Wastewater Sampling and Analysis for Commercial Passenger Vessels

Carolyn Morehouse, State of Alaska
Department of Environmental Conservation
410 Willoughby Avenue
Juneau, Alaska 99801
carolyn_morehouse@dec.state.ak.us

Abstract - Since July 1, 2001, Alaska law requires commercial passenger ships with at least 50 overnight passengers to take a minimum of two wastewater samples per year. Wastewater includes blackwater from toilets and graywater produced from sinks, showers and laundry facilities. From 2000-2002, the Alaska Department of Environmental Conservation received data from these sampling events. Obtaining truly representative sampling data for ships that do not discharge in port was difficult because the fecal coliform test has a 6-hour maximum holding time. When considered in its entirety, the sampling results obtained over the last three seasons do provide a representative picture of the range and averages of pollutants in various types of cruise ship discharges. The sampling results show whether treatment systems were functional and the effectiveness of the different treatment types. The data also shows the unique characteristics of different sources of wastewater.

I. BACKGROUND

Due to concerns regarding the quality and quantity of commercial passenger ship wastewater discharged into Alaska marine waters and the potential effects of those discharges, environmentalists, government agencies, the cruise ship industry, and other stakeholders formed the Alaska Cruise Ship Initiative in 1999. In 2000, this work group began a voluntary sampling program to test the wastewater effluents of large cruise ships that discharge in Alaska waters. Large cruise ships are defined as ships that have overnight accommodations for 500 or more people.

In June 2001, the Alaska legislature passed a law affecting commercial passenger ships operating in Alaska marine waters with overnight accommodations for 50 or more passengers.[i] The law set fecal coliform and total suspended solids (TSS) effluent discharge limits for both gray and blackwater.[ii] It also allows the Alaska Department of Environmental Conservation (ADEC) to perform necessary studies to determine if additional water quality limits are needed to protect human health and environment.

Commercial passenger ships produce two types of wastewater: blackwater and graywater. Blackwater is wastewater from ship's toilets and for the larger ships include medical facilities. Graywater is water produced from showers, sinks, and laundry. Graywater comes from three main sources: (1) galley or kitchen areas, (2) passenger/crew accommodations, and (3) laundry facilities. Anytime blackwater and graywater are combined the resulting wastewater is considered blackwater. For data comparison the gray and blackwater mix has been separated to see if its characteristics are different from other wastewater.

Cruise ship operators discharging wastewater in Alaska marine water sample for both conventional and priority pollutants. In 2002, the ADEC conducted a round of Whole Effluent Toxicity tests to determine the potential for effects of the effluent on marine organisms. This test was repeated in 2003 on vessels with different wastewater systems.

The ADEC compiled data from sampling events in 2000, 2001 and 2002 (samples received by September 30, 2002). Tables that summarize the data are included in **The Impact of Cruise Ship Wastewater Discharge on Alaska Waters, Appendix 5&6 November 2002** available on line at http://www.state.ak.us/dec/press/cruise/documents/impact/wastewatersampling.htm.

II. POLLUTANTS ANALYZED

Wastewater sampling and laboratory analysis provide measurements of conventional and priority pollutants.

All ships discharging in Alaska water were required by Alaska statute to sample twice a year for the following conventional pollutants:

- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Ammonia – Total
- Fecal Coliform
- pH
- Total and Free Residual Chlorine

In 2001, on the advice of the Science Advisory Panel[iii], the conventional pollutants monitoring requirements were increased to include the following parameters:

- Settleable Solids (SS)
- Oil and Grease
- Total Organic Carbon
- Specific Conductance (to measure seawater influx)
- Alkalinity
- Total Nitrogen (Ammonia, Nitrate, Nitrite, and Total Kjeldahl Nitrogen (TKN))
- Total Phosphorus

One of the two required sampling events must also test for priority pollutants. Priority pollutants include:

- Base/Neutrals, Acids
- PCBs
- Volatile Organic Chemicals (VOCs)
- Trace Metals (Total Recoverable and Dissolved)

There are 126 so-called "priority" pollutants on the EPA derived list[iv]. In 2000 and 2001, large ships sampled for all 126 pollutants. Since many of the priority pollutants were not discovered in these wastewater samples, the ADEC and United States Coast Guard (USCG) shortened the list to 55 pollutants in 2002. However, the 55 pollutants on the USCG list have 110 chemical constituents.[v] In order to reduce laboratory costs and under guidance from the Panel[vi], the USCG and ADEC removed pesticides from the pollutant list in 2002. The pesticides on EPA list were not detected in any of the 2000 or 2001 samples.

The Impact of Cruise Ship Wastewater Discharge on Alaska Waters Appendix 4 contains the list of pollutants that were analyzed in 2002.

III. SAMPLING STRATEGY

In 2000, the goal of the sampling program was to characterize the wastewater, determine if hazardous substances were discharged with the graywater, and determine the functionality of the wastewater treatment systems.

In 2000, large ships agreed not to discharge within 10 miles of the nearest port. Some of the 2000 in port samples were taken from holding tanks and Marine Sanitation Devices (MSD). The water in these holding tanks was not being discharged to the ambient water but instead held in double bottom (DB) or ballast tanks for later discharge. These 2000 sampling data were representative of the wastewater that vessels' discharged prior to the 2000 agreement to hold water in port.

The other sampling events in 2000 sampled the double bottom holding tanks. These tanks held a majority of the water but could only be sampled as the ship was discharging to the ambient water. The wastewater in the double bottom tanks was being held for up to 20 hours and discharged once the vessel was more than 10 miles from port.

The Federal legislation or the "Murkowski" bill passed in December 2000[vii] and the Alaska State law passed in June 2001. Since the summer of 2001, the purpose of the sampling shifted to assess compliance with the federal and state laws as well as conducting scientific impact analyses.

In 2001, the wastewater samples from large ships had to be taken as the wastewater was being discharged overboard. The samples also had to be delivered to the lab within 6 hours in order to meet the holding time requirements for the EPA approved analysis method. Therefore, the large ship samples originated from collecting tanks because the ballast tanks discharge occurred more than 6 hours from port. Small ships were sampled in port as they were discharging, but there were no people on board. The ferries' sampling occurred while there were stopped in Juneau, which typically lasted only 1-2 hours.

The number and types of samples taken depended on individual ship configuration and the ability to get the samples to a laboratory for analysis within a 6-hour time frame.

In 2002, the wastewater data from large ships reflected the increase in the number of large vessels that had installed advanced treatment technology, from two in 2001 to seven in 2002.[viii] Most of the ships with advanced treatment, met the USCG more stringent effluent standards[ix].

The wastewater sampling strategy from small ships in 2002 was similar to that of 2001. Small ships took their first priority pollutant data in 2002.

IV. SHIPS TREATMENT SYSTEMS FROM 2000 TO 2002

Black water treatment

All large ships treat black water using a US Coast Guard approved Marine Sanitary Device (MSD) or the black water is not treated and discharged when the ships are more than 12 miles from land. The MSD units use the following treatment systems: (1) biological treatment, (2) macerator/chemical, or (3) advanced treatment.

Biological systems clarify the wastewater by allowing solids to settle then use aeration to encourage biological growth that feeds on the organic waste. Biological systems use either chlorine or ultraviolet light for disinfecting the final discharge.

Macerator/chlorinator systems dilute the wastewater about 10:1 with ambient seawater. A macerator pump breaks up any solids. An electrochemical cell generates chlorine from the seawater and this is used for final disinfecting.

Advanced treatment systems that are discharging into Alaska water treat the wastewater using a biological process followed by ultrafiltration or reverse osmosis filtration. The advanced treatment systems then use either chlorine or ultraviolet radiation to kill bacteria. Currently, only large ships are using advanced treatment systems in Alaska water.

Graywater treatment

Graywater is usually not treated. Some vessels mixed the graywater with the blackwater where it gets treated in the blackwater treatment system or advance treatment system. Some ships add chlorine to their graywater collecting tanks to achieve some level of bacteria reduction. The state law gave large ships interim protection from complying with graywater standard until January 1, 2004. The law had this exemption to give owners and operators a period to install equipment necessary to meet the State graywater standard.

V. DATA ANALYSIS

In the following tables, the ADEC used one-half (½) the minimum detection limit (MDL) for results that are zeros or non-detects for statistical purposes. The ADEC included tables for all pollutants with geometric means greater than the MDL or where at least one sample result was over 10 times the detection limit in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters, Section 2**. Tables with all of the raw data are located in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Appendices 5&6.

Small Ships

Alaska Statute defines small ships as commercial passenger ships that have overnight accommodations for 50-249 passengers. Five of the Alaska Marine Highway System (AMHS) ferries are defined as small ships under Alaska law.

All small ships treat blackwater in an USCG approved Type II MSD[x]. Most small ships operating in Alaska treat sewage using a macerating/chlorinating system; two of the largest small ships treat sewage with a biological system. Two other vessels have biological systems but discharge outside Alaska water.

Small ships either collect graywater in tanks and then discharge using a pump, or discharge the graywater directly from drains to the ambient water. Some ships manage graywater using a combination of both practices. The graywater management practice depends on ship configuration. Most small ships do not have wastewater holding capacity.

The AMHS ferries and two small passenger ships mix their gray with the black water and treat both effluents with their MSD. Some small ships "treat" graywater with chlorine

injection. Chlorine is effective for disinfecting but excessive chlorine residual is toxic to marine life.[xi]

There were only three small ship samples taken from AMHS ferries in 2000, to few to analyze. In 2001, small ship samples were only analyzed for conventional pollutants. In 2002, the small ship samples were analyzed for both priority and conventional pollutants. **Impact of Cruise Ship Wastewater Discharge on Alaska Waters, Section 2** Tables 1 through 4 include all sample data received by the ADEC by September 30, 2002.

The data were separated into summary tables according to wastewater effluent type and type of treatment. The raw data tables are included in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Appendix 5. The geometric mean values for the conventional pollutants are presented in Table 1 of this paper. The highest geometric means for fecal coliforms are associated with untreated mixed graywater followed by treated blackwater (BW) and the treated black and graywater (BW&GW) mix.

The limited laundry and galley graywater data shows low fecal coliform densities for these types of graywater. The data from a laundry holding tank shows little to no bacteria growth occurring in that tank. The accommodation graywater only samples had two samples that were over 1,000 fecal coliforms per 100 ml, but the geometric mean is low at 9 fecal colonies per 100 ml. The galley sample has 50 fecal coliform per 100 ml with a 2.21 ppm chlorine residual. From this limited data we are unable to pinpoint the source for the large concentration of fecal coliforms in graywater. The data shows that the galley water contains highest BOD and fecals.

Table 1 shows that the treated BW and BW/GW mixed had similar results. This table excluded ammonia data, where the treated BW had much higher results. Ammonia was excluded because the geometric mean was less than MDL. Obviously chlorine treated mixed GW had lower fecal coliform bacteria counts than the untreated mixed GW. However, treated mixed GW also had higher BOD, COD, and TSS than untreated GW. The Panel had no explanation for this apparent abnormally.

In April 2002, the AMHS discovered that sampling had been occurring prior to the chlorinating stage. A separate review of the Alaska Marine Highway System (AMHS) is shown in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Section 2,Table II-2. This table is modified as Table 2. This explains the high fecal coliform count for samples taken prior to May 1, 2002. Table 2 shows that samples taken before May 1, 2002 have a fecal coliform geometric mean of 5,740 fecal bacteria per 100 ml of water compared to the geometric mean of 3 fecal bacteria per 100 ml for samples taken after May 1, 2002. This comparison shows that the correctly sampled samples have a slightly lower biological oxygen demand (BOD), lower chemical oxygen demand (COD) and higher chlorine residual.

Table 1- Small Ships: Summary Geometric Mean for Conventional Pollutants *2001 and 2002*

Waste water Type(# samples)	pH	BOD	COD	TSS	Total Cl	FREE CL	FECAL
		mg/L	mg/L	Mg/L	mg/L	mg/L	MPN/100 ml
Treated BW(14)	7.65	21.51	1,004.3	97.6	0.30	0.15	1,546
Treated BW&GW mixed (19)	7.25	58.08	930.0	61.1	1.12	0.38	1,414
Mixed GW (chlorine treated) (4)	7.90	382.70	880.4	186.9	78.62	58.72	1,225
Mixed GW (untreated)(9)	6.97	95.42	228.3	52.9	ND	ND	99,096
GW Accommodations(10) (treated & untreated)	6.74	164.28	174.0	24.3	0.11	0.05	9
GW Laundry (2) ((treated & untreated)	9.13	123.20	319.0	21.5	0.35	0.18	2
GW Galley (treated & untreated) (2)	Not analyzed	247.40	not analyzed	42.6	2.21	Not analyzed	50

Source: **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** *Section 2, Table II-1*

Table 2 - AMHS samples 2001 and 2002.

Time	Ammonia	pH	BOD	COD	TSS	Total Cl	Free Cl	Fecal
# samples	Mg/L		Mg/L	Mg/L	Mg/L	Mg/L	mg/L	MPN/100ml
Pre-April 2002 (11)	8.880	7.37	81.15	875.0	50.8	0.67	0.14	5,740
After April 2002 (6)	0.380	7.58	7.7	686.8	45.8	9.08	6.12	3

Source From **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Table B1 Section 2
http://www.state.ak.us/dec/press/cruise/documents/impact/wastewatersampling.htm

Table 3 shows the data from the pollutants recommended by the Science Panel. These samples were taken by the DEC and not the vessels. The panel used this data to discuss nutrient and phosphorus and other pollutants not address in the ship's conventional sampling. A complete discussion is included in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters**. High nutrient concentrations (nitrogen, phosphorous) in wastewater discharge can, under the right conditions, promote phytoplankton blooms in receiving waters, altering the immediate marine environment. The Science Advisory Panel investigated the possibility that nutrients in cruise ship wastewater discharge could stimulate unwanted events in Alaska marine waters.[xii] Because of ambient marine water concentration, nitrogen is probably the limiting nutrient in SE Alaska waters, but phosphate may also be limiting at times.

Table 3: 2002 Small Ship Science Panel Recommended Pollutants

Sample Type	Alkalinity As CaCO3	TOC	Oil& Grease	Settle-able solids	Phosphorous,	TKN
Units		Mg/l	Mg/L	mg/L	Mg/l	mg/l
MDL	0.5	0.3	1	0.05	0.22	0.1
Treated BW (1)	116	299	8.5	0.05	2.33	5.7
Mixed Treated BW&GW (5)	98.53	133.9	13.13	0.23	1.20	15.24

Source **Impact of Cruise Ship Wastewater Discharge on Alaska Water** and 2002 sampling data

The small ships did not take any priority pollutant data samples in 2001. All pollutant data is from samples received by September 30, 2002. Table 4 shows the geometric means of the 2002 data for conventional pollutants, metals, and base/neutral/acids (BNAs).

Mercury, cadmium, and silver (dissolved and total recoverable) and dissolved antimony were not detected in any sample and therefore not included in the analysis or tables. The highest dissolved and total recoverable lead result of any sample was 1.21 µg/l and 6.74 µg/l, respectively. These values are less than 10 times the MDL so lead results were excluded from Table 4. Dissolved and total recoverable thallium results were not included because the geometric mean was less than the MDL. **Impact of Cruise Ship Wastewater Discharge on Alaska Waters,** Table B9 in Appendix 5 includes the results from all pollutants.Only seven of the 72 base/neutral/acids pollutants had any constituents above detection levels. Of the seven pollutants, only four (benzoic acid, benzyl alcohol, bis (2-ethylhexyl)phthalate, and diethylphthalate) had geometric means that were above the MDL or had at least one sample that was 10 times the MDL.

Benzoic acid appeared in high levels. The maximum concentration of benzoic acid was 600 ug/L in one sample and the geometric was 63.4 ug/L compared with a MDL of 21 ug/L. Benzoic acid is a slightly hazardous chemical. It is a mild human skin irritant and is moderately toxic if ingested. When released into water, benzoic acid is expected to readily biodegrade with a half-life between 1 and 10 days.[xiii] The source of the benzoic acid is unknown at this time.

Table 4: 2002 Small Ship Conventionals and Priority Sampling

Parameter	Units	MDL	Min	Max	Geo Mean
Ammonia as N	mg/L	0.16	0.08	29.4	0.75
BOD-5 Day	mg/L	1	0.05	134	11.98
COD	mg/L	0.3	228	870	476.2
Conductivity	umhos/cm	1	369	34,500	13,058
TSS	mg/L	0.1	17.1	75.2	38.5
Fecal coliform	MPN/100ml	2	1	22	2
Free Cl residual	mg/L	0.1	0.1	25	3.94
pH (no units)		0.1	6.88	8.19	7.61
Total Cl residual	mg/L	0.1	0.05	40	6.19
Arsenic Dissolved	ug/L	1.3	0.3	53.2	16.1
Arsenic TR	ug/L	3.6	0.5	48	14.5
Chromium Dis	ug/L	1.9	0.6	10.3	3.9
ChromiumTR	ug/L	2.3	0.9	5	2.4
Copper Diss.	ug/L	1	8.5	163	48.2
Copper TR	ug/L	1.2	20.2	339	90.4
Nickel Dis	ug/L	1.5	1.8	21.2	10.9
Nickel TR	ug/L	1.1	2.6	23.2	10.4
Selenium Dis.	ug/L	4.2	0.6	233	52.4
Selenium TR	ug/L	4.8	1.2	132	46.9
Zinc Dis	ug/L	2.5	26.2	86.9	60.6
Benzoic Acid	ug/L	21	12	600	63.4
Benzyl Alcohol	ug/L	0.58	0.29	9	1.46
Bis(2-Ethylhexyl)Phthalate	ug/L	0.69	0.35	8	2.48
Diethylphthalate	ug/L	0.88	0.28	14	1.16

Source **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Section 2 Table II-3: Small Ships – Conventional Pollutants, Detectable Metals and BNAs http://www.state.ak.us/dec/press/cruise/documents/impact/wastewatersampling.htm and 2002 sampling data

Pollutants in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Table B12 were included in Table 5 if the geometric mean was greater than the MDL or at least one pollutant was 10 times the MDL. Twenty-two out of 75 pollutants were included as volatile organic compounds. The other 53 compounds were all below detection limits and not included in the analysis.

There were no PCBs detected in any sample except for two surrogates added by the lab for Quality Assurance. PCB results are included in the **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Appendix 5 as Table B10.

All the samples contained acetone. The acetone results ranged from 0.6 ug/L to 52 ug/L, with half of the samples containing at least 45 ug/L. All four mixed BW/GW samples contained bromoform at levels more than 100 times the MDL, while the treated blackwater sample and treated graywater samples were non-detects. The graywater sample had high levels of chloroform. Two of the four mixed BW&GW samples had chloroform levels over the detection limit. One

of the mixed BW&GW was high in the rest of the detected VOCs. The other samples were below or close to the MDL.

Bromoform, bromodichloromethane, dibromochloromethane and chloroform are formed as by-products when chlorine is added to kill bacteria so it is not surprising that these compounds were present in the wastewater treated by chlorine. Acetone is a product of certain cleaners and degreasers that may be used on the vessel. The conventional pollutant analyses done concurrently with the priority pollutants analyses for samples are included in Table 4 and have geometric means of 2 MPN/100 ml for fecal coliform, 38.5 mg/l for TSS, 6.19 mg/l for total chlorine, and 3.94 mg/l for free chlorine.

Volatile organic compounds that had a geometric mean equal or greater than the MDL or a minimum of one result ten times the MDL are included in Table 5.

Table 5: 2002 Small Ship Volatile Organics

Volatile Organic Compounds	Units	MDL	Min	Max	GeoMean
1,2,4-Trimethylbenzene	Ug/L	0.15	0.08	9.9	0.244
2-Butanone	Ug/L	0.51	0.26	8.3	0.769
4-Isopropyltoluene	Ug/L	0.11	0.06	2.4	0.069
Acetone	Ug/L	1.2	0.6	52.0	8.44
Benzene	Ug/L	0.18	0.09	2.6	0.264
Bromodichloromethane	Ug/L	0.23	0.14	31.0	1.87
Bromoform	Ug/L	0.32	0.12	130.0	9.2
Bromomethane	Ug/L	0.76	0.38	3.4	0.768
Carbon Disulfide	Ug/L	0.13	0.07	4.4	0.369
Chloroethane	Ug/L	0.36	0.18	1.4	0.352
Chloroform	Ug/L	0.25	0.13	140.0	1.76
Chloromethane	Ug/L	0.29	0.15	4.5	1.07
Dibromochloromethane	Ug/L	0.32	0.16	73.0	4.04
Iodomethane	Ug/L	0.42	0.21	3.1	0.33
m&p Xylenes	Ug/L	0.15	0.08	8.0	0.228
Naphthalene	Ug/L	0.1	0.05	8.5	0.197

Source **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Section 2

In summary, the wastewater sample data for small ships that the DEC received by September 30, 2002 contained priority pollutants that were byproducts of chlorination. The following priority pollutants' geometric mean was at least ten times the MDL.

- Bromoform
- Dibromochloromethane
- Arsenic (total recoverable and dissolved)
- Copper (total recoverable and dissolved)
- Nickel (total recoverable and dissolved)
- Selenium (total recoverable and dissolved)
- Zinc ((total recoverable and dissolved)

The following priority pollutants had a maximum, 100 times the MDL:

- Bromodichloromethane
- Bromoform
- Chloroform
- Dibromochloromethane
- Copper (total recoverable and dissolved)

Small ships did not participate in the voluntary 2000 sampling. They did not sample for priority pollutants in 2001. This analysis had to rely on the limited amount of priority pollutant data from 2002. We are, therefore, unable to draw broad conclusions characterizing the level of priority pollutants in the wastewater effluent of small ships at this time.

Large Ships

Voluntary sampling of large ships began in 2000. The federal government had legislation in place for the entire 2001 cruise season. The State of Alaska had legislation regulating wastewater discharges as of July 1, 2001.

Tables 6, 7, 8 and 9 include the geometric means of the individual tables to compare the effluent types. Table 6 and 7 compare whether the wastewater was held for periods of time versus collected and discharged immediately. The water from collecting tanks (CT) was sampled as it was discharged overboard or to a double bottom (ballast) holding tank. Samples from double bottom (DB) tanks could only be taken while the ship was discharging to ambient water. The wastewater was often stored in the double bottom tanks for up to 20 hours.

Table 6 Geometric Mean 2000 Large Ship data

Water type (# samples	Collected from	Fecal Coliform (MPN/100 ml)	TSS mg/l	BOD mg/l	COD mg/l	Cl mg/l
	MDL	2	0.1	1	3.4	0.05
Galley (14)	CT	13,750	420	728	1,317	0.05
Galley (10)	DB	784,072	512	1,587	2,404	0.05
Mixed GW(24)	CT	118,052	124	223	573	0.06
Accommodations (3)	CT	104	297	324	1340	0.05
Laundry (10)	CT	8	38	74	340	0.2
Accomo.Laundry (3)	CT	6.13	77.5	63	240	0.13
BW (22)	MSD	18,213	478	105	845	0.21
Mixed BW&GW (11)	DB	12,824	119	146	338	0.16

CT= Collecting Tank DB =Double Bottom Tank MSD = Marine Sanitation Device Source **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Section 2 Table II-5

Table 7 Geometric Mean 2001 Large Ship data

Type of Water (#sample)	Sample from	Fecal Coliform (MPN/100 ml)	TSS mg/l	BOD Mg/l	COD mg/l	Cl mg/l
	MDL	2	0.1	1	3.4	0.05
Accom (15)	DB	10,896	77	266	573	0.15
Accom (15)	CT	2,189	67	282	527	0.49
Galley (10)	DB	784,072	512	1,587	2,404	0.23
Galley (23)	CT	Missing*	349	728	1,414	0.34
Mixed GW (4)	DB	649,994	114	259	367	0.05
Mixed GW (13)	CT	38,933	108	246	474	0.11
Laundry (7)	DB	651,460	66	230	634	0.12
Laundry (2)	CT	30	22	86	571	0.32
Mixed BW&GW (16)	MSD	2	2.7	6.73	16.7	0.07

* The fecal coliform did not meet the 6 hour holding time and was not analyzed

Source **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Section 2, Table II-6

Table 8 Geometric Mean 2002 Large Ship data

Water type (# samples	Collected from	Fecal Coliform (MPN/100 ml)	TSS mg/l	BOD mg/l	COD mg/l	Cl mg/l
	MDL	2	0.1	1	3.4	0.05
Galley (7)	DB or CT	6,279	1,520	2,790	5,603	0.06
Mixed GW(19)	CT or DB	38,603	190	432	805	0.08
Accommodations (12)	DB or CT	47,357	145	304	589	0.16
Mixed advanced treated BW&GW (20)	various	5	0.21	3	83	0.05

CT= Collecting Tank DB = Double Bottom Tank MSD = Marine Sanitation Device

Source: ADEC Sampling results from 2002 season

Table 9: 2002 Geometric mean of Large Ship Science Panel Recommended Pollutants

Water type (# samples	from	Oil &Grease Mg/L	Phosphorous Total Mg/L	Nitrate as N Mg/Ll	TOC mg/l	Settleable Solids mg/l
	MDL	1.7	0.22	0.3	0.22	0.05
Galley (7)	DB or CT	315	12.18	0.15	1506	28.45
Mixed GW(19)	CT or DB	116	5.22	0.19	229	0.66
Accommodations (12)	DB or CT	125	4.71	0.15	188	0.43
Mixed advanced treated BW&GW (20)	DB, CT, or MSD	3	3.70	0.10	28	0.05

Source 2002 data submitted to ADEC.

For the 2000 season, the fecal coliform geometric mean of treated blackwater only that was sampled from the treatment system outlet was 18,213 MPN/100 ml with a TSS geometric mean of 478 mg/l. The geometric mean of ammonia for the treated blackwater (BW) was also high, 104.48 mg/l.[1] These results concluded that the blackwater treatment systems were not functioning properly.

The untreated BW&GW stored in the double bottom tank had a lower fecal coliform mean than the blackwater that was treated with the MSD. There are two plausible explanations for this. First, the blackwater system is blackwater only whereas the double bottom samples have graywater mixed with blackwater. Untreated blackwater should have higher fecal coliform counts than graywater. Secondly, the geometric mean from the double bottom tanks included two samples from advanced systems that had results below the detection limit for fecal coliforms. These two sample results lowered the geometric mean substantially for mixed treated blackwater and graywater.

Here is a summary of the 2000 and 2001 conventional pollutant geometric means: The fecal coliform geometric mean of all graywater types over 2000 and 2001 is 135,922 MPN /100ml from double bottom tanks compared with 515 MPN/100ml from collecting tanks. The TSS of graywater from double bottom tanks is 128.58 mg/L. versus 118.1 for the collecting tank.[xiv] The data suggests that the fecal coliform counts are increasing as the wastewater incubates in the double bottom tanks.

- 2000 - GW mixed in collecting tanks geometric mean is slightly acidic with a pH 6.62 and has COD geometric mean of 573 mg/l, and high fecal coliform geometric mean of 118,052 MPN/100ml.
- 2000 - GW laundry in collecting tanks is relatively benign with a fecal coliform geometric mean of 8 MPN/100ml and TSS of 38 mg/l.
- 2000 - Treated blackwater (BW) from biological treatment MSD had high ammonia of 104.5 mg/l, TSS and fecal coliform results are 478 mg/l and 18,213 MPN/100 ml. The MSDs were not treating wastewater as designed.
- 2000 - Treated BW&GW from double bottoms had high fecal coliform geometric mean of 12,824 MPN/100ml.
- 2001 - GW from accommodations stored in double bottom tanks had a high fecal coliform geometric mean of 10,896 MPN/100ml but the TSS geometric mean complied with the 150 mg/L standard at 77. Accommodation graywater stored in collecting tanks fecal coliform geometric mean is 2,189 MPN/100ml and a TSS of 67 mg/L. The chlorine residual of the collecting tanks was 0.49 mg/L compared with 0.15 mg/L in double bottom tanks.
- 2001 - GW Galley from double bottom tanks had the highest fecal coliform geometric mean of 784,072 MPN/100ml, the lowest pH of 4.8, a COD of 2,404 mg/L and 1,587 mg/L of BOD. 2001 GW Galley from collecting tanks COD geometric mean was 1,414 mg/L and the total chlorine was 2 mg/L and a residual of 0.34 mg/L.

[1] *Impact of Cruise Ship Wastewater Discharge on Alaska Waters* November 2002 Section 2, Table II-7: http://www.state.ak.us/dec/press/cruise/documents/impact/wastewatersampling.htm

- 2001 - GW laundry in double bottom tanks had a fecal coliform geometric mean of 651,460 MPN/100 ml and 66 mg/L of TSS.

- 2001 - GW laundry in collecting tanks had only two samples but both samples had fecal coliform of 30 mg/L, low TSS of 22 mg/L, and low levels of chlorine of 0.32 mg/L.

- 2001 - GW mixed from double bottom tanks fecal coliform geometric mean was 649,994 MPN/100 ml with a TSS of 113.5 mg/L. The graywater mixed from collecting tanks fecal coliform geometric mean and TSS was 38,933 MPN/100 ml and 108 mg/L

- 2001 - BW&GW mixed had low geometric mean for fecal coliform and TSS because most of the results were from advanced systems. Only ships with advanced treatment units and one ship that used a macerator chlorinating system discharged blackwater in Alaska. One ship that discharged their blackwater outside Alaska water sampled their blackwater voluntarily. All priority pollutant results with at minimum one result over the MDL, taken in 2000 and 2001 can be found in the tables C1-C33 in Appendix 6.

For 2002, the data shows the increasing number of advanced wastewater treatment systems, which have a fecal coliform geometric mean of 5 MPN/100ml and TSS of 0.21 mg/L. All large ships in the sampling program sought interim protective measures, which gave them an exemption from the graywater standards until January 1, 2003[xv]. Overall the fecal coliform levels for graywater decreased compared to 2000 and 2001 because of the increase of graywater treatment using chlorine disinfectant. More graywater was mixed. Galley graywater showed lower levels of fecal than the accommodations or mixed but the levels of BOD, COD, and TSS are much higher. Galley graywater was a more complex wastewater to treat than laundry or domestic wastewater.

One priority pollutants sample per year was taken on large ships discharging in Alaska water from 2000-2002. Priority pollutants are sampled to evaluate whether hazardous chemicals are present. A complete list is available in **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** Appendix 4.

The **Impact of Cruise Ship Wastewater Discharge on Alaska Waters** did not include the large ships priority pollutants because not enough results were received by the September 30, 2002 data cutoff date necessary for that report. Table 8 and 9 in this paper include the 2002 information. Table 10 and 11 compare the priority pollutant results from 2000, 2001, and 2002.

Blackwater results are Table 10. Pollutants are included in Table 10 if the pollutant's geometric mean is equal to or greater than the pollutant's minimum detection limit (MDL) or one sample result was ten times the MDL. There are only 15 pollutants that met this criterion.

Bromoform and chloroform are decreasing from 2000 to 2002. This is probably caused by the ships' reduced usage of chlorine in the blackwater treatment systems. Zinc and copper are the highest metals results, which could be caused by the piping system.

Table 10: Geometric Means for Priority Pollutants in Large Ships' Blackwater (includes mixed BW&GW).

ANALYTE	MDL	BW 2002	BW 2001	BW 2000
Acetone	**2.5**	**6.61**	**ND**	**ND**
Bromoform	**0.32**	**ND**	**0.78**	**2.17**
Chloroform	**0.25**	**1.21**	**5.86**	**8.84**
Cyanide	**1.6**	**ND**	**ND**	**2**
Bromodichloro methane	**0.46**	**ND**	**ND**	**2.58**
Dibromochloro methane	**0.32**	**ND**	**ND**	**1.59**
di-n-butyl phthalate	**1.4**	**1.39**	**ND**	**1.6**
Methyl Chloride	**1.2**	**ND**	**ND**	**1.6**
Phenol	**0.85**	**ND**	**ND**	**0.96**
Chromium	**2.3**	**1.26**	**ND**	**3.1**
Copper	**1.2**	**19.35**	**44.3**	**107.3**
Lead	**1.4**	**2.76**	**1.4**	**1.8**
Nickel	**1.1**	**17.75**	**12.8**	**ND**
Selenium	**4.8**	**3.29**	**12.89**	**ND**
Zinc	**2.8**	**246.89**	**112.29**	**124.1**

Source *Impact of Cruise Ship Wastewater Discharge on Alaska Waters* Section 2, Table II-12 and 2002 data. All units in parts per billion (ppb). ND = Non detect

The graywater priority pollutant geometric mean of all data received is included in Table 11. Table 11 includes priority pollutants that are byproducts of chlorination such as bromoform and chloroform

Table 11: Geometric Means for Priority Pollutants in Large Ships' Graywater.

ANALYTE	MDL	GW 2002	GW 2001	GW 2000
Acetone	**2.5**	**59**	**N/A**	**N/A**
Bis (2ethylhexyl) phthalate	**0.38**	**13**	**6.51**	**1.56**
Bromoform	**0.32**	**0.61**	**0.52**	**ND**
Chloroform	**0.25**	**57**	**7.77**	**4.19**
Benzoic Acid	**23**	**169**	**<MDL**	**<MDL**
Benzyl Alcohol	**0.55**	**9.21**	**<MDL**	**<MDL**
Butylbenzyl phthalate	**0.38**	**0.63**	**0.36**	**ND**
Diethylphthalate	**0.55**	**6.5**	**5.91**	**1.11**
Bromodichloromethane	**0.46**	**2.5**	**ND**	**ND**
Dibromochloromethane	**0.32**	**0.55**	**ND**	**ND**
di-n-butyl phthalate	**1.4**	**2**	**ND**	**1.37**
M&p Xylenes	**0.15**	**1.52**	**<MDL**	**<MDL**
Chromium	**2.3**	**5.49**	**3.8**	**13.82**
Copper	**1.2**	**130.21**	**103.4**	**1.55**
Lead	**1.4**	**11.51**	**4.0**	**1.8**
Nickel	**1.1**	**14.99**	**11.1**	**ND**
Selenium	**4.8**	**88.6**	**2.0**	**ND**
Zinc	**2.8**	**295**	**179.3**	**21.45**

Source *Impact of Cruise Ship Wastewater Discharge on Alaska Waters* Section 2, Table II-12 and 2002 data. All units in parts per billion (ppb). ND = Non detect

N/A = Non available because this was not inputted into the DEC database at this time.

Priority Pollutant Conclusions

A majority of priority pollutant results are below the minimum detection limit.

Out of the 55 priority pollutant categories sampled, blackwater contains only 15 pollutants and graywater contains 18 pollutants, sometimes in trace amounts. There is no evidence that any of the samples taken contain hazardous wastes discharged by ships via their wastewater systems. The pollutants that are present could be by products of chlorination. The metals that are present are probably picked up through the piping system.

Priority pollutants are a list of pollutants that have EPA methods. Some pollutants are quite dated. Pesticides, for example, have been dropped from the program because of the pesticides listed are outlawed and the sampling in 2000 and 2001 had all non-detection results. The DEC is working with EPA to try to locate standard methods for pesticides that are more commonly used today.

VI. CONCLUSIONS

The main purpose of the volunteer sampling program in 2000 was to monitor whether hazardous materials were being discharge by large cruise ships. Instead of hazardous materials being found, the sampling showed the blackwater systems were not treating the sewage to secondary treatment standards. The sampling also found that graywater had fecal coliform levels that met or exceeded blackwater.

The new fecal coliform and TSS standards have prompted most large ships to install advance treatment systems that meet tertiary treatment standards or to hold all of their wastewater for discharge outside of Alaska. The sampling results also show that sometimes the chlorine treatment can add hazardous by products to the wastewater. Sampling has indicated that hazardous chemicals are not being introduced into the wastewater treatment systems.

When considered in its entirety, the sampling results obtained over the last three seasons do provide a representative picture of the range and averages of pollutants in various types of cruise ship discharges. However, the sampling in 2003 will yield different results because all large ships that are discharging in Alaska have installed advanced treatment technology.

The small ships are still using chlorine for disinfection, which produces a residual that may exceed Alaska water quality standards. The products of chlorination can be hazardous. The DEC is conducting a risk screen on small vessels to determine if the pollutant concentrations are harmful to marine life.

The DEC is required by Alaska Statute to submit a report to our Governor that addresses the environmental impacts of commercial passenger vessels in Alaska by January 2004. This sampling analysis as well as the data collected in 2003 will be a vital piece in that report.

Endnotes and References

[i] Alaska Statute 46.03.460 - 490

[ii] AS 46.03.463 set graywater and blackwater effluent standards for fecal coliform at 200 colonies per 100 ml and 150 mg per liter for total suspended solids.

[iii] The Science Advisory Panel is a group of independent volunteer scientists that provides the ADEC Cruise Ship Program with scientific guidance.

[iv] The list used is from the *Compilation of the US EPA';s Water Quality Criteria for the Priority Toxic Pollutants* By Katy McKerney Sept 1997

[v] For example, the pollutant class PCB is actually comprised of seven PCBs.

[vi] Wastewater Constituents to Monitor for 2001, Science Advisory Panel, August 2001 http://www.state.ak.us/dec/press/cruise/pdf/sciencepan061501.pdf

[vii] "Title XIV – Certain Alaskan Cruise Ship Operations" of the Miscellaneous Appropriations Bill (H.R. 5666) on December 21, 2000 in the Consolidated Appropriations Act of 2001

[viii] This trend continued into the 2003 season. There are now 16 ships with advanced wastewater treatment technology.

[ix] Geometric mean from samples during a 30-day period do not exceed 20 fecal coliform /100 ml and not more than 10% of the samples exceed 40 fecal coliform /100 ml. Total residual chlorine not to exceed 10 mg/L Meet CFR 133.102 secondary treatment standards for BOD, suspended solids, and pH. Approval by the Captain of the Port than test results from at least 5 samples taken from the effluent over a 30 day period satisfy the criterion above.

[x] A type II marine sanitation device is a device that under certain test conditions produces an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter (Title 33 US Code of Federal Regulations Part 159, subpart A).

[xi] Whole Effluent Toxicity Testing, October 2002 available at http://www.state.ak.us/dec/press/cruise/documents/wetfinal.htm

[xii] http://www.state.ak.us/dec/press/cruise/documents/impact/impactwastewaternutrients.htm

[xiii] Material Safety Data Sheet for Benzoic Acid http://www.jtbaker.com/msds/englishhtml/b1356.htm

[xiv] Table 11-7 http://www.state.ak.us/dec/press/cruise/documents/impact/wastewatersampling.htm

[xv] AS 46.03.463 (c)