CRUISE SHIP WASTEWATER

2009-2012 SCIENCE ADVISORY PANEL PRELIMINARY REPORT

TO

ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION COMMISSIONER

November 1, 2012

Prepared by:
OASIS Environmental, Inc., an ERM Company

TABLE OF CONTENTS

TABLES

FIGURES

Appendices

ACRONYMS

µg/L	microgram per liter
AAC	Alaska Administrative Code
ACA	Alaska Cruise Association
APDEC	Alaska Pollutant Discharge Elimination System
AS	Alaska Statute
AWTS	Advanced Wastewater Treatment Systems
BAT	Best Available Technology
BOD	biochemical oxygen demand
BW	blackwater
CFR	Code of Federal Regulations
CWA	Clean Water Act
DAF	dissolved air flotation
DEC	Alaska Department of Environmental Conservation
DOC	dissolved organic carbon
ED	electrodialysis
EEZ	Exclusive Economic Zone
ELG	Effluent Limitation Guideline
EPA	U.S. Environmental Protection Agency
F/M	Organic Loading Rate
FC	fecal coliform
FOG	fat, oil, and grease
GW	graywater
HAL	Holland America
HB	House Bill
HRT	hydraulic retention time
IX	ion exchange
IMO	International Maritime Organization
LPRO	low pressure reverse osmosis
m^3	cubic meters
MARPOL	International Convention for the Prevention of Pollution from Ships
MBBR	moving bed bioreactor
MBR	membrane biological reactor
MEPC	Marine Environment Protection Committee
MF	microfiltration
mg/L	milligram per liter
MLSS	mixed liquor suspended solids
MSD	marine sanitation device
NA	not applicable
NCL	Norwegian Cruise Lines
NM (or nm)	nautical mile

NOI	Notice of intent
NPDES	National Pollutant Discharge Elimination System
NRWQC	National Recommended Water Quality Criteria
NSAF	Severn Trent TETRA® Nitrifying SAF
O&M	operations and maintenance
POTW	publicly-owned treatment works
RC	residual chlorine
RCCL	Royal Caribbean Cruise Lines
RO	reverse osmosis
SAP	Science Advisory Panel
SRE	Source Reduction Evaluation
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UF	ultrafiltration
USCG	U.S. Coast Guard
UV	ultraviolet
VGP	Vessel General Discharge Permit
WQC	Water Quality Criteria
WQS	Water Quality Standards
WWTP	wastewater treatment plant

{This page deliberately blank.}

EXECUTIVE SUMMARY

Appointed in 2009, the Alaska Cruise Ship Wastewater Science Advisory Panel has met for five face-to-face meetings in Juneau and participated in ten teleconferences since February 2010. All meetings and teleconferences were open to the public.

The Panel reviewed the legal framework of the Cruise Ship Program, House Bill (HB) 134; the existing water quality standards, Alaska Department of Environmental Conservation (DEC) cruise ship permits, and municipal wastewater permits.

The Panel compared the effectiveness of existing on-board treatment systems and reviewed the efforts that different cruise ship lines have taken to improve the quality of their wastewater discharge. The Panel researched available technologies used in shore-based facilities to decrease concentrations of ammonia and dissolved copper, dissolved nickel, and dissolved zinc for wastewater effluent.

The Panel worked with DEC to prepare data questionnaires about existing treatment systems, new technologies, and cost of installation and operation of current systems. Cruise operators responded to these questionnaires, providing valuable data that allowed the Panel to evaluate the cost of implementing currently used systems.

The Panel collaborated on this preliminary report that discusses: the sources of constituents of concern (ammonia, dissolved copper, dissolved nickel, and dissolved zinc); current levels of effluent quality achieved; current and additional methods of pollution prevention, control, and treatment; the environmental benefits of implementing additional methods, and the economic feasibility to do so.

The preliminary findings of the Panel are outlined below.

Advanced Wastewater Treatment Systems (AWTS) were designed to meet required criteria for conventional pollutants and are the most advanced, effective, and proven treatment systems available. This is especially true when AWTS are compared to municipal treatment plants discharging to marine waters.

Aquatic organisms, including fish and marine mammals, are protected through the cruise ship General Permit.

After evaluating all AWTS currently installed on cruise ships operating in Alaskan waters, the Panel found that none of those treating mixed blackwater and graywater consistently meet Alaska's marine Water Quality Criteria at the point of discharge for the constituents of concern (ammonia and dissolved copper, dissolved nickel, and dissolved zinc).

A dilution model developed by the first Alaska Cruise Ship Wastewater Science Advisory Panel and dye studies conducted by EPA demonstrate that concentrations lower than the Water Quality Criteria are attained within seconds following AWTS discharge and that acute and chronic exposures would not occur. Dilution modeling is used for permitting other wastewater discharges.

The Panel was unable to identify technologically effective and economically feasible treatment methods capable of consistently meeting the numeric Water Quality

Criteria at the point of discharge and that have been proven on cruise ships. Application of existing technologies in addition to AWTS, such as nitrification, ion exchange (IX) and reverse osmosis (RO), is expected to further reduce ammonia and dissolved metal concentrations. However, there is no evidence to prove adding additional technology will be technologically effective at meeting Water Quality Criteria, be economically feasible, or provide significant environmental benefit. Modifying operational procedures and additional staff training may help improve treatment performance. The panel recommends continued sampling and monitoring of cruise ship effluent.

Adaptation of emerging technologies from other industries to cruise ships presents significant feasibility challenges.

The Panel identified little additional environmental benefit to be gained by lowering the current permitted effluent limits to Water Quality Criteria at the point of discharge.

1. INTRODUCTION

Commercial passenger vessel[1] ("cruise ship") wastewater effluent quality and its management has been an issue of public concern in Alaska since the 1990s. As a result of effluent sampling that indicated cruise ship marine sanitation devices (MSD) were not working well, new federal and state laws were passed in 2000 and 2001. These laws regulated and set effluent limits for treated sewage (blackwater) and graywater (accommodations, galley, and laundry wastewater). To meet these more stringent effluent limits, cruise ships that discharge wastewater in Alaska installed new and improved wastewater treatment systems described in Section 4.4. These advanced wastewater treatment systems (AWTS) have been aboard all cruise ships discharging in Alaskan waters since 2003. However, companies may adopt different practices regarding the management of wastewater, such as not discharging into Alaska water either underway or in port.

In August 2006, Alaska voters approved Ballot Measure 2[2] ("Cruise Ship Taxation, Regulation and Disclosure"), which promulgated new regulatory requirements for large cruise ships operating in Alaskan waters. Among other requirements relating to taxation, gambling, and monitoring, the measure required that large passenger vessels may not discharge untreated sewage, treated sewage, graywater, or other wastewaters in a manner that violates any applicable effluent limits or standards under state or federal law, *including Alaska Water Quality Standards (WQS) governing pollution at the point of discharge* [emphasis added]. This requirement was interpreted by the Alaska Department of Environmental Conservation (DEC), with guidance from the Department of Law, as requiring cruise ship discharges to meet the WQS at the end-of-pipe without allowance for dilution of discharges through mixing with receiving waters in a mixing zone.[3] (A mixing zone means a volume of water adjacent to a discharge, in which wastes discharged mix with the receiving water.[4] See Section 7.3.1.1 for information about mixing zones and how they are typically used.)

---

[1] A.S. 46.03.490(2). "commercial passenger vessel" means a vessel that carries passengers for hire except that "commercial passenger vessel" does not include a vessel:

(A) authorized to carry fewer than 50 passengers;

(B) that does not provide overnight accommodations for at least 50 passengers for hire, determined with reference to the number of lower berths; or

(C) operated by the United States or a foreign government;

[2] See http://www.dec.state.ak.us/water/cruise_ships/Law_and_Regs/index.htm

[3] See page 15 in, DEC 2010. 2010 Large Commercial Passenger Vessel Wastewater Discharge General Permit Information Sheet.

[4] 18 AAC 70.990(42)

The Alaska WQS are found in the state's regulations at 18 AAC 70 and include assignments of designated uses to water bodies, numeric water quality criteria (WQC) protective of those designated uses, and anti-degradation provisions. In addition to listing some WQC, 18 AAC 70 adopts the following document by reference which contains a more complete listing of WQC: *The Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances.* The water quality standards include implementation tools including mixing zones, site-specific criteria and allowances for compliance schedules. The numeric WQC for parameters such as copper or ammonia are a part of the WQS. Regulations regarding the authorization of mixing zones are found in 18 AAC 70.240.

DEC issued the Large Commercial Passenger Vessel Wastewater Discharge General Permit Number 2007DB00002 in March 2008 (2008 General Permit) to meet the requirement of HB 134. DEC determined that the cruise ship AWTS met traditional wastewater quality parameters but did not meet WQC for ammonia, dissolved copper, dissolved nickel, and dissolved zinc. The 2008 General Permit established interim limits for these parameters during 2008 and 2009 that were less strict than the WQC. The average concentrations in effluent over time of traditional wastewater quality parameters and ammonia, dissolved copper, dissolved nickel, and dissolved zinc are shown in Figure 1 through Figure 7.

In 2008, the United States Environmental Protection Agency (EPA) issued a vessel general discharge permit (VGP). The VGP covers a range of discharge types (e.g. graywater, deck washdown, ballast, boiler blowdown, and others) and management practices for a variety of vessels. For cruise ships, the VGP essentially required that the municipal secondary treatment standards along with specific limits for bacteria and residual chlorine be met for graywater discharges and for discharges of mixtures of graywater and blackwater. A cruise ship that met the effluent limits established in the 2008 General Permit would generally also be in compliance with the graywater (which includes graywater plus blackwater) effluent limits in the EPA VGP. The VGP did not set effluent limits for blackwater only discharges. No cruise ships in Alaska discharge straight blackwater but instead treat and discharge a mix of gray and blackwater which has to meet the VGP graywater effluent limits. The VGP will be reissued, with modifications, effective December 2013, and has already gone through the public review and comment process.

On February 16 2009, DEC sponsored a Cruise Ship Technology Workshop in Juneau[5]. A number of vendors were brought in, but none were able to demonstrate that they had a system that could consistently meet WQC for both graywater and blackwater effluent at the point of discharge. Various technologies were identified that appeared to

[5] http://dec.alaska.gov/water/cruise_ships/pdfs/6_08_10_Feasibility_Report_Final.pdf

have potential to meet WQC when used with land based applications, but there are constraints to their application onboard cruise ships.

1.1. House Bill 134

In 2009, House Bill (HB) 134 was passed by the Alaska Legislature. Without HB 134, the Alaska WQS would have applied to large cruise ship wastewater at the point of discharge in 2010. HB 134 now allowed DEC, under prescribed conditions, to issue a new wastewater general permit to large cruise ships containing effluent limits at the point of discharge that were less stringent than the WQS if the permittee is unable to achieve compliance with numeric WQC at the point of discharge. HB 134 allowed DEC to issue this general permit for a period of three years only if DEC found that the permittee is using economically feasible methods of pollution prevention, control, and treatment that DEC considered to be the most technologically effective in controlling wastewater effluent at the point of discharge. DEC issued the 2010 Large Commercial Passenger Vessel Wastewater Discharge General Permit on April 22, 2010[6], which is valid until April 2013. This permit established effluent limits for ammonia, dissolved copper, dissolved nickel, and dissolved zinc that were higher than WQC at the point of discharge.

1.2. Cruise Ship Wastewater Science Advisory Panel

HB 134 also mandated that the DEC establish and consult with a Science Advisory Panel (Panel) to assist and advise the commissioner to conduct analyses and provide preliminary and final reports to the legislature that summarize the following information[7]:

(1) methods of pollution prevention, control, and treatment in use and the level of effluent quality achieved by commercial passenger vessels;

(2) additional economically feasible methods of pollution prevention, control, and treatment that could be employed to provide the most technologically effective measures to control all wastes and other substances in the discharge; and

(3) the environmental benefit and cost of implementing additional methods of pollution prevention, control, and treatment.

HB 134 also mandated the structure and roles of the Panel. Panel members, affiliations and statutory roles are listed below. Background information about the Panel, including biographical information about each Panelist, can be found on the 2009 Science Advisory Panel webpage[8].

---

[6] http://www.dec.state.ak.us/water/cruise_ships/gp/10gp.html

[7] AS 46.03.464

[8] http://dec.alaska.gov/water/cruise_ships/SciencePanel/index.htm

Mark Buggins*	Municipality of Sitka
Dr. Reinaldo Gonzalez	Burns and McDonnell
Kenneth Fisher	EPA
Juha Kiukas	Ecomarine
Lamberto Sazon	United States Coast Guard
Lincoln Loehr**	Stoel Rives LLP
Thomas Weigend	Meyer Werft
Steve Reifenstuhl***	Southeast Herring Conservation Alliance
Michelle Ridgway****	Oceanus Alaska Environmental Services
Dr. Silke Schiewer	University of Alaska Environmental Engineering
Dr. Simon Veronneau	HEC Montreal Supply Chain Research Group

* Mark Buggins fills the legislatively mandated coastal community Panel seat.
** Lincoln Loehr fills the legislatively mandated cruise ship industry Panel seat.
*** Steve Reifenstuhl fills the legislatively mandated commercial fishing industry Panel seat.
**** Michelle Ridgway fills the legislatively mandated NGO Panel seat.

The Panel met for the first time in February 2010 and since then has been working on this report in collaboration with DEC Cruise Ship Program staff and a contractor facilitator. They have attended five face-to-face meetings in Juneau, conducted ten teleconferences, and sponsored a technology workshop.

This preliminary report contains a description of the methods of pollution prevention, control, and treatment currently in use and the effluent quality currently attained by permitted large passenger vessels. The Panel used all available information to identify additional methods of pollution prevention, control and treatment. Potential additional methods are described in this report and discussion of the technical feasibility of these methods is provided. The Panel adopted a Best Available Technology framework to systematically evaluate current and potential methods of pollution prevention control and treatment. This report also provides a discussion of whether those methods can achieve WQS at the point of discharge and the environmental benefits and costs of implementing additional methods.

2. BACKGROUND

2.1. Overview of Alaskan Waters

Alaska contains over 50% of the total U.S. coastline, with approximately 45,000 miles of marine water shoreline.[9] The marine waters of the state include all waters within the boundaries of the state (three nautical miles from the Mean High Water Line). It also includes all of the waters of the Alexander Archipelago, even if not within the boundaries of the state. Waters of the Alexander Archipelago includes all waters under the sovereignty of the United States within or near Southeast Alaska.[10]

Alaska's commercial fisheries are the most productive and valuable in the nation, with a wholesale value of $3.6 billion.[11] Recent studies put the combined economic impact of commercial and sport fishing at $7.4 billion and 89,915 full-time-equivalent jobs.[12] The annual harvest from Alaskan waters is over 5 billion pounds of fish.

Alaska waters support robust fisheries. Tens of thousands of people harvest salmon, halibut, crab, trout, and other varieties of finfish and shellfish in subsistence, personal use, and sport fisheries. Subsistence and personal use fishing support a traditional way of life for many Alaskans. There are many subsistence fisheries for salmon, halibut, herring spawn-on-kelp, shellfish and groundfish throughout Southeast Alaska outside of the Juneau and Ketchikan non-subsistence use areas.[13] Subsistence fishing in Alaska also provides valuable wild harvests. Guides, lodges and charter operators provide residents and visitors with fishing experiences and contribute significantly to the tourism industry and economy.

The southeast Alaskan coast, where cruise ship traffic is concentrated, is very convoluted. It contains thousands of bays, estuaries, coves, fjords, and other water bodies. Southeast Alaska has a population of 75,526 people.[14] Its waterways are used extensively by the cruise ship industry. A total of 922,331 cruise ship passengers plus

[9] "2004 Southeast Alaska Coastal Survey Environmental Status," DEC, 2011. http://dec.alaska.gov/water/wqsar/monitoring/documents/SE_Final_Report_May_2011.pdf

[10] Alaska Statute 46.03.490

[11] Alaska Department of Fish & Game – Commercial Fisheries Website: http://www.adfg.alaska.gov/index.cfm?adfg=fishingCommercial.main

[12] Alaska Department of Fish & Game (http://www.adfg.alaska.gov/index.cfm?adfg=fishing.main)

[13] Alaska Department of Fish and Game: http://www.adfg.alaska.gov/index.cfm?adfg=ByAreaSubsistenceSE.fishingInfo

[14] Alaska Department of Labor (http://labor.alaska.gov/research/pop/popest.htm)

additional crew were expected to visit Alaska in 2012.[15] During the summer, the population of crew and passengers at any given time is about 60,000 (assuming 20 vessels with average of 3,000 people each).

2.2. Alaska Water Quality Standards

According to the EPA, water quality standards (WQS) are the foundation of the water quality-based control program mandated by the Clean Water Act[16]. WQS define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements:

1) Designated uses of the water body (e.g., recreation, water supply, aquatic life, agriculture),
2) Water quality criteria (WQC) to protect designated uses (numeric pollutant concentrations and narrative requirements),
3) An antidegradation policy to maintain and protect existing uses and high quality waters, and
4) General policies addressing implementation issues (e.g., low flows, variances, mixing zones).

Numeric WQC are developed to protect designated uses. Individual numeric criteria are based on specific data and scientific assessment of adverse effects. The numeric criteria are numbers that specify limits and/or ranges of chemical concentrations, like oxygen, or physical conditions, like water temperature. Numeric criteria for aquatic life protection usually contain a concentration (e.g. 5 mg/L) and averaging period. For toxic exposure effects, a one-hour averaging period applies for an acute (short-term) concentration, while a four-day average applies for a chronic concentration (long-term toxic exposure effects).

Alaska's marine water quality criteria (WQC) are described in *The Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances.*[17] The criteria are derived from EPA's National Recommended Water Quality Criteria.[18] The criteria include values intended to be protective of both acute

---

[15] Alaska Department of Environmental Conservation (http://dec.alaska.gov/water/cruise_ships/pdfs/2012_Large_Wastewater_Table.pdf)

[16] http://water.epa.gov/scitech/swguidance/standards/about_index.cfm

[17] DEC 2008. *Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances.* http://dec.alaska.gov/water/wqsar/wqs/pdfs/Alaska%20Water%20Quality%20Criteria%20Manual%20for%20Toxic%20and%20Other%20Deleterious%20Organic%20and%20Inorganic%20Substances.pdf

[18] http://water.epa.gov/scitech/swguidance/standards/current/upload/nrwqc-2009.pdf

(short term) and chronic (long term) exposure by aquatic life in marine water and include duration of exposure components: 4-day exposure for chronic criteria and 1 to 24-hour exposures for acute criteria.

Since the wastewater discharged from AWTS generally meets most requirements, with only the WQC for ammonia, copper, nickel and zinc commonly being exceeded, the Science Advisory Panel focused on the four contaminants which are considered "constituents of concern" for the purpose of this report.

The WQC for the constituents of concern are described in the following sections.

2.2.1. Ammonia

There are both acute and chronic aquatic life criteria and in marine water they vary with temperature, salinity and pH. Alaska DEC has determined that the applicable temperature, salinity, and pH to use are 10 to 15^{o}C, 20 parts per thousand salinity, and 8.2 pH units,[19] respectively, and the acute and chronic ammonia criteria for these conditions are:

- Acute Total Ammonia criterion = 6.5 mg-N/L applied as an average during a one hour period of exposure.
- Chronic Total Ammonia criterion = 1 mg-N/L applied as an average during a 4-day exposure.

2.2.2. Copper

The state's acute and chronic water quality criteria for copper in marine waters are:

- Acute aquatic life = 4.8 µg/L dissolved copper as a 24-hour average exposure.
- Chronic aquatic life = 3.1 µg/L dissolved copper as a 4-day average exposure.

The criteria also note that "when the concentration of dissolved organic carbon is elevated, copper is substantially less toxic and use of site specific criteria might be appropriate." [20]

2.2.3. Nickel

The state's acute and chronic water quality criteria for nickel in marine waters are:

- Acute aquatic life = 74 µg/L dissolved nickel as a 1-hour average exposure.

---

19 See footnote a in table 8 in, DEC 2010. 2010 Large Commercial Passenger Vessel Wastewater Discharge General Permit Information Sheet.
http://dec.alaska.gov/water/cruise_ships/pdfs/2010_Cruise_Ship_Info_Sheet_FINAL.pdf

20 EPA 2008 reported average total organic carbon (TOC) concentrations in cruise ship AWT effluents of 19.0 mg/L(±1.20). Given the high degree of filtration, most all of the TOC will be dissolved (DOC). Consequently the DOC would be expected to substantially reduce the availability and toxicity of the copper in the treated wastewater.

- Chronic aquatic life = 8.2 µg/L dissolved nickel as a 4-day average exposure.

2.2.4. Zinc

The state's acute and chronic water quality criteria for zinc in marine waters are:

- Acute aquatic life = 90 µg/L dissolved zinc as a 1-hour average exposure.
- Chronic aquatic life = 81 µg/L dissolved zinc as a 4-day average exposure.

Table 1 lists the WQC values for the constituents of concern under both chronic and acute exposure scenarios.

Table 1 Water Quality Criteria for Constituents of Concern

COC	Units	AWQC Chronic	AWQC Acute
Ammonia	mg/L	1 (4-day exposure)	6.5 (1-hour exposure)
Dissolved Copper	µg/L	3.1 (4-day exposure)	4.8 (24-hour exposure)
Dissolved Nickel	µg/L	8.2 (4-day exposure)	74 (1-hour exposure)
Dissolved Zinc	µg/L	81 (4-day exposure)	90 (1-hour exposure)

2.3. Overview of Cruise Ships Discharging in Alaskan Waters

Table 2 illustrates the number and types of cruise ships registered and discharging wastewater in Alaska.

Table 2 Large Cruise Ship Statistics by Year

Year	# Registered	Voyage Count	Passenger Capacity	Number with AWTS	Permitted/ Authorized to Discharge[3]	Discharging In Alaska	% Registered Ships Discharging
2012	29	452	922,331	22	17	16	55%
2011	27	446	865,541	21	16	15	56%
2010[2]	28	449	859,512	21	16	15	54%
2009	32	514	988,154	25	19	18	56%
2008[1]	31	516	1,038,590	25	25	21	68%
2007	30	509	1,002,439	23	18	17	57%
2006	29	496	909,312	24	25	23	79%

Year	# Registered	Voyage Count	Passenger Capacity	Number with AWTS	Permitted/ Authorized to Discharge[3]	Discharging In Alaska	% Registered Ships Discharging
2005	29	490	918,751	21	20	20	69%
2004	29	475	905,819	20	Unknown	20	69%
2003	32	458	854,000	20	Unknown	16	50%
2002	25	423	805,791	9	Unknown	15	60%
2001	24	249	500,741	7	Unknown	10	42%
2000	21	Unknown	Unknown	2	Unknown	Unknown	NA

[1] the 2008 General Permit added interim limits for ammonia, copper, nickel, and zinc.
[2] The 2010 Permit had new limits that were based on the type of wastewater technology that was used.
[3]DEC authorization to discharge. Prior to 2008 US Coast Guard authorization is listed.
For a listing of which ships had Advanced Wastewater Treatment systems please see the annual Wastewater Discharge tables at:
http://www.dec.state.ak.us/water/cruise_ships/reports.htm

Table 3 shows the distribution of cruise ship visits throughout west coast ports and some significant locations that cruise ships visit while not disembarking passengers (e.g. Hubbard Glacier) in 2010. In Alaska, cruise ship traffic is concentrated in the Southeast towns of Juneau, Ketchikan, and Skagway. Minor ports of call include Sitka, Haines, Homer, Whittier, Seward, Anchorage, and Kodiak. Cruise ships may bunker potable water at most docks. The volume of treated wastewater discharge varies from vessel to vessel. It ranges from 91,711 gallons per day (approximately 366 cubic meters/day) to 330,000 gallons per day (approximately 1,250 cubic meters per day).[21]

Table 3 2010 Port Visits and Passenger Counts

Port	Total Visits	Passenger Count	Type of Port
Anchorage	9	12,420	Dock
Astoria, OR	4	5,137	Dock
College Fjord	64	105,866	Glacier
Dutch Harbor	2	922	Dock & anchorage
Endicott Arm	1	1,432	Glacier
Glacier Bay	220	398,194	Glacier

[21] 2010 Large Commercial Passenger Vessel Wastewater Discharge General Permit Information Sheet (http://dec.alaska.gov/water/cruise_ships/pdfs/2010_Cruise_Ship_Info_Sheet_FINAL.pdf)

Port	Total Visits	Passenger Count	Type of Port
Haines	24	29,874	Dock
Homer	9	12,420	Dock & anchorage
Hubbard Glacier	135	240,792	Glacier
Juneau	447	848,355	Dock & anchorage
Ketchikan	428	804,936	Dock & anchorage
Kodiak	19	19,022	Dock
Los Angeles, CA	9	14,848	Dock
Misty Fjords	2	1,552	Fjord
Nanaimo, Canada	2	4,950	Dock (new in 2011)
Point Sophia (Hoonah)	63	130,978	Anchorage
Prince Rupert, Canada	22	49,690	Dock
San Diego, CA	8	15,884	Dock
San Francisco, CA	28	52,630	Dock
Seattle, WA	222	458,465	Dock
Seward	55	76,887	Dock
Sitka	105	136,683	Anchorage
Skagway	339	684,137	Dock
Tracy Arm	186	354,447	Glacier
Valdez	1	540	Dock
Vancouver. Canada	169	287,028	Dock
Victoria, Canada	223	440,537	Dock
Whittier	28	62,312	Dock
Wrangell	1	540	Dock

Water availability depends on docks used and requirements of the vessel.

Figure 8 and 9 show the regulatory off shore boundaries in Southeast Alaska, Federal waters, vessel routes, and ports. Discharge regulations are based upon the location of the discharge. Ships discharging within 3 nautical miles of shore are subject to both State and Federal regulations. Ships discharging between 3 and 12 nautical miles are subject to Federal regulations. Ships outside 12 nautical miles are not required to treat wastewater. However, all major cruise lines operating in Alaska (Alaska Cruise Association [ACA] members) have adopted an internal policy to not discharge untreated blackwater, even outside of 12 nautical miles. See Table 4.

Discharge practices vary among the ships and are impacted by holding capacity, type of installed treatment system, planned itineraries, as well as other factors. There are basically three general practices; 1) continuous discharges, 2) discharges when moving at 6 knots or faster, and 3) holding within state waters, treating and discharging outside of 3 nautical miles. One cruise line has an arrangement and docking connection to discharge graywater to the Juneau Douglas Wastewater Treatment plant and one ship from that line discharged occasionally in 2011.

Storage capacity varies by vessel and ranges from two to five days. While storage capacity can be increased on some vessels, in general, most vessels have to discharge at least one or two times during a seven day cruise. The effluent limits for ammonia, copper, nickel, and zinc are often higher (i.e. less stringent) for underway versus continuous discharge.) The number of vessels that discharged and the type of discharge during the years 2008 through 2010 are shown in Table 5.

Table 4 Discharge Boundaries

What?	Within 3 nm	3 nm to 12 nm	Outside 12 nm
Treated Wastewater	AK GP	Yes	Yes
Untreated Wastewater	No	MSD treated, not AWTS	Yes
Sludge/Biosolids	No	No	Yes

Table 5 Number of Vessel Discharge Permits for 2008-2012 Seasons

	2008[1]	2009[1]	2010	2011	2012
Continuous Discharge	--	--	6	6	5
Underway Discharge	--	--	8	8	10
Both[2]	25	21	2	2	2
None	6	11	12	11	12
Total Registered Vessels	31	32	28	27	29

[1]In 2008 and 2009, permitting was not done separately for continuous and underway discharge.
[2]For vessels that do both, continuous discharge = graywater only; underway discharge = mixed blackwater/greywater.

2.4. Wastewater Management on Cruise Ships

On cruise vessels, water is obtained from shore and also produced through distillation. On cruise vessels traveling to Alaska, sewage and various graywater streams are treated using advanced wastewater treatment systems (AWTS). AWTS generally provide improved screening, biological treatment, solids separation (using membrane filtration or dissolved air flotation), and disinfection (using ultraviolet light) compared to traditional Type II Marine Sanitation Devices (MSDs). However, cruise ships have highly variable wastewater treatment strategies, depending on numerous variables in addition to the type of AWTS installed such as: cruise company environmental policies, wastewater collection and treatment systems, equalizing, holding and mixing capacities, as well as the age of the ship, operational profile, customer services provided, and cruise ship-specific reasons.

One of the major challenges of producing a stable, good-quality effluent from cruise ship wastewater treatment systems is the highly fluctuating nature of wastewater influent that is commonly produced on cruise ships. Wastewater concentration and production peaks must be handled with good equalizing and mixing systems to try to insure a relatively constant quality of influent to the treatment system. Even with equalization and mixing, the influent will still be much more variable than for land-based municipal treatment systems.

Operational and wastewater management practices have perhaps the highest impact on the wastewater treatment system design. Graywater constitutes approximately 80-95% of the produced wastewater. The percentage depends on what type of graywater is measured (total graywater, or only accommodation graywater). If a cruise company selects to treat only sewage[22], the treatment system is small and compact. Graywater is in this case normally discharged directly to sea in areas where this is allowed or held in dedicated holding tanks for later discharge to sea or to a shore-based treatment system. If a cruise company selects to hold some of the wastewater to discharge it to the ocean at later stage, holding tank capacities have to meet that operational profile.

Other wastewater management options include mixing accommodation graywater (from showers and sinks) with sewage prior to treatment or treatment of all wastewater streams (all graywater and blackwater). The reason for mixing accommodation graywater with sewage is that this provides the range of influent concentrations that the treatment systems are designed to treat and to provide the proper hydraulic loading.

On older ships, where the AWTS is retrofitted, wastewater management practices may also be dictated by the selected treatment technology. This is due to the fact that the available space onboard is extremely limited.

The sewage influent processed through AWTS is much more concentrated than the sewage influent received by municipalities. Cruise ship toilet systems generally use fresh water vacuum flushing and conveyance to reduce water use per flush. The quantity of blackwater can be estimated to 7-8 toilet flushes per person per day, each at approximately 2 liters per flush. This creates approximately 15 liters of blackwater per person per day. The average home toilet uses 6 liters per flush (45 liters of blackwater per person/per day). The amount of organic waste loading per person is probably slightly higher onboard a cruise ship due to a high number of meals available. Almost all AWTS include a biological step to break down the organic waste. The size of the bioreactor is

[22] Also known as "black water," generally meaning human body wastewater from toilets, bidets and urinals. On ships, medical sink and medical floor drain wastewater is combined with sewage for treatment.

based on the amount of organic loading. If there is no space for a bigger bioreactor, some wastewater streams may have to be excluded from treatment.

Graywater consists of non-sewage wastewater, including drainage from dishwashers, showers, laundry, baths, galleys, and washbasins. Sometimes whirlpool waters are also plumbed into the graywater collecting system. Graywater represents the largest amount of fluid waste generated by cruise ships. The amount of wastewater depends on the ship type.

The average wastewater amounts and organic concentrations in BOD_5 which are commonly used for sizing cruise ship wastewater treatment systems are listed below:

- Blackwater	15 liters/person/day	45g BOD_5/person/day
- Accommodation graywater	150 liters/person/day	20g BOD_5/person/day
- Galley graywater	50 liters/person/day	125g BOD_5/person/day
- Laundry graywater	25 liters/person/day	5g BOD_5/person/day
- Food waste reject water	3 liters/person/day	90g BOD_5/person/day

An AWTS normally includes the following stages:

- Collecting, equalizing and mixing;
- Pretreatment;
- Biological treatment;
- Clarification and/or filtration;
- Disinfection and clean effluent discharge or holding; and
- Sludge management.

Wastewater pretreatment (mechanical solid separation and screening) protects the other phases of the treatment process. Sewage contains a lot of solid waste and grease that may cause problems in the later stages of the process. The pretreatment process reduces the amount of solids in the wastewater. Effective pretreatment also reduces the need for oxidation. The solids separation and screening results in an approximate 50% reduction in organic load. The remaining organic compounds have to be oxidized.

During biological treatment, micro-organisms use the organic waste compounds in the sewage as nourishment. There are several types of bioprocesses and the most common biological process is the activated sludge treatment plant, where the sewage is mixed in a continuous-action aeration tank and active biomass is recycled through the process. On cruise ships, membrane bioreactors are the most common biological treatment process. Bioreactors with different type of carrier materials are also used as biological treatment plants. In these devices, the bacteria that destroy the impurities attach to the carrier material. A biological treatment component is the most economical way of reducing the biochemical oxygen demand (BOD). The effectiveness of the bioprocess depends on the amount of active biomass and the bacteria living conditions. The disadvantages of biological treatment are the long startup period and its sensitivity to external disturbances.

In the activated sludge process, after oxidation, the biomass from the bioreactor is separated as sludge and a portion returned back to the aeration tank or pumped to a separate sludge tank. Separating the active biomass, sediment particles and bacteria from the water is a critical phase in the wastewater purification process. The clarification and filtration processes used in the ships are membrane filtration, dissolved air flotation (DAF), and settling.

The DAF system relies on the injection of pressurized air into the incoming wastewater stream. When released to atmospheric conditions, microscopic air bubbles are formed and attached to the particles causing them to float to the surface of the tank. The floated particles or float are continuously skimmed off and removed from the system for disposal. Any settled particles are continuously removed from the bottom of the tank for disposal. It is useful when treating waters that are high in total suspended solids (TSS) or fat, oil and grease (FOG), or have highly variable suspended solids content.

The last phase of a wastewater treatment process is disinfection, which on AWTSs is normally performed with ultraviolet (UV) light.

During the design phase of a cruise ship wastewater treatment system it is vital to understand:

Sizing wastewater influent / effluent parameters:

- Flow parameters and patterns (management of hydraulic peaks)
- Variation of wastewater concentrations (management of organic peaks)
- Process risks (e.g. caused by toxic substances)
- Permitted effluent limits

Hydraulic design of the process:

- Hydraulic Retention Time (HRT) of the process
- Equalizing/holding/redundancy expectations
- Design flux for various process steps such as membranes/DAF/UV etc.

Organic design of the process:

- Pre-filtration rate
- Mixed Liquor Suspended Solids (MLSS), Organic Loading Rate (F/M)
- Sludge age and other sizing parameters according selected process

Supporting processes

- Sludge management (Holding, dewatering, drying and/or incinerating)
- Effluent holding and discharge
- Discharge time and UV disinfection demand

During the shipboard installation of wastewater treatment systems there are also many limiting factors compared to land based installations such as:

- Limited space
  - It is difficult to work efficiently as there is no space around the components
  - Time consuming, i.e. expensive
- Low deck height causing issues such as:
  - Oxygen transfer height may be low
  - Removal of large elements difficult
  - Ventilation above the bioprocess is low
  - ”Foaming space” is low so effective foam killing equipment is needed
- Transport routes
  - Large components must sometimes be cut into pieces to be able to transport them to their installation locations
- In addition to above:
  - Sludge has to be managed
  - Ship is a closed structure and venting difficult so proper odor control is important
  - The systems and routing of vent pipes are very complicated and creation of water pockets in the venting systems must be avoided
  - Because of the concentrated nature of the waste, biological systems can be more prone to chemical upset

After the system installation and startup, it can take up to a couple of months until the process and biomass is stabilized and correct bacteria populations for the treatment process are created. During startup, a representative of the treatment system supplier is normally present onboard because AWTS and their control processes are complex and require continuous attention from qualified staff. After the start-up, it can take significant time for the crew to learn how to balance water streams, feed chemicals, use holding capacities, and understand similar issues before the AWTS meets the expected treatment performance. Due to the complexity of the treatment process, cruise operators normally dedicate an environmental engineer to operate the AWTS. The engineer onboard must be well-trained by the system supplier and have basic knowledge of biological treatment processes. Ideally, they are chemical or process engineers. Unlike operators of land-based municipal systems, engineers onboard ships may change every month or two. Continuous watch of the system by qualified trained engineers is mandatory for systems to work properly. Operational parameters and maintenance servicing must all be documented. Good documentation and record keeping improves performance despite changes in staff.

{This page deliberately blank.}

3. SOURCES OF CONSTITUENTS OF CONCERN

3.1. Ammonia

3.1.1. Blackwater

The primary source of ammonia in wastewater effluent is in sewage, e.g. blackwater. Raw sewage contains urea and fecal matter. During the transport and storage of sewage, organic nitrogen is hydrolyzed to ammonium/ammonia in a process called ammonification. Ammonium and ammonia species are in equilibrium with each other and the actual amount of each species present at any time is a function primarily of pH[23], as shown below:

$$NH_3\ (aq) + H^+(aq) \rightleftharpoons NH_4^+(aq)$$

The actual ammonia loading per person per day on cruise ships is slightly higher than the loadings to land based municipal systems. In addition, sewage ammonia concentrations on cruise ships are higher than municipal sources due to the use of low volume-per-flush toilets that are employed as a water conservation measure. This presents a significant treatment challenge for reducing the ammonia concentrations to the WQC.

3.1.2. Graywater

Graywater has a higher volume, but lower ammonia concentrations than blackwater. Graywater treated with AWTS that may be discharged in Alaska is produced from the following sources:

- Accommodations
- Laundry
- Galley including cleaning stream
- Whirlpool
- Food waste reject water

The DEC does not collect data on the concentration of parameters in influent; information to assess compliance with permits is based on concentrations of parameters in effluent. EPA collected influent concentration data as part of their 2008 *Cruise Ship Discharge Assessment Report*. Table 6 summarizes the results of ammonia concentrations from most of the above graywater sources based on samples collected by EPA in 2004. Note that high ammonia concentrations were detected in food waste reject. Currently, this waste stream is usually not included in the graywater.

[23] pH measures hydrogen ion (H^+) concentration

Table 6 Summary of EPA's 2008 Cruise Ship Discharge Assessment Report for Average Ammonia Concentrations in Untreated Graywater

Analyte	Ammonia -Nitrogen
Unit	mg-N /L
Alaska Water Quality Criteria	Acute = 6.5 Chronic = 1.0
Accommodations Wastewater[1] (not including blackwater)	0.383* (6 detects/12 samples)
Laundry Wastewater[1]	0.439* (6 detects/12 samples)
Galley Wastewater[1]	2.93* (8 detects/12 samples)
Food Waste Reject Wastewater[1]	17.5* (3 detects/ 4 samples)
Average of Graywater[2]	2.13* (23 detects/40 samples)

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

[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent a mixed stream of untreated effluent

* Average includes at least one non-detect value; this calculation uses detection limits for non-detected results.

Separate treatment of graywater and blackwater has been identified as a potential method to reduce effluent nutrient concentrations in the Baltic Sea[24]. In Alaska, separately treated graywater will likely meet ammonia WQC; however, the blackwater effluent concentrations will be higher than WQC and will need to be retained on board or discharged to shore if cruise ships are ultimately required to meet WQC at the point of discharge. In the 2011 cruise season, two ships began operating what DEC refers to as "split systems." In this configuration, one unit of the AWTS is used to treat graywater only while the other unit is used to treat mixed blackwater and graywater. This arrangement allows the ship to discharge treated graywater continuously. However, most systems are currently designed for the common treatment of black and graywater.

Treating wastewater onboard is a balancing act. Graywater with lower concentrations of ammonia is needed to balance highly concentrated blackwater to meet the discharge criteria for BOD after treatment. Because untreated graywater does not meet the discharge criteria, holding tanks or some sort of graywater treatment is needed. Graywater treatment directly by membrane filtration without some sort of pre-treatment (biological or chemical) is generally not capable of meeting discharge criteria.

[24] Hanninen, Saara and Sassi, Jukka. 2009. Estimated nutrient load from waste waters originating from ships in the Baltic Sea area. VTT-R-07396-08.

Cruise ships that mix black and various graywater sources have lower influent ammonia concentrations to treatment systems than those that treat just blackwater. Ammonia concentrations in mixed black and graywater influent are highly dependent on the mixture ratio, as shown in Table 7[25]. There is no standardization of the mixture from ship to ship, creating significant variability in the effluent concentrations of blackwater and graywater for observed ammonia. The variability in the ammonia effluent concentrations between the treatment systems does not necessarily represent a variability in the treatment effectiveness.

Table 7 Ammonia Concentrations in Mixed Black and Graywater System Influent

Analyte	Ammonia -Nitrogen
Unit	mg-N /L
Blackwater + 50 % of accommodation graywater	150
Blackwater + all accommodation graywater	82
Blackwater + accommodation gray + laundry water	68
Blackwater + accommodation gray + laundry + galley graywater	50

3.1.3. Other Sources of Ammonia

Neither land-based bunker water, nor potable water produced on board will contribute to ammonia in cruise ship water or wastewater systems. Ammonia is generally not expected at significant concentrations in cruise ship drinking water. A single potable water sample collected in an EPA study from a drinking water fountain (*Sampling Episode Report – Princess Cruise Lines - Island Princess - Sampling Episode 6505* (March 2006) *for Ammonia and Metals Concentrations in Source Water)* revealed an ammonia concentration of 0.035 mg/L Ammonia (as N).

3.2. Metals

3.2.1. Potable and Non-potable Piping

The combination of water properties and piping materials can affect the introduction of dissolved metals into the water. A variety of piping materials are used on vessels. The most

[25] W. Chen, Hamworthy Memo June 2010).

common materials include copper, nickel, plastic, galvanized steel (steel coated with zinc), cast iron and others. Copper is commonly used in shipboard potable water piping. On one cruise ship, the potable water piping system is made of galvanized steel for the bigger diameters in the machinery spaces and copper piping for deck distribution.

Evaporator distillate or water demineralized through ion exchange or reverse osmosis is somewhat corrosive. Demineralized/distilled water can leach copper and nickel from piping, pump impellers and fittings. The small quantities of copper, nickel and zinc leached from piping contribute to the metals discharged in treated wastewater.

3.2.2. Evaporator Cleaning / Descaling Chemicals

Chemicals used to clean and de-scale evaporators and associated piping may also dissolve copper and nickel by lowering the pH in the evaporator water. Increased acidity will encourage leaching of metals from piping.

3.2.3. Contribution From Different Graywater Sources

Table 8 summarizes copper, nickel and zinc concentrations in graywater sources based on samples collected in 2004. More recent data are needed to evaluate the effects of the Source Reduction Efforts implemented by the cruise ships in 2008 to present.

Table 8 Summary of EPA's 2008 Cruise Ship Discharge Assessment Report for Average Dissolved Metals Concentrations in Untreated Graywater

Analyte	Copper	Nickel	Zinc
Units	µg/L	µg/L	µg/L
Alaska Water Quality Criteria (chronic)	3.1	8.1	88
Alaska Water Quality Criteria (acute)	4.8	74	90
Accommodations Wastewater[1,3] (not including blackwater)	167	17.2	792
Laundry Wastewater[1,3]	253	4.85	266
Galley Wastewater[1,3]	232	26.4	1,070
Food Waste Reject Wastewater[1,4]	15.3	31.1	47,800
Average of Graywater[2]	195	18.2	1,610

[1] Based on data collected by EPA in 2004.
[2] EPA used flow rates for the individual graywater sources to calculate a flow-weighted average to represent untreated
[3] 12 detects/12 samples
[4] 3 detects/3 samples

From Table 8, the highest concentration of copper is shown in laundry wastewater. Copper may be related to the use of some types of soaps in laundry which may change the pH of the water promoting pipe corrosion. In addition, some cruise vessels use the condensate from the air conditioning system for the laundry. This water is created by humidity condensing on the copper cooling coils.

An extremely high zinc concentration was observed in Food Waste Reject Wastewater. No explanation was provided in the report to explain this value. Zinc is a common ingredient in floor waxes and may end up in the wastewater from mop buckets and in stripper wastewater. However, the zinc contribution from chemical use is presumed inconsequential from preliminary testing. Zinc may be leached from galvanized pipe and the use of chemicals, such as anti-scaling chemicals.

3.2.4. Bunker Water

Potable water that is bunkered in port from municipalities was evaluated as a potential source of metals in wastewater. Bunker water is a significant source of potable water used on cruise ships. Cruise ships operating in Alaska obtain bunker water from coastal cities in Alaska, the lower 48 and Canada. Exploratory sample data collected by Admiralty Environmental funded by the Alaska Cruise Association reported that some metals were occasionally detected above WQC in bunker water. Copper concentrations in bunker water samples ranged from below detection limits to 280 µg/L. Zinc concentrations ranged from below detection limits to 1500 µg/L. Nickel concentrations ranged between below detection limits to 470 µg/L.

However, the concentrations of metals found in bunker water, while in some instances significant, are likely a minor source of dissolved metals. When EPA measured the metal concentrations in wastewater onboard ships in 2004, the data showed that different waste water streams (laundry, accommodation, food waste reject water, and galley) have significantly different metal concentrations on board the same ship on the same dates. Since source water in each of these instances comes from the same potable water holding tank, this data indicates that additional metal loads in the wastewater stream are coming from elsewhere on the ship (piping, valves, human behavior, machines, or chemicals etc.), and the amount of metal originating in bunker water is relatively insignificant.

For example total copper concentrations measured on Holland America Lines (HAL) Veendam were:

- Laundry: 258 µg/L
- Accommodation 975 µg/L
- Pulper: 400 µg/L
- Galley: 88 µg/L

A potential reason for the high accommodation copper concentration is due to long potable water copper pipelines with perhaps high chlorine disinfection of water and lower flow on each branch pipe.

{This page deliberately blank.}

4. CURRENT METHODS OF POLLUTION PREVENTION, CONTROL AND TREATMENT

4.1. Effluent Quality Currently Achieved by Commercial Passenger Vessels

Domestic effluent quality is typically evaluated based on concentrations of fecal coliform bacteria, TSS, BOD, and chlorine. Prior to 2000, cruise ships only used marine sanitation devices (MSDs) which proved to be ineffective at removing fecal coliform bacteria.

The quality of wastewater effluent significantly improved from 2000 to 2003. In 2000, wastewater treatment pilot systems were installed on selected ships. By 2003, all large cruise ships discharging in state waters had advanced wastewater treatment systems (AWTS). AWTS currently installed on cruise ships meet most requirements for conventional constituents at the point of discharge. Cruise ships generally have followed the International Maritime Organization (IMO) International Convention for the Prevention of Pollution on Ships (MARPOL) requirement and installed approved sewage treatment systems in accordance with resolution MEPC.2(VI) and its subsequent revisions. Operating in Alaska, cruise ships have been required to install AWTSs that comply with 33 CFR 159, Subpart E ("Murkowski") standard that was implemented in 2001. Most AWTS provide screening for solids, bioreactors for BOD removal, followed by solids separation (flotation or filtration), and some means of disinfection.

AWTS-equipped cruise ships that have discharge permits have been generally in compliance with the effluent limits for conventional pollutants that include TSS BOD, Fecal coliform (FC) bacteria, and residual chlorine (RC). The effluent limits in the 2010 General Permit are provided below:

- FC bacteria 14 FC/100 ml (monthly arithmetic average)
  43 FC/100 ml (daily maximum)
- Residual chlorine 10 µg/L
- TSS 150 mg/L
- BOD 30 mg/L (monthly arithmetic average)
  60 mg/L (daily maximum)

Historically, the reductions of conventional pollutants correlate with the installation of the AWTSs, as shown in Figures 1-3 for FC bacteria, TSS and BOD respectively. Cruise ships also have to comply with EPA's Vessel General Permit which for graywater and graywater-blackwater mixes must meet federal secondary treatment standards.

The 2010 General Permit includes a range of limits as shown in Table 9 for ammonia, copper, nickel and zinc. The effluent limits are ranges because they vary depending on the mix of blackwater and graywater treated and the type of AWTS used. See the 2010 General Permit Fact Sheet[26] for more information. Table 10 shows that generally the cruise ships are meeting the 2010 General Permit Limits, but they do not meet the Alaska WQC. Data from the Carnival Spirit GW, which generally attained Alaska WQC, is an exception. Figures 4 through 7 show the reductions of these pollutants over time as a result of installation of AWTS.

Table 9 Cruise Ship General Permit Effluent Limits

	Ammonia (mg/L)	**Copper (µg/L)**	**Nickel (µg/L)**	**Zinc (µg/L)**
Stationary	12 to 28	10 to 87	10 to 63	112 to 395
Underway	12 to 143	10 to 157	10 to 63	112 to 395

Daily limits vary based on the type of wastewater treatment system used on the ship and the influent streams treated.

Table 10 2011 Exceedances in Permit Limits and Water Quality Standards

Ship	Number Exceedances of General Permit /Number of Samples Analyzed in 2011				Number of Exceedances of AK WQC /Number of Samples Analyzed in 2011			
	Ammonia	Copper	Nickel	Zinc	Ammonia	Copper	Nickel	Zinc
Disney Wonder	0/9	0/9	0/9	0/9	9/9	4/9	8/9	8/9
Princess Coral	0/10	0/10	0/10	0/10	10/10	10/10	3/10	6/10
Princess Diamond	1/9	0/10	0/10	0/10	9/9	10/10	10/10	9/10
Princess Golden	0/10	0/10	0/10	0/10	3/10	8/10	10/10	5/10
Princess Island	0/10	0/10	0/10	0/10	9/9	10/10	1/10	6/10
Princess Sapphire	1/10	1/10	1/10	0/10	9/10	10/10	10/10	9/10
Princess Sea	0/10	0/10	0/10	0/10	10/10	10/10	1/10	2/10
Holland America Statendam	0/10	0/10	0/10	0/10	10/10	5/10	10/10	1/10
Holland America Volendam	0/10	0/10	0/10	1/10	8/9	9/10	8/10	7/10
Holland America Zaandam	2/11	0/11	0/11	0/11	11/11	7/11	9/11	0/10
Norwegian CL Pearl	0/10	0/10	0/10	0/10	10/10	8/10	1/10	4/10
Norwegian CL Star	0/10	0/10	0/10	0/10	10/10	7/10	0/10	5/10
Seven Seas Navigator	0/9	0/9	0/9	0/9	9/9	2/9	2/9	1/9
Oceania Regatta (P+S systems)	4/16	0/16	0/16	0/16	13/16	16/16	9/16	9/16
Carnival Spirit GW	0/10	0/10	0/10	0/10	1/10	2/10	0/10	0/10

AWTS are very successful in meeting treatment objectives for conventional pollutants such as BOD, FC bacteria, TSS and pH. The existing AWTSs remove a significant portion of the ammonia and metals; however, they have not consistently succeeded in producing effluent concentrations of ammonia and the dissolved metals (copper, nickel, and zinc) that are equal to or below the WQC because they are not designed to do so. For context, the municipal discharges in Alaska do not meet WQC for these constituents either.

Influent data from 2012 and 2011 effluent wastewater quality data for ammonia and metals for DEC permitted ships are shown in Table 11. Note that the effluent data and influent data are different sets of data because influent data are infrequently collected and represent a single snapshot in time, while effluent data are collected as part of regular monitoring and there are more effluent samples that can be averaged than influent samples. Monitoring influent data are not required by statute.

It is important to note that there is inherent sample variation and probability of error in laboratory analyses. This is of particular concern when the threshold limits are very low. There can be instances when the normal variability or margin of error of a sample result may indicate a value above a low criterion.

The data illustrates a wide variability in the AWTS influent and effluent percent removals of ammonia and metals. Individual ammonia influent values as high as 539 mg/l were reported with removals as high as 96 percent; however, none of the ships that treat combined black and graywater are meeting the ammonia WQC. One ship, the Carnival Spirit, which treats only graywater, has a treated effluent whose average sample results meet the WQC for ammonia and metals; however, the ammonia data is due to low ammonia levels in the influent, not removal of ammonia by treatment.

None of the ships that treat combined gray and blackwater have been able to meet the copper WQC. Some ships have been able to meet the nickel and zinc WQC. However, the results are ship-specific and there is no correlation between the type of AWTS used and effluent concentration. The variability in the effluent values of ammonia and metals for ships with similar types of AWTS may be a result of variance in the influent values as opposed to treatment efficiency. Additionally, operators cannot identify conclusively if the WQC were met as a result of treatment, prevention or control techniques, operations and maintenance, or operator experience and skill.

Existing data indicate that there are no currently installed wastewater treatment systems on board cruise vessels that consistently meet the Alaska Water Quality Standards for ammonia, copper, nickel, and zinc at the point of discharge. For context purposes, the same is true for all marine discharging permitted municipal sewage treatment plants in Alaska.

An additional concern is that the effluent data in Table 11 are arithmetic averages. There are values higher than WQC in the effluent for all the data sets. The voter initiative that imposes the requirement to meet WQC at the point of discharge also includes potential fines of $10,000 per day for each violation, as well as a provision that citizens can bring enforcement actions against permittees and collect 25 to 50% of the fines for themselves. Hence, for vessels to be able to discharge treated wastewater to Alaskan waters, the treatment systems would have to consistently treat to below the sum of the WQC and the margin for analytical variability for ammonia, copper, nickel and zinc. A system that can only achieve levels below the WQC some of the time, or as an average, is not sufficient to protect against such liability.

Table 11 DEC 2012 Survey Influent data compared to DEC 2011 Effluent Monitoring Data

Item	**Disney Wonder n=9**	**Coral Princess n=10**	**Diamond Princess n=10**	**Golden Princess n=10**	**Island Princess n=10**	**Sapphire Princess n=10**	**Sea Princess n=10**	**HAL Stdam n=10**	**HAL Voldm n=10**	**HAL Zndm n=11**	**NCL Pearl n=10**	**NCL Star n=10**	**Seven Seas Navig. n=9**	**Oceania Regatta n=16 (2 systems)**	**CCL Spirit GW n=10**
Influent Ammonia, Average, mg/L	(BW) 207-539	165	221	240	165	238	156	75	75	75	No Data	140*	No Data	5.0	No Data
Effluent Ammonia, mg/L 2011 average	20.34	31.4	79.9	3.6	50.4	59.6	51.1	33.1	4.1	21.2	15.0	24.3	19.51	19.15	**0.63**
Influent Copper, µg/L	Wide Range	68	71	73	68	72	68	76	76	76	No Data	59*	No Data	130	No Data
Effluent Copper 2011 average, µg/L	**3.01**	9.2	6.0	5.1	19.2	18.4	23.3	3.7	20.1	4.2	6.9	4.4	3.76	10.55	**2.32**
Influent Nickel, average, µg/L	Wide Range	12.5	12.5	12.5	12.5	12.5	12.5	40.2	40.2	40.2	No Data	19*	No Data	60	No Data
Effluent Nickel, 2011 average, µg/L	10.76	**8.0**	14.6	11.6	**7.4**	18.4	**7.9**	21.1	11.6	13.0	**5.6**	**5.4**	**6.9**	9.1	**Non detect**
Influent Zinc, µg/L	Wide Range	317	305	324	316	322	316	205.9	205.9	205.9	No Data	95*	No Data	22	No Data
Effluent Zinc, 2011 average, µg/L	158.8	105.4	133.8	88.4	93	122	**55**	**45.6**	116.4	**52.5**	**69.5**	**71.3**	**29.1**	**77.1**	**6.41**

n = # of effluent samples taken; * Influent data based on one grab sample ** Did not operate in AK in 2011; Bold/Green shading = effluents are < or equal to WQC

4.2. Pollution Prevention Methods

Various pollution prevention activities were proposed by some of the permitted cruise ships in their 2008-2010 Source Reduction Evaluation (SRE) reports and updates and verified in the *2012 DEC Data Collection Survey for Pollution Prevention, Control, and Treatment for Large Cruise Ships Operating in Alaska Waters* (2012 Survey). Pollution preventions refers to the use of materials, processes, or practices that reduce or stop the creation of pollutants or waste at the source. It includes improved operating practices like material substitution, process and equipment modifications, and energy and wastewater conservation. The Data Collection Survey did not verify what pollution prevention methods were implemented or any resulting reductions in effluent concentrations as a result of the methods. The proposed methods described in the SRE reports are detailed in Section 5.1, Additional Pollution Prevention Methods.

4.3. Control Methods

Control methods are defined as any context in which a ship transfers effluent off the ship prior to treatment or discharges outside of State regulatory boundaries. Control methods are those technologies or methods that cause cruise ship wastewater effluent to not exceed WQC *in Alaska waters*. The Data Collection Survey did not provide any evidence that ships with AWTSs implemented control methods as a primary means of reduction in effluent concentrations of the constituents of concern.

4.4. Treatment Methods

A wastewater treatment process generally consists of up to four major phases whether performed as a land-based process or as a shipboard process: 1) primary treatment or solids separation, 2) secondary treatment or biological oxidation of organics, 3) clarification, and 4) disinfection. These processes are not necessarily distinctly separate. For example the primary treatment mechanism may include some forms of filtration, oxidation, and clarification processes.

It is important to note that land-based wastewater treatment plants are generally less limited by space and have the ability to use large tanks to complete the various process phases. These large tanks allow land-based treatment systems to use gravity separation and longer retention times to achieve the treatment objectives. Conversely, shipboard wastewater treatment systems have more limited space and time to complete these water treatment phases. Therefore, shipboard systems typically employ alternative compact processes to achieve the objectives of each treatment phase.

Many of the advanced wastewater treatment systems (AWTS) on board cruise ships certified[26] for discharge in Alaska are some of the most effective and most expensive available for marine wastewater treatment[27]. These AWTS treat both sewage and graywater. The large commercial passenger vessels currently authorized to discharge under the DEC 2010 general permit use one of the technologies listed in Table 12 to complete treatment.

4.4.1. Advanced Wastewater Treatment Systems in use on Permitted Ships in Alaska

Specific treatment systems currently used on permitted ships in Alaska are described in this section:

Hamworthy's Membrane Bioreactor (MBR) system uses aerobic biological treatment followed by ultrafiltration and ultraviolet (UV) disinfection. In one example, the Hamworthy MBR system treats combined accommodation gray and blackwater. Wastewater is first treated in screen presses to remove paper and other coarse solids. Bacteria digest the organic matter (BOD) present in the waste in a two-stage bioreactor. Wastewater is then filtered through tubular ultrafiltration membranes to remove particulate matter and biological mass. Biomass from the membranes is returned to the bioreactor. In the final step, the treated wastewater undergoes UV disinfection to reduce pathogens.

The Scanship treatment system uses aerobic biological oxidation followed by dissolved air flotation and UV disinfection. Typically, blackwater and graywater from the galley, accommodations, and laundry are combined in a holding tank. The combined wastewater is pumped through a coarse drum filter and then through two separate aerated bioreactors. Free-floating plastic beads are used in the bioreactors to support biological growth. Solids separation is done using dissolved air flotation (DAF) units followed by additional solids removal through polishing screen filters. Pathogens are reduced in the final stage of treatment through UV disinfection.

The Zenon ZeeWeed® MBR system uses aerobic biological oxidation followed by ultrafiltration and UV disinfection. Typically, laundry, galley and accommodation graywater is combined with blackwater. The combined wastewater flows through two coarse screens into a collection tank. From the collection tank, the wastewater is pumped to an aerated bioreactor. After the bioreactor, the wastewater flows through the proprietary ZeeWeed® hollow-fiber ultrafiltration membrane system under a vacuum. The final step is UV disinfection to reduce pathogens.

[26] Certified means approved by the US Coast Guard and Alaska Department of Environmental Conservation for continuous discharge under 33 CFR 159 Subpart E and the 2008 General Permit, respectively.

[27] EPA, 2008. Cruise Ship Discharge Assessment Report. EPA842-R-07-005

The Hydroxyl CleanSea® system consists of aerobic biological oxidation followed by dissolved air flotation and UV disinfection. In a typical application, black and graywater are combined and pumped to a fine wedgewire screen for coarse solids removal. Next, the wastewater enters the ACTIVECELL™ biological reactors. Free-floating plastic beads support biological growth. The wastewater then enters the ACTIVEFLOAT™ dissolved air flotation units for solids separation. Final treatment steps include polishing filters and UV disinfection to reduce pathogens.

The ROCHEM Bio-Filt® system uses vibratory screens to remove coarse solids, bioreactors to biologically oxidize the waste, ultrafiltration membranes to remove particulate matter and biological mass (which are returned to the bioreactors), and UV disinfection to reduce pathogens. The ROCHEM LPRO (Low Pressure Reverse Osmosis) utilizes reverse osmosis membranes to remove particulates and dissolved solids, and UV disinfection to reduce pathogens. In application, ROCHEM LPRO and ROCHEM Bio-Filt® system are installed to treat separate and combined black and graywater. The ROCHEM LPRO part of the system treats wastewater from laundry and accommodations while the ROCHEM Bio-Filt® treats graywater from the galley and blackwater, as well as the reject stream from the ROCHEM LPRO system.

The MariSan250 can be used for combined black and graywater. Primary treatment consists of gross screening, but can also include pH adjustment and/or chemical coagulation, followed by solids separation through dissolved air flotation (DAF). Additional solids separation is accomplished through microfiltration and UV or ozone disinfection.

In the Triton Water Membrane Reactor process, the membranes are submerged into an activated sludge reactor. Treated water is extracted through the membranes with a vacuum pump. Continuous flow passes over the membrane plates. Air is used to keep the membrane surfaces free of fouling, resulting in high flux rates. Ion exchange resins can be added as a post treatment to remove dissolved metals.

For all AWTS, the remaining solids separated are typically dewatered and incinerated on board. Screened solids are removed before the bioreactors are incinerated, but not biomass solids.

Table 12 AWTS Technologies Used on Vessels in 2008 to 2012 Discharging in Alaska for Shipboard Wastewater Treatment

AWTS	Treatment				Vessels in 2008	Vessels in 2009	Vessels in 2010	Vessels in 2011	Vessels in 2012
	Primary Solids Separation	**Secondary** Microbial Oxidation	**Tertiary** Clarification	**Disinfection**					
Hamworthy Bioreactor	Screen Press	Aerobic Biological Oxidation (Membrane Bioreactor)	Ultrafiltration Membranes	UV	9	9	7	7	9
Scanship	Wedgewire Screen	Aerobic Biological Oxidation (Moving Bed Bioreactor)	Dissolved Air Flotation (DAF) / Polishing Filter	UV	3	4	3	3	3
Zenon	Coarse Screen	Aerobic Biological Oxidation (Membrane Bioreactor)	Ultrafiltration Membranes	UV	5	3	4	3	3
Rochem	Vibratory Screens	Low Pressure Reverse Osmosis (LPRO)	Reverse Osmosis Membranes	UV	1	1	1	1	1
Marisan 250	Coarse Screen	Chemical Coagulation	Dissolved Air Flotation (DAF) / Microfiltration	Ozone	1	1	*1	*1	1*
Hydroxyl Cleansea	Coarse Drum Filter	Aerobic Biological Oxidation (Moving Bed Bioreactor)	Dissolved Air Flotation (DAF) / Polishing Filter	UV	1	0	0	0	0
Rochem Bio-Filt	Vibratory Screens	Aerobic Biological Oxidation (Membrane Bioreactor)	Ultrafiltration Membranes	UV	1	0	0	0	0
Triton	Screening	Aerobic Biological Oxidation (Membrane Bioreactor)	Ultrafiltration Ion Exchange	UV	0	0	0	1	0

* Permitted to discharge but did not discharge.

5. ADDITIONAL POLLUTION PREVENTION, CONTROL, AND TREATMENT METHODS

The Panel's focus has been on prevention, control and treatment technologies capable of meeting the WQC for ammonia, and dissolved copper, nickel and zinc.

As a condition to the 2010 General Permit, cruise lines are required to provide DEC with information relating to wastewater treatment, pollution avoidance, and pollution reduction measures used on the vessel, including testing and evaluation procedures and economic and technical feasibility analyses. DEC requested information in a 2012 Data Collection Survey (Appendix A). Operators that responded to the 2012 Survey included:

- Holland America Line (Four ships)[28]
- Princess Cruise Line (Six ships)
- Carnival Spirit
- Norwegian Cruise Lines (NCL) (Two ships)
- Prestige Cruise Lines (Two ships)
- Silver Shadow (Silversea Cruises)
- Disney

Information from the survey responses was used to evaluate both current and potential additional methods of pollution prevention, control, and treatment.

5.1. Additional Pollution Prevention Methods

The main source of information for prevention methods came from the cruise ship Source Reduction Evaluations (SRE), the 2012 Survey and panel input. In the SRE's, information was provided about potential prevention methods; however, there was no correlation or verification data of the implementation of any particular source reduction technology and the resulting concentration reduction in the effluent at the point of discharge. Prevention methods and source reduction alone are not expected to be adequate to reduce effluent quality to below WQC.

5.1.1. Ammonia

5.1.1.1. Ammonia Source Reduction

Blackwater is the primary source of ammonia. There is no method to reduce the amount of ammonia generated in raw sewage. The responses to the 2012 Survey agreed with this statement. None of the respondents had knowledge of any viable pollution prevention activity that was proven to be effective in reducing ammonia in the influent. Ammonia-based cleaners only contribute a negligible amount of ammonia compared to the concentration of ammonia in sewage, so product evaluation and replacement would not be effective in this case.

[28] One ship, the Westerdam, does not discharge, information was supplied voluntarily.

5.1.2. Metals

5.1.2.1. Piping

From the Source Reduction Evaluations, the cruise industry proposed the following options:

- Replace copper-nickel potable water piping with United States Public Health service approved plastic,
- Replace galvanized piping,
- Evaluate pump materials of construction, fittings, couplings and other pipe system appurtenances,
- Replace plumbing systems with non-copper, non-nickel, and non-zinc alternatives,
- Minimize corrosion potential of demineralized/distilled water,
- Continuous monitoring of the corrosion status of on board piping, and
- Continuous dosing of demineralized/distilled water distribution piping with a potable water stabilizer.

Respondents indicated that there was no conclusive proof that any of the listed pollution prevention activities would have any impact on effluent concentrations, and one respondent stated that the ship's piping was polypropylene.

It is important to note that widespread replacement of pipes is not feasible for existing ships. Most new ships utilize potable water distribution plastic pipes in accommodation water systems; metal piping must be used in industrial portions of the ship due to fire regulations.

It is also important to note that in establishing drinking water standards for copper, the U.S. Environmental Protection agency did not establish a Maximum Contaminant Level, instead it established a Treatment Technique standard that requires systems to control the corrosiveness of their water.

5.1.2.2. Product Substitution

From the Source Reduction Evaluations, the following options were proposed:

- Chemical evaluation of all products currently used for copper, nickel and zinc,
- Replace with non-metals containing product where feasible, and
- Implement future program to evaluate metals content of all new products.

No other methods for pollution prevention were identified in the 2012 Survey.

5.2. Additional Control Methods

Control methods are defined as any context in which a ship transfers effluent off the ship prior to treatment or discharges outside State regulatory boundaries. In the context of the BAT evaluation, control methods are those technologies or methods that cause cruise ship wastewater effluent to not exceed WQC *in Alaska waters*.

The SREs and the 2012 Survey were used to identify additional methods for control. Most methods identified are already in limited use. These methods are listed below.

- Hold all effluent for discharge outside Alaska waters
- Treat and discharge selected waste streams within Alaska waters and hold others for discharge outside State waters
- Discharge to Publicly Owned Treatment Works (POTW)
- Discharge to dedicated cruise ship wastewater effluent treatment facility on land

Discharge to a cruise ship-specific wastewater treatment facility that treated effluent to WQC at the point of discharge was evaluated as an additional control method.

Several respondents to the DEC 2012 Survey indicated that they would consider treating and holding for off-shore discharge as their first choice for control method. However, they would need to perform a cost/benefit analysis to determine overall effect of changes to itineraries which would result from implementing this option. Holland America stated that in 2009, due to operating problems with membranes, the Volendam needed to hold wastewater for off-shore discharges. The estimated costs added $10,000 per week in fuel costs due to both extra sailing on offshore excursions for discharge, as well as sailing at higher speeds in Alaska waters to make itinerary while accommodating these excursions. Since fuel costs are higher now than in 2009, the cost of this option would be even higher.

In the 2012 Survey, Princess Cruise Lines indicated their second control choice would be to discharge to on-shore facilities, however, they would need to "1) Determine capacity of each local wastewater treatment facility to manage expected waste water load from cruise vessels, and cost to upgrade capacity as necessary, 2) Determine infrastructure improvements necessary to transport wastewater from ship to treatment plant, and 3) Install upgrades as necessary to shore-based wastewater treatment plants and associated infrastructure."

5.2.1. Holding for discharge outside Alaska waters

This control method involves holding all or some effluent for discharge outside Alaska waters. The effluent could be treated or untreated. Vessels that elect this control strategy may spend less time in Alaska marine waters. The amount of effluent that can be held depends on the holding capacity of the vessel. Vessels that discharge outside Alaska waters might also treat and discharge some of their effluent inside Alaska waters, which extends the amount of time the vessel can remain in Alaska waters. If excursions to outside Alaska waters are necessary just to discharge, the vessel incurs additional fuel costs, and may also reduce the amount of time that passengers experience in port.

5.2.1.1. Hold all effluent for discharge outside Alaska waters

This option requires enough holding capacity, and vessel itineraries must be set to accommodate the discharge needs. Tables 2 and 5 illustrate that about 40% of the vessels in the Alaska operations currently employ this option. Based on responses to the Data Collection Survey, the current holding capacities of ships currently permitted to discharge range between 56 and 91 hours.

5.2.1.2. Treat and discharge selected waste streams within Alaska waters and hold others for discharge outside State waters

Graywater makes up the majority of volume of wastewater. There is benefit to treating and discharging just graywater and it may be possible to meet WQC with this practice. The graywater-only waste stream has less ammonia. An advantage with this control method is that less holding capacity is required so there is less negative impact on itineraries and routes. One vessel in the Alaska trade currently employs this approach.

The current limits in the permits vary between the in port and underway situation. The in port limits are based on a dilution factor of 28, while the underway limits are based on the demonstrated performances of the individual systems. A vessel could, under the limits, treat a graywater only waste stream and discharge continuously (even in port) and also treat a gray-blackwater mixed waste stream continuously, but discharge the treated effluent only when underway. There are several vessels in Alaska doing this now.

5.2.2. Discharge to Publicly-Owned Wastewater Treatment Plants

One cruise ship operator currently discharges some of their wastewater to the Juneau Douglas Wastewater Treatment Plant. The wastewater discharged is galley wastewater which has high BOD loading. They indicated \$70/m^3 to be the maximum acceptable fee for this discharge. Four operators indicated they would use this option if it were affordable. One respondent indicated \$15/m^3 as the maximum cost for shore-side treatment that would be feasible. Three operators said they would not consider using shore-side facilities. If this option was widely adopted by cruise ships, additional facilities would have to be installed in other ports and/or existing facilities expanded.

The Federal Clean Water Act requires that all municipal wastewater treatment plants use primary treatment (using gravity to separate solids from liquids) and secondary treatment (using aerobic bacteria [bacteria that need oxygen to grow] to break down the organic waste left after primary treatment) before discharging their water.

In 1972, Congress passed the Federal Water Pollution Control Act Amendment, which required wastewater treatment plants to achieve secondary treatment capability by 1977. Some municipalities that discharged into marine waters raised the issue that that this requirement might be unnecessary on the grounds that marine discharging treatment plants tend to discharge into deeper waters with large tides and substantial currents, which allow for greater dilution and dispersion than their freshwater counterparts. As a result, Congress added Section 301(h) to the Clean Water Act in 1977, allowing for a case-by-case review of treatment requirements for marine dischargers. Eligible applicants that met the set of environmentally stringent criteria in Section 301(h) would receive a National Pollutant Discharge Elimination System (NPDES) permit with limits for BOD and TSS less stringent than the secondary treatment requirements.

All treatment plants under the program have minimum requirements to conduct primary treatment of their wastewater effluent. The addition of secondary treatment, however, provides for the removal of more TSS and BOD than primary treatment alone.

In Alaska, neither industries nor municipalities discharging to marine waters are required to meet the stringent WQC at the point of discharge. Many Alaskan municipalities, including Anchorage, Alaska's largest population center, provide only primary treatment[29] and are permitted by EPA to do so under Section 301(h) of the Clean Water Act. Neither the primary treatment nor the secondary treatment facilities[30] meet Alaska's WQC at the point of discharge, especially for ammonia and dissolved copper.[31] They do meet water quality-based effluent limits at the point of discharge, when such limits are applied because water quality-based effluent limits are established after a thorough consideration of mixing zone regulations to assure water quality standards are met in the receiving water. When permitting determines water quality-based effluent limits are needed, they are established after consideration of dilution. There are some permits in Alaska for municipal discharges to marine waters with limits for copper, but none require limits for ammonia, nickel or zinc[32].

The Mendenhall wastewater treatment plant (WWTP) (Juneau, AK), which discharges to fresh water, is allowed to discharge a monthly average of 28.5 milligrams per liter of ammonia (Ref. NPDES Permit # AK-002295-1). The Juneau Douglas WWTP, which discharges to marine water, does not have discharge limits for ammonia. Juneau's charges depend on the BOD loading. The permit only requires reporting ammonia concentrations twice per year (NPDES Permit # AK-002321-3). The maximum ammonia concentration reported between 2005 and 2009 was 12 mg/L.

Table 13 presents information on ammonia and metals data and limits[33] (if any) for Alaskan municipal marine discharges. The limits listed for municipal discharges are for the effluent at the point of discharge. Table 9 presents information on the limits for these parameters in cruise ship effluents from the 2010 General Permit.

---

[29] Anchorage, Haines, Ketchikan, Petersburg, Sitka, Skagway, Unalaska and Wrangell

[30] Cordova, Homer, Juneau, Kenai, Kodiak, Seward and Valdez

[31] Maximum copper values for the municipalities range from 23 to 167 µg/L. Maximum ammonia values for the municipalities range from 4 to 64 mg/L. (Values determined from review of permit fact sheets and discharge monitoring reports.)

[32] http://dec.alaska.gov/Applications/Water/WaterPermitSearch/Search.aspx

[33] Some municipal effluent limits are for total recoverable metals. Cruise ship effluent limits are for dissolved metals. Total recoverable metal concentrations can be converted into dissolved metal concentrations by a default or site specific conversion factor.

Table 13 Municipal Wastewater Treatment Plants with Marine Outfalls

City	Ammonia		Copper		Nickel		Zinc limits	
	Limit	Max Result mg/L	Limit	Max Result µg/L	Limit	Max Result µg/L	Limit	Max Result µg/L
Homer	Report	64	None	no data	None	no data	None	no data
Cordova	Report	17	None	no data	None	no data	None	no data
Wrangell	Report	25	None	114*	None	no data	None	no data
Skagway	None	21*	Monthly Avg. 150 µg/L, Daily Max. 210 µg/L	73	None	no data	None	no data
Sitka	Report	22	Monthly Avg. 243 µg/L, Daily Max. 354 µg/L	109	None	no data	None	no data
Petersburg	Report	34	None	50*	None	no data	None	no data
Haines	None	no data	Monthly Avg. 78 µg/L, Daily Max. 156 µg/L	60	None	no data	None	no data
Seward	Report	24	None	no data	None	no data	None	no data
Juneau/Douglas	Report	11	Report	44*	None	5.95	None	82.7
Kodiak	Report	15.7*	None	no data	None	no data	None	no data
Craig	None	no data	None	no data	None	no data	None	no data
Anchorage	None	26	None	45*	None	no data	None	no data
Kenai	None	3.8*	None	23*	None	no data	None	no data
Unalaska	None	34	None	167	None	no data	None	no data
Barrow	None	no data	None	no data	None	no data	None	no data

Discharge Monitoring Reports (DMRs) period evaluated January 2008 through June 2010 If value marked by "*", then no current DMR monitoring requirement and maximum comes from the permit fact sheet. Some municipal effluent limits are for total recoverable metals. Cruise ship effluent limits are for dissolved metals. Total recoverable metal concentrations can be converted into dissolved metal concentrations by a conversion factor.

5.2.3. Discharge to an On-Shore Facility for Polishing Treatment

An alternate to onboard treatment is to discharge the cruise ship treated effluent to an on-shore facility dedicated to cruise ships only. The concept is to provide additional treatment or a polishing step to the currently treated wastewater from the cruise ships in order to meet regulations. Treatment at an on-shore facility does not necessarily mean that existing municipal wastewater treatment plants will be used to treat the cruise ship wastewater. That could be the case only if they are at the right locations and are appropriate for installation of the polishing treatment. On-shore facilities would need to be installed at strategic locations within the established cruise ship routes and at distances that allow the cruise ships to stop for effluent discharge without additional storage capacity within the ship.

On-shore facilities would eliminate the need for retrofitting existing vessels to accommodate potential polishing treatment. Retrofitting an existing vessel to accommodate new equipment can be very costly and time consuming, especially because of space constraints within the vessel and the need for compliance with stringent marine codes and regulations, permitting, and perhaps the work may need to be done while the ship is in operation.

The following is a list of potential issues/concerns to be addressed when considering discharge to on-shore facility:

- Location: Where and how many? Itinerary and cruise ship routing should be considered in selecting the locations.
- Ownership: Who will own and operate these facilities? Options are: communities, private parties, Native American corporations, cruise ship operators individually or in partnership.
- Regulatory: The Cruise Ship Program's statutes apply only to wastewater discharged into the waters of the state. So from the perspective of the program, and probably from DEC, if a ship discharges to a shore facility they are beyond the statutory authority of the statutes that relates to marine discharge. What final effluent discharge regulations will apply to the on-shore facilities? How to ensure that each cruise ship is in compliance with the discharge regulations?
- Discharges and Sampling: What would the sampling requirements be?
- Off-Season Operations: Depending on the type of treatment at the land based facilities, operational issues during off-season may be an issue. Restart of the system at the beginning of the cruise season would also be a concern.

On the other hand, treatment at on-shore facilities can offer some operational advantages such as:

- Operational flexibility and reliability
- Flow and composition equalization by providing equalization tanks
- Treated effluent holding tanks to ensure that the quality of the treated wastewater is in compliance with the discharge regulations. In case the effluent is not in

compliance, it can be sent back to the head of the treatment plant for further treatment.

- Space requirements should be less of an issue

5.2.4. Additional Control Methods Evaluation

Discharging less treated effluent offshore does not mean ships are meeting WQC. They are moving waste to a different location not subject to the state's permit. Even in this situation, because of the very high rate of dilution when discharging, WQC are achieved very rapidly in the receiving waters.

Discharging to a POTW such as Juneau's does not require the ship to meet WQC. Rather, the effluent is transferred to a shore facility that does not have the same strict regulatory limits on the pollutants of concern. This is still protective of Alaska's marine waters because the limits for POTWs are according to state and federal procedures that assure WQC are achieved in the receiving waters. If many ships were to offload to a POTW, there could be a need to modify the POTW's permit to account for the change.

Discharge to a polishing treatment facility is transferring a treated effluent to a shore facility for further treatment with the intent that the pollutant concentrations would not exceed WQC at the point of discharge to the environment. This method would protect Alaska waters. This control method is not currently available and feasibility and cost are unknown at this time. There might not be any significant environmental benefit to this compared with discharging the AWTS treated effluent when underway.

5.3. Additional Treatment Methods

Treatment technologies that are not already commonly used in cruise ship AWTS were identified and considered for treatment of ammonia and heavy metals. Information to establish additional treatment technologies came from multiple sources including:

- Feasibility Study[34]
- Literature review
- Cruise line reports and data
- EPA Cruise Ship literature and data
- Vendor information
- Shipbuilder input
- Other panel member input

[34] *Reducing Concentrations of Dissolved Metals and Ammonia in Large Passenger Vessel Wastewater Discharges*, Final, June 1, 2010 (OASIS, 2010)

5.3.1. Ammonia

5.3.1.1. Nitrification for Ammonia Removal

Ion exchange, air stripping, and breakpoint chlorination are less common land-based methods for reducing ammonia in wastewater. These technologies have potential to meet 1 mg/L WQC for ammonia. Ion exchange has seen limited use on cruise ships and is described in Section 5.3.2.4. No data are available to determine whether air stripping and breakpoint chlorination could be adapted to cruise ship operations.

Ammonia originates from human and animal waste. The majority of the land-based treatment experience comes from the municipal sewage, animal waste industries, and diverse types of industrial applications including food processing facilities.

The technology most commonly used ammonia reduction method in municipal wastewater treatment is nitrification. This process also occurs to some extent in the biological component present in most AWTS on cruise ships. In the nitrification process, nitrifying bacteria convert ammonia (NH_3) to nitrite (NO_2^-), followed by the conversion of nitrite to nitrate (NO_3^-). Nitrate has less of an impact on marine receiving water than ammonia. Whereas there are marine water quality standards for ammonia, there are no marine water quality standards for nitrate. This process requires aerobic, or oxygen-rich, conditions. Nitrification converts ammonia to nitrate, but does not remove total nitrogen.

Optimal conditions for nitrification include a highly aerobic environment provided through aeration within the reactor, sufficient surface area or contact between the bacteria and the compounds to be oxidized, sufficient residence time for microbiological oxidation, the right pH and temperature, and sufficient alkalinity for the reactions. Nitrification may be carried out in the same tank as BOD removal (activated sludge or fixed film) or in a separate stage. In either case, longer total residence times are required than for BOD treatment alone, because nitrification is a slower process. This means in practice that larger aerated bioreactors have to be installed. More recently, an up-flow, fixed film biological system has been developed and claims to be capable of reducing ammonia concentrations to as low as 1 mg/l. That system is available in a range of sizes – from small modular to custom-made configurations for large plants (Severn Trent TETRA® Nitrifying SAF (NSAF)) according to the manufacturer.

Nitrification is the most commonly used method to reduce ammonia in municipal wastewater treatment and several industrial type facilities and is currently used on cruise ships. However, in order for wastewater effluent to meet the 1 mg/L ammonia WQC, large add-on or extended aeration systems, increasing volume by as much as 33%, would need to be added to cruise ships.

Furthermore, ships would need to significantly improve conditions in the biological reactor to enhance nitrification such as appropriate air supply; right pH, temperature, and alkalinity; reduction of inhibitory compounds. Foam control must be added. Control of ammonia removal onboard can be extremely challenging for the system operators.

5.3.1.2. Air/Steam Stripping

Stripping of ammonia from wastewater using air or steam is not a common practice in municipal wastewater treatment. Air stripping is considered a cross-media transfer, the pollutant is removed from the liquid phase and discharged intact into the air. Stripping and collection of ammonia gas on cruise ships is not a practical or viable option due to safety issues. Venting ammonia gas is problematic as well. Ammonia gas is an air pollutant, an irritant in small concentrations and has a low odor threshold.

5.3.1.3. Breakpoint Chlorination

Breakpoint chlorination involves the addition of chlorine gas to wastewater to react with the ammonia/ammonium oxidizing it to nitrogen. The active chlorine is simultaneously reduced to chloride[35]. The end products of the breakpoint reaction are primarily nitrogen gas (N_2), secondarily nitrate (NO_3^-) and chloride (Cl^-)[36]. Breakpoint chlorination is generally used for treatment of drinking water and swimming pools. It is not commonly used in wastewater treatment because nitrification is generally easier and less expensive. There are significant air quality and safety issues associated with the use of chlorine gas. Any residual chlorine not consumed in the oxidation reaction would have to be removed before the wastewater could be discharged. Breakpoint chlorination might cause larger ecological impacts than the ammonia that it would remove.

5.3.1.4. Experimental Methods

Thermally Activated Charcoal - Research has been conducted in laboratory studies of ammonia removal from wastewater using adsorption by thermally activated charcoal. A number of optimum removal parameters were determined, including temperature, retention time, and adsorbate concentration[37].

Anaerobic Ammonium Oxidation - The Agricultural Research Service's Coastal Plains Soil, Water and Plant Research Center has found a way to use anaerobic bacteria to convert nitrite and ammonium to nitrogen gas. The anaerobic bacteria called anammox are derived from swine sludge. Ammonium (NH_4^+) acts as the electron donor and nitrite (NO_2^-) as the electron

---

[35] Lenntech (2009) This website presents an excellent discussion of the disinfection properties of chlorine, including a description of breakpoint chlorination. http://www.lenntech.com/water-disinfection/disinfectants-chlorine.htm

[36] Brooks, M. (1999) Breakpoint Chlorination as an Alternate Means of Ammonia-Nitrogen Removal at a Water Reclamation Plant. Master's Thesis. Virginia Polytechnic Institute and State University

[37] Rashid, S. Islamabad, Pakistan (2008) Note: No citation given. Located on technology blog site http://www.finishing.com/336/95.shtml

acceptor to create nitrogen gas (N_2). Primary advantages are energy savings and cost savings[38].

Ammonia Recovery - Liqui-Cel® Membrane Contactors provides a system that has a large reaction surface area for extraction of ammonia and does not produce a secondary waste. Membrane Contactors offer a superior solution for stripping. For ammonia removal, wastewater flows through the outside of membrane, while an acid solution will flow countercurrent through the inside of the membrane. If sulfuric acid is used, it will convert ammonia into ammonium sulfate. Ammonium sulfate is widely used as a fertilizer and it could be sold with commercial value.

RCAST Process for ammonium recovery - The RCAST Process combines flash vacuum distillation with ion exchange to remove 90% of the ammonia from wastewater and recovering a saleable product, ammonium sulfate, a common fertilizer. Pretreatment of the wastewater is required to remove suspended solids nor precipitates. For high ammonia concentrations vacuum stripping using RCAST ammonia captures the volatile ammonia (about 80%). The influent (<300 ppm ammonia-nitrogen) passes through a selective ion exchange system which removes the remaining ammonia. To produce ammonium sulfate, sulfuric acid is used to regenerate the exchange resins. The sulfuric acid renegerant is used multiple times and the solution increases to an ammonia concentration of several thousand ppm. This solution is then stripped, and the final product is a commercial-grade (about 40%) solution of ammonium sulfate.

Additives to increase Ammonia Nitrification - BIO-SYSTEMS International Corporation markets a BIOBUG® NB bacterial powdered Nitrification product to increase ammonia nitrification. It contains a special blend of microorganisms i.e. nitrifying bacteria such as *Nitrosomonas* spp. and *Nitrobacter* spp. The *Nitrosomonas* spp. convert ammonia to nitrite and the Nitrobacter spp. convert the nitrite to nitrate. The main purpose of using this product is to ensure *that* the bacterial population remains consistent and viable. BIOBUG® NB bacterial cultures can function over a wider range of pH values than those normally encountered in the naturally present nitrifying population.

5.3.1.5. Summary of more and less promising technologies

A summary of the treatment methods evaluated for ammonia is provided in Table 14. All of the potential treatment options have operational characteristics, such as use of hazardous chemicals or creation of hazardous waste, that make them challenging for application on cruise ships as described in Table 14.

[38] Szogi, A.A., M. B. Vanotti, M.C. Garcia Gonzalez, A. Kunz. Development of Anammox Process for Animal Waste. International Symposium on Air Quality and Waste Management for Agriculture Proceedings. Broomfield, Colorado, September 16, 2007.

Table 14 Key Features of Available Methods for Ammonia Removal

	Technically Feasible for ammonia concentrations found in Cruise Ships	Commonly used in Land based treatment systems for this application	Currently in use in Cruise Ships for this application	Acids/Bases/ Hazardous Chemical usage required	Residual Waste produced	Energy Required
Nitrification	Yes	Yes	Partially (no add-on or extended aeration systems)	No	Yes (biosolids)	High
Ion Exchange (zeolite)	Yes, as post treatment to biological	No	No	Yes (for regeneration)	Yes	Medium
Air/Steam Stripping	Yes	No	No	Yes	Yes (transfer to air)	High
Breakpoint Chlorination	Yes	No	No	Yes (chlorine gas)	Yes (residual chlorine needs to be removed before discharge)	Low

5.3.2. Metals

Since none of the AWTS currently installed on cruise ships consistently meet the WQC at the point of discharge, the Panel sought to identify existing shore-based treatment processes that had potential as add-on treatment technology.

There are two EPA-defined point categories that commonly require treatment systems for metals: electroplating (40 CFR 413) and metal finishing (40 CFR 433). The electroplating category includes copper, nickel and zinc plating and the metal finishing point source category includes manufacturing processes including electro plating and electroless plating, anodizing, surface coating such as chromating, chemical etching and mill and printed circuit board manufacturing.

The typical metal finisher discharges to a Publicly Owned Treatment Works (POTW) under the conditions of a pretreatment permit. Effluent limitations for existing point sources are set by the EPA, but the local POTW can impose more stringent limitations based on the limitations of the POTW's discharge permit. For discharge to the POTW, from the Metal Finishing Point Source Category, the Best Available Technology Economically Achievable (BAT) Effluent Limits (40 CFR 433.14) for copper nickel and zinc are listed in Table 15.

Table 15 Best Available Technology (BAT) Economically Achievable Effluent Limitations for the Existing Metal Finishing Point Source Category (40 CFR 433.13 and 433.14)

Pollutant	Unit	BAT Effluent Limits	
		Maximum for any 1 day	Monthly Average, shall not exceed
Copper, total	µg/L	3,380	2,070
Nickel, total	µg/L	3,980	2,380
Zinc, total	µg/L	2,610	1,480

Typical influent levels into the pretreatment systems for copper (EPA's Design for Environment Study) for the Printed Circuit Board manufacturing point source category ranged from 0.4 mg/L to greater than 100 mg/L. Similar concentrations for nickel and zinc from electroplating sources could be expected. Based on these influent levels, it is most common for an electroplater or metal finisher to be located within a community where pretreatment and discharge to a POTW is allowed. Historically, the technologies commonly used for metals treatment are based on pretreatment, not direct discharge to a receiving stream. The WQC are much lower than the BAT limits for pretreatment of metal finishing effluent.

With this caveat, a survey of 318 metal finishing shops[39] found the following metal removal technologies in use with the percentage of shops employing the methods shown in (%):

- Chemical precipitation by pH adjustment (90%)
- Atmospheric evaporation (22%)
- Electrowinning (19%)
- Ion exchange (11%)
- Reverse osmosis (2%)
- Electrodialysis (<1%)

There are shore-side facilities currently operating around the United States and the world that achieve very low contaminant concentrations, in some cases reaching the WQC. For example, ammonia concentrations of 1 mg/L or less were achieved by nitrification to treat graywater for reuse as well as for refinery and beef processing wastewater. Copper concentrations of 3 µg/L and zinc concentrations of 20 µg/L were achieved for treatment of contaminated groundwater by ion exchange. However, there are significant differences between the waste streams of these facilities and wastewater from the cruise ships. The facilities are treating a smaller, more concentrated waste stream that does not contain a

[39] Cushnie, 1994

significant organic load. Table 16 lists a sample of known systems designed by one consultant, Burns and McDonnell, that are achieving the limits. The table also lists where the waste stream originates and the location of the installations. Other installations likely exist that are not listed here.

Table 16 Systems Achieving Stringent Effluent Limits

Wastewater	Treatment Process	No. of Installations	Location
Ammonia			
Municipal	Nitrification (Activated Sludge)	15	Arkansas (4), Kansas (5), Missouri (2), Monterrey, Mexico (1), Wyoming (3)
Municipal/Commercial (combined)	Nitrification (MBR)	4	New Hampshire (3)**, North Carolina (1)**
Graywater Reuse	Nitrification (MBR)	3	Doha, Qatar**
Refinery	Nitrification (Kaldness/Activated Sludge)	1	Texas
Beef Processing	Nitrification (Activated Sludge)	7	Illinois (1), Kansas (2), Nebraska (3), Washington (1)
Pork Processing	Nitrification (Activated Sludge)	6	Illinois (2), Iowa (2), Nebraska (1), Oklahoma (1)
Metals			
Plating and metal finishing containing low concentrations of multiple metals, oils, surfactants, acids, and alkaline cleaning agents	RO and Ion Exchange	1	Pennsylvania
Plating and metals finishing containing low concentrations of multiple metals, oils, surfactants, acids, and alkaline cleaning agents	Chemical Precipitation, Ultrafiltration, RO	1	Florida
Industrial Facility	Carbon Adsorption and Ion Exchange	1	Arizona
Laboratory	RO and Ion Exchange	1	Arizona
Metal Finishing	RO and Ion Exchange	1	Arizona
Aerospace Facility	RO and Ion Exchange	1	Kansas
Aerospace Facility	Electrodialysis	1	Kansas

**Designed for NH_3-N concentration of less than 2.9 mg/L. Not operational yet.

5.3.2.1. Chemical Precipitation

Chemical precipitation is commonly used by industrial sources for pretreatment of mixed metal streams. Multiple metals can be removed in a single process. It is not commonly found in municipal wastewater treatment systems for metals removal, as municipal wastewater treatment systems typically achieve metal discharge limits without any process designed specifically for metal removal. In practice, chemical precipitation works best with influent metal concentrations greater than 20 mg/L. There a number of common and proprietary chemicals used in the electroplating and metal finishing industry for metals precipitation. The choice of the chemical precipitant depends on the species of the metal, the presence of other constituents and the effluent limit the process is trying to achieve. Metal complexes or metals in the presence of chelating agents as commonly found in electroplating and electroless plating are not easily precipitated. Ammonia acts as a complexing agent for copper and significantly impacts the reduction of copper achievable through precipitation.

The most commonly used precipitants are hydroxide based, including lime, hydrated lime, or magnesium hydroxide and sodium hydroxide, and sulfide-based chemicals. Metal sulfides have much lower solubilities than the corresponding metal hydroxides and are more effective in the presence of complexing or chelating agents. Therefore lower residual metal concentrations in the treated wastewater can be achieved. Soluble metal ions bond to hydroxide or sulfide ions and precipitate out as insoluble metal solids. Based on minimum solubilities, theoretically, reductions of copper and nickel hydroxide to concentrations of 1 µg/L, and zinc hydroxide to 100 µg/L are possible. Practically, each metal has a minimum solubility at a specific pH; the pH is different for copper, nickel and zinc. Precipitation processes for multiple metals select a pH value that will remove the maximum of each metal. After precipitation, metal hydroxide solids precipitates exist as small solid particles and must be removed from the wastewater. Removal could be achieved through sedimentation or filtration. Calcium and magnesium hydroxide sludges are particularly voluminous since the weight of the metal and the precipitant is combined. Metal solids from settling tank are typically dewatered or decanted, and then passed through a filter press. Sludge dryers can be used to reduce the volume of solids. Alternatively, the solids created from precipitation have been removed by membrane filtration. This reduces the number of steps, but still results in a residual solid waste product that requires storage and disposal. Additionally, for hydroxide precipitation, the treated water will need the addition of acid to reduce the pH prior to discharge.

In conclusion, chemical precipitation is the most commonly used method for reducing metals (at higher concentrations) in metal finishing wastewater. However, it is not technically feasible for influent metals concentrations less than 20 mg/L, such as found in cruise ships. (See Table 11) Theoretical metal reduction levels are not possible due to other pollutants from the mixture of sanitary wastewater (sewage). The systems require significant space for process equipment and chemicals. This treatment requires handling of lime or other precipitants. A metal-contaminated sludge is produced creating an additional waste stream that requires disposal.

5.3.2.2. Evaporation

Evaporators have been used to recover high quality water from industrial wastewater in zero discharge strategies or where no POTW is available and discharge to a receiving stream is the only other option. There are no municipal wastewater treatment facilities using evaporators as a primary treatment. Cruise ships use evaporators for producing potable water when bunkered water is not available. As a primary wastewater treatment process, capital and energy costs are prohibitive.

There are a number of thermal or vapor compression evaporators or brine concentrators that could be used to reduce the volume of wastewater treatment residuals, such as RO reject, or ion exchange regeneration waste. Many of these evaporators can utilize waste heat source to defray the cost of operation. These systems may be used for smaller flow industrial wastewater sources where water recovery is the goal. The systems produce high quality water that could be recovered for non-potable water uses such as cooling tower or boiler water makeup. Waste heat could be used to reduce energy costs.

In conclusion, these systems are not technically or economically feasible for wastewater treatment. No systems are currently in operation on cruise ships. They may have potential application for reducing the volume of wastewater; however, they have significant energy and space requirements.

5.3.2.3. Electrowinning

Electrowinning is used in mining and also metal finishing industries to recover metals from concentrates (metal concentrations greater than 500 mg/L). There are no municipal wastewater treatment systems using electrowinning for primary treatment. In metal finishing it is used to reduce metal concentrations on spent baths and other concentrated metals wastewater such as ion exchange regeneration wastewater. It is only used if there is a significant cost-benefit for the metal recovery. Electrowinning is the process of electrodepositing metals from a solution. The solution is circulated past an anode (+) and cathode (-) where a low voltage direct current is applied through the solution causing metal ions to be reduced at the cathode and water or another ion to be oxidized at the anode. As the metal cation is attracted to the cathode it is deposited on the electrode producing a metal plate.

In conclusion, electrowinning is commonly used in the mining industry, and sometimes used by metal finishing industry facilities if there is a favorable cost/benefit. It produces a plated metal for potential resale and a highly acidic wastewater that requires disposal. This treatment is not technically or economically feasible for primary wastewater treatment. It is not suitable for low metal concentrations such as cruise ship influent. There are no systems currently in operation on cruise ships and there are significant space requirements.

5.3.2.4. Ion Exchange

Ion exchange can be used to remove electrically charged molecules, including metals and ammonia. Ion exchange is an appropriate technology for copper, nickel and zinc at concentrations less than 20 mg/L. Simplistically, the 'free' copper ion in the aqueous solution (wastewater) can then be attracted to a solid bead (resin) and exchanged for a more weakly bound positively charged ion (ex. Na^+) on the resin. A generic ion exchange chemical separation in a resin column can be described by the following equation where R-COO refers to the resin chemistry (in this case a weak acid cation exchanger), which will vary between ion exchange resin types:

$$(R\text{-}COO)\text{-}Na_2 + Cu^{+2} = (R\text{-}COO)\text{-}Cu + 2\ Na^{+}$$

Normally a weak acid cation exchange resin in the sodium form is used for divalent (metals with a charge of $^{+2}$) metals. A variety of resins may be used independently or in conjunction with each other to achieve the ultimate goals. For the metals to be treated in the uncomplexed, cationic state, a weak acid resin may be selected for treatment. There are also ion-selective or chelating resins that may be employed to single ions or in conjunction with other preferred ions.

Naturally occurring zeolites (aluminosilicate minerals), particularly clinoptilolite and to a lesser extent, synthetic resins, have potential for removal of ammonia. Due to their negative charge, they attract positively charged ions (cations). Zeolites remove ammonium ions from wastewater by means of ion-exchange, and, at higher concentrations, through adsorption. Zeolites can also remove copper, nickel, and zinc.

In addition to zeolites, Carbtrol[40] offers selective ion exchange resins for ammonia removal from wastewater. The media removes only the ammonia and operates like a standard ion exchange system. When the resin becomes saturated, it may be regenerated or sent offsite for processing. Carbtrol claims that ammonia can be reduced to low ppb levels.

Ion exchange used to treat multiple cations and anions in wastewater is more complicated. If there are a number of different cations in addition to ammonia, copper, nickel and zinc present in the wastewater, the adsorption capacity per ion will be lower as a consequence of competition between the different cations. Ion selective resins may be employed to selectively remove particular ions from the waste stream. Separate cation and anion beds or mixed bed exchangers can be used. Ion exchange will tend to remove all cations and anions, removing more than just the contaminants of concern. It will be necessary to have a full profile of all ions and compounds within the waste stream to determine the viability and selection of appropriate resins.

Standard ion exchangers could be adapted for use on cruise ships, however, extensive pretreatment including filtration and activated carbon adsorption are needed. Suspended solids must be removed prior to ion exchange through at least 5 micron (nominal particle size) filtration. Residual organic material can foul resins beds by coating available ion exchange sites on the resins. Therefore, organic material must be removed using activated carbon prior to ion exchange. Multiple cations including naturally occurring calcium, magnesium and others present in the pretreated wastewater compete for exchange sites.

When the column reaches saturation by having all active resin sites holding a dissolved metal ion, or other unwanted cation, the resin column must be regenerated (i.e. bonding sites made available again). While sodium exchangers are regenerated with brine (sodium chloride) solutions, anion, cation and selective ion exchangers are regenerated with acid (sulfuric acid)

[40] Carbtrol Corporation 955 Connecticut Ave., Ste. 5202 Bridgeport, CT 06607

and basic (sodium hydroxide) solutions. Storage handling, mixing and distribution of these hazardous chemicals used to regenerate the resin column present safety issues as well as space consideration for the additional equipment needed.

Another option to on-ship regeneration is the “load and burn” option, where the resins are run to exhaustion, the column is taken out of service and the resin removed and replaced. No regeneration equipment or hazardous chemicals would then be needed on the ship. An ion exchange vendor or technician could periodically come aboard, change out the columns, and take saturated columns ashore for regeneration, or a supply of resins could be stored on the ship and replaced by a ship technician.

Retrofitting of the AWTS with ion exchange columns could be difficult in a cruise ship main engine room where other wastewater treatment is currently located, even though ion exchange columns are relatively compact. Columns are usually sized as a ratio of water volume to resin volume, typically 2 to 4 gal/min per cubic foot of resin (0.26 to 0.52 liter/min per liter of resin). [EPA, 1981] For a maximum flow rate of 60 cubic meters of wastewater per hour the maximum resin column volume would be calculated using the EPA rule:

$$60\ m^3/\text{hour} = 1\ m^3/\text{min} = 1000\ \text{L/min};$$

$$1000\ \text{L/min}/0.26\ \text{L} = 3846\ \text{L of resin} = 3.8\ m^3\ \text{resin}$$

The time to breakthrough would vary for each application and depend on the quality of the influent. Faster breakthrough would occur where there is a high concentration of cations other than copper, nickel and zinc. Column size could be more precisely calculated as vendors and application engineers investigate design.

Ion exchange could potentially be used to treat source water (evaporated water or bunker water) if that is deemed to be a major source of metal contamination. However, as discussed in Section 3.2.4, bunker water is likely not the main source of metals.

In conclusion, installing an ion exchange system after the AWTS and pretreatment to remove the organic matrix could achieve WQC. However, media vessels (i.e. ion exchanger columns) are bulky and change out would be difficult. The alternative, regeneration of ion exchanger media on board, would require additional storage of salt, acid, and/or caustic solutions, storage of waste regeneration solution, containment systems, and pumps.

One ship implemented ion exchange in addition to their AWTS to treat both gray and blackwater. The Oceania Regatta replaced their wastewater treatment systems with a new AWTS in part to meet Alaska wastewater discharge permit requirements for large cruise ships. Triton Water AG designed a system that included a Membrane Bioreactor with a polishing ion exchange system to treat all black and graywater and to meet the WQC for ammonia and metals. The new AWTS was installed while the ship was in operation. The results of the discharge monitoring for 2011 are shown in Table 11. There were multiple exceedances of the permit limits for ammonia and WQC for ammonia and metals. Therefore, this system was not successful during its first year in operation in achieving the reductions required to meet the WQC. Average nickel and zinc were below WQC in the effluent and copper was 97% reduced.

5.3.2.5. Reverse Osmosis

Reverse osmosis (RO) is a membrane filtration system that is used worldwide to produce freshwater and treat wastewater. RO is more commonly used to purify a raw water source or in sea water reclamation. RO membranes work by applying pressure to one side of a selective membrane with pores of a particular size. This allows the purified water (permeate) to remain on one side of the membrane and the contaminants (reject) to concentrate on the other side of the membrane. If the membrane were not pressurized, the liquid solvent would move from the less concentrated (contaminated) side of the membrane to the more concentrated (contaminated) side of the membrane in order to reduce the difference in concentrations. According to a manufacturer, RO systems will remove 90-99% of dissolved inorganics. However, the separation efficiency of RO is dependent upon the influent concentration, operating pressure, the water flux rate, and system configuration.[41] Additional water recovery can be achieved by adding a second stage RO system or configuring the system with a circulation loop.

The RO systems on cruise ships with AWTS were designed to remove conventional pollutants including fecal coliforms and TSS as well as organic and inorganic compounds, and metals. RO may also be employed on source water to provide additional purification prior to use to reduce contaminants from evaporated or bunkered water systems.

RO technology has been installed and operated as part of an AWTS on cruise ships that operate in Alaska since 2000. Celebrity and Holland America have operated vessels in Alaska with RO systems. Holland America reports that the systems were not able to treat the graywater influent that is typical of their operations without repeated clogging and diminished throughput. The throughput of these systems was insufficient to serve the needs of the ship while sailing on Alaska itineraries and the RO systems are no longer in use. Although there is data from 2005 that indicates that the RO system installed on the *Celebrity Mercury* meets the interim and Alaska Water Quality standards, the system experienced similar clogging and throughput issues reported by Holland America. The Carnival Spirit, which uses the ROCHEM RO system, consistently achieves interim and Alaska Water Quality Criteria for ammonia, copper, nickel, and zinc. However, this vessel only treats accommodation graywater, which has a low concentration of metals and ammonia, so its results cannot be used to represent what RO can do with mixed graywater streams. In addition, the utilization rate for the *Carnival Spirit* is low. Therefore, the clogging and throughput concerns are not as critical as is the case on most other cruise ships. The ships that used RO/ultra-filtration to treat combined graywater and blackwater *(Celebrity Mercury and Celebrity Galaxy)* were unable to produce an adequate volume of treated effluent due to clogging and no longer use these systems to discharge wastewater in Alaska. Therefore, DEC does not have as large a wastewater effluent data set for RO compared to other wastewater treatment systems.

---

[41] Crittenden, John; Trussell, Rhodes; Hand, David; Howe, Kerry and Tchobanoglous, George. Water Treatment Principles and Design, Edition 2. John Wiley and Sons. New Jersey. 2005 ISBN 0-471-11018-3

Current wastewater treatment systems installed on cruise ships could be modified or expanded to incorporate RO membranes. Conventional spiral wound RO membranes are not expensive on a per unit basis. However, they can be quickly clogged by high levels of suspended solids and particles or blocked by cationic polymers such as shampoo, personal care products, or detergents. Cruise ships use cleaning solutions with cationic polymers to reduce Norwalk virus. While cruise lines have control over the selection and use of cleaning agents used on board, they do not have control over products introduced by guests. Therefore, the RO membranes may need to be replaced at higher than expected rates when used on cruise ships. If a filter clogs quickly or frequently, the system will shut down. This can be combatted by having a larger system, but that would incur addition costs from more membranes, more space, higher labor costs for operation, and more frequent cleaning/recovery costs.

These constituents would have to be removed prior to the RO system. Newly engineered membranes are available that are capable of handling a higher concentration of suspended solids and would need to be chosen on a ship-by-ship basis. For those vessels utilizing MBR units, the suspended solids and particulates are removed within the MBR unit, thus RO could be recommended as a polishing treatment after the MBR treatment process. For those vessels using moving bed bioreactor (MBBR) units, an additional filtration step will need to be added before the RO treatment to help prevent fouling.

Non-chlorine disinfection methods are common on ships, however, chlorination may be still be used periodically for piping disinfection, incidental disinfection, and pool and spa water. This can be a problem for ships that discharge the pool and spa waters through the treatment system. (Such a practice is effectively encouraged by the EPA vessel general permit issued in February 2009). Newer technology RO membranes can tolerate low chlorine concentrations but free chlorine is considered detrimental to the membrane. Free chlorine that enters the wastewater stream will likely be consumed or eliminated within the biological treatment system as the chlorine reacts with biomass. Therefore, the concentration of free chlorine is not expected to present at detrimental levels if the RO system is installed downstream of a MBR AWTS. The pretreatment processes needed to effectively use RO could also include the addition of a reducing agent or activated carbon which should remove any residual chlorine.

Filtration systems that are already present in many AWTS would reduce the cost of the pre-filtration process and RO units could be installed as an end-of-pipe add-on technology. However, there may still be problems with this application including low water recovery and downtime required for cleaning. Systems would need to be designed with sufficient capacity to compensate for the downtime, requiring additional shipboard space. Depending on the influent quality, 10-25% of wastewater treated using RO is reject water that does not meet high standards for discharge and thus must be stored and disposed outside state waters. One manufacturer states that higher water recovery rates (95%) can be achieved but this would require a second stage RO unit similar to what is supplied for land-based treatment. This would effectively require a three stage AWTS system (e.g. MBR + RO + RO). In addition, membrane cleaning processes generate wastewater that require disposal. In addition, a relatively high pressure is required for RO, which may have associated high energy and maintenance costs.

5.3.2.6. Electrodialysis and Electrocoagulation

Electrodialysis (ED) is an electrochemical process in which ions migrate through ion-selective semipermeable membranes as a result of their attraction to two electrically charged electrodes. A DC voltage is applied to the electrodes. ED is able to remove most charged dissolved ions, including ammonium. EDs use alternating semi-permeable anion and cation ion-exchange membranes, the spaces between the membranes create compartments of concentrate and clean water. Clean water can be discharged or recovered. The concentrated copper, nickel and zinc wastewater requires storage and disposal.

ED's primary use had been for treating raw water for potable and non-potable uses. Applications include desalination, drinking water, laundry wastewater, and agricultural water. However, it has been used in the metal finishing industry for nickel recovery[42] . An ED unit is capable of removing 50% to 94% of dissolved solids from a feed water, up to 12,000 mg/L total dissolved solids (TDS)[43] . The recovered concentrate containing copper, nickel, zinc and any other dissolved ions would be removed for special waste handling which could include metal recovery for recycling or disposal.

ED could likely be incorporated into an existing AWTS after biological treatment. The ED process, unlike RO, is chlorine tolerant and could be used after disinfection even if chlorination is used as part of the AWTS. ED, when used for raw water treatment, is a very reliable process with minimal maintenance and attended control of the equipment. Scaling and other issues associated with its application for wastewater is unknown.

Electrocoagulation was developed as a process to treat bilge and ballast water[44]. The electrocoagulation process described by Global Advantech is a continuous flow system that also removes suspended solids, emulsified hydrocarbons and many dissolved organic compounds, heavy metals, bacteria, algae, larvae and other pollutants. It consists of pairs of closely spaced parallel metal plate electrodes with a low voltage applied at high current densities. The current flowing between the electrodes neutralizes electrical charges on solid and liquid (oil) particles, causing the particles to coagulate and/or coalesce. Oil agglomerates and particle flocs are floated to the top for collection assisted by the hydrogen and oxygen gas bubbles produced in the electrode reactions. Global Advantech claims heavy metal removals greater than 99 percent in a two pass system. The recovered solids containing copper, nickel, zinc and any other dissolved ions would be removed for disposal.

Electrodialysis used in the metal finishing industry for water treatment and metal recovery. Electrocoagulation has been used to treat bilge water in marine applications. While

---

[42] Cushnie, G. National Center for Manufacturing Sciences Pollution Prevention and Control Technology for Plating Operations (1994) http://www.nmfrc.org/bluebook/tocmain.htm (Note: Some graphics are missing.)

[43] U.S. Bureau of Reclamation, 2010

[44] Global Advantech Technology Data Sheet TDS801

there are no systems currently in operation on cruise ships for this application; membrane systems are commonly used in cruise ships.

In conclusion, ED and EC require pretreatment to remove residual organic matrix and suspended solids is required. ED/EC concentrate contains the removed pollutants in a higher concentration and requires storage and disposal. Chemical membrane cleaning requires down time and produces another wastewater stream that requires storage and disposal. There are significant power and energy requirements; as well as need for space for equipment and chemicals.

5.3.2.7. Experimental Technologies for Metal Removal

Several experimental technologies are described here to give a very basic understanding of alternative approaches beyond those described in the previous sections. There was limited information available in the literature or from the manufacturer on these technologies so the discussions are brief. Further development and research may show that these techniques have marine applications; however, these processes are not used in marine applications or widely used commercially in other applications. Use of these experimental techniques is less advisable than using proven commercial techniques such as ion exchange or reverse osmosis, especially on cruise ships, where space, efficiency, and reliability are extremely important.

Oxycell Process - The Oxycell is an electroflotation process for removing heavy metals in contaminated wastewater containing multiple pollutants including oil and solids. The product literature claims the process is low cost and requires no chemical addition. However, the first step in the product literature shows pH neutralization, which would require chemicals. After neutralization, wastewater is pumped into the electroflotation reactor, where it appears that compressed air is added. It is not clear, but assumed that a current is added to cause flocculation of metals. Flocculated particles are separated during flotation. The next step involves solids dewatering with a filter press. The filtrate is the final effluent, however, recirculation back into the reactor can be done until the effluent meets the desired limits. It is not clear what the removal efficiencies are for copper, nickel and zinc.

Biosorption of heavy metals - Microorganisms such as fungi or bacteria are known to have the ability to remove metal ions from water through adsorption, metabolism, and/or transport. Biomass of plants and algae can also be employed to capture heavy metals. Experimental work demonstrates that a variety of heavy metals can be bound by biosorbents, achieving very high effluent quality. For example Cu was removed from actual waste streams to sub-parts-per-billion levels using bacterial cells immobilized in a calcium alginate matrix[45]. Larger biosorbent particles from e.g. algal or plant material may not need immobilization. The metal laden biosorbent can be removed from the waste stream using e.g. filtration. An

---

[45] Ogden, K. and Muscat, A. Investigating the use of biosorption to treat copper CMP wastewater. Intel. (2007) University of Arizona. http://www.micromagazine.com/archive/01/07/green.html

alternative is application in packed bed columns similar to those used in ion exchange, however further work is needed for application to continuous-flow wastewater treatment[45].

In conclusion, the experimental technologies discussed in this section are not proven in terms of pollutant removal or widely available. Each process also needs to be evaluated in the context of cruise ship installation. There is not enough installation history with these technologies that design, capital, or operating costs could be evaluated. They show promise but are not developed to the point that they could be implemented by cruise ships within the next 5-10 years.

5.3.3. Summary

A summary of the treatment methods evaluated for metals is provided in Table 17.

Table 17 Key Features of Methods for Metals Removal

	Technically Feasible for Metal Concentrations found in Cruise Ships	Commonly Used in Land based Treatment Systems	Currently in Use in Cruise Ships for this Application	Acids/Bases/ Hazardous Chemical usage required	Residual Waste produced	Energy Required
Precipitation	No	Yes	No	Yes	Yes (high)	Low
Evaporation	No	No	No	No	Yes	Highest
Electrowinning	No	No	No	Yes	Yes	High
Ion Exchange	Yes	Yes	Yes	Yes	Yes	Low
Reverse Osmosis	Yes	Yes	No	Yes (descaling/ cleaning)	Yes (high)	High
Electrodialysis/ Electrocoagulation	Yes	Yes (raw water treatment)	No	Yes (descaling/ cleaning	Yes	High

As summarized in the Table 14, nitrification is the most promising technique for ammonia removal. From Table 17, ion exchange, reverse osmosis and electrodialysis are most promising for metal removal. Therefore these processes are included in the potential treatment system combinations described in Section 5.3.4.

5.3.4. On Ship Treatment System Combinations

The technologies described in Section 5.3 could theoretically be used for treatment of the constituents of concern and may have the ability to treat effluent to WQC. However, there are significant, space, waste, and energy considerations for each technology. A combination of two or more of the technologies, AWTS plus an add-on polishing step, could potentially be effective. Potential combinations of treatment methods are described in the following sections with block flow diagrams showing how the technology will fit into a currently operating system. Note that there may be additional steps required, such as ultrafiltration prior to using RO.

Note the combinations described in this section are entirely theoretical. Limited space, weight limitations, and increased energy consumption are extremely critical to consider when designing systems for cruise ships. Without performing actual engineering design with these considerations, it is unknown whether any combinations are feasible. Ship-specific engineering design, pilot testing and treatability verification will need to be completed to determine the applicability to each individual ship. The process flow diagrams for treatment system combinations are conceptual. None of these combinations are currently in operation in cruise ships.

All treatment system combinations described in this section include a membrane bioreactor for ammonia removal by nitrification (i.e. conversion to nitrate), which is the standard practice for ammonia removal in land-based municipal wastewater treatment system. This process is recommended because the cruise ship fleet visiting Alaskan waters typically already has a membrane bioreactor (or other bioreactor) installed for reducing organic matter measured as BOD. The same reactor (with slightly larger sizing) can also remove ammonia, which already occurs to some extent in the existing cruise ships wastewater treatment systems. Nevertheless, elevated ammonia levels are measured frequently, requiring either optimized use of this reactor or further treatment steps. Nitrates produced during nitrification are an issue in drinking water supplies, but WQC have not been established for nitrates. However, both RO and ion exchange can remove nitrates if designed for that purpose.

A further commonality between the systems presented here is that they rely on RO and/or ion exchange as a polishing step to reduce metal (and ammonia) levels to WQC. Unlike chemical precipitation, evaporation, electrowinning, electrodialysis and electrocoagulation, the RO and ion exchange processes are based on a modular system that makes it potentially feasible to fit into spaces of different size. Both create waste streams (reject or spent regenerant) that would be a fraction of the treated wastewater volume.

Additional pretreatment for organics is still required after bioreactors but before RO or ion exchange. Otherwise the residual organic matter will foul RO membranes and/or ion exchange resins.

5.3.4.1. AWTS / Two Stage Reverse Osmosis

In this option, effluent from the AWTS will pass through a two stage RO system. In practice, this option provides the maximum water (permeate) recovery and the lowest amount of residual waste. The conceptual process flow diagram is shown in Figure 11. Further research is needed to establish if RO alone can meet the WQC and the actual permeate recovery rates.

This will vary based on the influent water quality and would be specific to each cruise ship. Wastewater from the bioreactor would be first disinfected to reduce biological growth on the downstream equipment, followed by pretreatment to remove any fine particles and the residual organic matrix. Both of these pretreatment steps generate liquid and solid wastes. The smaller volume reject from the first stage RO is then passed through a second stage RO. The reject from the second stage could either be stored for off-site disposal or sent to a fluid concentrator (evaporator) and converted to a residual solid waste.

5.3.4.2. AWTS / Single Stage Reverse Osmosis and Ion Exchange

Metals will be removed in a two-step process: reverse osmosis followed by ion exchange similar to that described in Section 5.3.2.5 but with an ion exchanger taking the place of the second stage RO. The wastewater will be initially passed across a single-pass membrane system with an estimated removal efficiency 90+% whereby 50-75% of the influent flow are recovered as purified permeate. Further study is needed to determine the actual removal percentage and the amount of permeate and reject generated. The RO reject would be stored in a holding tank and discharged to an appropriate waste handler or discharged offshore outside 12 nm. The RO permeate will be passed across a series of ion exchange resins (strong acid cation, weak acid cation, ion selective, chelating or combinations thereof) for final metals removal. The treated water should be monitored for pH and adjusted if necessary prior to discharge from the system. The regeneration waste of the ion exchange resins should be stored in holding tanks and discharged to an appropriate waste handler. A block flow diagram for this option is presented in Figure 12.

5.3.4.3. AWTS / Ion Exchange

The effluent from the bioreactor followed by disinfection would be treated by ion exchange alone. The wastewater will be passed across a series of ion exchange resins such as strong acid cation, weak acid cation, ion selective, chelating or combinations thereof. The process is similar to that described in Section 5.3.4.2 except that the RO treatment is replaced by additional ion exchangers. A block flow diagram for this option is presented in Figure 13.

5.3.4.4. AWTS / Electrodialysis and Ion Exchange

In this option, the bioreactor is the same, but the metals will be treated with a two-step process involving electrodialysis or electrocoagulation (instead of RO as in Section 5.3.4.2) followed by ion exchange. The wastewater will be initially passed across a series of semi-permeable membranes and charged with an imposed current to concentrate the metals. The dilute wastewater will be passed across a series of ion exchange resins. A block flow diagram for this option is presented in Figure 14.

5.4. Additional Treatment Methods Evaluation

Among the methods discussed earlier in this report, currently used methods such as ion exchange, reverse osmosis and potential methods such as electrodialysis/electrocoagulation can be used as polishing steps and may have potential to meet WQC if installed on cruise ships after appropriate pretreatment processes. However, it is questionable whether cruise companies would want to install treatment systems for regenerate/reject waste streams, which would entail additional cost and space requirements.

Other techniques, such as precipitation or electrowinning are more commonly used for higher metal concentrations, and therefore could find application in treatment of waste streams with higher metal concentration (e.g. spent ion exchanger regenerate or reject from electrodialysis (ED) and RO). No data could be found that indicates that precipitation or electrowinning have been developed for use on a ship. Furthermore, each of the methods appear to have significant feasibility and adaptability limitations

All add-on treatment technologies have additional space requirements that create difficulties for implementation on cruise ships. Many processes require the use of acids, bases or other chemicals that can also pose safety concerns. Most processes create waste streams that must be stored for land disposal or treated on board with further unit processes, requiring additional space and investment cost.

The successful operation of an AWTS in compliance with effluent regulations greatly depends on the system operators.

{This page deliberately blank.}

6. APPLICATION OF BEST AVAILABLE TECHNOLOGY FRAMEWORK

The Science Advisory Panel was asked to advise DEC regarding the most technologically effective and economically feasible options for prevention, control, and treatment of cruise ship wastewater so that cruise ship wastewater effluent could meet WQC at the point of discharge. Existing AWTS are very effective at reducing pollutants in effluent, but none of the AWTS operating on cruise ships in Alaska have demonstrated the ability to consistently meet WQC at the point of discharge for ammonia and dissolved copper, nickel and zinc. Thus, the term "technologically effective" was defined by the Panel as having potential for meeting WQC at the point of discharge.

The Panel looked for a systematic framework to compare various alternatives for pollution prevention, control, and treatment and identified the framework used for evaluating Best Available Technology (BAT) Economically Achievable as a tool to help them organize and rank potential alternatives.

Under the Clean Water Act (33 USC 1314(b)(1)(B), the EPA developed effluent limitation guidelines (ELGs) that were intended to represent the greatest pollutant reductions that are economically achievable for an industry. For the purposed of discharge permits, EPA defines Best Available Technology (BAT) Economically Achievable as the "*technology-based standard established by the Clean Water Act (CWA) as the most appropriate means available on a national basis for controlling the direct discharge of toxic and nonconventional pollutants to navigable waters. BAT effluent limitations guidelines, in general, represent the best existing performance of treatment technologies that are economically achievable within an industrial point source category or subcategory*" (EPA NPDES Glossary website). A BAT analysis, as defined in the Clean Water Act, evaluates the *"…best existing performance of treatment technologies that are economically achievable within an industrial point source category…"* In the evaluation of technologies for BAT, the following items are generally considered:

- The total cost of application of technology/method in relation to the effluent reduction benefits to be achieved from such application,
- The age of equipment and facilities involved,
- The process employed,
- The engineering aspects of the application of various types of control techniques,
- Process changes, and
- Non-water quality environmental impacts (including energy requirements).

EPA has developed ELGs for many industries based on available technologies but they have not developed ELGs for cruise ships or other vessels.

The Panel was asked to evaluate additional technologically effective, economically achievable methods of treatment but quickly realized it was not feasible to use the wastewater treatment EPA BAT process on potential alternatives because there are significant data gaps for considering the necessary parameters for evaluation. None of the data necessary are available to evaluate BAT for the additional wastewater treatment technologies ***on a vessel***. The data available to the Panel were the SRE reports, DEC monitoring data, and a short survey sent by the Panel to Cruise companies in November 2010.

In an effort to fill data gaps and identify the BAT for new alternatives and methods, the Panel first developed a specification questionnaire to request that vendors supply estimates of installation, performance and cost for new systems that would meet WQC in effluent. Panelists with vendor relationships informally discussed these specification requests to cruise ship AWTS vendors. However, no estimates could be supplied by vendors because no applications or technologies were under development. The Panel also determined that if a process were in development, the vendors stood to suffer financially and competitively by disclosing their data or cost estimates. Furthermore, they are under no regulatory obligation to disclose this type of information to DEC or the Panel.

In 2012, the Panel attempted to obtain additional information from the Cruise Operators. They worked with DEC to prepare a Data Collection Survey based on the EPA cruise ship discharge assessment[46]. The questionnaire was sent to the seven cruise operators permitted to discharge in 2012 and information regarding 17 ships were returned (one ship was not discharging in 2012, but returned the survey because they had performed an AWTS upgrade this year).

Questions about the following were asked in the survey to characterize the variability between ships:

- Influent concentrations,
- Removal efficiencies with current treatment systems,
- Mass loadings,
- Different gray and blackwater mixing,
- Different treatment systems,
- Treatment flow rates,
- Storage capacity, hold and treat schemes,
- Ammonia and metals removal efficiency data for currently used processes, and
- Capital and Operations and Maintenance (O&M) costs.

The 2012 Surveys were returned in June 2012. A blank survey is provided in Appendix A. The information the Panel received is summarized in Appendix B. The information from the Data Collection Surveys was valuable to understand current wastewater treatment systems cost to install and operate and this information is summarized in Section 8.0.

In order to do a systematic comparison between the various alternatives for prevention, control and/or treatment, the panel identified a qualitative set of criteria for a technology or method to be identified as “best available”. The eight criteria and definitions are listed in Table 18.

[46] EPA, 2008. Cruise Ship Discharge Assessment Report. EPA842-R-07-005

Table 18 BAT Criteria Definitions

Criteria for rating BAT		Definition
1st	Effectiveness	Whether the technology/method will enable Cruise Ship Wastewater Effluent to meet WQC in Alaska waters
2nd	Feasibility of operation	The practical feasibility of the technology/method in terms of engineering and operational aspects
3rd	Feasibility of Installation	The practical feasibility of using technology/method on cruise ships (compatible weight, space and power requirements)
4th	Availability	Whether technology or method is available for commercial purchase for installation on a ship
5th	Transferability	Whether technology/method is transferable to shipboard application (ship motion, odor, health)
6th	Compatibility	Whether technology/method of prevention is compatible with existing operations and technologies in use.
7th	Cost	How much the alternative costs – capital and operating expenses that are economically achievable
8th	Environmental Benefit	What the benefit to the environment is from implementing the alternative.

Environmental benefits/costs and financial cost will be discussed separately in Sections 7 and 8, respectively.

6.1. Prevention

No methods of prevention for ammonia or metals could be identified that achieved WQC. The panel considers prevention alone as insufficient for achieving WQC for metals.

6.2. Control

The control method most surveyed operators prefer is the *Treat Selected Waste Streams and Hold for Off-shore Discharge* method. An estimate for the additional fuel costs was provided for one ship. Partially treating and holding for offshore discharge does meet the BAT effectiveness criterion of cruise ship effluent meeting WQC in Alaska waters.

Some operators would consider discharge to on-shore facilities; however, most responded that the infrastructure is not in place to allow this to happen. There is currently only one on-shore facility that treats wastewater from some cruise ships. That water is not treated to WQC standards, but is treated to the facility’s NPDES permit requirements.

6.3. Treatment

In Section 5, Table 14 and Table 17 assess the potential technologies for ammonia and metals removal, respectively. Those tables identify and qualitatively assess each treatment alternative on the following criteria:

1) Technically feasible for removing the constituent concentrations found on cruise ships
2) Commonly used in land-based treatment systems
3) Currently in use in cruise ships for this application
4) If there are hazardous chemicals required for operations
5) If there is residual waste produced
6) The energy required

The Panel identified several treatment alternatives as reasonable to evaluate further. These alternatives are nitrification and ion exchange for treatment of ammonia; and ion exchange, reverse osmosis, and electrodialysis for treatment of metals. In part, these technologies are already in place in the existing AWTS and adding some of these systems in combination to existing AWTS may reduce concentrations of constituents of concern. However, none of these alternatives have been demonstrated to meet the effectiveness criterion of "concentrations of the constituents of concern in wastewater effluent to be below WQC" and it is unknown whether installation of these combinations is economically achievable.

7. ENVIRONMENTAL BENEFIT AND COST OF IMPLEMENTING ADDITIONAL METHODS

7.1. Approach

This section describes the environmental benefit and environmental costs of implementing additional methods by first describing Alaska's marine waters with special focus on the four parameters of concern, ammonia, copper, nickel and zinc. Background or ambient concentrations for these parameters will be described, as will application of Alaska's marine water quality criteria.

This section also discusses the background on the voter's initiative that requires cruise ship discharges to meet Alaska's water quality criteria at the point of discharge and the later legislation that led to the tasking of this Science Advisory Panel to consider the environmental benefit and cost of doing so.

To understand impacts on receiving waters, there will be a discussion of effluent concentrations compared to the numeric water quality criteria and a discussion of mixing zones, dilution factors, and mass loading compared to natural sources. The rate of dilution is well understood from both moving and stationary cruise ships. Although the initiative mandates meeting WQC at the point of discharge, dilution will still be considered here as it is significant to understanding the potential for environmental effects to Alaska's receiving waters and potential environmental benefits from additional treatment.

This scenarios and calculations in this section are based on the worst case scenario, i.e., the highest effluent concentrations for ammonia, dissolved copper, dissolved nickel and dissolved zinc observed in Alaska cruise ship discharges from advanced wastewater treatment systems in the 2008-2009 seasons, and evaluates the resulting concentrations of direct undiluted discharge, the mix of the effluents and receiving waters if discharged from a stationary cruise ship in-port, and if discharged into the wakes of moving cruise ships. The calculations also consider the time rate of dilution, how fast the discharges dilute and how that relates to duration of exposure components of the state's WQC.

The analysis allows an understanding of the incremental changes in concentration of these parameters resulting from the existing discharges, which can be compared to the incremental changes were the discharges to meet the WQC at the point of discharge. The analysis allows an understanding of the incremental exposure time difference to levels above the criteria from the current discharges compared to meeting the numeric criteria at the point of discharge.

In addition to looking at environmental impacts at the points of discharge, the analysis also estimates the mass loading of copper from all the cruise ships in a year and compares it to the mass loading of copper from just the Mendenhall River (near Juneau, a center of cruise ship activity) prior to any additional copper from the domestic wastewater plant that discharges to this river. The comparison is not to say that either is a problem, but to help provide some context.

In this report, it is the benefits to the receiving waters that are most pertinent. However, there are also other environmental impacts associated with requiring cruise ships to meet water quality standards at the point of discharge. Cruise ships unable to comply may elect to hold their wastewater and discharge at sea, requiring extra fuel consumption and associated carbon dioxide emissions. These impacts could be reduced by a change of policy that still protects aquatic life yet allows for a mixing zone prior to application of WQC, as is allowed for numerous other industrial and domestic wastewater discharges in Alaska and elsewhere in the country.

7.2. Constituent Levels in Alaska Marine Waters

Very little data are available for ammonia in Alaskan marine waters, but ammonia is expected to be very low in concentration. Metals data are available for Hawk Inlet, Chatham Strait, Gastineau Channel and Skagway Harbor. These data were compared to other marine metals data from Possession Sound in Washington State.

Marine waters are well mixed and metals concentrations are expected to vary within a very small range. In much of Alaska, surface estuarine waters are significantly diluted with large volumes of glacial melt and glacial fed rivers, such that metals concentrations will reflect a blend of these two sources. For some metals, such as arsenic or cadmium, the freshwater may dilute the marine concentrations, while for some other metals the freshwater may increase the marine concentrations, though not to levels that approach or exceed WQC.

7.2.1. Ammonia

Ammonia is taken up by phytoplankton as a preferred nutrient. Ammonia is also combined in receiving waters with oxygen to form the nutrients nitrite and nitrate. Hence, ammonia is not a conservative parameter. A total of 91 measurements of ammonia as N (mg/L) were taken in Gastineau Channel from 1989 to 1991 (Echo Bay Alaska, Inc., 1991.) The overall average was 0.021 mg/L. Because ammonia is not conservative, and because Gastineau Channel has several ammonia sources (two municipal wastewater plants and at least one fish processor) it is likely that background ammonia concentration in most Alaskan marine waters will be even lower. This value (0.021 mg/L) is well below the applicable chronic WQC of 1 mg/L.

7.2.2. Copper

Dissolved copper concentrations in Hawk Inlet and Chatham Strait were measured in 2006-2010. The average of 60 samples was 0.41 µg/L dissolved copper. There were 86 measurements of total recoverable copper obtained from nine locations in Gastineau Channel in 1989-1991. The average was 0.73 µg/L as total recoverable copper. EPA's marine copper criteria use a factor of 0.83 to convert total recoverable copper to dissolved copper, so it is reasonable to assign an average concentration of 0.61 µg/L to Gastineau Channel. There were 39 observations of dissolved copper between 1999 and 2000 in Possession Sound (part of Puget Sound) in Washington State and the average dissolved copper concentration was 0.34 µg/L. Based on these observations, it is reasonable to use 0.5 µg/L as a background dissolved copper concentration for Alaskan marine waters. This is well below the chronic water quality criterion of 3.1 µg/L dissolved copper.

7.2.3. Nickel.

There were 86 measurements of total recoverable nickel obtained from nine locations in Gastineau Channel in 1989-1991. The average was 0.97 µg/L as total recoverable nickel. EPA's marine nickel criteria use a factor of 0.99 to convert total recoverable nickel to dissolved nickel, so here we will just assume dissolved nickel is about the same as total recoverable nickel. There were 42 observations of dissolved nickel between 1999 and 2000 in Possession Sound in Washington State and the average dissolved nickel concentration was 0.44 µg/L. For this analysis we will conservatively use 1 µg/L as the background dissolved nickel concentration in Alaskan marine waters. This is well below the applicable chronic water quality criterion of 8.2 µg/L.

7.2.4. Zinc.

Dissolved zinc concentrations in Hawk Inlet and Chatham Strait were measured in 2006-2010. The average of 60 samples was 1.17 µg/L dissolved zinc. There were 85 measurements of total recoverable zinc obtained from nine locations in Gastineau Channel in 1989-1991. The average was 1.6 µg/L as total recoverable zinc. EPA's marine zinc criteria use a factor of 0.946 to convert total recoverable zinc to dissolved zinc, so it is reasonable to assign an average concentration of 1.5 µg/L to Gastineau Channel for dissolved zinc. There were 42 observations of dissolved zinc between 1999 and 2000 in Possession Sound in Washington State and the average dissolved zinc concentration was 0.63 µg/L. For this analysis we will use 1.2 µg/L as the background dissolved zinc concentration in Alaskan marine waters. This is well below the applicable chronic water quality criterion of 81 µg/L.

7.2.5. Impaired waters

The State's list of impaired waters indicates metals impairment in marine waters at only three places, Skagway, Klag Bay on West Chichagof Island, and Salt Chuck Bay on Prince of Wales Island. The State does not list any marine waters as impaired for ammonia.[47] All the metals in the list are associated with mining and metals in the sediment. The Superfund listing information for Salt Chuck Bay emphasizes the tailings and the sediments but also notes that metals were elevated in the water. It is not stated whether WQC for metals were exceeded.

7.3. Environmental Effects of Cruise Ship Wastewater Discharges.

7.3.1. Development of Water Quality Standards and Criteria

As described in Section 2.2, a water quality standard consists of four basic elements:

1) Designated uses of the water body (e.g., recreation, water supply, aquatic life, agriculture),
2) WQC to protect designated uses (numeric pollutant concentrations and narrative requirements),

---

[47] See, http://dec.alaska.gov/water/wqsar/Docs/2010impairedwaters.pdf

3) An antidegradation policy to maintain and protect existing uses and high quality waters, and
4) General policies addressing implementation issues (e.g., low flows, variances, mixing zones).

Individual numeric criteria are based on specific data and scientific assessment of adverse effects. Numeric criteria for aquatic life protection contain a concentration (e.g. 5 mg/L) and an averaging period. For toxic exposure effects, a one-hour averaging period applies for an acute (short-term) concentration, while a four-day average applies for a chronic concentration (long-term toxic exposure effects). An exception is that the marine copper acute criterion is based on a 24-hour average. See Section 2.2. for more details about Alaska's WQC for ammonia, copper, nickel and zinc.

7.3.1.1. Understanding Mixing Zones

Before one can evaluate the environmental effects of an effluent, or the environmental benefits of improvements of effluent quality, it is important to consider how EPA, Alaska, and other states use mixing zones when implementing water quality criteria during permitting of treated waste discharges. Numeric WQC are applicable to in situ concentrations in surface waters, and were not intended to be effluent limits.

Alaska's Water Quality Standards and Alaska's Pollutant Discharge Elimination System (APDES) permitting regulations include mixing zone provisions.[48] Wastewater discharge permits issued in Alaska by EPA and by DEC routinely include mixing zones. Alaskan municipal dischargers to marine waters have mixing zone allowances and do not have effluent limits requiring them to meet Alaska's water quality standards at the point of discharge[49]. EPA approves of the use of mixing zones and notes that:

> *"Mixing zones provide a useful link between water quality standards and National Pollutant Discharge Elimination System (NPDES) permits. Water Quality-Based Effluent Limits are derived from and comply with water quality standards and may incorporate dilution based on mixing zone policies where appropriate." (EPA 2006[50])*

---

[48] 18 AAC 70.240 and 18 AAC 83.435(c)

[49] See NPDES permits and fact sheets for Anchorage, Cordova, Haines, Homer, Juneau, Kenai, Ketchikan, Petersburg, Sitka, Skagway, Unalaska and Valdez. Also see Alaska's proposed general permit for small POTWs and other small treatment works providing secondary treatment of domestic wastewater and discharging to surface water which includes mixing zones for 50 small communities.

[50] See, Memo from Benjamin Grumbles, Assistant Administrator at EPA dated July 13, 2006 announcing the *Compilation of Mixing Zone Documents*.
http://water.epa.gov/scitech/swguidance/standards/upload/2006_07_19_standards_mixingzone_covermemo.pdf

EPA views mixing zones as providing the link between water quality standards applicable to receiving waters and permitted discharges. EPA evaluated the effectiveness of advanced wastewater treatment systems on cruise ships operating in Alaska and compared the effluent quality directly to EPA's National Recommended Water Quality Criteria (NRWQC), but provided the following qualifier to put the comparison in context.

> "*EPA's NRWQC are recommended concentrations of analytes* ***in a waterbody*** *that are intended to protect human health and aquatic organisms and their uses from unacceptable effects from exposures to these pollutants.* ***The NRWQC are not directly comparable to analyte concentrations in a discharge*** *for a number of reasons. First, NRWQC not only have a concentration component, but also a duration and frequency component. Second, it is not always necessary to meet all water quality criteria within the discharge pipe to protect the integrity of a waterbody (EPA, 1991). Sometimes it is appropriate to allow for ambient concentrations above the criteria in small areas near outfalls. These are called mixing zones. To ensure mixing zones do not impair the integrity of the waterbody, it should be determined that the mixing zone will not cause lethality to passing organisms and, considering likely pathways of exposure, that there are not significant human health risks. Third, under EPA's water quality permitting regulations (40 CFR 122.44(d)(1)(ii)), when determining whether a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric criteria within a state water quality standard, the permitting authority is directed to use procedures which account for, among other things, the dilution of the effluent in the receiving water, where appropriate*." (EPA 2008[51]) (**emphasis added**)

The reference to EPA, 1991 in the above quote is to EPA's *Technical Support Document for Water Quality-based Toxics Control*[52], which is the basic guidance used by EPA and many states including Alaska when evaluating the need for water quality-based effluent limits in permits, and the development of limits when needed. The guidance incorporates mixing zones.

7.3.2. Potential Effects of Undiluted Cruise Ship Effluent

As discussed in Section 2.2, marine WQC identify threshold concentrations and exposures of toxic constituents of concern. Recent effluent data are compared to the concentration components of the WQC in Table 19.

[51] See 2-225, 2-26, and 3-20 in, EPA 2008, *Cruise Ship Discharge Assessment Report*. EPA842-R-07-005. http://www.epa.gov/owow/oceans/cruise_ships/pdf/0812cruiseshipdischargeassess.pdf

[52] http://www.epa.gov/npdes/pubs/owm0264.pdf

Table 19 Analysis of Ammonia, Copper, Nickel and Zinc Discharges of Undiluted Effluent

Parameter	Ambient Level	AWQC Chronic	AWQC Acute	2008-2009 max	2011 Average
Ammonia mg/L	0.021	1 (4-day exposure)	6.5 (1-hour exposure)	160	23.87
Copper µg/L	0.5	3.1 (4-day exposure)	4.8 (24 hour exposure)	140	23.87
Nickel µg/L	1	8.2 (4-day exposure)	74 (1-hour exposure)	420	12.8
Zinc µg/L	1.2	81 (4-day exposure)	90 (1-hour exposure)	501	91.65

Based upon these data, average undiluted discharge concentrations in cruise ship effluents in 2011 exceed ambient seawater levels for these constituents. Average ammonia, copper, and zinc concentrations in the effluents were above the acute and chronic water quality criteria (ignoring the element of duration of exposure inherent in the criteria). However, as noted by EPA in Section 7.3.2.1, the WQC are not directly comparable to analyte concentrations in a discharge for a number of reasons. Just knowing the concentration in a discharge tells us nothing about the duration of exposure. These concentrations would only be toxic to organisms in the receiving water if there were exposures to levels above the numeric criteria and exposure duration.

7.3.3. Potential Effects of In-Port Stationary Discharges

Dilution from a stationary discharging vessel can be used to evaluate effluent data. DEC has determined a dilution factor of 28 is attained within 15 meters distance from a stationary cruise ship discharge and would apply to an in-port vessel discharging at rest. Not surprisingly, the dilution benefit from a moving vessel is much greater than the dilution benefit from a stationary one. The dilution from a stationary vessel is comparable to the dilution benefit from a municipal discharger, although dilution factors for municipal discharges in Alaskan marine waters are typically developed for distances greater than 15 meters. EPA 2008 acknowledged the dilution from cruise ships discharging when in-port[53.]

Table 20 presents the maximum detected concentrations of ammonia and the three metals from the 2008-2009 Alaska cruise season along with an analysis considering dilution. The analysis considers the background concentrations and the concentration of the mix after an

[53] EPA 2008 at 2-32, 2-36, 2-37, 3-26, 3-27, 3-29, 3-30

in-port dilution factor of 28 from a stationary cruise ship and allows a comparison to the chronic water quality criteria. The dilution factor of 28 was achieved within a few minutes after the effluent left the side of the vessel with an initial jet velocity, when the fastest mixing occurs. The analysis also identifies how much dilution is needed to meet the chronic water quality criteria and provides an estimate of how long it takes to attain that dilution.

Table 20 Analysis of ammonia, Copper, Nickel and Zinc Discharges From Stationary Cruise Ships

Analysis of worst case for in-port discharge	Ammonia (mg/L)	Copper (µg/L)	Nickel (µg/L)	Zinc (µg/L)
Maximum value 2008-2009	160	140	420	501
Chronic water quality criterion (exposure duration)	1 (4-day exposure)	3.1 (4-day exposure)	8.2 (4-day exposure)	81 (4-day exposure)
Acute water quality criterion (exposure duration)	6.5 (1-hour exposure)	4.8 (24-hour exposure)	74 (1-hour exposure)	90 (1-hour exposure)
Background concentration	0.021	0.5	1	1.2
Concentration of mix after dilution factor of 28	5.735	5.482	15.964	19.050
Incremental increase	5.714	4.982	14.982	17.857
Dilution factor needed for effluent to meet chronic WQC	164	54	59	6.3
Estimated time before effluent meets chronic WQC	1-4 hours	tens of minutes	tens of minutes	< minute

The table illustrates that following the initial dilution:

- The increased ammonia of 5.735 mg/L exceeds the chronic WQC of 1 mg/L but meets the acute WQC of 6.1 mg/L. If the dilution factor could be increased to 164 then the chronic water quality criterion for ammonia would be attained. Time to attain this dilution is estimated to be 1 to 4 hours.
- The increased copper of 5.482 µg/L exceeds the chronic WQC of 3.1 µg/L, but if the dilution factor could be increased to 54 then the chronic water quality criterion for copper would be attained. Time to attain this dilution is estimated to be ten minutes to less than 1 hour.
- The increased nickel of 15.964 µg/L exceeds the chronic WQC of 8.2 µg/l, but if the dilution factor could be increased to 59 then the chronic water quality criterion for nickel would be attained. Time to attain this dilution is estimated to be ten minutes to less than 1 hour.
- The increased zinc of 19.050 µg/L is well below the chronic WQC of 81 µg/L and a dilution factor of only 6.3 is sufficient to meet the chronic water quality criterion. Time to attain this dilution is estimated to be less than 1 minute.

Alaska and EPA's chronic water quality criteria are based on a four-day duration of exposure. Table 20 illustrates that the possible duration of exposure for organisms to concentrations exceeding the chronic criteria will be less than 1 to 4 hours when a vessel is discharging in port. Even if several cruise ships discharged during their stay in-port during the same visitation period there would be more than an adequate movement of water into and out of the port such that aquatic life would never experience the 4-day chronic exposure period. The table suggests that if something can be done to increase the allowed in port dilution factor to 160 or greater, then in port discharge of even the highest effluent concentrations would still be protective of water quality. This could be done by allowing a larger size mixing zone such as is often the case for Alaskan municipal wastewater dischargers.

To summarize this section, in the case of discharges from stationary cruise ships with the current advanced wastewater treatment systems, the maximum observed concentrations of ammonia, copper, nickel and zinc are diluted to below the chronic water quality criteria in a few hours or less, which is protective to aquatic life given the 4 day duration of exposure component of the chronic WQC. Ships discharging in-port do so only if they can meet more stringent limits based on a dilution factor of 28, and that dilution will occur in less than 10 minutes and is protective. Under typical APDES[54] permitting, a larger mixing zone could be allowed for chronic WQC.

[54] APDES stands for the Alaska Pollutant Discharge Elimination System and is the state's means of implementing the federal National Pollutant Discharge Elimination System (NPDES). These are the regulatory tools used in permitting and regulating discharges to surface waters.

7.3.4. Potential Effects of Underway Discharges

There are several studies that have looked at the fate and transport of cruise ship effluent discharges. The EPA 2008 study compared effluent quality from cruise ships directly to the NRWQC. EPA also evaluated the effluent quality in the context of dilution from an underway vessel and dilution from a vessel at rest. There was an earlier Science Advisory Panel in Alaska that evaluated cruise ship wastewater discharges[55] and that Panel developed a simple formula for calculating a conservative dilution factor for discharges from large moving cruise ships. The formula was based in part on dye dilution studies conducted by EPA 2002. The formula follows:

$$\text{Initial Dilution Factor for Ships Underway} = \frac{4 * (\text{Ship Width [m]} * \text{Ship Draft [m]} * \text{Ship Speed [m/sec]})}{\text{Volume Discharge Rate [m}^3\text{/sec]}}$$

The EPA 2002 dye dilution studies found dilution factors varied from 200,000 to 900,000 under various rates of discharge and ship speed[56]. The first Alaska Cruise Ship Science Advisory Panel, established in 2001 when the Alaska Cruise Ship Initiative began, calculated that for a large cruise ship traveling at 6 knots and discharging at a high discharge rate of 200 cubic meters per hour, the dilution factor would be >50,000. The first Alaska Cruise Ship Science Advisory Panel then used that dilution factor in evaluating cruise ship discharges sampled between 2000 and 2001 and demonstrated that water quality criteria were easily and rapidly attained. This is particularly noteworthy because much of the data were from before advanced wastewater treatment systems were in place. The first Science Advisory Panel's work was published in a peer reviewed journal[57]. Papers concerning the first Science Advisory Panel's work and concerning EPA's dye studies were presented at the International Oceans 2003 conference in San Diego in September 2003[58,59,60,61,62,63,64]. In September 2011, Dr. Alan

[55] Science Advisory Panel and Alaska Department of Environmental Conservation Commercial Passenger Vessel Environmental Compliance Program, 2002. *The Impact of Cruise Ship Wastewater Discharge on Alaska Waters*. http://dec.alaska.gov/water/cruise_ships/SciencePanel/documents/impactofcruiseship.pdf

[56] EPA 2002. *Cruise Ship Plume Tracking Survey Report*. Pp 17-18. http://water.epa.gov/polwaste/vwd/upload/2002_09_25_oceans_cruise_ships_plumerpt2002_plumereport.pdf

[57] Loehr, L.C., C-J Beegle-Krause, K. George, C.D. McGee, A.J. Mearns, and M.J. Atkinson, 2006. The significance of dilution in evaluating possible impacts of wastewater discharges from large cruise ships. *Marine Pollution Bulletin.* 52(2006) 681-688.

[58] Morehouse. C. and D. Koch. 2003. *Alaska's Cruise Ship Initiative and the Commercial Passenger Vessel Environmental Compliance Program.* pp 372-375 in Proceedings, IEE/MTS Oceans '03.

[59] Morehouse. C. 2003. *Wastewater sampling and analysis for commercial passenger vessels.* pp 376-385 in Proceedings, IEE/MTS Oceans '03.

[60] Loehr, L.C., M. Atkinson, K. George and CJ Beegle-Krause. 2003. *Using a simple dilution model to estimate wastewater contaminant concentrations behind moving passenger vessels.* pp 390-393 in Proceedings, IEE/MTS Oceans '03.

Mearns, a member of the first Science Advisory Panel gave a presentation to the current Science Advisory Panel. He presented the results of the first panel, and noted the importance of dilution[65]. In evaluating Alaska cruise ship discharges, EPA 2008 cited the 2002 dye dilution studies and the first Science Advisory Panel's underway dilution formula, and EPA provided an example calculation for a large ship discharging at 25 m^3/hr while traveling at 6 knots, which resulted in a dilution factor of 420,000[66].

The First Science Advisory Panel had reviewed an earlier modeling study prepared for the Alaska SeaLife Center[67] that evaluated dilution from moving cruise ships. The Alaska SeaLife Center study evaluated the dilution for effluents from the discharge point to the stern. In this stretch, the effluent would be entrained in, and mixed with a boundary layer of water adjacent to the hull. The Alaska SeaLife Center study concluded that because the boundary layer would emerge from the stern above the propellers, then the propellers would not provide any further mixing benefit[68]. The First Science Advisory Panel concluded that the mass of displaced water collapsing behind a moving cruise ship, and the mixing action of the two counter rotating propellers would actually provide a very substantial mixing benefit and therefore rejected the conclusion in the Alaska SeaLife Center study. Subsequent dye studies by EPA and direct observations of turbulent mixing in cruise ship wakes by the First Science Advisory Panel supported the dilution formula developed by the First Science Advisory Panel.

The Alaska SeaLife Center study is still useful to help answer the question of how rapid initial dilution occurs before the effluent reaches the stern, and it provides a means of estimating when sufficient dilution occurs for the highest effluent concentrations from 2008 and 2009 for ammonia, copper, nickel and zinc to meet water quality criteria. The Alaska SeaLife Center study modeling indicated that the dilution factors up to the stern for a large cruise ship,

---

[61] Heinen, E., K. Potts, L. Snow, W. Trulli and D. Redford. 2003. *Dilution of wastewater discharges from moving cruise ships.* pp 386-389 in Proceedings, IEE/MTS Oceans '03.

[62] McGee, C.D. and L.C. Loehr. 2003. *An assessment of fecal coliform bacteria in cruise ship wastewater discharge.* pp. 733-736 in Proceedings, IEE/MTS Oceans '03.

[63] Mearns, A.J., M. Stekoll, K. Hall, CJ Beegle-Krause, M. Watson and M. Atkinson. 2003. *Biological and ecological effects of wastewater discharges from cruise ships*. Pp. 737-747 in Proceedings, IEE/MTS Oceans '03.

[64] Eley, W.D. and C.H. Morehouse. 2003. *Evaluation of new technology for shipboard wastewater treatment.* pp. 748-753 in Proceedings, IEE/MTS Oceans '03.

[65] http://dec.alaska.gov/water/cruise_ships/SciencePanel/documents/Binder/Mearns-presentation-to-SAP2AJM.ppt.pdf

[66] EPA 2008 at 2-37, 2-38 and 3-30

[67] Colonell, J.M., S. V. Smith and R. B Spies. November 12, 2000. Cruise Ship Wastewater Discharge into Alaskan Coastal Waters. Prepared for The Alaska SeaLife Center and The North West Cruiseship Association.

[68] See page 12 in Colonell et al.

discharging at 200 cubic meters per hour (a high rate) varied with speed, associated with different behavior of boundary water[69]. Dilution factors varied from 600 to 2,500 for different speeds. Assuming discharges occur about 300 feet forward of the stern, travel times to reach the stern vary with speed. At 6 knots, the travel time is 30 seconds, while at 10 knots the travel time is only 18 seconds. Table 21 uses the dilution calculations from the Alaska SeaLife Center study for different speeds, derives the time for the discharge to reach the stern, and proportionately allocates the dilution factor over time, assuming a uniform rate of dilution. (In actuality, the dilution in the first seconds would be expected to be greater than using an average incremental dilution rate because of the jet action and turbulence at the point of discharge.) An estimated time to achieve dilution factors of 6, 60 and 164 is also presented.[70] It's evident that for discharges from cruise ships while underway, the dilution factor of 164 is attained within a matter of seconds, and hence water quality criteria are also attained within a matter of seconds. The duration of exposure to organisms to concentrations greater than the numeric criteria is much shorter than the exposure duration components of the WQC.

Table 21 Underway Cruise Ship Dilution Factors From Point of Discharge to the Stern and Estimated Dilution-Time-Distance Relationships for Key Dilution Factors.

Speed	Dilution Factor at stern	Travel time to stern	Dilution Factor increase each second	Time and distance to achieve Dilution Factor of 164	Time and distance to achieve Dilution Factor of 60	Time and distance to achieve Dilution Factor of 6
6 kts	710	30 seconds	24	7 seconds (70 feet)	< 3 seconds (<30 feet)	< 1 second (<10 feet)
8 kts	2,500	22.5 seconds	111	< 2 seconds (<20 feet)	< 1 second (<10 feet)	< 1 second (<10 feet)
10 kts	600	18 seconds	33	5 seconds (<85 feet)	< 2 seconds (<30 feet)	<1 second (about 3 feet)

*Note: data are based on one cruise ship modeled. Time to travel to stern will vary depending on how close the discharge port is to the stern and the ship speed. This discharge ports for large cruise ships are typically about 300 feet from the stern. This model is not linear.

[69] From page 11 in Colonell, et al., the "boundary layer" is the region of the flow where the surrounding fluid accommodates the velocity difference between the moving body and the stationary fluid. The thickness of the boundary is arbitrarily defined as that distance from the solid boundary at which the fluid velocity is 99% of the surrounding fluid.

[70] As shown in Table 21, these factors are relevant to the dilution needed for the highest effluent concentrations of ammonia, and the metals to meet chronic water quality criteria.

Table 22 presents the highest effluent concentrations of ammonia, copper, nickel and zinc from the 2008-2009 Alaska cruise season along with an analysis considering dilution. The analysis considers the background concentrations and the concentration of the mix after a conservative dilution factor of 50,000[71] and allows a comparison to the chronic water quality criteria. The analysis also identifies how much dilution is needed to meet the (more stringent, i.e. lower) chronic water quality criteria and provides an estimate of how long it takes to attain that dilution.

The discharge port is about 300 feet from the stern, so dilution factors sufficient to meet the WQC are attained before the treated effluent even reaches the stern.

Table 22 Analysis of Ammonia, Copper, Nickel and Zinc Discharges from Underway Cruise Ships

Analysis of worst case for underway discharge	**Ammonia (mg/L)**	**Copper (µg/L)**	**Nickel (µg/L)**	**Zinc (µg/L)**
Maximum value 2008-2009	160	140	420	501
Chronic water quality criterion (exposure duration)	1 (4-day exposure)	3.1 (4-day exposure)	8.2 (4-day exposure)	81 (4-day exposure)
Acute water quality criterion (exposure duration)	6.5 (1-hour exposure)	4.8 (24-hour exposure)	74 (1-hour exposure)	90 (1-hour exposure)
Background concentration	0.021	0.5	1	1.2
Concentration of mix after dilution factor of 50,000	0.024	0.503	1.008	1.210
Incremental increase	0.003	0.003	0.008	0.010

71 A dilution factor of 50,000 is conservative because it assumes a high discharge rate of 200 cubic meters per hour and a speed of only 6 knots. Actual discharge rates from AWTS equipped vessels are typically 2 to 5 times lower, and vessel speeds are 2 to 3 times higher.

Analysis of worst case for underway discharge	**Ammonia (mg/L)**	**Copper (µg/L)**	**Nickel (µg/L)**	**Zinc (µg/L)**
Dilution factor needed for effluent to meet chronic WQC	164	54	59	6.3
Estimated time before effluent meets chronic WQC	less than 10 seconds	less than 5 seconds	less than 5 seconds	less than 1 second

The table illustrates that following the initial dilution,

- The increased ammonia concentration of 0.003 mg/L in the wake is trivial (1/333rd) compared to the chronic WQC of 1, and therefore not toxic. The estimated time to dilute the highest effluent ammonia concentration to a value below the 4 day average chronic ammonia criteria is less than 10 seconds.
- The increased copper concentration of 0.003 µg/L in the wake is trivial (1/1000th) compared to the chronic WQC of 3.1 µg/L and therefore not toxic. The estimated time to dilute the highest effluent copper concentration to a value below the 4 day average chronic copper criteria is less than 5 seconds.
- The increased nickel concentration of 0.008 µg/L in the wake is trivial (1/1000th) compared to the chronic WQC of 8.2 µg/L and therefore not toxic. The estimated time to dilute the highest effluent nickel concentration to below the 4 day average chronic nickel criteria is less than 5 seconds.
- The increased zinc concentration of 0.010 µg/L in the wake is trivial (1/8100th) compared to the chronic WQC of 81 µg/L and therefore not toxic. The estimated time to dilute the highest effluent zinc concentration to below the 4 day average chronic zinc criteria is less than 1 second.

The chronic water quality criteria have a four-day duration of exposure component (see discussion in Section 2.2). The table illustrates that the possible duration of exposure to concentrations exceeding the criteria will be less than 10 seconds from an underway discharge.

The above table clearly demonstrates that neither acute (1 to 24 hour averages) nor chronic (4-day average) exposures above criteria are expected to occur from underway vessel discharges. The table also shows that the concentrations following initial dilution are in compliance with WQC which may be an indication that the implementation of the permit limits may not have significant additional environmental benefit. Note that Alaska DEC makes a similar demonstration in the Information Sheet for the 2010 General Permit:

"*For example, an exceedance equivalent to the highest measurement from the 2004-2009 data set for each parameter would yield the following: ammonia at 160 mg/L with a dilution* *factor of 1:50,000 would be 0.0032 mg/L, well below the water quality standard of 1 mg/L; copper at 172 µg/L with a dilution factor of 1:50,000 would be 0.00344 µg/L, well below the water quality standard of 3.1 µg/L; nickel at 420 µg/L with a dilution factor of 1:50,000 would be 0.0084 µg/L, well below the water quality standard of 8.2 µg/L; and zinc at 501 µg/L with a dilution factor of 1:50,000 would be 0.01002 µg/L, well below the water quality standard of 81 µg/L. In summary, even if vessels discharge these substances at the highest concentrations seen to date, concentrations in receiving waters would still be less than one percent of the water quality standards*." (DEC 2010[72])

The same information sheet provided a table presenting the maximum value detected, the underway dilution factor of 50,000, the expected concentration in the receiving water and the water quality standard, similar to this Science Advisory Panel's table above.

To summarize this section, in the case of discharges from moving cruise ships with the current advanced wastewater treatment systems, the maximum observed concentrations of ammonia, copper, nickel and zinc are diluted to below the chronic water quality criteria in less than 10 seconds. This dilution happens well before the discharge even reaches the stern of the vessel. There are no anticipated measureable exceedances of water quality criteria in the wake behind the stern of a vessel discharging from the existing advanced wastewater treatment systems. After the dilution period, neither acute nor chronic exposure levels occur in the water column. Ammonia, copper, nickel and zinc concentrations in the existing underway discharges from advanced wastewater treatment systems currently in use in the Alaskan cruise ship fleet do not now result in acute or chronic impact to aquatic organisms because of the rapid dilution to concentrations below standards and indistinguishable from background concentrations. Consequently, minimal environmental benefit is expected from attaining the water quality criteria a few seconds faster.

7.3.5. Mass Loading Considerations

Evaluation of the total mass loadings to Alaskan waters from the ammonia, copper, nickel and zinc discharged from all the cruise ships in a year is possible. However, mass loading information can be miss-leading and imply something that appears both large and in need of being reduced. A mass loading calculation by itself is not very useful, as mass loading calculations need to be put in context. To understand effects on water quality, (1) concentrations, (2) duration of exposures to concentrations higher than the WQC, and (3) concentrations following dilution are what matters, and mass loading concerns can be a distraction. Also, when contemplating the total mass of any particular pollutant entering the water of southeast Alaska, one should also consider the fact that the whole ocean water body is

[72] See pages 14 and 15 in, DEC 2010. 2010 Large Commercial Passenger Vessel Wastewater Discharge General Permit Information Sheet .
http://dec.alaska.gov/water/cruise_ships/pdfs/2010_Cruise_Ship_Info_Sheet_FINAL.pdf

moving up the coast and there is a constant influx of "new" water into the area, with historic pollutants being carried off.

With the above caveat in mind, one member of the Science Advisory Panel made a conservative calculation of the total amount of copper discharged in a cruise season by all the ships in Alaska and then for context made a similar calculation for the total amount of copper discharged from just one river (the Mendenhall River in southeast Alaska). The Panelist used 14 µg/L average concentration of copper in cruise ship effluents using AWTSs[73], and estimated the total volume discharged from all cruise ships in a year[74] to calculate an annual mass loading of 88 pounds of copper. This calculation was then compared with the Mendenhall River mass loading using 0.83 µg/L average concentration of dissolved copper in the Mendenhall River (upstream of the City's secondary treatment plant)[75] and a mean annual river flow of 1,250 cubic feet per second. The annual loading of dissolved copper from just the Mendenhall River is over 2,000 pounds per year which is about 23 times greater than the total annual copper loading from all the cruise ships combined. The Mendenhall River is just one of many rivers discharging to Southeast Alaskan waters.

The loading from the Mendenhall River is not a water quality concern. The River easily meets the copper water quality criteria. Similarly, the much lower copper loading from all the cruise ships is very broadly dispersed and meets water quality criteria before the discharges even reach the sterns of the vessels. Thus the cruise ship discharges are not a concern because the copper water quality criteria are met very rapidly in the receiving water as discussed above and the total mass loading is negligible compared to natural sources.

7.3.6. Potential Effects of Constituents Of Concern On Marine Organisms

One panelist expressed concern that the localized effects of repeated effluent discharge by multiple ships along transit routes and in frequently used discharge areas on marine phytoplankton, zooplankton and other species may include impacts on productivity and biological diversity. This panelist requested that long-term effects of repeated discharges in specific areas be determined through examining fate and transport of contaminants through ocean currents, foodweb transfer and by assessing potential synergystic effects of the discharged constituents with particles and chemical composition of the water column.

The Panelist is concerned that the long-term effects of excessive ammonia concentrations on phytoplankton communities cannot be fully predicted. It is possible that species shifts due to varying nutrient uptake strategies could occur. Where exotic plankton species are present that can exploit high ammonia levels and outcompete indigenous species,

---

[73] from Table 2-7 in EPA 2008 *Cruise Ship Discharge Assessment Report*

[74] Used 800 cubic meters/day x 20 ships x 180 days. The 20 ships is a conservative estimate since it assumes all ships discharge in Alaska Waters, when some lines do not.

[75] From ambient monitoring data collected by the City and Borough of Juneau

invasive species can bloom, some of which may generate harmful algal bloom effects such as eutrophication and toxicity to other organisms.

Heavy metals are both essential elements for many marine organisms yet can be toxic to some species. Long term studies on the cumulative effects of adding heavy metals the marine ecosystem have identified means by which metals are concentrated in foodwebs to toxic levels especially in higher trophic level organisms. Bioaccumulation, bioconcentration, and biomagnification of metals in the marine environment are known to have impacts upon survival and reproductive success of vertebrates and invertebrates. The Panelist believes that the potential long-term effects of copper, nickel and zinc from cruise ship effluent on the Alaskan food web and species is not currently known.

7.4. Non-Water Quality Environmental Consequences of Meeting Alaska Water Quality Standards

It is a common perception that increasing regulatory standards will benefit the environment. This is not always the case. There are often environmental trade-offs and in the case where standards become so stringent, there even can be net environmental loss. The trade-off issue was raised during a presentation by Dr. Mearns, a member of the 2002 Science Advisory Panel.

Non-water quality environmental consequences of the requirement to meet Alaska Water Quality Standards at the point of discharge have several nuances. There are some environmental consequences associated with additional treatment. There are also environmental consequences associated with fuel consumption for vessels that meet Alaska's permit requirements by holding wastewater and waiting to discharge when outside of state waters. The fuel consumption consequences are probably the most significant, and the issue cuts several ways.

It is not the intention of this report to provide specific conclusions regarding non-water quality environmental benefits of meeting Alaska Water Quality Standards at the point of discharge. To be that specific would require the identification of installed and fully operational technology as well as evaluation of many aspects of a vessel and the surrounding environment.

This section is intended to highlight several issues, which should be considered when determining whether meeting AWQC given the current proven technology would result in a net environmental benefit.

Installing additional technology onboard may require additional space, additional energy to operate and additional staff, which result in additional food, water, cleaning and other basic living requirements.

Certain technologies require the use of additional chemicals. Some technologies may change the water characteristics such as pH, requiring additional chemicals and treatment to restore. Additional mechanical equipment may lead to leaching metals into the waste stream and may require increased fuel consumption for power generation.

Additional treatments added on to the existing AWTS may result in concentrates that present challenges for disposal. Concentrates from ion exchange resin regeneration would probably need to be offloaded to shore facilities for handling. Reverse Osmosis reject water would have elevated concentrations that could probably be held and discharged at sea.

Additional treatment options include increased aeration requirements for the bioreactors, carrying an energy demand with associated environmental effects (fuel consumption, air emissions including carbon dioxide).

The greater non-water quality environmental issue is the very substantial additional fuel consumption associated with vessels adjusting their itinerary in order to discharge treated or untreated effluent outside of state waters. Vessels are already doing this. As noted earlier in Section 5.2.1 and Tables 2 and 5 it is apparent that about 40% of the vessels in the Alaska operations currently do not discharge in state waters. Future permits establishing limits for ammonia, copper, nickel and zinc equal to Alaska's WQC without any benefit of dilution increase the likelihood that more vessels (perhaps all vessels) will find it necessary to hold their treated effluent to discharge outside of state waters or even untreated wastewater outside federal waters, and this will have environmental effects associated with substantial additional fuel consumption.

The following is a computation of the added fuel consumption for a hypothetical situation, but helps to illustrate that the consumption can be quite substantial. Assuming a typical cruise ship making one extra trip offshore per week to discharge would consume considerable extra fuel, with substantial carbon dioxide emissions, as well as other air emissions. (In addition to global warming concerns, carbon dioxide emissions now are also viewed as contributing to ocean acidification, so they have an indirect water quality environmental concern too.) For a rough approximation, assume that a typical large cruise ship burns about 0.4 metric tons of fuel per nautical mile, and that one extra trip offshore to discharge added 100 nautical miles to the week. The extra trip per week would use 40 metric tons of fuel which result in about 120 metric tons of carbon dioxide $_2$ emissions per week, or for a 20 week cruise season, 2,400 metric tons of carbon dioxide. There are also other air emissions typical of hydrocarbon fuels. Fuel costs around $700/metric ton, so the fuel cost alone for the one extra trip offshore per week would be about $28,000, or for a 20 week cruise season, $560,000 per ship. Anything that can reduce the number of extra offshore trips for cruise ships in Alaska will reduce this fuel consumption rate, and anything that will cause the number of extra offshore trips for cruise ships in Alaska to increase, will increase this fuel consumption rate.

All ship itineraries will have some ordinary transit time outside of state waters. The need for ships to make additional excursions offshore will depend on their holding capacity, their ability to treat some or all of their wastewater to levels permitted for discharge inside state waters, how those permit conditions might change, and their ability to offload some of their wastewater to shore based treatment facilities such as the Juneau Douglas wastewater treatment plant. The fuel costs of additional trips offshore are factors that cruise lines will balance against additional wastewater treatment costs and capabilities, and the complexity of permit compliance for discharging in Alaska waters. Changes in permit conditions could result in substantial increases in fuel consumption, or substantial decreases in fuel consumption, each with associated non-water quality environmental effects. Changes in treatment capability could also affect the need for excursions offshore.

7.4.1. Background on the Requirement to Meet Alaska's WQC

In August 2006, Alaska voters approved Ballot Measure 2[76] ("Cruise Ship Taxation, Regulation and Disclosure"), which promulgated new regulatory requirements for large cruise ships operating in Alaskan waters. Among other requirements relating to taxation, gambling, and monitoring, the measure required that large passenger vessels may not discharge untreated sewage, treated sewage, graywater, or other wastewaters in a manner that violate any applicable effluent limits or standards under state or federal law, *including Alaska Water Quality Standards governing pollution at the point of discharge* [emphasis added]. This requirement was interpreted by DEC as requiring cruise ships' discharges to meet the water quality standards at the end-of-pipe without any recognition or benefit of a mixing zone.[77]

In public statements, the initiative backers stated that "the initiative would make the cruise industry adhere to the same standards as the fishing industry, municipalities and gas and oil companies,"[78] and "cruise ships are the only major polluters not required to have a discharge permit and meet ALL Alaska water quality standards."[79]

In Alaska, neither industries nor municipalities discharging to marine waters are required to meet water quality standards at the point of discharge. Many Alaskan municipalities provide only primary treatment[80] and are permitted by EPA and DEC to do so under Section 301(h) of the Clean Water Act. Neither the primary treatment nor the secondary treatment facilities[81] meet Alaska's water quality standards <u>at the point of discharge</u>, especially for ammonia or copper.[82] They do meet water quality-based effluent limits at the point of discharge, when such limits are applied because water quality-based effluent limits are established to assure water quality

---

[76] See http://www.dec.state.ak.us/water/cruise_ships/Law_and_Regs/index.htm

[77] See page 15 in, DEC 2010. 2010 Large Commercial Passenger Vessel Wastewater Discharge General Permit Information Sheet.

[78] Article quoting Joe Geldhof about Ballot Measure 2 in the Skagway News, August 11, 2006, http://www.skagwaynews.com/081106stories.html.

[79] Statement prepared by Gershon Cohen and Joe Geldhof in Support of Ballot Measure 2 in State of Alaska Primary Election Voter Pamphlet for Primary Election August 22, 2006. Page 19 in http://www.elections.alaska.gov/doc/bmp/2006/2006_bmp.pdf.

[80] Anchorage, Haines, Ketchikan, Petersburg, Sitka, Skagway, Unalaska and Wrangell

[81] Cordova, Homer, Juneau, Kenai, Kodiak, Seward and Valdez

[82] Maximum copper values for the municipalities range from 23 to 167 µg/L. Maximum ammonia values for the municipalities range from 4 to 64 mg/L. (Values determined from review of permit fact sheets and discharge monitoring reports.)

standards are met in the receiving water after allowing for dilution in a mixing zone. Analyses that consider dilution often show that water quality-based effluent limits are not necessary, even though the effluents themselves do not meet Alaska's numeric water quality standards at the point of discharge. When permitting determines water quality-based effluent limits are needed, they are established after consideration of dilution.

Statements that the requirement imposed by the citizen's initiative was an application of the state's standards in a manner comparable to other Alaskan facilities are not accurate. Alaskan municipal and industrial dischargers to marine waters, as well as Alaskan fish processors, are all allowed mixing zones and then, after consideration of this dilution, must meet Alaska's Water Quality Standards at the mixing zone boundary.

The objective of ultimately meeting Alaska Water Quality Standards at the point of discharge remains as the driver for AS.46.03.464.c2, while the environmental benefit analysis is specific to the benefits of going beyond what is currently done. In order to evaluate the benefit to Alaska's receiving waters, the critical environmental benefit to be evaluated is based on a comparison between (1) where the water quality standards are met with the current methods of treatment, and (2) improving cruise ship wastewater discharges to the point of meeting Alaska water quality standards at the point of discharge. To understand where the water quality standards are currently met, it is necessary to understand mixing zones as discussed in Section 7.3.1.1.

7.5. Conclusions

Undiluted effluent concentrations at 2011 average levels do exceed acute and chronic WQC for ammonia, copper, nickel and zinc. Reducing effluent discharge concentrations will reduce the total amounts of these contaminants released to Alaska marine waters.

WQC for ammonia, copper, nickel and zinc include duration of exposure components. Organisms should not be exposed to levels above acute criteria for more than a 1 hour duration (24 hours in the case of copper), and should not be exposed to concentrations above chronic criteria for more than 4 days. The panel is not aware of any evidence that commercial passenger vessels operating in Alaska waters with AWTS cause acute or chronic toxic exposure to marine organisms.

For the in port discharges, the dilution rate is similar to municipal point sources. DEC determined that a dilution factor of 28 is attained in 15 meters. In-port cruise ships authorized to discharge as stationary dischargers have limits in the current permit driven by that dilution factor. Assuming they meet those limits, the time to achieve dilution to below the chronic criteria is about 10 minutes following termination of the discharge event, significantly less time than the 4 day duration of exposure component of the chronic water quality criteria and organisms in the receiving water will not receive acute or chronic toxic exposure.

For the underway discharges from the existing advanced wastewater treatment systems, using the highest observed effluent concentrations for 2008-2009, there would be no water quality criteria exceedances in the wake behind a moving cruise ship, and dilution to levels lower than the chronic criteria will occur in less than 10 seconds, long before the discharged effluent even reaches the stern of the moving vessel. The Panel sees no measurable environmental benefit to meet criteria less than 10 seconds sooner than is currently met.

The copper mass loading exercise demonstrated that the Mendenhall River discharges about 23 times as much copper in a year to the waters of southeast Alaska than all the cruise ships combined. The Mendenhall River is not a problem. It meets the copper water quality criteria. Similarly, the cruise ships are not a problem, as there is no evidence of acute or chronic exposure to marine organisms in Alaska Waters from commercial passenger vessels operating in Alaska Waters using AWTS..

Municipal treatment plants in Alaska do not meet Alaska's water quality criteria at the point of discharge for ammonia, copper, nickel or zinc. Both Alaska DEC's and EPA's discharge permitting decisions recognize that dilution is an appropriate consideration for these, and consequently, most do not have any limits. Some municipalities have limits for copper, which are established based on dilution and the facilities have to meet the limits, but not the WQC at the point of discharge.

There are consequences to setting the effluent discharge limits to WQC concentrations. In the absence of available treatment systems that will be capable of consistently meeting limits, ships are forced to hold wastewater effluent and discharge offshore outside State waters. Fuel usage will increase and the levels of treatment may decrease substantially.

It is required by law; however, there appears to be little environmental benefit of treatment above and beyond that which current advanced wastewater treatment plants provide. Since 2003, effluent quality has undergone significant improvement (See Figures 2-7). AWTS meet WQC concentrations or technology-based limits at the point of discharge for conventional pollutants. Organisms are not exposed to chronic or acute toxic exposure for ammonia or dissolved metals while ships are underway. Costs expended to implement further treatment will not produce substantial additional environmental benefit.

8. ECONOMIC FEASIBILITY

The Statute mandates that the Panel identify the costs of current and additional methods. It is not written broadly to include an assessment of the impact of those costs on the industry. Nevertheless, economic feasibility is a two part issue. What are the costs to implement additional methods of prevention, control, and treatment? And, what are the considerations of these costs to the cruise ship industry and to coastal towns visited by cruise ships.

The Panel was able to obtain estimates of current costs for wastewater treatment methods. This information is outlined in Section 8.

No commercially available additional treatment systems that could meet WQS at the point of discharge were identified. Thus, costs to install and implement systems were not available. Were treatment systems identified, the methodology to evaluate costs is outlined in Section 8.2.

Characteristics of the cruise ship industry are outlined in Section 8.3.

There are significant data gaps associated with estimating costs of additional methods of prevention, control, and treatment and the Panel was not able to obtain comparable, verifiable costs for future alternatives.

Table 23 Financial and Quantitative Aspects of Treatment Technologies Currently in Use

Ship/ Maximum Passengers + Crew DEC Notice of Intent (NOI)	Wastewater Generated (typical)	Treatment System/ Total Design capacity AWTS m^3/ 24 hours	Average Volume Treated per day in 2011, m^3	Capital Cost (including direct and indirect costs) , $	Annual O&M Cost (including labor, energy, chemical, training, etc.), $*
1. Disney Wonder/ 3754 (data for this ship from Oasis 2011 survey, except where noted)	Mixed, 100% of wastewater treated in continuous operation, 40 m3/day BW with 710 m3/day GW (2012 survey)	2 Hamworthy MBR, designed to MEPC159(55) & 33 C.F.R.159/1200	750 (2012 Survey)	$6 mil (2009)	$500,000
2. Princess Coral/3310	Mixed- continuous operation, 200 m3/day BW with 910 m3/day GW; #1 &2 MBRs treat GW+BW	2 Hamworthy Membrane Bioreactor MBRs, USCG Type II) including 1 x UV system at final output of the two MBRs/640	#1 200 #2 150	$2,228,000 (2002-2003)	$457,087 (2011)
3. Princess Diamond/ 4278	Mixed- continuous operation, 220 m3/day BW with 1010 m3/day GW; ; #1 MBR treats GW+BW, #2 &#3 treat GW only	3 Hamworthy MBR, USCG Type II, including 1 x UV system at final output of the three MBRs/960	#1 270 #2 211 #3 211	System capital costs not available, $226,012 expense for UV system and spares (2004)	$641,813 (2011)
4 Princess Golden/ 4216	Mixed- continuous operation, 240 m3/day BW with 1125 m3/day GW; #1 MBR treats GW+BW, #2 &#3 treat GW only	3 Hamworthy MBR, USCG Type II, including 1 x UV system at final output of the three MBRs/960	#1 98.5 #2 175 #3 180	$3,490,821 (2006-2007)	$719,639 (2011) (includes $70,391 for transfer to shore-side facility)
5. Princess Island/ 3312	Mixed- continuous operation, 200 m3/day BW with 910 m3/day GW; #1 &2 MBRs treat GW+BW	2 Hamworthy Membrane Bioreactor MBRs, USCG Type II) including 1 x UV system at final output of the two MBRs/960	#1 156 #2 159	$2,228,000 (2002-2003)	$566,433 (2011) (includes $34,339.49 for transfer to shore-side facility)
6. Princess Sapphire/ 4269	Mixed- continuous operation, 220 m3/day BW with 1010 m3/day GW; #1 & #2 MBRs treat GW only, #3 treats GW+BW	3 Hamworthy MBR, USCG Type II, including 1 x UV system at final output of the three MBRs/960	#1 –172.9 #2 –169.3 #3 --161.8	System capital costs not available, $226,307 expense for UV system and spares (2004)	$765,774 (2011)

Ship/ Maximum Passengers + Crew DEC Notice of Intent (NOI)	**Wastewater Generated (typical)**	**Treatment System/ Total Design capacity AWTS m^3/ 24 hours**	**Average Volume Treated per day in 2011, m^3**	**Capital Cost (including direct and indirect costs) , $**	**Annual O&M Cost (including labor, energy, chemical, training, etc.), $***
7. Princess Sea/ 3180	Mixed- continuous operation, 80 m3/day BW with 760 m3/day GW; #1 &2 MBRs treat GW+BW	2-Hamworthy Membrane Bioreactor MBRs, USCG Type II) including 1 x UV system at final output of the two MBRs/452	#1 –211.9 #2 –197.9	$2.678,000 (2008-2009)	$435,932 (2011) (includes $711.45 for transfer to shore-side facility)
8. Holland America Statendam/ 2609	Mixed- continuous operation, 40 m3/day BW with 470 m3/day GW	1-Zenon I, Bio/UF designed to Murkowski/660	510	$2,230,000 (2000)	$237,350 (2011)
9. Holland America Volendam/ 2887	Mixed- continuous operation, 30 m3/day BW with 474 m3/day GW	1-Zenon II, Bio/UF designed to Murkowski/710	482	$2,730,000 (2001)	$242,000 (2011)
10. Holland America Zaandam/ 2887	Mixed- continuous operation, 40 m3/day BW with 465 m3/day GW	1-Zenon II, Bio/UF designed to Murkowski/710	249.4	$2,730,000 (2001)	$242,400 (2011)
11. Norwegian CL Pearl/ 4130	Mixed- continuous operation, 160 m3/day BW with 880 m3/day GW	1-Scanship AWTS, FA45 Mussel/1780	1040	$3,000,000 (2006)	$88,136 (2011)
12. Norwegian CL Star/ 4000	Mixed- continuous operation, 150 m3/day BW with 800 m3/day GW	1-Scanship AWTS, FA40 Mussel /1400	1023	$2,260,000 (2004)	$292,903 (2011)
13. Seven Seas Navigator/ 870	Mixed, continuous operation, 20 m3/day BW with 230 m3/day GW	Scanship WO-1062/1780	300	$1,000,000 (2009)	$500,000 (2011)
14. Silver Shadow/ 740	Mixed, continuous operation, 25 m3/day BW with 255 m3/day GW	Marisan 250 TPD/250	0	$400,000 (2004)	$82,000 (2011)
15. Oceania Regatta / 1150	Mixed, continuous operation, 15 m3/day BW with 235 m3/day GW	2-Triton MBRs Model MSTP9- MF (Port and Starboard) 2011 Retrofit/480	170	Not provided (2011)	$91,700 (2011)
16. Carnival Spirit GW (Note: will no longer operate in AK after 2012)	GW only in Rochem LPRO, 1020 m3/day; BW treated in separate MSD	RoChem LPRO, BIP/50??	250	$1,230,988 (2011)	$26,965 (2011

*O&M was self-reported by operators in the Data Surveys. There is no information provided regarding what individual operators included as O&M, thus there are limitations to comparing these values.

8.1. Current Treatment Costs

The Data Collection Surveys submitted by cruise operators provided costs and data for past retrofits and implementation of treatment systems. Cost information collected in the surveys varied between operators. Most operators were unable to break down both the capital and operating costs or provide detail of what went into their estimates (i.e. installation costs for capital, energy, labor or chemical costs in the operating estimates). Therefore, side-by-side comparison of costs between ships are inaccurate and cannot be done. This information is only useful to get a rough order of magnitude of the capital and operating costs. With this qualification, estimates are provided in two ways: 1) costs for wastewater treatment per cubic meter (Table 24) and 2) costs of wastewater treatment per passenger (Table 25). The current cost of wastewater treatment ranges between $0.76 and $4.95 per cubic meter treated, and $0.41 and $4.37 per passenger. These wide ranges of unit costs reflects the variability in the survey responses.

It should also be noted that these ships have installed AWTSs only because of the Alaska permit requirements. Operation of AWTSs are not required outside of Alaska waters. However, since many of the AWTSs are biological in nature, they cannot easily be shut down and restarted. Therefore, AWTSs are frequently operated continuously. For this analysis, all of the costs of operating these AWTS in the cost analysis are attributed to operation in Alaska.

The Oceania Regatta installed a new AWTS that included a Membrane Reactor and Ion Exchange system for polishing the effluent. The system was intended to meet the ammonia, copper, nickel and zinc WQS. Samples collected during the 2011 cruise season showed that the treatment system was unable to consistently meet any of the WQS (Table 10)[83].

Table 24 Treatment Costs from DEC 2012 Survey

Item	Average number of days AWTS operated in 2011	Average amount of wastewater treated in AWTS in 2011, m3/day	Average volume treated in AWTS in 2011, m3	On-shore Treatment Costs, $	O& M Costs in 2011 $ (excluding on-shore treatment costs)	Total O& M Costs in 2011, $	Treatment Cost, excluding on shore treatment $/m3	Total Treatment Cost, $/m3
Disney Wonder	355	750	266,250	0	$500,000	$500,000	$1.88	$1.88
Coral Princess	365	350	127,750	$13,654	$443,433	$457,087	$3.47	$3.58

[83] Reference: Alaska DEC Oceania Regatta 2011 Pilot Project *A Glance at Wastewater Metal and Ammonia Reduction Technology*, September 20 2011

Item	Average number of days AWTS operated in 2011	Average amount of wastewater treated in AWTS in 2011, m3/day	Average volume treated in AWTS in 2011, m3	On-shore Treatment Costs, $	O& M Costs in 2011 $ (excluding on-shore treatment costs)	Total O& M Costs in 2011, $	Treatment Cost, excluding on shore treatment $/m3	Total Treatment Cost, $/m3
Diamond Princess	365	692	252,580	$24,046	$617,767	$641,813	$2.45	$2.54
Golden Princess	365	453.5	165,528	$70,391	$649,248	$719,639	$3.92	$4.35
Island Princess	363	315	114,345	$34,339	$532,094	$566,433	$4.65	$4.95
Sapphire Princess	364	504	183,565	0	$765,774	$765,774	$4.17	$4.17
Sea Princess	363	409.8	148,757	$711	$435,220	$435,932	$2.93	$2.93
HAL Stdam	365	510	186,150	0	$237,350	$237,350	$1.28	$1.28
HAL Voldm	365	482	175,930	0	$242,000	$242,000	$1.38	$1.38
HAL Zndm	365	249.4	91,031	0	$242,000	$242,000	$2.66	$2.66
NCL Pearl	365	1040	379,600	0	$288,136	$288,136	$0.76	$0.76
NCL Star	365	1023	373,395	0	$292,903	$292,903	$0.78	$0.78
Seven Seas Navig.	365	0	-	0	$500,000	$500,000		
Silver Shadow	6	0	-	0	$82,000	$82,000		
Oceania Regatta	198	170	33,660	0	$91,700	$91,700	$2.72	$2.72
CCL Spirit GW	120	250	30,000	0	$26,965	$26,965	$0.90	$0.90

*O&M cost excludes $70,391 for shore treatment transfer

**O&M cost excludes $34,339.49 for shore treatment transfer

***O&M cost excludes 711.45 for shore treatment transfer

Table 25 Treatment Costs per Revenue Passenger from DEC 2012 Survey

Item	Total No of Passengers in AK in 2011	No of days AWTS operated in AK in 2011	No. of days AWTS operated in 2011	% of Operating days in AK in 2011	Total O&M Costs in 2011 $	Total O&M Costs in AK in 2011 $	Treatment Cost, per Passenger
Disney Wonder	51,012	90	355	25	$500,000	$126,761	$2.48
Coral Princess	35,532	99	365	27	$457,087	$123,977	$3.49
Diamond Princess	53,560	101	365	28	$641,813	$177,598	$3.32
Golden Princess	50,084	76	365	21	$719,639	$149,843	$2.99
Island Princess	35,532	99	363	27	$566,4337	$154,482	$4.35
Sapphire Princess	48,204	72	364	20	$765,774	$151,472	$3.14
Sea Princess	26,208	52	363	14	$435,932	$62,448	$2.38
HAL Stdam	22,680	99	365	27	$237,350	$64,377	$2.84
HAL Voldm	24,344	99	365	27	$242,000	$65,638	$2.70
HAL Zndm	27,208	103	365	28	$242,000	$68,290	$2.51
NCL Pearl	47,880	80	365	22	$288,136	$63,153	$1.32
NCL Star	46,960	78	365	21	$292,900	$62,593	$1.33
Seven Seas Navig.	8,640		365		$500,000	$0	
Silver Shadow			6		$82,000	$0	
Oceania Regatta	6,993	66	198	33	$91,700	$30,567	$4.37
CCL Spirit GW	38,700	70	120	58	$26,965	$15,730	$0.41

8.2. Life Cycle Cost Evaluation

In comparing remedial alternatives, the EPA recommends[84] that the following costs are assessed: (1) Capital costs, including both direct and indirect costs; (2) Annual operations and

[84] A Guide to Developing and Documenting a Cost Estimate during the Feasibility Study", (EPA 540-R-00-002, July 2000)

maintenance costs; and (3) Net present value of capital and O&M costs. Present value analysis reflects the one-time capital and ongoing operating costs over the equipment useful life in one figure. This method provides a way to compare life cycle costs for different treatment alternatives in a single cost figure. The present value assumes certain economic conditions in a discount rate, typically 7 percent annually to account for the time value of money. Since the present value takes into account the useful life of the equipment, it is an assessment of the life cycle cost. The panel was unable to perform the life cycle cost analysis with the information collected in the surveys. Detailed information and a breakdown on capital and operating costs are needed, as well as a consistent basis for how the estimates were calculated. The survey information did not provide this level of detail.

8.3. Characteristics of the Cruise Ship Industry

The cruise industry is considered an oligopolistic market (i.e., a quasi-monopoly, controlled by four large corporations). This is the result of years of mergers and acquisitions in the industry were necessary to achieve some economies of scale as well as opportunities in market downturns that better positioned performing companies for future market return. The shipping industry in general is notorious for cycles in the market, and the cruise industry is no exception.

Much like airline companies, the cruise operators aim for good yield management, maximizing the net revenue per ship. Hence, a ship performing poorly in a market could see the future itinerary modified in order to better utilize the asset. Fluctuating capacity in a given market will directly affect the price that is paid by passengers, and the yield a ship will bring. Given the cost of large cruise ships which now ranges anywhere from $750M to $1.5B, the yield of the ships is of prime importance to the operators.

Unlike shore-side hotels, resorts, or even manufacturing operations, the assets are fully moveable. Hence ships assigned to Alaska can be re-assigned to a better yielding market or a growth market (e.g. Asia, Australia) that will generate a better yield. A caveat to this is for operators that have invested heavily in fixed assets such as local hotels and private destinations. Nevertheless, a decrease in yield per ship for a destination would typically be met with a capacity reduction to re-establish a normal yield. While operators with fixed assets can be slower to re-assign ships, operators with no assets can be as nimble as cancelling the next season and offering alternatives to passengers already booked for a cruise.

8.4. Destinations as Products

A destination could be compared to a product offered within a product line. When demand for a product decreases production is adjusted. Likewise when profitability in producing a product decreases it can be abandoned. Unless outside marketing supports a renewed demand for a destination, marketing of the company for a destination would still contribute to lower yield for that product.

The cruise industry is market-driven. In most cases, they are publicly traded companies. The pressure to compete against one another is strong and shareholders demand good return on their investments. The wild fluctuation of prices one can observe in the offering in various markets indicates the position of price takers. There is currently more capacity than demand and this capacity excess is dealt with using marketing and price cutting strategies.

The current overall economic situation is affecting many sectors of the economy and the cruise industry is not immune to it. Current issues in Europe and the USA reduced overall demand for the cruise product given its added associated costs. The 2012 accident in Italy[85] further dampens demand. Latest quarter results released by the cruise companies indicate mixed successes but overall reduced revenues and performance.

8.5. Cruise Revenues

It is important to understand that cruise revenues are composed of two important components: onboard revenues and ticket revenues, the former compromising shore excursions and everything sold onboard and the latter the transaction price to book a cabin. While ticket revenue is a general indication, it is not necessarily a proxy for overall profits. Currently, most cruise ships sail with a good occupancy level but at a discounted rate. Further compounding the issue is that people are spending much less onboard than they used to. They splurge to take the cruise, but book less excursions and overall consume less while onboard. Traditionally, it can be seen that onboard revenues across companies accounts for approximately 1/3 of the revenues. Reduction in ticket prices coupled with reduced onboard revenues had the effect that companies had lower profits and even losses in the second quarter of 2012 and revised downward projection for the rest of the fiscal year.

The new low sulphur fuel requirement for ships operating within the Exclusive Economic Zone (EEZ) of the United States will cause an increase of approximately 25-30% of their fuel cost. Fuel is a ship's number one expense. Hence this new fuel requirement will further decrease the yield of ships currently operating in U.S. waters.

8.6. Destinations and Product Lifecycle

Destinations can be seen as a product. As discussed above these products go through similar lifecycles as other consumable goods. The normal product lifecycle consists of the introduction phase with a small demand followed by a growth phase with exponential demand, to the maturity phase, which shows a plateau in demand to finally a decline. The only thing that keeps product line from declining is for a new model to be introduced or in the cruise market for the product to be updated with new ships, or new excursions and for the marketing to promote this. Therefore, not only is the cruise industry bound to some market cycle in line with the economy it is also subject to product maturation and fluctuation in demand.

Quantifiable cost or "hard" costs are not the only costs that must be taken into consideration when evaluating a project. Soft costs, which represent general costs that are hard to account for, such as managerial oversight cost, loss of focus on the core mission, and brand image risk, are also important factors considered by management when evaluating alternatives.

[85] Grounding of the *Costa Concordia* in January 2012.

These soft costs are hard to evaluate and are qualitatively part of a final decision to purchase new systems or change operational procedures.

8.7. Potential Economic Impact of New System Requirements

It is hard to provide an exact figure of what would be a negative impact on the companies and Alaskan community. In terms of hard cost for the company, the Panel obtained general figures for costs to upgrade technology before planned replacement. However it is difficult to quantitate the additional soft costs. Nevertheless, the hard cost should be seen as a minimum and some approximation must be made for soft cost.

The economic impact of added cost of operations depends on one thing; the elasticity of demand for the Alaskan cruise product. This could be found by conducting an in depth study of current passenger mix and how sensitive they are to price change. In lieu of having this data, we could approximate this elasticity of demand by using the head tax information data. While this might not be an exact reference point, it would be a good general estimate of passenger traffic reduction based on price increase. Another measure of economic impact may be the reduction in shore side spending and excursions as a result of ticket price increase.

Hence using the overall passenger traffic before the head tax and correlating it to the decrease in passenger traffic after the head tax and averaging this with the increase of passengers after the reduction in head tax would provide an overall sensitivity of passenger to dollar change in the cost of cruising to Alaska.

While this measure is not exact it would be a starting point in approximating what would be the potential impact of increasing cost of operations in Alaska. Indeed other factors (e.g. overall economy) also play in this dynamic choice of cruise vs. other type of vacation: however it is the best method we would have at this point to measure economic impact of cruise policy decision on Alaskan community welfare.

{This page deliberately blank.}

9. FINDINGS

AWTS were designed to meet required criteria for conventional pollutants and are the most advanced, technologically effective, and proven treatment systems available, especially compared to municipal treatment plants discharging to marine waters. Aquatic organisms, including fish and marine mammals, are protected through the cruise ship General Permit.

After evaluating all AWTS currently installed on cruise ships operating in Alaskan waters, the Panel found that none of those treating mixed blackwater and graywater consistently meet Alaska's WQC at the point of discharge for the constituents of concern (ammonia and dissolved copper, nickel, and zinc).

The Panel was unable to identify technologically effective and economically feasible treatment methods, expected to consistently meet the numeric water quality criteria at the point of discharge that have been proven on cruise ships. Application of existing technologies in addition to AWTS, such as nitrification, ion exchange (IX) and reverse osmosis (RO), is expected to further reduce ammonia and dissolved metal concentrations; however, there is no evidence to prove adding additional technology will be technologically effective at meeting WQC, be economically feasible, or provide much environmental benefit. Modifying operational procedures and additional staff training may help improve treatment performance. This panel recommends continued sampling and monitoring of cruise ship effluent.

Adaptation of emerging technologies from other industries to cruise ships presents significant feasibility challenges.

A dilution model developed by the first Alaska Cruise Ship Wastewater Science Advisory Panel and dye studies conducted by EPA demonstrate that concentrations lower than WQC are attained rapidly following AWTS discharge from a moving vessel and acute and chronic exposures would not occur. Similarly, dilution modeling is used for permitting other wastewater discharges.

The Panel identified little additional environmental benefit to be gained by lowering the current permitted effluent limits to WQC at the point of discharge.

{This page deliberately blank.}

FIGURES

{This page deliberately blank.}

Figure 1 Fecal Coliform Bacteria Geometric Mean 2000-2011 in Discharge from Cruise Ships (Note: log scale)

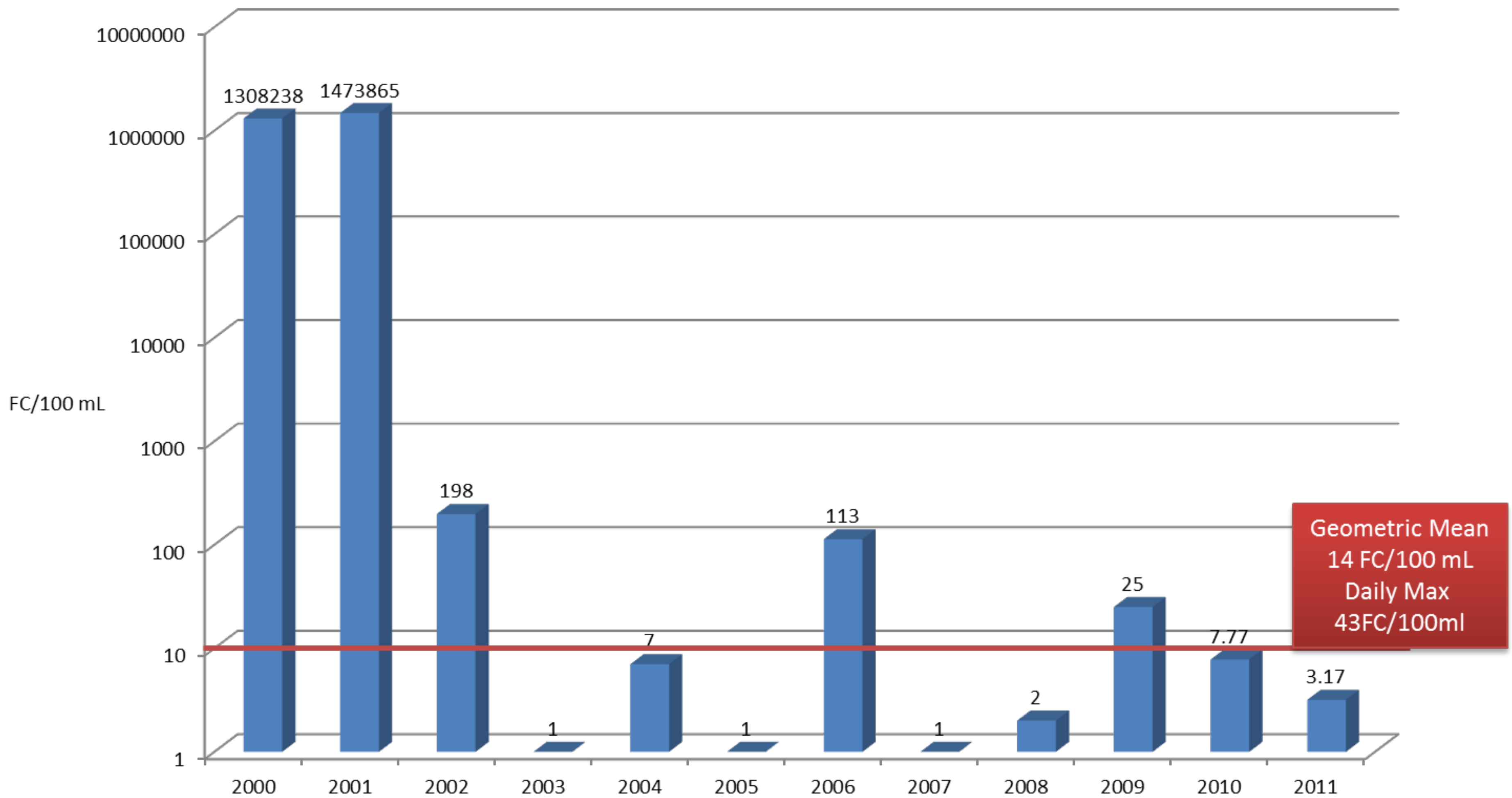


Figure 2 Total Suspended Solids Average Value 2000-2011 in Discharge from Cruise Ships

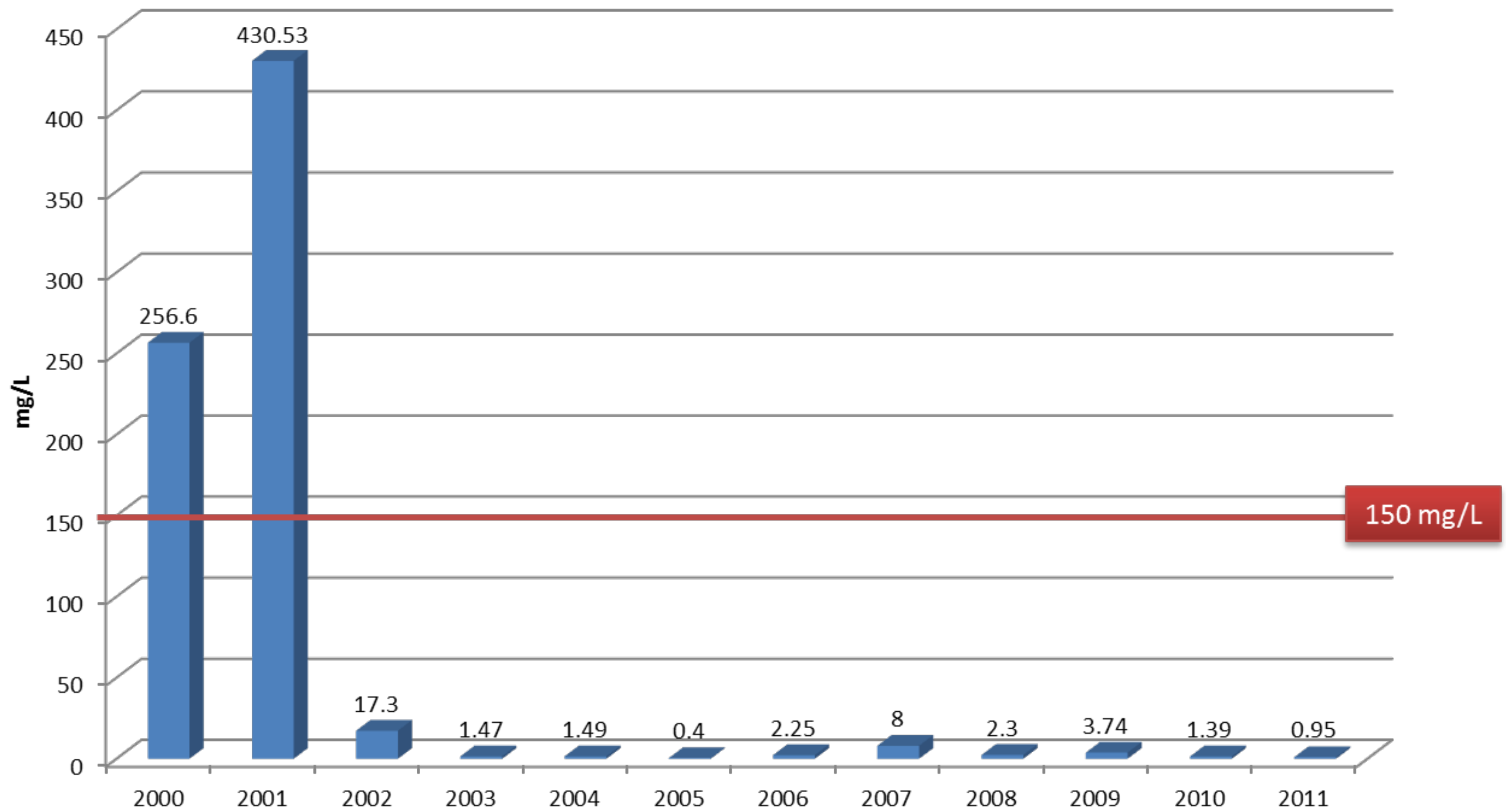


Figure 3 Biochemical Oxygen Demand Average Value 2000-2011 in Discharge from Cruise Ships

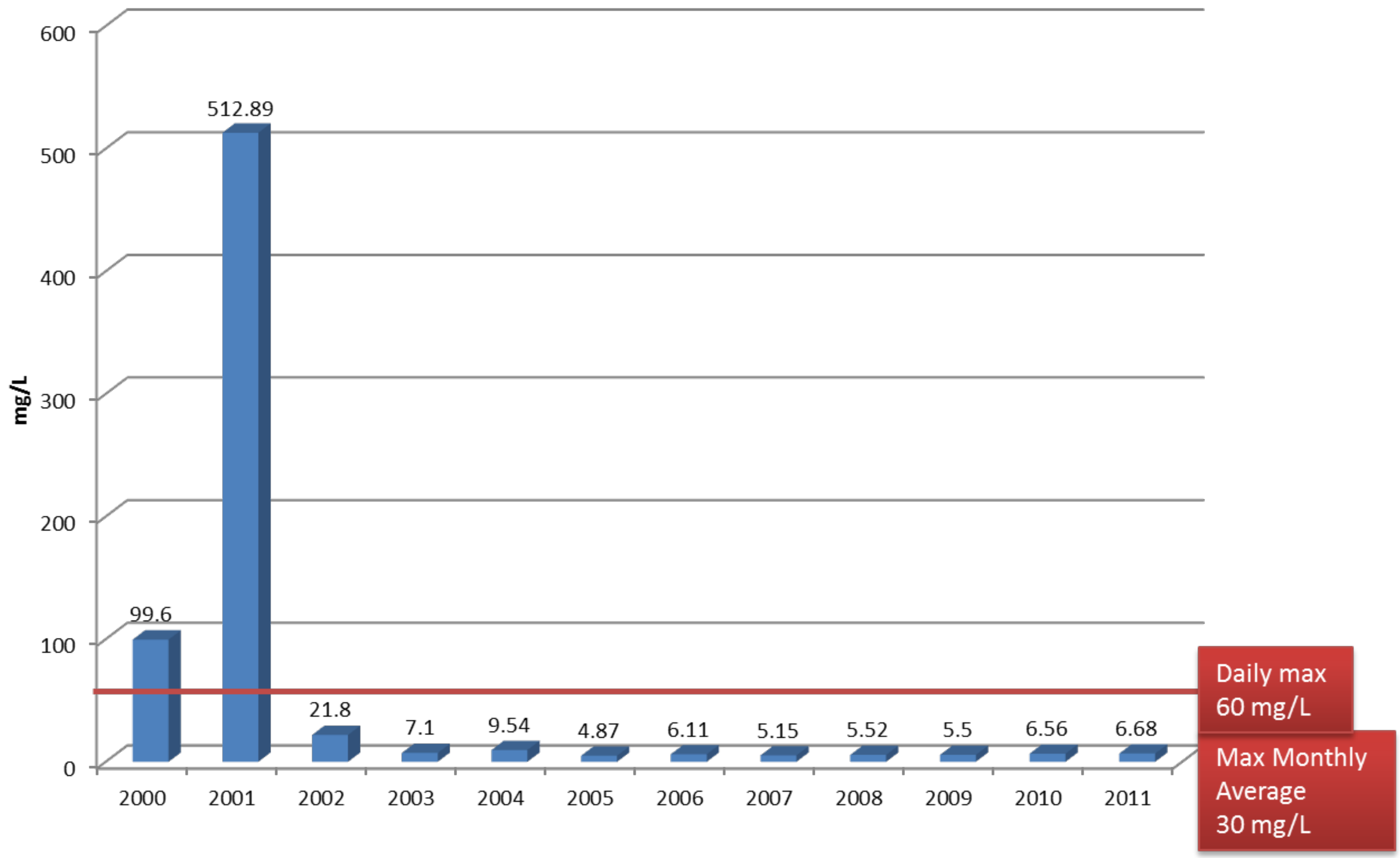


Figure 4 Ammonia Average Concentration 2000-2011 in Discharge from Cruise Ships

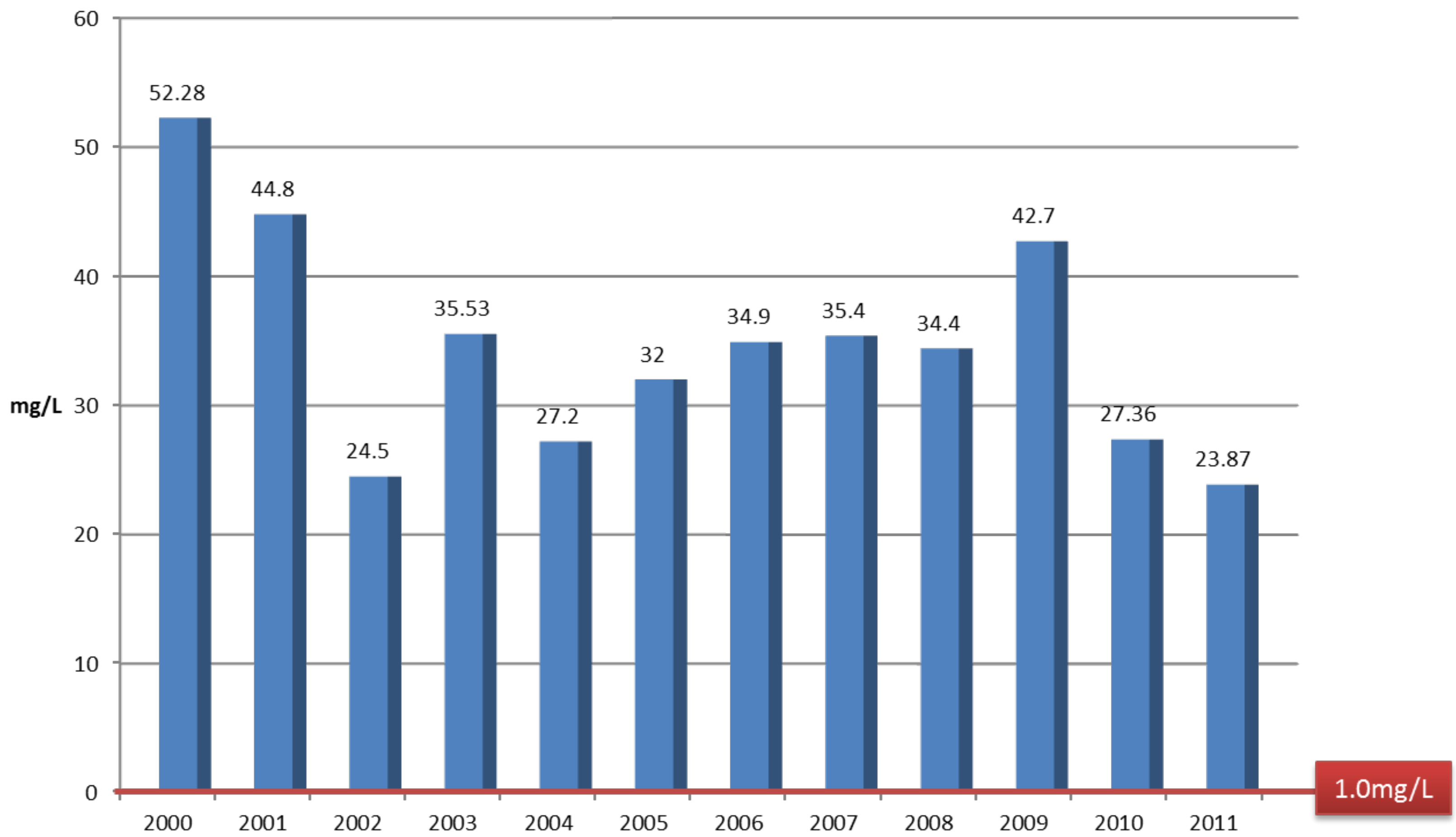


Figure 5 Dissolved Copper Average Concentration 2001-2011 in Discharge from Cruise Ships

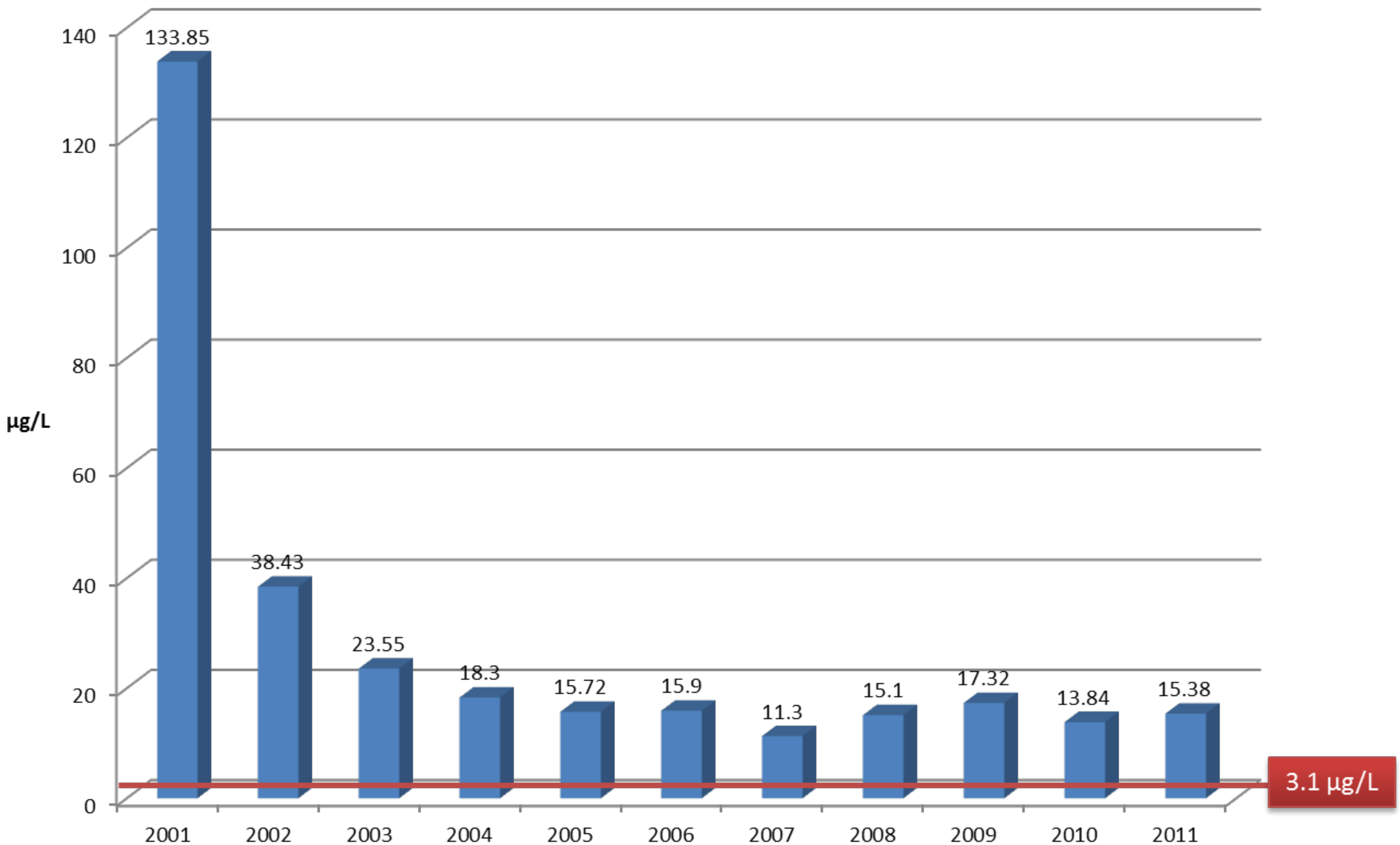


Figure 6 Dissolved Nickel Average Concentration 2001-2011 in Discharge from Cruise Ships

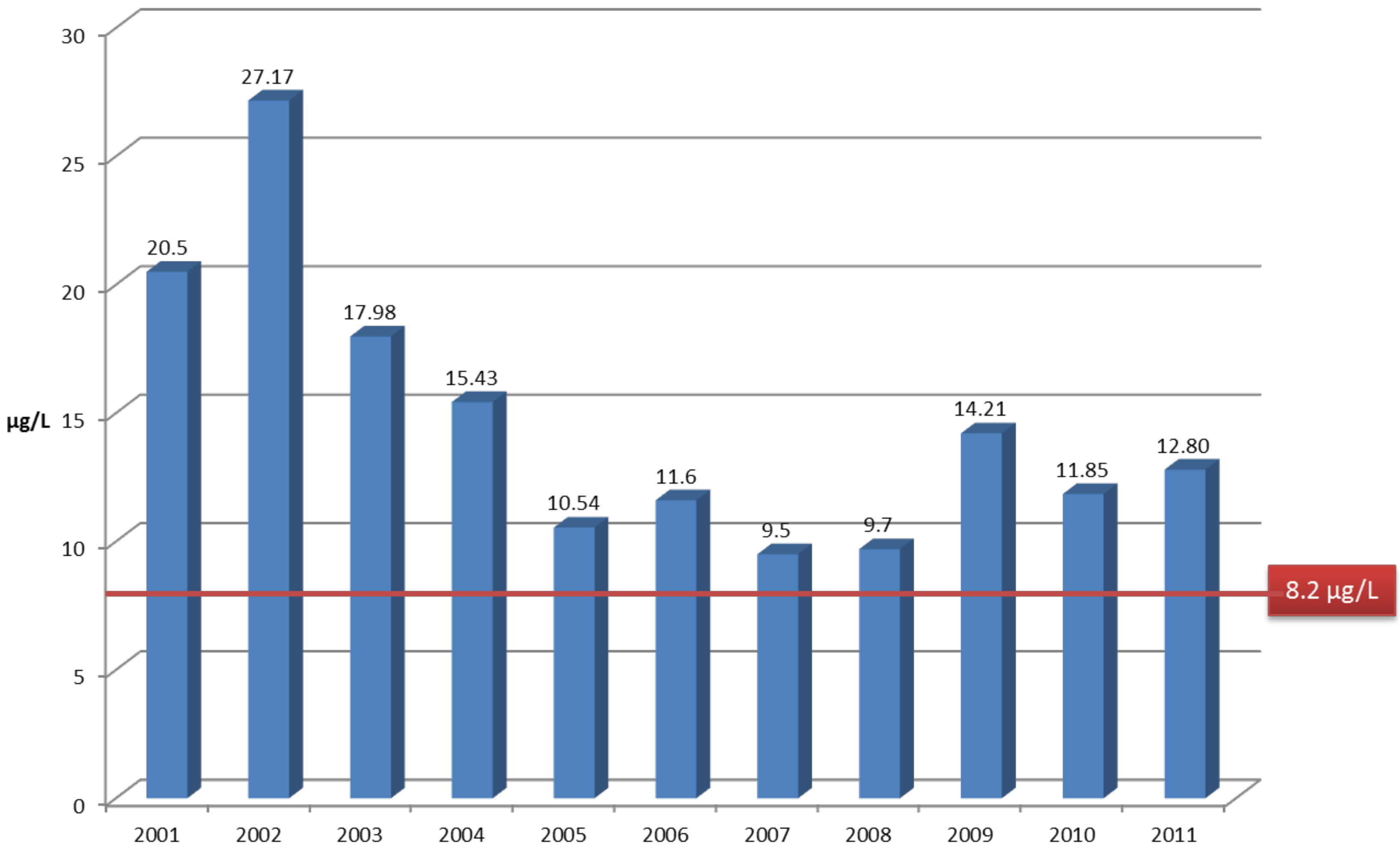


Figure 7 Dissolved Zinc Average Concentration 2001-2011 in Discharge from Cruise Ships

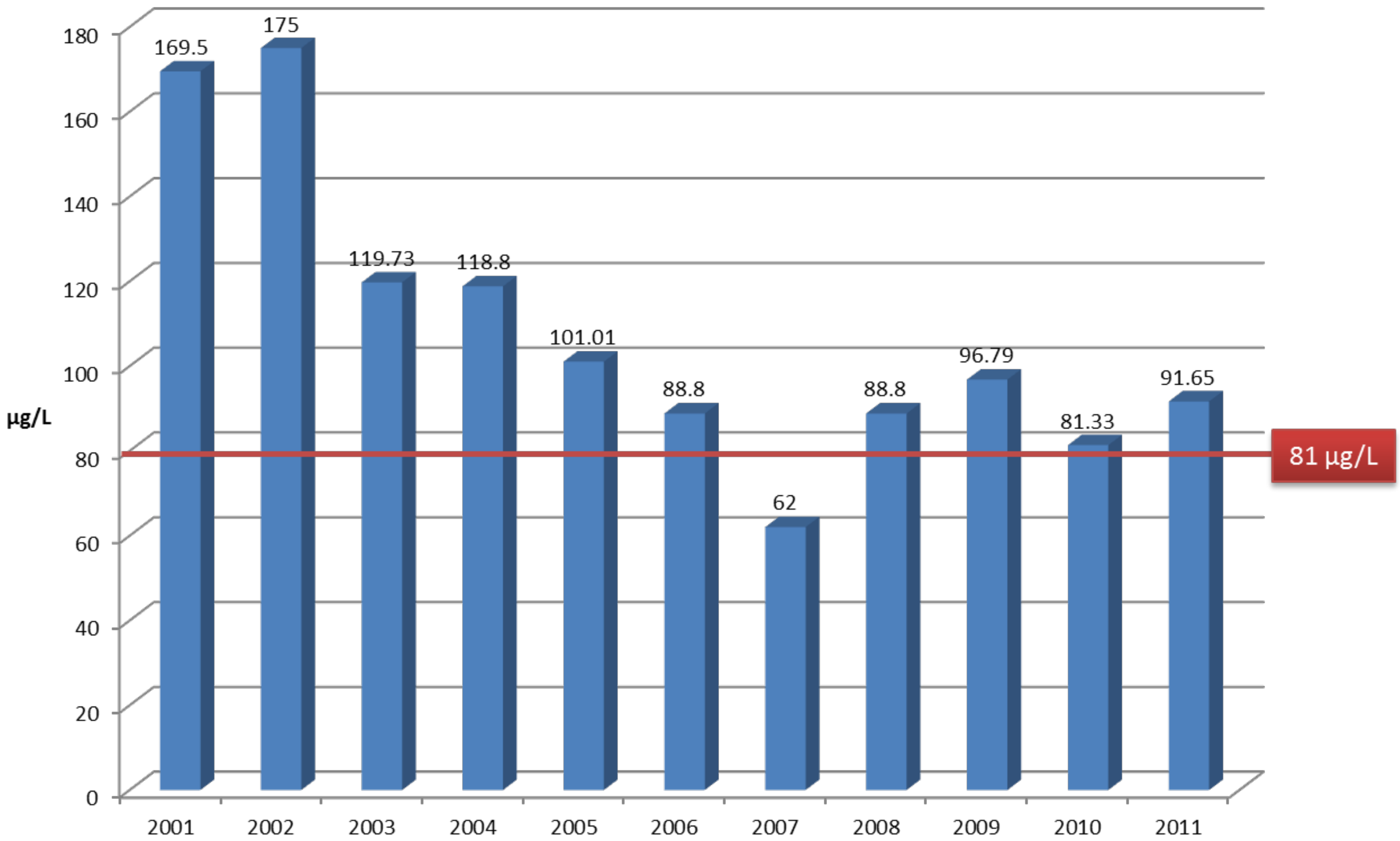


Figure 8 Cruise Ship Ports and Regulatory Zones

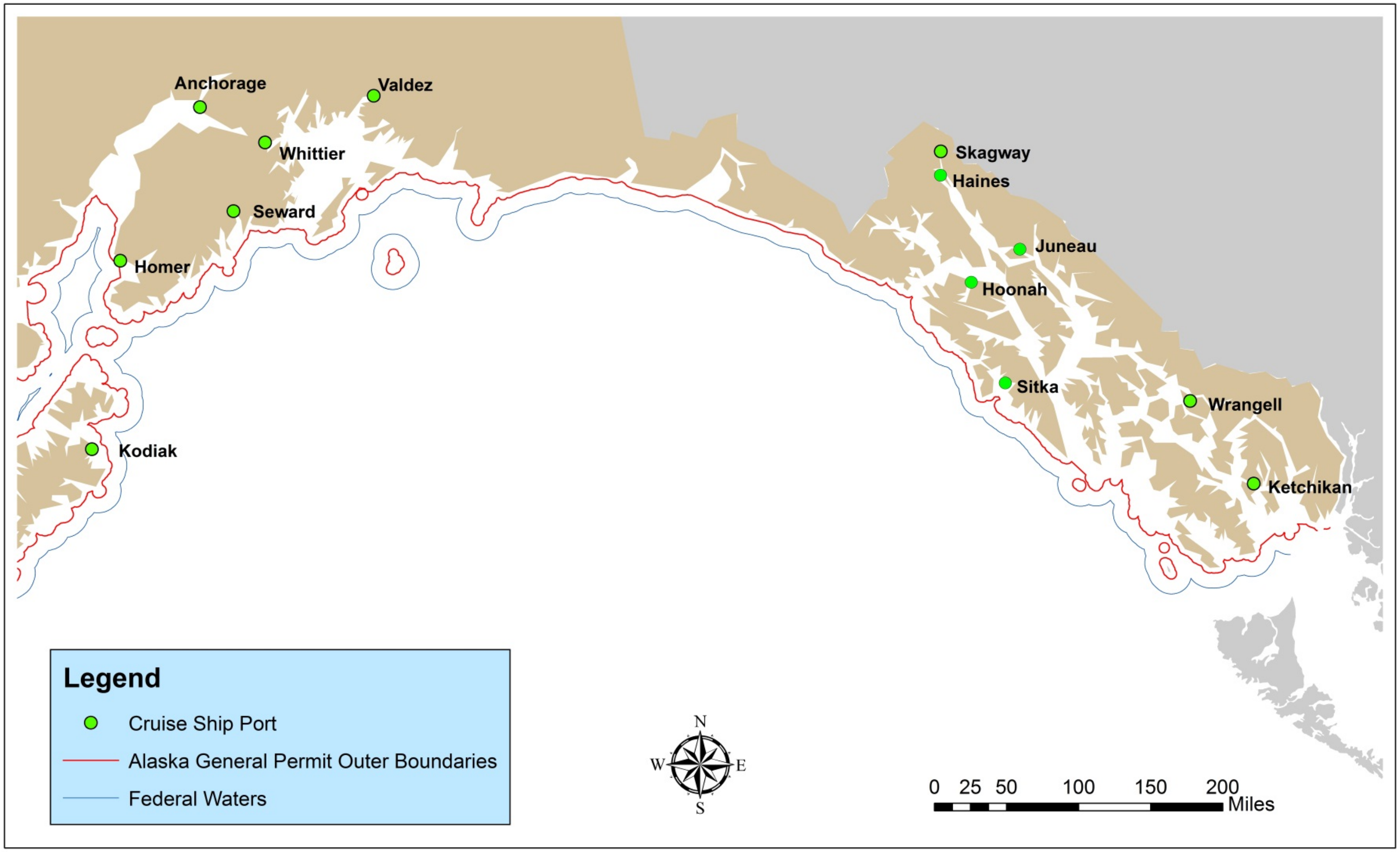
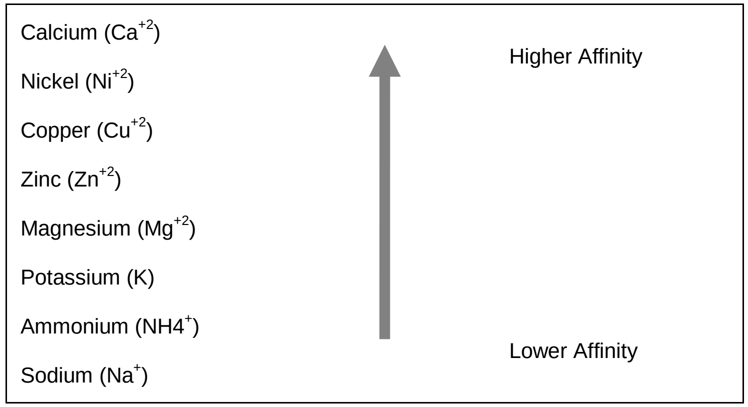


Figure 9 Cruise Ship Routes

Figure 10 Selected Ion Affinity for Cationic Ion Exchange Resin[86]



[86] Remco Engineering: Water Systems and Controls. (2009) The Remco website has a 'frequency asked questions' section on their website. http://www.remco.com

Figure 11 AWTS / Multi-Stage Reverse Osmosis

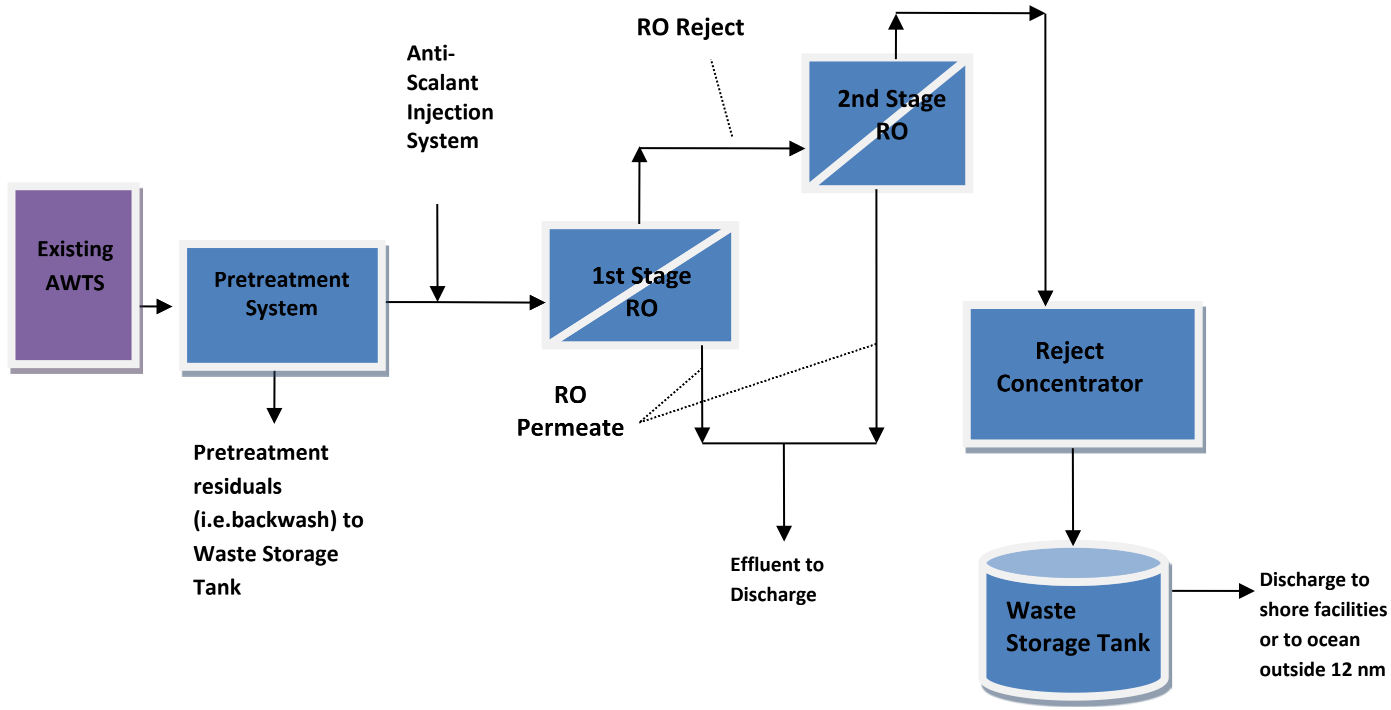


Figure 12 AWTS / Single Stage Reverse Osmosis and Ion Exchange

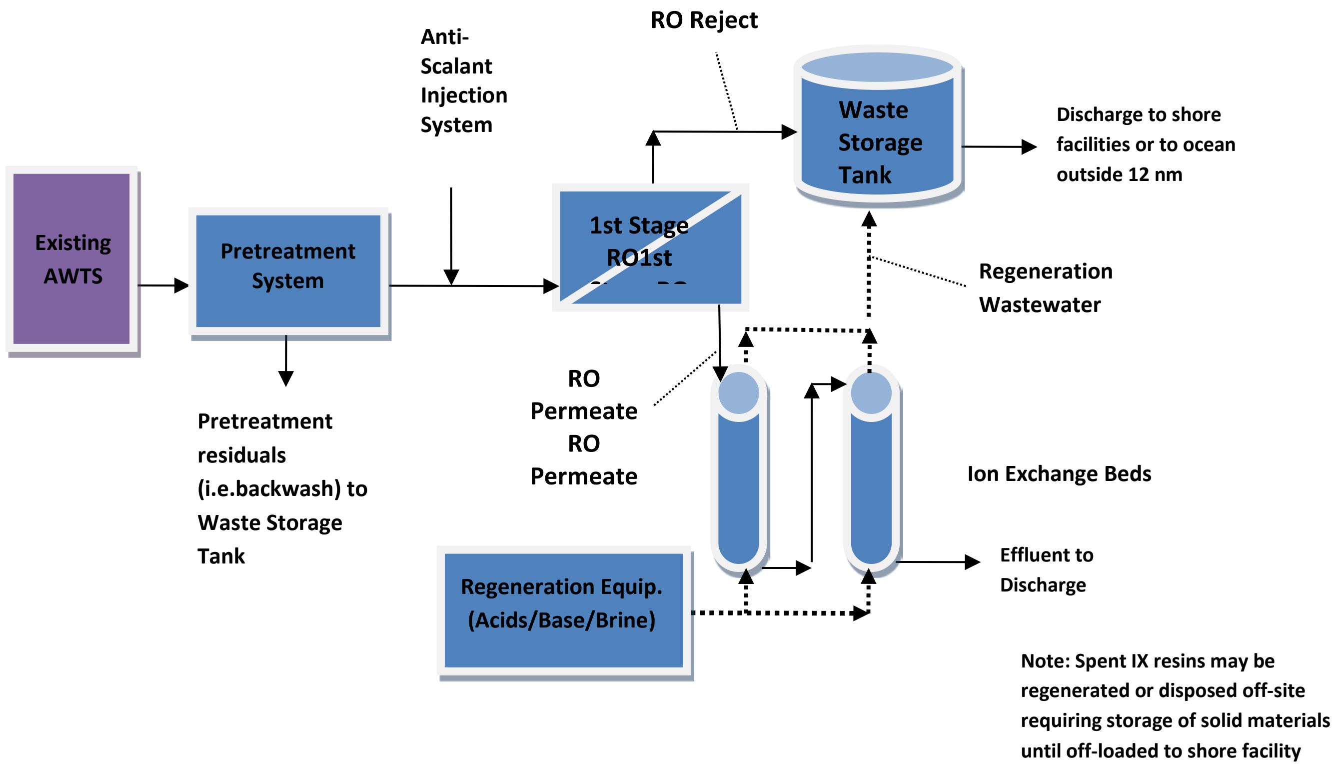


Figure 13 AWTS / Ion Exchange

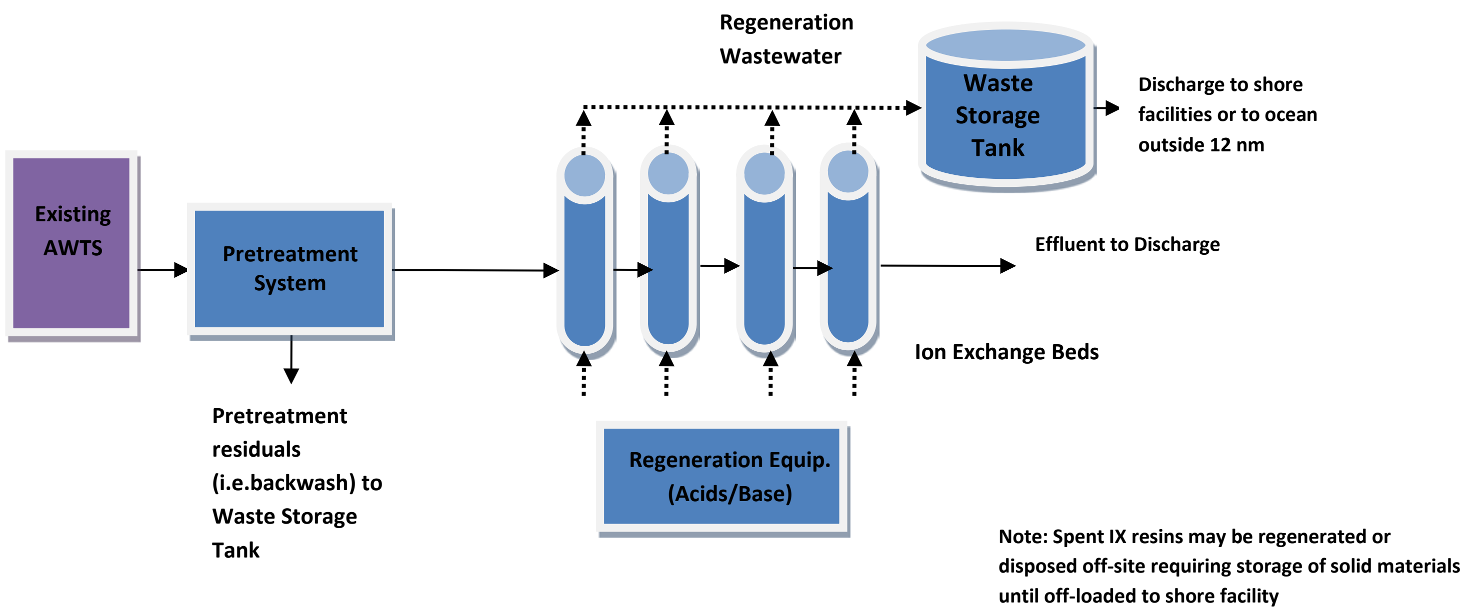
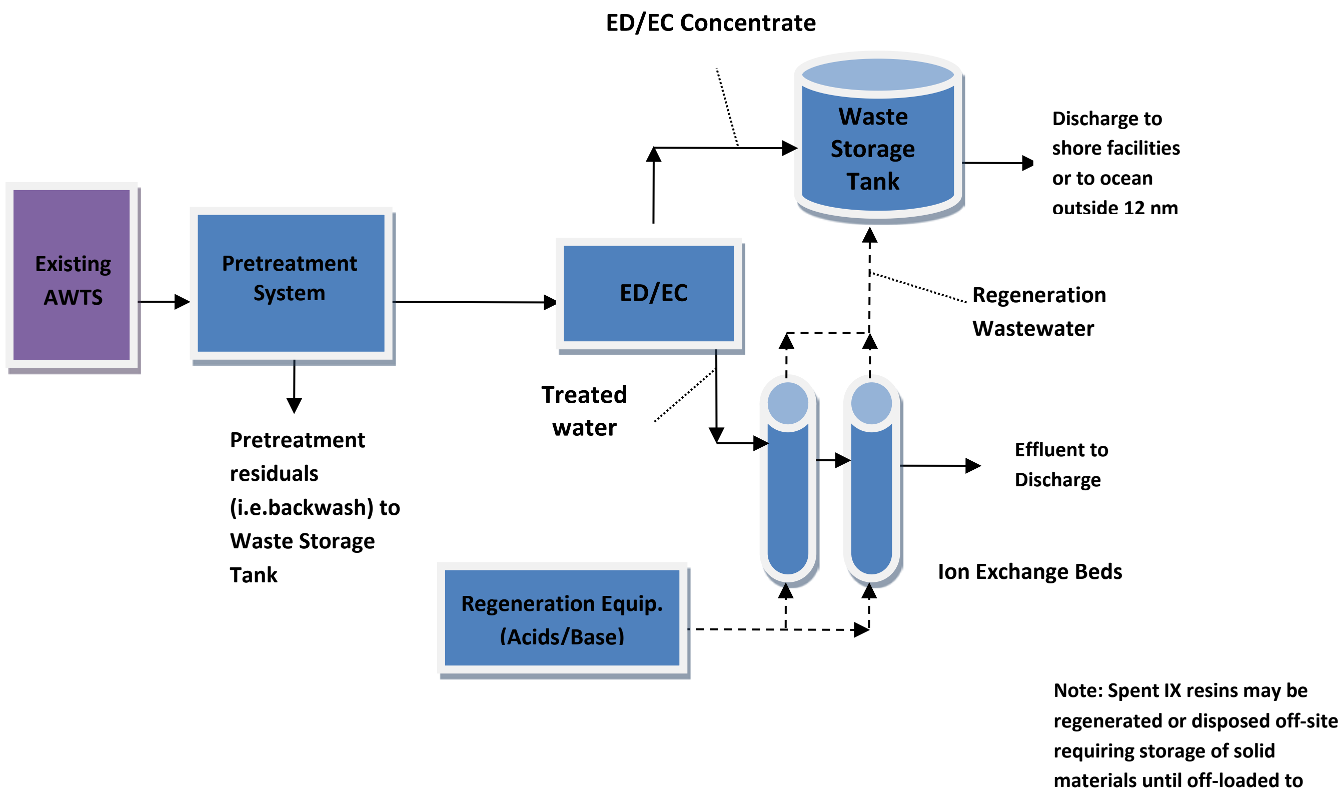


Figure 14 AWTS / Electrolysis or Electrocoagulation and Ion Exchange



APPENDIX A

2012 Cruise Ship Data Collection Survey

{This page deliberately blank.}

Re: Cruise Ship Data Collection Survey

Dear ________:

The Alaska Department of Environmental Conservation (ADEC) is requesting your company's cooperation in collecting the information described in the enclosed survey. The requested information will be used by ADEC to prepare the next Large Commercial Passenger Vessel Wastewater Discharge General Permit. The current permit expires in April 2013. The requested information will also be used by ADEC and the Cruise Ship Wastewater Science Advisory Panel (Panel) in developing a preliminary report on treatment and other waste reduction options due to the Alaska Legislature by January 1, 2013.

The Alaska Legislature passed legislation in 2009 modifying ADEC's authority relating to the issuance of permits to cruise ships for the discharge of treated wastewater into waters of the state. This new authority allows ADEC to relax the statutory requirement that the discharge meet all state water quality standards at the point of discharge, but only if ADEC "finds that the permittee is using economically feasible methods of pollution prevention, control, and treatment the department considers to be the most technologically effective in controlling all wastes and other substances in the discharge…" As ADEC prepares the draft of the new General Permit it is important we collect available data relevant to making this finding.

The legislation passed in 2009 also directs ADEC to work with an expert panel to provide a preliminary report to the Legislature on treatment options by January 1, 2013. Finally, the Legislature added a provision to Alaska law (AS 46.03.465(h)), requiring owners or operators of cruise ships needing permits to respond to requests for information from ADEC. This survey is being provided pursuant to that provision.

We appreciate that the time and other resources needed to complete this survey are not insubstantial, and this survey may come at a time when your company has important safety, security and other obligations it must also meet. We have worked hard to assure the survey focuses on that information needed by ADEC and the Panel, and that is not available from other sources.

There are instructions at the beginning of the survey form that explain how your company may request additional time to respond to specific questions, how you might qualify certain answers if you are uncertain about the response, and how you may ask that confidential information be protected from public disclosure. If you have any questions, please contact Rob Edwardson, Manager of the Division of Water's Cruise Ship Program, at (907) 465-5312.

I extend my appreciation for your cooperation in this important project and wish you a successful 2012 cruise season.

Sincerely,

Michelle Bonnet

Director

Enclosure

DATA COLLECTION SURVEY
FOR POLLUTION PREVENTION, CONTROL, AND TREATMENT METHODS FOR LARGE CRUISE SHIPS OPERATING IN ALASKA WATERS

As authorized by AS 46.03.464, the Cruise Ship Wastewater Science Advisory Panel (Panel) was established and charged with assisting and advising the Commissioner of the Alaska Department of Environmental Conservation (ADEC) in preparing a report that summarizes:

(1) methods of pollution prevention, control, and treatment in use and the level of effluent quality achieved by commercial passenger vessels;
(2) additional economically feasible methods of pollution prevention, control, and treatment that could be employed to provide the most technologically effective measures to control all wastes and other substances in the discharge; and
(3) the environmental benefit and cost of implementing additional methods of pollution prevention, control, and treatment identified under subsection (2), above.

AS 46.03.464(c). In order for the Panel to prepare this report, and for the Commissioner to prepare a subsequent required report to the Alaska Legislature in accordance with AS 46.03.464(d), ADEC is, pursuant to AS 46.03.465(h), requesting that you provide information responsive to this survey.

Table of Contents

PURPOSE OF THE SURVEY

ADEC, in conjunction with the Science Advisory Panel (Panel,) intends to use the information collected in this survey to assess the potential for the vessel to meet Alaska Water Quality Standards at the point of discharge or to achieve incremental improvements above 2010 limits towards that goal, and estimate the costs and benefits associated with implementing pollution prevention, control, and treatment methods. This information will:

1) Allow the Panel to provide an informed report to the ADEC Commissioner, who will in turn report to the Legislature as mandated in AS 46.03.464; and
2) Inform the development of the next Large Commercial Passenger Vessel General Permit to be issued by ADEC in 2013, and assist the Department in providing support for the effluent limits included in that permit.

Not All Questions Will Be Applicable to Every Vessel
ADEC prepared this survey to be applicable to a variety of vessels and treatment systems; therefore, not all of the questions will apply to every vessel. Complete each applicable item in the survey. If a question is not applicable to your company or vessel, write "NA."

CONFIDENTIALITY OF INFORMATION

If you believe that any information that you are providing in response to this survey should be treated as confidential information and exempt from public disclosure under AS 40.25.120 or other law or regulation, please clearly mark that information "confidential" and provide a full explanation of the specific reason(s) that the information should be exempt from disclosure. Claiming the information is confidential and exempt from disclosure does not mean the information is automatically exempt, or even that ADEC will conclude it is exempt. The Department will consider the reasons you provide for the claimed exemption, and will notify you as to whether the Department concurs.

WHEN AND WHERE TO RETURN THE SURVEY

All cruise lines that receive this survey must respond to it within 60 days of receiving it. Failure to timely respond in accordance with the survey's instructions may result in fines and other sanctions, as provided by law.

If you wish to request an extension or discuss a delivery schedule for a company with multiple vessels, you must do so in writing within 21 days of receipt of this survey. Blanket requests for extensions will not be considered. Written requests may be e-mailed to Melissa Goldstein at melissa.goldstein@alaska.gov or may be mailed to her at the address below.

Extension requests will be evaluated on a case-by-case basis. Submittal of an extension request to DEC does **not** alter the due date of your survey unless and until DEC agrees to the extension and establishes a new date.

Please submit the signed original and an electronic version of survey responses to:

Dr. Melissa Goldstein
Alaska Department of Environmental Conservation
Commercial Passenger Vessel Environmental Compliance Program
410 Willoughby Ave., P.O. Box 111800
Juneau, AK 99811-1800
melissa.goldstein@alaska.gov

GENERAL INSTRUCTIONS

Read all question-specific instructions. Carefully read any instructions for specific questions.

Mark responses for each question. Fill in the appropriate response(s) to each question. Please use **black ink** or **type** in the spaces provided. Answer the questions in sequence unless you are directed to SKIP. Do not leave an entry blank if the answer is zero. **If a question is not applicable, write "NA."**

Include any clarifying attachments. If additional attachments are required to clarify a response, please place the associated question number and your vessel name in the top right corner of each page of the attachments. The following list contains examples of items which may need to be included as attachments to this survey:
– Cruise line brochure, pamphlet, general description;
– Sailing route map;
– Piping and sewage and graywater treatment flow diagrams;
– Manufacturers specifications;
– Hard copy summaries of analytical data collected from monitoring locations;
– Discharge logs;
– Discharge practices outline;
– Wastewater treatment operation and maintenance logs;
– Electronic analytical data collected from monitoring locations; and
– Pollution prevention or management practices.

Provide best estimates when data are not available. ADEC intends that responses to all questions be based upon available data and information. Please provide the best estimates possible based on your best professional judgment when data and information are not available. If you provide an estimate, note the methods that were used to make the estimate on the "Comments" page (page 3, A-2) along with the question number to which the estimate refers. You are not required to perform new or non-routine tests or measurements solely for the purpose of responding to this survey.

You may need to make copies of some pages before responding. Some pages in the survey will need to be photocopied before you respond. Indicate how many copies of the page you are submitting by writing "Copy ____________ of _____________" in the top right corner.

Pay close attention to the measurement units requested (e.g., cubic meters [m^3], kilograms [kg]). Report answers in the units that are specified, unless the question requires you to specify the units. Alternatively, if your records are kept in different units (e.g., gallons instead of cubic meters), you may report in those units. In this case, BE SURE TO INDICATE WHAT UNITS YOU ARE USING.

Questions? If you have any questions regarding the completion of this survey, please contact Melissa Goldstein at melissa.goldstein@alaska.gov or (907)465-5278.

BE SURE TO RETAIN A COPY OF THE COMPLETED SURVEY FOR YOUR RECORDS.

CERTIFICATION STATEMENT

The individual responsible for directing or supervising the preparation of the survey must read and sign the Certification Statement listed below. The certifying official must be a responsible corporate official or his/her authorized representative.

The Certification Statement should be completed and signed if this cruise vessel operated in the navigable waters of the United States within the State of Alaska during calendar year 2011.

Certification Statement

I certify that the attached survey, completed for the referenced vessel, was prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. The information submitted is, to the best of my knowledge and belief, accurate and complete and responsive to the survey instructions. In those cases where the requested information was not available, the information provided is based on best professional judgment and provides best estimates. I am aware that there are significant penalties for submitting a false statement or failing to comply with this survey, including the possibility of civil penalties (AS 46.03.760(f)) and/or criminal penalties (AS 46.03.790.)

________________________________ ________________________________

Signature of Certifying Official Date

________________________________ (   )____________________________

Printed Name of Certifying Official Telephone Number

____

Title of Certifying Official

____

Cruise Line Name

____

Cruise Vessel Name

SECTION A: GENERAL INFORMATION

A-1. Provide the following primary contact information for the technical information supplied in this questionnaire:

Primary Contact Name: ____________________

Title: ____________________

Telephone Number: ____________________

Fax Number: ____________________

E-Mail Address: ____________________

Convenient time to call: ____________________

Street Address or Post Office Box: ____________________

City, State Zip Code: ____________________

A-2. Please identify any comments for this survey. Cross reference by question number. If you need additional space, please photocopy this page before writing on it, and number each copy in the top right corner.

Question Number	Comments

A-3. During calendar year 2011, how many days did this cruise vessel operate in Alaska waters?

__________ Days.

A-4. Was this amount of time in Alaskan waters: (specify)

☐ typical of previous years
☐ higher than previous years
☐ lower than previous years
☐ 2011 was first year of operation in Alaskan waters

A-5. Do you plan to operate this cruise vessel in waters in and near Alaska in calendar year 2013?

☐ Yes ☐ No

If yes, do you plan to discharge treated wastewater within Alaska waters during 2013?

☐ Yes ☐ No

A-6. Do you plan to make any modifications within the next 4 years (before 2016) to the current advanced wastewater treatment system (AWTS) operated onboard this cruise vessel?

☐ Yes ☐ No

If yes, please fill in the table below.

Type of Modification		**Calendar Year(s) Modification to occur**
Upgrade of existing AWTS	☐ Yes ☐ No	
Add-on to existing AWTS	☐ Yes ☐ No	
Replacement of existing AWTS	☐ Yes ☐ No	

SECTION B: WASTEWATER SOURCES

Section B requests information on graywater and sewage sources, flows, and destinations. This information will be used to outline the vessel's wastewater generation, collection, and treatment practices and to evaluate possible pollution prevention, control, and treatment options.

If you provide an estimate, note the methods that were used to make the estimate on the "Comments" page (page 3, A-2) along with the question number to which the estimate refers.

B-1. Indicate the destination for each wastewater source.

Wastewater Source Description	To Graywater WWT System?	To Sewage WWT System?	To Other? (Specify)
Example: Photo lab sinks	☐**Yes** ☒**No**	☐**Yes** ☒**No**	**Drains to waste container for transfer onshore as hazardous waste**
Galley (e.g., food preparation, food pulper, restaurants, and bars)	☐Yes ☐No	☐Yes ☐No	
Dishwasher	☐Yes ☐No	☐Yes ☐No	
Bath (e.g., tub, shower, and sinks)	☐Yes ☐No	☐Yes ☐No	
Laundry	☐Yes ☐No	☐Yes ☐No	
Launderette	☐Yes ☐No	☐Yes ☐No	
Dry cleaning floor drains	☐Yes ☐No	☐Yes ☐No	
Dry cleaning spent solvent	☐Yes ☐No	☐Yes ☐No	
Dry cleaning wastewater (condensate separator water)	☐Yes ☐No	☐Yes ☐No	
Sewage from toilets, urinals, and other human waste receptacles	☐Yes ☐No	☐Yes ☐No	
Bilge water	☐Yes ☐No	☐Yes ☐No	
Ballast water	☐Yes ☐No	☐Yes ☐No	
Desalination brine	☐Yes ☐No	☐Yes ☐No	
Pool and whirlpool water	☐Yes ☐No	☐Yes ☐No	
Refrigeration and air conditioner condensate	☐Yes ☐No	☐Yes ☐No	
Salon and day spa water	☐Yes ☐No	☐Yes ☐No	
Photo lab sinks	☐Yes ☐No	☐Yes ☐No	
Photo lab floor drains	☐Yes ☐No	☐Yes ☐No	
Engine room shop sinks	☐Yes ☐No	☐Yes ☐No	
Engine room shop floor drains	☐Yes ☐No	☐Yes ☐No	
Non-engine room shop sinks (e.g,. upholstery, wood working, carpentry)	☐Yes ☐No	☐Yes ☐No	
Non-engine room shop floor drains (e.g,. upholstery, wood working, carpentry)	☐Yes ☐No	☐Yes ☐No	

Wastewater Source Description	To Graywater WWT System?	To Sewage WWT System?	To Other? (Specify)
Medical facility sinks	☐Yes ☐No	☐Yes ☐No	
Medical facility floor drains	☐Yes ☐No	☐Yes ☐No	
Chemical storage area sinks	☐Yes ☐No	☐Yes ☐No	
Chemical storage area floor drains	☐Yes ☐No	☐Yes ☐No	
Other wastewater (specify source):	☐Yes ☐No	☐Yes ☐No	

B-2. Please identify the typical flow rates for each sewage and graywater source.

Sewage and Graywater Source	Typical Total Flow Rate
Galley (e.g., food preparation, food pulper, restaurants, and bars)	m^3/day
Dishwasher	m^3/day
Bath (e.g., tub, shower, and sinks)	m^3/day
Laundry	m^3/day
Sewage from toilets, urinals, and other human waste receptacles	m^3/day
Other - please describe: ________________________________	m^3/day
Other - please describe: ________________________________	m^3/day

B-3. Provide the vessel's total average sewage and graywater holding capacities in hours.

Sewage:____________________________hrs

Graywater: ___________________________hrs

B-4. Did you transfer **untreated** graywater or sewage to shore side facilities in Alaska in 2011?

☐ Yes
☐ No

If yes, what was the average unit cost of **untreated** wastewater transfers in Alaska in 2011?

__________________________ (\$ per m^3)

B-5. Provide the total volume of **untreated** graywater or sewage transferred to shore side facilities in Alaska in 2011.

Wastewater Description	Volume Transferred in 2011 (m^3)
Galley (e.g., food preparation, food pulper, restaurants, and bars)	
Dishwasher	
Bath (e.g., tub, shower, and sinks)	
Laundry	
Sewage from toilets, urinals, and other human waste receptacles	
Other - please describe: ___________________	
Other - please describe: ___________________	

B-6. Did you transfer **treated** graywater or sewage to shore side facilities in Alaska in 2011?

☐ Yes ☐ No

If yes, what was the average unit cost of **treated** wastewater transfers in Alaska in 2011?

___________________ (\$ per m^3)

B-7. Provide the volume of **treated** graywater or sewage transferred to shore side facilities in Alaska in 2011.

Wastewater Description	Volume Transferred in 2011 (m^3)
Galley (e.g., food preparation, food pulper, restaurants, and bars)	
Dishwasher	
Bath (e.g., tub, shower, and sinks)	
Laundry	
Sewage from toilets, urinals, and other human waste receptacles	
Other - please describe: ___________________	
Other - please describe: ___________________	

SECTION C: EXISTING WASTEWATER TREATMENT SYSTEM DESIGN AND OPERATING PARAMETERS

Section C requests information on graywater and sewage treatment technologies used onboard this cruise vessel. Specifically, the information requested in this section includes design and operating specifications; sources of influent; chemical additions; operating and maintenance procedures; and discharge practices. This information will be used to evaluate technology options and develop cost estimates.

If you provide an estimate, note the methods that were used to make the estimate on the "Comments" page (page 3, A-2) along with the question number to which the estimate refers.

NOTE: If the vessel has more than one wastewater treatment system, photocopy Questions C-1 through C-9 before writing on them. In addition, if a treatment system is a split system (i.e., the system is made up of more than one treatment unit) please answer questions C-1 through C-9 for each UNIT of the system. An example would be an AWTS that has a starboard treatment unit and a port treatment unit.

WASTEWATER TREATMENT SYSTEM # __________

C-1. Provide the wastewater treatment system name below.

____

C-2. Wastewater treatment system manufacturer ____

C-3. Is this wastewater treatment system batch or continuous?

☐ Batch

☐ Continuous *(Skip to Question C-6)*

C-4. On average how many batches per day did this wastewater treatment system treat in 2011?

_____________ average batches per day

C-5. What was the typical batch volume treated by this wastewater treatment system in 2011?

_____________ m^3/batch

C-6. What was the average volume treated per operating day by this wastewater treatment system in 2011?

_____________ m^3/day

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

C-7. **Indicate in the following table where your vessel operated this wastewater treatment system in 2011. Please be sure you have one response per cell in this table.**

Vessel Location	Do you operate this wastewater treatment system at all times in the following locations?
Within 1 nm from shore in Alaska waters	☐ Yes ☐ No ☐ Other
Outside 1 nm from shore In Alaska waters	☐ Yes ☐ No ☐ Other
Outside Alaska waters, but within 12 nm of Alaska shore	☐ Yes ☐ No ☐ Other
During Alaska cruises, but outside 12 nm of Alaska shore	☐ Yes ☐ No ☐ Other
Within 3 nm of shore of U.S. States other than Alaska	☐ Yes ☐ No ☐ Other
Outside 3 nm of shore of U.S. States other than Alaska	☐ Yes ☐ No ☐ Other

Explain any responses of “other” in the table above.

____

____

C-8. a. How much time (i.e., days) was this wastewater treatment system **operated** in 2011?

_____________ days in 2011

AND

b. How much time (i.e., days) was this wastewater treatment system **operated** in Alaska waters in 2011?

_____________ days in Alaska waters in 2011

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

C-9. **Indicate in the following table where your vessel discharged from this wastewater treatment system in 2011. Please be sure you have one response per cell in this table.**

Vessel Location	Did this wastewater treatment system discharge at any time in the following locations?
Within 1 nm from shore in Alaska waters	☐ Yes ☐ No ☐ Other
Outside 1 nm from shore In Alaska waters	☐ Yes ☐ No ☐ Other
Outside Alaska waters, but within 12 nm of Alaska shore	☐ Yes ☐ No ☐ Other
During Alaska cruises, but outside 12 nm of Alaska shore	☐ Yes ☐ No ☐ Other
Within 3 nm of shore of U.S. States other than Alaska	☐ Yes ☐ No ☐ Other
Outside 3 nm of shore of U.S. States other than Alaska	☐ Yes ☐ No ☐ Other

Explain any responses of “other” in the table above.

____

____

C-10. a. How much time (in hours) did this wastewater treatment system **discharge** outside Alaska waters, but within 12 nm of Alaska shore in 2011?

_____________ hours in 2011

AND

b. How much time (in hours) did this wastewater treatment system **discharge** in Alaska waters in 2011?

_____________ hours in Alaska waters in 2011

SECTION D: WASTEWATER GENERATION, COLLECTION,AND TREATMENT COSTS

Section D requests information on the costs for each graywater and/or sewage treatment system (including holding tanks) onboard this cruise vessel. Specifically, the information requested in this section includes capital costs and operating costs (in U.S. Dollars) for the wastewater treatment system, space availability on the cruise vessel, and power generation.

NOTE: If you have more than one wastewater treatment system, photocopy Questions D-1 through 13 before writing on it, and indicate the Wastewater Treatment System #. In addition, if a treatment system is a split system (*i.e.*, the system is made up of more than one treatment unit) please answer questions D-1 through D-13 for each UNIT of the system. An example would be an AWTS that has a starboard treatment unit and a port treatment unit.

WASTEWATER TREATMENT SYSTEM # __________

D-1. Complete the table below for the **original** costs associated with each graywater and/or sewage treatment systems identified in this survey, including the collection and holding tanks (include the year each cost was incurred). *Only include costs for wastewater treatment systems that treat graywater and sewage*. If you have data for costs itemized differently, complete the table below using best engineering estimates and provide the additional data as an attachment.

Type of Cost	Project	Cost	Year Cost Incurred
Direct	***Purchased equipment*** (includes all equipment for the installation or upgrade: mechanical equipment; electrical equipment; spare parts and noninstalled equipment spares; freight charges; taxes, insurance, and duties)	$	
	Purchased equipment installation (includes installation of all equipment: electrical equipment, mechanical equipment, structural supports, insulation, and paint)	$	
	Instrumentation and control (includes purchase, installation, and calibration)	$	
	Piping (includes cost of pipe, pipe hangars, fittings, valves, insulation, and installation)	$	
Indirect	***Engineering costs*** (includes process design and general engineering, drafting, cost engineering, consulting fees, supervision, inspection)	$	
	Construction expenses (includes construction tools and equipment; permits, taxes, insurance)	$	
	Contractor's fees (includes contractor costs for procurement, handling, and oversight)	$	
	Contingency actually expended (to compensate for unpredictable events such as storms, floods, strikes, price changes, errors in estimates, design changes (unexpected retrofit costs), etc.)	$	
	Total capital cost for project	$	

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

D-2. In the table below, apportion the “purchased equipment” and “purchased equipment installation” costs provided in Question D-1 among the wastewater treatment units (e.g., biological treatment, membrane filtration, ultraviolet disinfection). If data are not readily available in this format, use best engineering estimates.

Major Piece of Wastewater Treatment System	Purchased Equipment Cost	Installation Cost	Year Cost Incurred
	$	$	
	$	$	
	$	$	
	$	$	
	$	$	
	$	$	
	$	$	
	$	$	
TOTAL:	$	$	

D-3. What date was the wastewater treatment system installed? _______________/____ (mm/yy)

What date did the wastewater treatment system begin operations? _________/____ (mm/yy)

D-4. Provide actual operating and maintenance (O&M) costs paid and rates for this wastewater treatment system during calendar year 2011. Include operating labor, maintenance labor, maintenance equipment and contracted services, sampling/monitoring costs, chemical costs, and sludge, oil, or other residual transfer fees.

O&M Category	2011 Cost	Rate
Ship’s labor (operating and maintenance)	$	$________ per/hr (average rate of labor)
Training Costs (specific to operations of wastewater treatment system)	$	$________ per/hr (average rate of labor)
Contractor labor (operating and maintenance)	$	$________ per/hr (average rate of labor)
Maintenance: equipment and materials (e.g., spare parts, replacement equipment)	$	

O&M Category	2011 Cost	Rate
Maintenance: contracted services (e.g., contractors, vendors)	$	
Costs for laboratory analysis	$	
Chemical costs	$	
Wastewater transfer (i.e., at shore-side facility)	$	$________ per m^3
Sludge transfer	$	$________ per m^3
Other sludge transfer, if other classifications apply to your area *(specify type)*:	$	$________ per m^3
Oil transfer (specify source):	$	$________ per m^3
Other treatment residual *(specify)*:	$	$________ per m^3
Energy Costs	$	$________ per ______ mW $________ per ______ kW
Other *(specify)*:	$	$________ per m^3 (if applicable)
Other *(specify)*:	$	$________ per m^3 (if applicable)
Total	**$**	

D-5. The wastewater aeration process used for the AWTS is fundamental to ammonia reduction performance. Please provide information on how the aeration process is performed on this vessel, including the operations and maintenance of the aeration system.

____

____

____

____

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

D-6. Is the aeration system designed and operated according to the AWTS Vendor recommendations?

☐ Yes ☐ No

D-7. Have you made any recent changes to the aeration system on this vessel in an attempt to improve ammonia reduction performance of the AWTS?

☐ Yes ☐ No

D-8. Are you currently researching aeration system modifications that could improve ammonia reduction performance of the AWTS installed on this vessel?

If yes, what estimated costs would be incurred to implement an improved aeration of tanks as set out by the AWTS Vendor?

Installation Costs $____________________ (USD)

Operational Costs $____________________ per year (USD)

D-9. Provide information on any modifications from the original as-built vendor specifications and/or greater than 24 hour shut downs which have occurred to this wastewater treatment system since 2004. Modifications may include the replacement, upgrade, or addition of one or more wastewater treatment system components. Explain why treatment system components have been replaced, upgraded, or added (*e.g.*, compliance with wastewater permit.) I f the treatment system was shut down, please explain why. Include the costs for these modifications or shutdowns.

Shut Down or Modification?	Date Range (mm/dd/yy – mm/dd/yy)	Treatment System Affected	Reason	Cost (USD)
☐ Shut Down ☐ Modification				$
☐ Shut Down ☐ Modification				$
☐ Shut Down ☐ Modification				$
☐ Shut Down ☐ Modification				$

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

D-10. Provide information on any modifications from the original as-built vendor specifications and/or greater than 24 hour shut downs planned to occur to this wastewater treatment system during the next five years (2012 through 2016). Explain why the treatment system will be replaced, upgraded, or added. If the treatment system will be shut down, please explain why. Include the estimated costs for these modifications or shutdowns.

Shut Down or Modification?	Year Planned	Treatment System Affected	Reason	Cost (USD)
☐ Shut Down ☐ Modification				$
☐ Shut Down ☐ Modification				$
☐ Shut Down ☐ Modification				$
☐ Shut Down ☐ Modification				$

D-11. Provide information on any modifications to the sewage or graywater generation, piping, or collection/holding systems (other than treatment) since 2004. Modifications may include the replacement, upgrade, rerouting, or addition of system components. Explain why the components have been replaced, upgraded, rerouted, or added (e.g., reroute graywater sources from overboard discharge to graywater collection and holding tanks). Include the costs for these modifications.

Modification	Date	Reason for Modification	Cost (USD)
			$
			$
			$
			$

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

D-12. Provide information on any modifications for the sewage or graywater generation, piping, or collection/holding systems (other than treatment) planned to occur during the next five years (2012 through 2016) in order to reduce ammonia and/or dissolved metals in effluent. Explain why the systems will be replaced, upgraded, rerouted, or added. Include the estimated costs for these modifications.

Planned Modification	Year Planned	Reason	Cost (USD)
			$
			$
			$
			$

D-13. In the table below, provide the location and dimensions of the spaces housing the wastewater treatment system(s) (excluding all holding tanks). Include space needed to support the wastewater treatment system, such as on-board laboratory space and/or chemical/equipment storage space. In addition, provide the wastewater treatment system components housed in each space. All wastewater treatment system components indicated in Section 3 and/or ancillary equipment should be included in this table. Assign each space a name (*e.g.*, Space #1).

Space Name	Location on Cruise Vessel	Dimensions	Treatment System Components Housed in this Space
		____________ Length (m) ____________ Width (m) ____________ Height (m)	
		____________ Length (m) ____________ Width (m) ____________ Height (m)	
		____________ Length (m) ____________ Width (m) ____________ Height (m)	
		____________ Length (m) ____________ Width (m) ____________ Height (m)	

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

D-14. Is space available to install add-on wastewater treatment system components in or near the space housing the wastewater treatment system?

☐ Yes ☐ No *(Go to Question D-15)*

In the table below, provide the dimensions of the areas of the spaces housing the wastewater treatment system(s) available to install additional wastewater treatment units, if required.

Space Name	Dimensions of Area Available to Install Additional Wastewater Treatment System Components
	____________ Length (m) ____________ Width (m) ____________ Height (m)
	____________ Length (m) ____________ Width (m) ____________ Height (m)
	____________ Length (m) ____________ Width (m) ____________ Height (m)
	____________ Length (m) ____________ Width (m) ____________ Height (m)

D-15. If you had to install add-on wastewater treatment system components, indicate below the location and dimensions of spaces, including spaces elsewhere on the cruise vessel where wastewater treatment system components might be installed. This space could include space currently occupied by obsolete equipment. In addition, provide whether the space has access to utilities and the distance of the space from the current wastewater treatment system.

Location on Cruise Vessel	Dimensions of Space	Access to Utilities?	Distance from Current Wastewater Treatment System	Wastewater Treatment System No.
	________ Length (m) ________ Width (m) ________ Height (m)	☐ Yes ☐ No	________ m	
	________ Length (m) ________ Width (m) ________ Height (m)	☐ Yes ☐ No	________ m	
	________ Length (m) ________ Width (m) ________ Height (m)	☐ Yes ☐ No	________ m	
	________ Length (m) ________ Width (m) ________ Height (m)	☐ Yes ☐ No	________ m	
	________ Length (m) ________ Width (m) ________ Height (m)	☐ Yes ☐ No	________ m	
	________ Length (m) ________ Width (m) ________ Height (m)	☐ Yes ☐ No	________ m	

WASTEWATER TREATMENT SYSTEM # __________ (cont.)

D-16. Would it be feasible for this ship to install additional wastewater treatment system components specific to ammonia and/or dissolved metals removal, in terms of available space?

☐ Yes

☐ No

If you answered no, please explain the limiting factors:

____

____

____

____

____

____

D-17. If additional AWTS components were to be installed in the future, how much power generation capacity is available on the ship to operate those additional components?

______________ kW/hour

SECTION E: POLLUTION PREVENTION METHODS

Section E requests information to evaluate the status of current pollution prevention methods used onboard this cruise vessel, identify pollution prevention technologies, and quantify the performance of the methods. The information will identify specific methods that may be described by the Panel.

If you provide an estimate, note the methods that were used to make the estimate on the "Comments" page (page 3, A-2) along with the question number to which the estimate refers.

E-1. Pollution Prevention Methods

Please list environmental management, pollution prevention, or waste reduction methods implemented to reduce concentrations of pollutants in effluent during the 2011 cruise season.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________
7. ______________________________
8. ______________________________
9. ______________________________
10. ______________________________

E-2. For each pollution prevention method listed above, please answer the following questions (make a copy of this and the following page for each method.)

(a) Identify the list number from E-1 and describe method: ______________________________________

____

____

(b) Was the method employed year-round or only while the vessel was operating in Alaska waters?

☐ Year-round ☐ Only in Alaska waters

(c) List affected cruise vessel process(es) and wastewater streams:______________________________

____

____

(d) List targeted pollutants: ____

____

____

(e) Cost and/or savings of implementing method: $ ____

Cost of installation/implementation $____

Net change in operating costs as a result of the method: $________________

(f) What was the reduction in the quantity of wastewater generated as a result of this method?

____________________ m^3/day

(g) What was the reduction in the quantity of fresh (potable) water requirements as a result of this method?

____________________ m^3/day

E-2. (cont.) Method number from E-1: _________________

(h) Did the method result in a change in chemicals/pollutants discharged in wastewater?

☐ Yes ☐ No *(Go to Question E-3)*

(i)

What was the change in chemicals/pollutants discharged in wastewater?

Chemical/Pollutant	***Increase*** **or** ***Decrease*** **in Quantity Discharged?**	**Change in Quantity?**
	☐ increase ☐ decrease	___________ kg/day ___________ liters/day
	☐ increase ☐ decrease	___________ kg/day ___________ liters/day
	☐ increase ☐ decrease	___________ kg/day ___________ liters/day

(i) What was the change in the quantity of solids generated?

Solid	***Increase*** **or** ***Decrease*** **in Quantity Discharged?**	**Change in Quantity?**
	☐ increase or ☐ decrease	___________ kg/day
	☐ increase or ☐ decrease	___________ kg/day
	☐ increase or ☐ decrease	___________ kg/day

E-3. Implementation of Future Pollution Prevention Practices

Do you plan on implementing any pollution prevention, pollution management, or waste reduction practices in the future? If so, please list below.

Practice	Scheduled Implementation (date)
________________________________	________________________________
________________________________	________________________________
________________________________	________________________________

SECTION F: POLLUTION DISCHARGE PRACTICES

Section F requests information to evaluate the pattern of discharge practices for this cruise vessel, identify pollution control methods, and quantify the performance of the practices. The responses will inform ADEC about holding alternatives used by the vessel to meet permitted standards.

F-1. Describe your **treated** wastewater discharge practices while operating in waters in and near Alaska. Please check all that apply and indicate the reasons this cruise vessel uses this method.

☐ Discharge wastewater in waters in and near Alaska only when more than 1 nautical mile from shore while traveling at more than 6 knots ______________________

____

☐ Continuous discharge of wastewater in waters in and near Alaska ______________

____

☐ Hold wastewater for discharge outside Alaska waters (outside 3 nm) ____________

____

☐ Other ______________________________________

____

F-2. Is the **treated** wastewater reused?

☐ Yes
☐ No

If yes, for what?

____

____

If no, state the reason(s) the treated wastewater is not reused.

____

____

F-3. If shore-side treatment facilities were available, would you off-load wastewater to them instead of using the vessel's wastewater treatment system?

- ☐ Yes
- ☐ No

Explain why or why not.

____

____

F-4. At approximately what unit cost would use of shore-side facilities become prohibitive?

$ ____________ per m^3

F-5. How do you view your vessel's wastewater discharge patterns:

- ☐ A manageable part of doing business in Alaska
- ☐ A burden to setting an ideal cruise itinerary
- ☐ A significant disruption to business operations
- ☐ An operational compromise that reduces overall profits
- ☐ Other - Please describe: ____________________________

F-6. Does receiving a continuous discharge approval help ease the burden of managing wastewater during Alaska cruises? If so, how?

____

____

F-7. Do existing state or federal wastewater regulations affect this vessel's itineraries? If so, please describe how.

____

____

____

F-8. Do existing state or federal wastewater regulations affect this vessel's discharge practices? If so, please describe how.

____

____

____

F-9. Do you foresee making changes to this vessel's itineraries based on meeting Alaska wastewater permit conditions in the future? Please explain why or why not.

____

____

____

F-10. Do you foresee making changes to this vessel's discharge practices based on meeting Alaska wastewater permit conditions in the future? Please explain why or why not.

____

____

____

F-11. Please provide any further comments you wish to share with ADEC regarding this vessel's wastewater discharge strategies.

____

____

____

____

____

SECTION G: BEST AVAILABLE CONTROL TECHNOLOGY EVALUATION

Section G requests information needed to evaluate methods for pollution prevention, control, and treatment using a Best Available Control Technologies (BACT) framework. Please provide your best estimates of feasibility and cost for pollution prevention, control, and treatment options.

Treatment options consist of add-on polishing units to reduce concentrations of ammonia, dissolved copper, dissolved nickel, and dissolved zinc to Alaska Water Quality Standards (AWQS) at the point of discharge. In addition, a worksheet is provided in the event your plans include replacing the AWTS for an individual ship.

Please complete the gray areas of each worksheet with the most accurate information or estimates available.

G-1: Influent/Effluent Information
G-2: Add-on Wastewater Treatment Options
G-3: Pollution Prevention Methods
G-4: Pollution Control Methods
G-5: Replacement Wastewater Treatment System Options

Best Available Technology Evaluation
G-1: Influent/Effluent Information

Instructions:

In the table below, ADEC's Cruise Ship Program used information provided with the Notice of Intent for General Permit 2009DB0026 to outline effluent concentrations that are typically discharged from the ship. Please provide influent concentrations and removal percentages for pollutants listed below; this will allow ADEC to better understand the performance of the AWTS currently installed on the ship. AS 46.03.362

Name of Permitted Operator/Vessel:
Maximum Passenger + Crew Capacity:______
Existing WWT System:
Design Capacity:
Maximum BW Generation:____Maximum GW Generation:
Average Discharge Flow rate:_____________Maximum Discharge Flow rate:_

Pollutant	**AWQS**	**Influent Mass Loading, pounds per day operated (provide range and average)**	**Influent Concentrations (provide range and average of potential influent concentrations)**	**Average 2011 Effluent Concentrations (n=X)**	**Removal (Percent)**
Ammonia	**1.0 mg/l**				
Copper	**3.1 µg/l**				
Nickel	**8.2 µg/l**				
Zinc	**81.0 µg/l**				
BOD	**60 mg/l Limit, Maximum**				
TSS	**150 mg/l Limit, Maximum**				

Pollutant	AWQS	Influent Mass Loading, pounds per day operated (provide range and average)	Influent Concentrations (provide range and average of potential influent concentrations)	Average 2011 Effluent Concentrations (n=X)	Removal (Percent)
Fecal Coliform	**43 per 100 milliliters Limit, Maximum**				
Residual Chlorine	**0.0075 mg/l Limit, Maximum**				

GW = Gray Water
BW = Black Water
AWQS = Alaska Water Quality Standards

Best Available Technology Evaluation
G-2: Add-on Wastewater Treatment (WWT) Options

Instructions: Please provide information on add-on wastewater treatment (WWT) technologies that are intended to meet Alaska Water Quality Standards at the point of discharge or to improve effluent quality for ammonia and dissolved metals. Add-on WWT technologies are defined here as wastewater treatment systems (or components) that can be added on to and enhance the removal performance of an existing advanced wastewater treatment system (AWTS.)

Name of Permitted Operator/Vessel: **Individual Cruise Ship**

Pollutant	**Add-On WWT Options**						
	Potential Add-On WWT Technology	**Estimated Additional Removal (%) – Technical Effectiveness**	**Estimated design capacity (m^3/day)**	**Technical Feasibility** **Please rate from of 0 (low) to 10 (high). Use last page to explain rating.**	**Est. Capital Cost (USD)** **From Note 1, below**	**Est. Annual O&M Cost (USD/yr)** **From Note 2, below**	**Rank Options as First, Second, etc. based on feasibility and cost.**
Ammonia	1. Membrane Process						
	2. Adsorption						
	3. Other (specify)						
Copper	Based on this data, no add-on treatment needed for copper						

Pollutant	**Add-On WWT Options**						
	Potential Add-On WWT Technology	**Estimated Additional Removal (%) – Technical Effectiveness**	**Estimated design capacity** **(m^3/day)**	**Technical Feasibility** **Please rate from of 0 (low) to 10 (high). Use last page to explain rating.**	**Est. Capital Cost (USD)** **From Note 1, below**	**Est. Annual O&M Cost (USD/yr)** **From Note 2, below**	**Rank Options as First, Second, etc. based on feasibility and cost.**
Nickel	1. Membrane Process						
	2. Ion Exchange (IX) Polishing-On-ship Regeneration						
	3. (IX) Polishing-Load & Dispose of Resins						
	4. Other (specify)						
Zinc	1. Membrane Process						
	2. Ion Exchange (IX) Polishing-On-ship Regeneration						
	3. (IX) Polishing-Load & Dispose of Resins						
	4. Other (specify)						

In the space below, please provide your reasoning for the technical feasibility ratings you have assigned to the options above. Reference a specific add-on treatment option, where applicable.

Feasibility is a subjective rating of the practicality of the technology in terms of engineering and other operational aspects. For example, is there adequate space, capacity and power to operate add-on technologies?

Cost Calculation Tables (please photocopy and fill out Notes 1 and 2 for each Add-on WWT Option listed in the table above.)

Note 1

Type of Cost	Capital Costs	Cost (USD)
Direct	***Purchased equipment*** (includes all equipment for the installation or upgrade: mechanical equipment; electrical equipment; spare parts and noninstalled equipment spares; freight charges; taxes, insurance, and duties)	$
	Purchased equipment installation (includes installation of all equipment: electrical equipment, mechanical equipment, structural supports, insulation, and paint)	$
	Instrumentation and control (includes purchase, installation, and calibration)	$
	Piping (includes cost of pipe, pipe hangars, fittings, valves, insulation, and installation)	$
Indirect	***Engineering costs*** (includes process design and general engineering, drafting, cost engineering, consulting fees, supervision, inspection)	$
	Construction expenses (includes construction tools and equipment; permits, taxes, insurance)	$
	Contractor's fees (includes contractor costs for procurement, handling, and oversight)	$
	Contingency actually expended (to compensate for unpredictable events such as storms, floods, strikes, price changes, errors in estimates, design changes (unexpected retrofit costs), etc.)	$
	Total capital cost for option	$

Note 2

O&M Category	Estimated Annual Cost (USD)	Rate (USD)
Ship's labor (operating and maintenance)	$	$________ per/hr (average rate of labor)
Training Costs (specific to operations of wastewater treatment system)	$	$________ per/hr (average rate of labor)
Contractor labor (operating and maintenance)	$	$________ per/hr (average rate of labor)
Maintenance: equipment and materials (e.g., spare parts, replacement equipment)	$	
Maintenance: contracted services (e.g., contractors, vendors)	$	
Costs for laboratory analysis	$	
Chemical costs	$	
Wastewater transfer (i.e., at shore-side facility)	$	$________ per m^3
Sludge transfer	$	$________ per m^3
Other sludge transfer, if other classifications apply to your area *(specify type)*:	$	$________ per m^3
Oil transfer (specify source):	$	$________ per m^3
Other treatment residual *(specify)*:	$	$________ per m^3
Energy Costs	$	$________ per ______mW $________ per ______kW
Other *(specify)*:	$	$________ per m^3 (if applicable)
Other *(specify)*:	$	$________ per m^3 (if applicable)
Total O&M Costs	**$**	

Best Available Technology Evaluation
G-3: Pollution Prevention Methods

Instructions: Please provide information regarding pollution prevention methods that are capable of reducing the amount of ammonia and dissolved metals in cruise ship wastewater and help your vessel achieve compliance with AWQS at the point of discharge. Prevention methods are defined here as those measures that reduce the amount of a pollutant that enters wastewater streams that are subsequently discharged from the cruise ship. Examples include banning ammonia based cleaners and substitution of piping material.

Name of Permitted Operator/Vessel: **Individual Cruise Ship**

Pollutant	Prevention Methods						
	Method capable of reducing amount of pollutant entering wastewater	Method currently in use? (yes/no)	Reduction with Prevention Method (%) – Technical Effectiveness	Technical Feasibility Please rate from 0 (low) to 10 (high). Use next page to explain rating.	Implementation Feasibility Please rate from 0 (low) to 10 (high). Use next page to explain rating.	Estimated Annual Cost (USD)	Rank Methods as First, Second, etc.
Ammonia	1. Product Substitution						
	2. Other (specify)						
	3. Other (specify)						
Copper	1. Product Substitution						
	2. Management of water hardness						

Pollutant	Prevention Methods						
	Method capable of reducing amount of pollutant entering wastewater	**Method currently in use? (yes/no)**	**Reduction with Prevention Method (%) – Technical Effectiveness**	**Technical Feasibility Please rate from 0 (low) to 10 (high). Use next page to explain rating.**	**Implementation Feasibility Please rate from 0 (low) to 10 (high). Use next page to explain rating.**	**Estimated Annual Cost (USD)**	**Rank Methods as First, Second, etc.**
	3. Substitute piping material						
	4. Other (specify)						
Nickel	1. Product Substitution						
	2. Management of water hardness						
	3. Substitute piping material						
	4. Other (specify)						
	5. Other (specify)						
Zinc	1. Product Substitution						
	2. Management of water hardness						

Pollutant	**Prevention Methods**						
	Method capable of reducing amount of pollutant entering wastewater	**Method currently in use?** **(yes/no)**	**Reduction with Prevention Method (%) – Technical Effectiveness**	**Technical Feasibility** **Please rate from 0 (low) to 10 (high). Use next page to explain rating.**	**Implementation Feasibility** **Please rate from 0 (low) to 10 (high). Use next page to explain rating.**	**Estimated Annual Cost** **(USD)**	**Rank Methods as First, Second, etc.**
	3. Substitute piping material						
	4. Other (specify)						
	5. Other (specify)						

Feasibility Questions for Prevention—Use in determining technical feasibility and implementation feasibility (please photocopy this page and fill out for each prevention method listed in the table above.)

Prevention Method: ______________________	Steps/Action Items	Costs (USD) Please indicate whether it is a one-time cost or ongoing (annual)
List of Steps/Actions needed to implement prevention method.	1.	
	2.	
	3.	
	4.	
	5.	
Steps that are in place or could be implemented at minimal cost.	1.	
	2.	
	3.	
	4.	
	5.	
Steps that are infeasible and why.	1.	
	2.	
	3.	
	4.	
	5.	

In the space below, please provide your reasoning for the technical and implementation feasibility ratings you have assigned to the methods above. Reference a specific pollution prevention method, where applicable.

Technical Feasibility:
Implementation Feasibility:

Best Available Technology Evaluation
G- 4: Pollution Control Methods

Instructions: Please provide information on pollution control methods for ammonia and dissolved metals in cruise ship wastewater. Control methods are defined here as those measures that reduce the amount of pollutant in wastewater discharged by this vessel into Alaska waters. Examples may include treating partial waste streams and holding for discharge outside of permit limits, and discharge to an on-shore treatment system.

Name of Permitted Operator/Vessel: **Individual Cruise Ship**

Pollutant	**Control Methods**							
	Method capable of reducing the amount of pollutants discharged	**Method currently in use? yes/no**	**Currently/expected to apply to what Percentage (%) of treated sewage?**	**Currently/expected to apply to what Percentage (%) of treated graywater?**	**Technical Feasibility Please rate on from 0 (low) to 10 (high). Use next page to explain rating.**	**Implementation Feasibility Please rate from 0 (low) to 10 (high). Use next page to explain rating.**	**Estimated Annual Cost (USD)**	**Rank Methods as First, Second, etc.**
Ammonia	1. Treat and Hold for Off-shore discharge.							
	2. Discharge to On-shore treatment system							
	3. Other (specify)							

Pollutant	**Control Methods**							
	Method capable of reducing the amount of pollutants discharged	**Method currently in use?** **yes/no**	**Currently/expected to apply to what Percentage (%) of treated sewage?**	**Currently/expected to apply to what Percentage (%) of treated graywater?**	**Technical Feasibility** **Please rate on from 0 (low) to 10 (high). Use next page to explain rating.**	**Implementation Feasibility** **Please rate from 0 (low) to 10 (high). Use next page to explain rating.**	**Estimated Annual Cost** **(USD)**	**Rank Methods as First, Second, etc.**
Nickel	1. Treat and Hold for Off-shore discharge.							
	2. Discharge to On-shore treatment system							
	3. Other							
Zinc	1. Treat and Hold for Off-shore discharge.							
	2. Discharge to On-shore treatment system							

Feasibility Questions for Control—Use in determining technical feasibility and implementation feasibility (please photocopy this page and fill out for each control method listed in the table above.)

Control Method: ______________________	**Steps/Action Items**	**Costs (USD)** **Please indicate whether a one-time or ongoing cost (annual.)**
List of Steps/Actions needed to implement control method.	1.	
	2.	
	3.	
	4.	
	5.	
Steps that are in place or could be implemented at minimal cost.	1.	
	2.	
	3.	
	4.	
	5.	
Steps that are infeasible and why.	1.	
	2.	
	3.	
	4.	
	5.	

In the space below, please provide your reasoning for the technical and implementation feasibility ratings you have assigned to the methods above. Reference a specific pollution control method, where applicable.

Technical Feasibility:
Implementation Feasibility:

Best Available Technology Evaluation
G-5: Replacement Wastewater Treatment Systems

Instructions: Please provide information on new installations of advanced wastewater treatment systems (AWTS) that are potentially capable of producing cruise ship effluent that meets AWQS at the point of discharge, including those for ammonia and dissolved metals.

Name of Permitted Operator/Vessel: **Individual Cruise Ship**

1. What was the expected economic life of your current AWTS when it was originally installed? ________________ years

2. What is its current expected economic life, taking modifications and upgrades into consideration?

Please describe in detail:____

____

____

____

____

3. Have you considered or researched a replacement AWTS that would be capable of producing effluent that meets AWQS at the point of discharge for all pollutants, including ammonia and dissolved metals? ☐ Yes ☐ No

If yes, please answer the following questions regarding the replacement AWTS considered/researched:

Please describe the system in detail:____

____

____

____

Make and Model ____

____

Design Capacity (m^3/day) ______________________________

Percentages of treated: Graywater: ____________________ Blackwater: __________________

Total percentage of all wastewater treated: ___________________

Please provide the estimated Removal Efficiency (%) that the replacement AWTS described above can achieve for the following pollutants:

Pollutant	Removal Efficiency (%)	Performance Guarantee? Yes/No	Conditions of Guarantee
Ammonia			
Dissolved Copper			
Dissolved Nickel			

Dissolved Zinc			
BOD			
TSS			
Fecal coliform			
Chlorine			

Technical Effectiveness **Please rate from 0 (low) to 10 (high).** **Use next page to explain scoring.**	**Implementation Feasibility** **Please rate from 0 (low) to 10 (high).** **Use next page to explain scoring.**	**Est. Capital Cost of Replacement AWTS (USD)** **(From Note 1, below)**	**Est. Annual O&M Cost for Replacement AWTS (USD per year)** **(From Note 2, below)**

In the space below, please provide your reasoning for the technical effectiveness and implementation feasibility ratings you have assigned to the replacement AWTS above.

Technical Effectiveness:
Implementation Feasibility:

Cost Calculation Tables for replacement AWTS considered.

Note 1

Type of Cost	Capital Costs	Cost (USD)
Direct	***Purchased equipment*** (includes all equipment for the installation or upgrade: mechanical equipment; electrical equipment; spare parts and non-installed equipment spares; freight charges; taxes, insurance, and duties)	$
	Purchased equipment installation (includes installation of all equipment: electrical equipment, mechanical equipment, structural supports, insulation, and paint)	$
	Instrumentation and control (includes purchase, installation, and calibration)	$
	Piping (includes cost of pipe, pipe hangars, fittings, valves, insulation, and installation)	$
Indirect	***Engineering costs*** (includes process design and general engineering, drafting, cost engineering, consulting fees, supervision, inspection)	$
	Construction expenses (includes construction tools and equipment; permits, taxes, insurance)	$
	Contractor's fees (includes contractor costs for procurement, handling, and oversight)	$
	Contingency actually expended (to compensate for unpredictable events such as storms, floods, strikes, price changes, errors in estimates, design changes (unexpected retrofit costs), etc.)	$
	Total capital cost for replacement AWTS	$

Note 2

O&M Category	Estimated Annual Cost	Rate (USD)
Ship's labor (operating and maintenance)	$	$________ per/hr (average rate of labor)
Training Costs (specific to operations of wastewater treatment system)	$	$________ per/hr (average rate of labor)
Contractor labor (operating and maintenance)	$	$________ per/hr (average rate of labor)
Maintenance: equipment and materials (e.g., spare parts, replacement equipment)	$	
Maintenance: contracted services (e.g., contractors, vendors)	$	
Costs for laboratory analysis	$	
Chemical costs	$	
Wastewater transfer (i.e., at shore-side facility)	$	$________ per m^3
Sludge transfer	$	$________ per m^3

O&M Category	Estimated Annual Cost	Rate (USD)
Other sludge transfer, if other classifications apply to your area *(specify type)*:	$	$________ per m^3
Oil transfer (specify source):	$	$________ per m^3
Other treatment residual *(specify)*:	$	$________ per m^3
Energy Costs	$	$________ per ______mW $________ per ______kW
Other *(specify)*:	$	$________ per m^3 (if applicable)
Other *(specify)*:	$	$________ per m^3 (if applicable)
Total O&M Costs	**$**	

APPENDIX B

Summarized Results of Survey

{This page deliberately blank.}

Key:
✓ = answered
o = not answered at all
\ = answered in part
n/a = marked as n/a

		Carnival Spirit	Norwegian Star[1]	Norwegian Pearl	Disney Wonder	Seven Seas Navigator	Oceania Regatta
A-1	Contact Information	✓	✓	✓	✓	✓	✓
A-2	Comments	o	✓	✓	✓	o	o
A-3	2011 Days in AK water	20	78	78	90	64	66
A-4	Typical?	Typ	Typ	Typ	First	Higher	First
A-5	Plan to be in AK for 2013?	No	No	No	Yes	Yes	Yes
A-6	Planned Modifications?	No	No	No	No	No	No
B-1	Waste Destination	✓	✓	✓	✓	✓	✓
B-2	Flow Rates	✓	✓	✓	✓	✓	✓
B-3	Holding Capacity (hours)	o	61/77	61/77	57.7 combined	72/72	72/72
B-4	Untreated waste to Shore?	No	No	No	No	No	No
B-5	Volume and type transferred	✓	n/a	n/a	n/a	n/a	n/a
B-6	Treated waste to Shore?	No	No	No	No	No	No
B-7	Volume and type transferred	✓	n/a	n/a	n/a	n/a	n/a
C-1	System Name	chem/Graywa	Scanship	Scanship	Hamworthy	Scanship WO	on Water AG N
C-2	System Manufacturer	✓	✓	✓	✓	✓	Norderstedt
C-3	Batch or Continuous	Cont	Cont	Cont	Cont	Cont	Cont
C-4	How many batches/day	n/a	n/a	n/a	n/a	n/a	n/a
C-5	Batch Volume	n/a	n/a	n/a	n/a	n/a	n/a
C-6	Average volume m3/day	250	1023	1023	750	300	170
C-7	Location of WWTS operation	✓	✓	✓	✓	✓	✓
C-8	Days WWTS operated/in AK	120/70	365/78	365/78	355/72	365/64	198/66
C-9	Where Discharge?	✓	✓	✓	✓	✓	✓
C-10	Time discharge outside and inside of A	0/1700	30/850	30/670	36/924.5	38/1416	14.5/1236.5

		Carnival Spirit	Norwegian Star[1]	Norwegian Pearl	Disney Wonder	Seven Seas Navigator	Oceania Regatta
D-1	Original Cost of WWTS	\	\	\	o	✓	n/a
D-2	purchase vs installation cost	\	\	✓	o	✓	n/a
D-3	Date of installation and ops	✓	✓	✓	✓	✓	✓
D-4	O&M Costs	\	✓	✓	\	✓	✓
D-5	Aeration description	n/a	✓	✓	✓	✓	✓
D-6	Aeration system used to spec	n/a	✓	✓	✓	✓	✓
D-7	Changes to aeration to improve?	n/a	✓	✓	✓	✓	✓
D-8	Research for mods to aeration	n/a	✓	✓	✓	✓	✓
D-9	Info on mods	✓	✓	✓	\	✓	n/a
D-10	Planned mods?	n/a	✓	✓	\	✓	n/a
D-11	Mods to piping and holding	n/a	✓	✓	o	✓	n/a
D-12	Mods planned to reduce metals and ar	n/a	✓	✓	o	✓	n/a
D-13	Space dimensions	✓	✓	✓	✓	✓	✓
D-14	More space available	No	No	No	No	No	No
D-15	describe	n/a	✓	✓	✓	✓	n/a
D-16	feasible to add components	n/a	✓	✓	✓	Yes	✓
D-17	power available?	n/a	✓	✓	o	✓	n/a
E-1	pollutions prevention methods	✓	None	None	✓	✓	✓
E-2	description of methods	✓	n/a	n/a	\	✓	✓
E-3	future plans	✓	✓	✓	✓	✓	✓
F-1	Treated discharge practices	✓	✓	✓	✓	✓	✓
F-2	Treated water reused?	No	No	No	No	No	No
F-3	Would you use shore facilities	No	Yes	Yes	Yes	Yes	No
F-4	Cost at not feasible to use $/m3	\	>$0	>$0	Unknown	o	$10-15
F-5	How do you view patterns	Manageable	Manageable	Manageable	Manageable	Manageable	Manageable
F-6	Does continuous discharge help	Yes	Yes	Yes	Yes	Yes	Yes
F-7	Do regs affect itineraries	No	Yes	Yes	Yes	No	No
F-8	Do regs affect discharge	No	Yes	Yes	Yes	No	No
F-9	Would you change intineraries	n/a	Possibly	Possibly	No	No	No
F-10	Would you change discharge practices	n/a	Yes	Yes	Yes	No	No

		Carnival Spirit	Norwegian Star[1]	Norwegian Pearl	Disney Wonder	Seven Seas Navigator	Oceania Regatta
F-11	Comments	o	o	o	o	✓	✓
G-1	BAT Influent/Effluent Information	o	\	\	\	\	✓
G-2	BAT Add-on Options	n/a	n/a	n/a	\	\	\
G-3	BAT PP Methods	n/a	n/a	n/a	\	\	n/a
G-4	BAT Control	n/a	n/a	n/a	\	\	\
G-5	BAT Replacement	n/a	\	\	✓	✓	\
EPA Survey		YES	YES	No	No	No	No

1 NCL Includes Vendor Proposal from Scanship
2 Note detailed pollution prevention text
3 Operated but didn't discharge
4 Much of response not legible
5 All princess docs have same information for Section E
6 Replacing gray water system

Key:
✓ = answered
o = not answered at all
\ = answered in part
n/a = marked as n/a

		Statendam[2]	Volendam[2]	Westerdam[2]	Zaandam[2]	Silver Shadow[3]4	Coral Princess[5]	Diamond Princess
A-1	Contact Information	✓	✓	✓	✓	✓	✓	✓
A-2	Comments	o	o	o	o	o	✓	✓
A-3	2011 Days in AK water	99	99	99	103	94	99	101
A-4	Typical?	Typ	Typ	Typ	Typ	Higher	Typ	Typ
A-5	Plan to be in AK for 2013?	Yes	Yes	Yes	Yes	Yes/No	Yes	Yes
A-6	Planned Modifications?	No	No	: and addon exi	No	No	No	No
B-1	Waste Destination	✓	✓	✓	✓	✓	✓	✓
B-2	Flow Rates	✓	✓	✓	✓	✓	✓	✓
B-3	Holding Capacity (hours)	72/72	78/78	543.6/56.3	78/78	87/87	72/72	57/57
B-4	Untreated waste to Shore?	No	No	No	No	No	No	yes 6.72 $/m3
B-5	Volume and type transferred	n/a	n/a	n/a	n/a	n/a	n/a	✓
B-6	Treated waste to Shore?	No	No	No	No	No	Yes	No
B-7	Volume and type transferred	n/a	n/a	n/a	n/a	n/a	✓	n/a
C-1	System Name	Zenon	Zenon	ROCHEM/OVIV(	Zenon	risan 250/Biop	amworthy)	Hamworthyx3
C-2	System Manufacturer	✓	✓	✓	✓	✓	✓	✓
C-3	Batch or Continuous	Cont	Cont	Cont	Cont	Cont	Cont	Cont
C-4	How many batches/day	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C-5	Batch Volume	n/a	n/a	n/a	n/a	n/a	n/a	n/a
C-6	Average volume m3/day	510	482	200/342	249.4	0/25	200/150	270/211/211
C-7	Location of WWTS operation	✓	✓	✓	✓	✓	✓	✓
C-8	Days WWTS operated/in AK	365/99	365/99	365/82	365/103	6/0 : 365/91	365/99	365/101
C-9	Where Discharge?	✓	✓	✓	✓	✓	✓	✓
C-10	Time discharge outside and inside of A	294/671	21.46/982	0/0 : 13/0	18/1882.5	0/0 : 0/0	48/748	72/750

		Statendam[2]	Volendam[2]	Westerdam[2]	Zaandam[2]	Silver Shadow[3]4	Coral Princess[5]	Diamond Princess
D-1	Original Cost of WWTS	✓	✓	\/✓	✓	\	x	\
D-2	purchase vs installation cost	✓	✓	\/✓	✓	\	n/a	\
D-3	Date of installation and ops	✓	✓	✓	✓	\	✓	✓
D-4	O&M Costs	✓	✓	✓	✓	\	✓	✓
D-5	Aeration description	✓	✓	✓	✓	\	✓	✓
D-6	Aeration system used to spec	✓	✓	✓	✓	o	✓	Yes
D-7	Changes to aeration to improve?	✓	✓	✓	✓	✓	✓	No
D-8	Research for mods to aeration	✓	✓	✓	✓	✓	o	No
D-9	Info on mods	✓	✓	✓	✓	✓	n/a	n/a
D-10	Planned mods?	✓	✓	✓	✓	o	n/a	n/a
D-11	Mods to piping and holding	✓	✓	✓	✓	✓	n/a	n/a
D-12	Mods planned to reduce metals and ar	✓	✓	✓	✓	o	n/a	No
D-13	Space dimensions	✓	✓	✓	✓	✓	✓	✓
D-14	More space available	No	No	No	No	No	No	No
D-15	describe	\	\	\	\	\	n/a	n/a
D-16	feasible to add components	✓	✓	✓	✓	✓	✓	No
D-17	power available?	✓	✓	✓	✓	o	✓	\
E-1	pollutions prevention methods	✓	✓	✓	✓	✓	✓	✓
E-2	description of methods	✓	✓	✓	✓	\	✓	✓
E-3	future plans	\	\	✓	\	o	✓	✓
F-1	Treated discharge practices	✓	✓	✓	✓	✓	✓	✓
F-2	Treated water reused?	No	No	No	No	No	No	No
F-3	Would you use shore facilities	No	No	No	No	Yes/No	Yes	Yes
F-4	Cost at not feasible to use $/m3	n/a	n/a	n/a	n/a	Unknown	$70	$70
F-5	How do you view patterns	Burden	Burden	Burden	Burden	Managble but expensive	Burden/Other see note	Burden/Other see note
F-6	Does continuous discharge help	Yes	Yes	Yes	Yes	Yes/No	Yes	Yes
F-7	Do regs affect itineraries	Yes	Yes	Yes	Yes	o	Yes	Yes
F-8	Do regs affect discharge	Yes	Yes	Yes	Yes	o	Yes	Yes
F-9	Would you change intineraries	Yes	Yes	Yes	Yes	o	No	No
F-10	Would you change discharge practices	Yes	Yes	Yes	Yes	o	No	No

		Statendam[2]	Volendam[2]	Westerdam[2]	Zaandam[2]	Silver Shadow[3]4	Coral Princess[5]	Diamond Princess
F-11	Comments	✓	✓	✓	✓	✓	✓	✓
G-1	BAT Influent/Effluent Information	✓	✓	✓	✓	n/a	✓	✓
G-2	BAT Add-on Options	✓	✓	✓	✓	✓	\	n/a
G-3	BAT PP Methods	✓	✓	✓	✓	o	\	\
G-4	BAT Control	✓	✓	✓	✓	✓	\	o
G-5	BAT Replacement	✓	✓	✓	✓	\	✓	\
EPA Survey		YES	YES	No	YES	No	Yes	Yes

1 NCL Includes Vendor Proposal from Sca
2 Note detailed pollution prevention text
3 Operated but didn't discharge
4 Much of response not legible
5 All princess docs have same informatio
6 Replacing gray water system

Key:
✓ = answered
o = not answered at all
\ = answered in part
n/a = marked as n/a

		Golden Princess	Island Princess	Sapphire Princess	Sea Princess
A-1	Contact Information	✓	✓	✓	✓
A-2	Comments	✓	✓	✓	✓
A-3	2011 Days in AK water	76	99	72	52
A-4	Typical?	Typ	Typ	Typ	Typ
A-5	Plan to be in AK for 2013?	Yes	Yes	Yes	No
A-6	Planned Modifications?	No	No	No	No
B-1	Waste Destination	✓	✓	✓	✓
B-2	Flow Rates	✓	✓	✓	✓
B-3	Holding Capacity (hours)	208/80.4	72/72	57	91/91
B-4	Untreated waste to Shore?	es 17.43/m	es 4.69 $/m	No	es $4.40/m3
B-5	Volume and type transferred	✓	✓	n/a	✓
B-6	Treated waste to Shore?	No	No	No	No
B-7	Volume and type transferred	n/a	n/a	n/a	n/a
C-1	System Name	amworthy	worthy/Ham	worthy MB	worthy MBRx2
C-2	System Manufacturer	✓	✓	✓	✓
C-3	Batch or Continuous	Cont	Cont	Cont	Cont
C-4	How many batches/day	n/a	n/a	n/a	n/a
C-5	Batch Volume	n/a	n/a	n/a	n/a
C-6	Average volume m3/day	8.5/175/18	156/159	.9/169.3/1	211.9/197.9
C-7	Location of WWTS operation	✓	✓	✓	✓
C-8	Days WWTS operated/in AK	365/76	363/99	364/72	363/52
C-9	Where Discharge?	✓	✓	✓	✓
C-10	Time discharge outside and inside of A	13/1102	182/731	20/1062	9/493

		Golden Princess	Island Princess	Sapphire Princess	Sea Princess
D-1	Original Cost of WWTS	✓	✓	✓	✓
D-2	purchase vs installation cost	n/a	n/a	n/a	n/a
D-3	Date of installation and ops	✓	✓	✓	✓
D-4	O&M Costs	✓	✓	✓	✓
D-5	Aeration description	✓	✓	✓	✓
D-6	Aeration system used to spec	Yes	Yes	Yes	Yes
D-7	Changes to aeration to improve?	No	No	No	No
D-8	Research for mods to aeration	No	No	No	No
D-9	Info on mods	n/a	n/a	n/a	n/a
D-10	Planned mods?	No	No	No	No
D-11	Mods to piping and holding	Yes	No	Yes	No
D-12	Mods planned to reduce metals and ar	No	No	No	No
D-13	Space dimensions	✓	✓	✓	✓
D-14	More space available	No	No	No	No
D-15	describe	n/a	n/a	n/a	n/a
D-16	feasible to add components	No	No	No	No
D-17	power available?	\	\	\	\
E-1	pollutions prevention methods	✓	✓	✓	✓
E-2	description of methods	✓	✓	✓	✓
E-3	future plans	✓	✓	✓	✓
F-1	Treated discharge practices	✓	✓	✓	✓
F-2	Treated water reused?	No	No	No	No
F-3	Would you use shore facilities	Yes	Yes	Yes	Yes
F-4	Cost at not feasible to use $/m3	$70	$70	$70	$70
F-5	How do you view patterns	Burden/Other see note	Burden/Other see note	Burden/Other see note	Burden/Other see note
F-6	Does continuous discharge help	Yes	Yes	Yes	Yes
F-7	Do regs affect itineraries	Yes	Yes	Yes	Yes
F-8	Do regs affect discharge	Yes	Yes	Yes	Yes
F-9	Would you change intineraries	No	No	No	No
F-10	Would you change discharge practices	No	No	No	No

		Golden Princess	Island Princess	Sapphire Princess	Sea Princess
F-11	Comments	✓	✓	✓	✓
G-1	BAT Influent/Effluent Information	✓	✓	✓	✓
G-2	BAT Add-on Options	n/a	n/a	n/a	n/a
G-3	BAT PP Methods	n/a	No	No	No
G-4	BAT Control	\	\	\	\
G-5	BAT Replacement	\	✓	✓	✓
EPA Survey		No	Yes	Yes	No

1 NCL Includes Vendor Proposal from Sca
2 Note detailed pollution prevention text
3 Operated but didn't discharge
4 Much of response not legible
5 All princess docs have same informatio
6 Replacing gray water system