam	Mixed WW	2005	AWTS	50%	50%		50%		50%	50%
Norwegian Dream	Mixed WW	2005	AWTS	50%	25%	1.56%	12.5%	25%	50%	12.5%
Serenade of the Seas	Mixed WW	2005	AWTS	50%	25%	12.5%	12.5%		50%	25%
Sun Princess	Mixed WW	2005	AWTS	25%	12.5%	3.125%	50%	25%	50%	50%
Empress of the North	Mixed WW	2006	MSD II	25%	12.5%	3.13%	12.5%	<1.56%	6.25%	<1.56%
Celebrity Infinity	Mixed WW	2006	AWTS	50%	25%	6.25%	25%	50%	50%	50%
Island Princess	Mixed WW	2006	AWTS	50%	50%	12.5%	50%	12.5%	50%	50%
Statendam	Mixed WW	2006	AWTS	25%	25%	6.25%	12.5%	1.56%	50%	6.25%
Oosterdam	Mixed WW	2006	AWTS					25%	50%	50%

Not tested or failed QA

NOEC- no observable effect concentration.

Treated Grey Water WET 2017-2019 Summary

WET Testing- AWTS GW 2017-2019				Topsmelt 96 hr NOEC	Topsmelt 7 day NOEC	Topsmelt 7 day growth NOEC	Mussel 48 hr dev NOEC
Ship	WW Type	Date	Treatment				
Ruby Princess	GW	5/8/17	AWTS	50%	50%	50%	50%
Star Princess	GW	5/9/17	AWTS	25%	25%	25%	6.25%
Grand Princess	GW	5/11/17	AWTS	50%	50%	50%	50%
Grand Princess	GW	6/1/17	AWTS	50%	50%	50%	50%
Ruby Princess	GW	6/5/17	AWTS	50%	50%	50%	50%
Star Princess	GW	6/14/17	AWTS	50%	50%	50%	12.5%
Star Princess	GW	7/18/17	AWTS	50%	50%	50%	12.5%
Ruby Princess	GW	7/24/17	AWTS	50%	50%	50%	50%
Star Princess	GW	8/1/17	AWTS	50%	50%	50%	12.5%
Grand Princess	GW	8/10/17	AWTS	50%	50%	50%	50%
Ruby Princess	GW	8/21/17	AWTS	50%	50%	50%	50%
Star Princess	GW	9/6/17	AWTS	50%	50%	50%	25%
Grand Princess	GW	9/8/17	AWTS	50%	50%	50%	50%
Ruby Princess	GW	9/18/17	AWTS	50%	50%	50%	50%
Golden Princess	GW	5/22/18	AWTS	50%	50%	50%	25%
Emerald Princess	GW	6/20/18	AWTS				12.5%
Emerald Princess	GW	7/11/18	AWTS	50%	50%	50%	50%
Golden Princess	GW	7/25/18	AWTS	50%	50%	50%	25%
Golden Princess	GW	8/8/18	AWTS	50%	50%	50%	13%
Emerald Princess	GW	8/29/18	AWTS	50%	50%	50%	50%
Golden Princess	GW	9/5/18	AWTS	50%	50%	50%	50%
Emerald Princess	GW	9/12/18	AWTS	50%	50%	50%	50%
Royal Princess	GW	5/14/19	AWTS	50%	50%	50%	12.5%
Royal Princess	GW	6/11/19	AWTS	50%	50%	50%	25%
Royal Princess	GW	7/9/19	AWTS	50%	50%	50%	25%
Royal Princess	GW	8/6/19	AWTS				50%
Royal Princess	GW	8/28/19	AWTS	50%	50%	50%	
Royal Princess	GW	9/11/19	AWTS	50%	50%	50%	25%

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Treated Mixed Sewage and Grey Water WET 2017-2019 Summary

WET Testing- Mixed 2017-2019				Topsmelt 96 hr. NOEC	Topsmelt 7 day NOEC	Topsmelt 7 day growth NOEC	Mussel 48 hr. dev NOEC
Ship	WW Type	Date	Treatment				
Volendam	Mixed	5/12/17	AWTS	50%	50%	50%	12.5%
Norwegian Jewel	Mixed	5/23/17	AWTS	50%	50%	50%	3.12%
Norwegian Pearl	Mixed	5/23/17	AWTS	50%	25%	25%	0.78%
Sojourn	Mixed	5/25/17	AWTS	50%	50%	50%	6.25%
Zaandam	Mixed	5/25/17	AWTS	50%	50%	50%	25%
Norwegian Sun	Mixed	5/31/17	AWTS	25%	25%	25%	1.56%
Zaandam	Mixed	6/8/17	AWTS	50%	50%	50%	13%
Volendam	Mixed	6/9/17	AWTS	25%	25%	25%	1.56%
Norwegian Pearl	Mixed	6/13/17	AWTS	25%	25%	25%	1.56%
Sojourn	Mixed	6/16/17	AWTS	50%	50%	50%	25%
Norwegian Jewel	Mixed	6/20/17	AWTS	50%	50%	25%	3.12%
Norwegian Sun	Mixed	6/22/17	AWTS	25%	25%	25%	6.25%

WET Testing- Mixed 2017-2019				Topsmelt 96 hr. NOEC	Topsmelt 7 day NOEC	Topsmelt 7 day growth NOEC	Mussel 48 hr. dev NOEC
Ship	WW Type	Date	Treatment				
Volendam	Mixed	7/7/17	AWTS	25%	25%	3.12%	3.12%
Sojourn	Mixed	7/11/17	AWTS	50%	50%	50%	25%
Grand Princess	Mixed	7/12/17	AWTS	50%	50%	50%	50%
Norwegian Sun	Mixed	7/13/17	AWTS	50%	50%	50%	6.25%
Norwegian Pearl	Mixed	7/18/17	AWTS	50%	50%	25%	6.25%
Zaandam	Mixed	7/20/17	AWTS	50%	50%	50%	12.5%
Norwegian Jewel	Mixed	7/25/17	AWTS	50%	50%	50%	6.25%
Norwegian Jewel	Mixed	8/8/17	AWTS	50%	50%	50%	1.56%
Zaandam	Mixed	8/17/17	AWTS	50%	50%	25%	6.25%
Volendam	Mixed	8/18/17	AWTS	50%	50%	25%	6.25%
Norwegian Pearl	Mixed	8/22/17	AWTS	50%	50%	25%	1.56%
Sojourn	Mixed	8/23/17	AWTS	50%	50%	50%	25%
Norwegian Sun	Mixed	8/24/17	AWTS	50%	50%	50%	6.25%
Volendam	Mixed	9/1/17	AWTS	50%	50%	25%	12.5%
Norwegian Sun	Mixed	9/7/17	AWTS	50%	50%	50%	6.25%
Norwegian Pearl	Mixed	9/12/17	AWTS	50%	50%	50%	3.12%
Sojourn	Mixed	9/14/17	AWTS	25%	25%	25%	12.5%
Zaandam	Mixed	9/14/17	AWTS	50%	50%	25%	6.25%
Norwegian Jewel	Mixed	9/19/17	AWTS	25%	50%	50%	12.5%
Norwegian Bliss	Mixed	6/12/18	AWTS	50%	50%	50%	12.5%
Norwegian Bliss	Mixed	7/24/18	AWTS	50%	50%	50%	3.12%
Regatta-port	Mixed	7/26/18	AWTS	50%	50%	50%	50%
Regatta-starboard	Mixed	7/26/18	AWTS	50%	50%	50%	50%
Norwegian Bliss	Mixed	8/21/18	AWTS	50%	50%	50%	6.25%
Regatta-port	Mixed	8/23/18	AWTS	50%	50%	50%	50%
Regatta-starboard	Mixed	8/23/18	AWTS	50%	50%	50%	50%
Norwegian Bliss	Mixed	9/4/18	AWTS	50%	50%	50%	12.5%
Regatta-port	Mixed	9/20/18	AWTS	50%	50%	50%	12.5%
Regatta-starboard	Mixed	9/20/18	AWTS	50%	50%	50%	6.25%
Le Soleal	Mixed	7/11/19	AWTS	50%	50%	50%	12.5%
Maasdam	Mixed	5/21/19	AWTS	25%	25%	25%	6.25%
Maasdam	Mixed	6/10/19	AWTS	50%	50%	25%	6.25%
Maasdam	Mixed	7/15/19	AWTS	50%	50%	50%	6.25%
Norwegian Joy	Mixed	5/6/19	AWTS	50%	50%	50%	6.25%
Norwegian Joy	Mixed	6/4/19	AWTS				25%
Norwegian Joy	Mixed	7/16/19	AWTS	50%	50%	50%	12.5%
Norwegian Joy	Mixed	8/13/19	AWTS	50%	50%	50%	12.5%
Norwegian Joy	Mixed	9/10/19	AWTS	50%	50%	50%	25%
Regatta_Port	Mixed	7/29/19	AWTS	50%	50%	50%	12.5%
Regatta_Port	Mixed	8/23/19	AWTS	50%	50%	50%	25%
Regatta_Stbd	Mixed	7/29/19	AWTS	50%	50%	50%	12.5%
Regatta_Stbd	Mixed	8/23/19	AWTS	50%	50%	50%	12.5%
Viking Orion	Mixed	5/30/19	AWTS	50%	50%	50%	12.5%
Viking Orion	Mixed	6/19/19	AWTS	50%	50%	50%	6.25%
Viking Orion	Mixed	7/10/19	AWTS	50%	50%	50%	6.25%
Viking Orion	Mixed	8/16/19	AWTS	50%	50%	50%	3.12%

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