Royal Caribbean Cruises Ltd.
Source Reduction Evaluation
2008 Annual Report & Update

January 14, 2009

Submitted per Section 1.9.12 of the
Alaska Cruise Ship General Permit

Source Reduction Evaluation

Royal Caribbean Cruises Ltd.

Source Reduction Evaluation

Source Reduction Evaluation Overview

Purpose

In submitting the Notices of Intent for the discharge of sewage, graywater or other waste waters (as defined) under the Alaska Department of Environmental Conservation Large Commercial Passenger Vessel Wastewater Discharge Permit No. 2007DB0002 from the vessels identified in the table below, Royal Caribbean Cruises Ltd (Royal Caribbean International and Celebrity Cruises Inc.) has requested to discharge under the interim discharge limits for the identified constituents. As the Rhapsody of the Seas may be operational in time for the 2009 Alaska cruise season, we are including her in this evaluation.

2009 Update: The Rhapsody of the Seas will most likely be operational for the 2009 season, but may not discharge into Alaska State waters. However, as she has an AWP system (Navalis, see attached description) installed that in land-based operations has had very promising ammonia removal capabilities, we would like to include her in the SRE. Rhapsody of the Seas will also possibly be used to research metals removal from the effluent as well.

Vessel	Constituents Seeking Discharge Under Interim Limits	Vessel Class	Potable Water systems	AWP system
Celebrity Infinity	Ammonia, copper, nickel, zinc	Millennium	Flash Evaporators & Reverse Osmosis	Zenon
Serenade of the Seas	Ammonia, copper, zinc, nickel	Radiance	Flash Evaporators & Reverse Osmosis	Scanship
Radiance of the Seas	Ammonia, copper, zinc, nickel	Radiance	Flash Evaporators & Reverse Osmosis	Hydroxyl
Celebrity Millennium	Ammonia, copper, zinc, nickel	Millennium	Flash Evaporators & Reverse Osmosis	Hydroxyl
Rhapsody of the Seas	Ammonia, copper, zinc, nickel	Vision	Flash Evaporators	Navalis

Advanced Wastewater Purification system descriptions for the ships included can be found at **appendix 1.**

Pursuant to section 1.9.1 in the General Permit No. 2007DB0002, Royal Caribbean Cruises Ltd. submitted a Source Reduction Evaluation (SRE) to identify methods to reduce the presence of these constituents in the discharges authorized by this permit.

The goals of this Source Reduction Evaluation are to:

1. Identify the potential sources for each parameter (e.g. ammonia, copper, nickel and zinc) for which we have requested approval to discharge under the interim effluent limits.
2. Establish an action plan and timeline **(see appendix 2)** to meet the long term effluent limits.
3. Report on the success or failure of actions that are implemented to reduce pollutant loading. We will provide an annual progress report to ADEC on or about **January 14th, 2010.**

It should be recognized that this Source Reduction Evaluation plan has been developed in response to the General Permit issued March 25, 2008. As such, it is anticipated that this plan will be updated and amended as further information is gathered in the process of completing this evaluation.

2009 Update:
We will continue to evaluate all ships listed in the SRE. However, as the *Serenade of the Seas* will be the only Royal Caribbean ship of the 5 listed in this Source Reduction Evaluation that will actually discharge in Alaska State waters in 2009, we will focus much of our influent and technology evaluation on this ship. In addition, the *Rhapsody of the Seas* with a completely new type of Advanced Wastewater Purification technology (advanced ozone oxidation) and company (Navalis) likely being ready for the 2009 season, we will also focus a lot of attention and resources on determining this technology's capabilities. It is our belief that lessons learned on these two ships is exportable to the others listed. *Radiance of the Seas* is undergoing AWP process improvement work and as such has not discharged into Alaskan State waters and had no 2010 Final Effluent Limit testing done to date.

Fundamental Principles

The four contaminants of interest in this Source Reduction Evaluation are ammonia, and three metals: copper, nickel and zinc.

Contaminant	2010 Limit	Interim Limit
Ammonia	2.9 mg/L	80.49 mg/L
Copper	0.0031 mg/L	0.066 mg/L
Nickel	0.0082 mg/L	0.182 mg/L
Zinc	.081 mg/L	0.230 mg/L

Past studies of water systems onboard and recent sampling, indicates that metals contamination can come from shore (bunkered water) and shipboard potable water sources (evaporators, reverse osmosis and condensate), and the leaching from plumbing systems, such as copper or other types of steel/iron pipe.

Current metals removal technology options will most likely be effective against all three of these metals. While some technologies may perform better on one metal over the others, for the most part, a removal system for one will likely positively impact concentrations of the others.

It is widely accepted that the overwhelming majority of ammonia found in the wastewater effluent originates in human bodily wastes (both feces and urine). There is little that can be done to reduce the influent levels, thus leaving AWP process improvements or end of pipe treatment as the only real options.

Efforts under our plan will fall into one of three categories of activities:

1. Source Reduction Evaluation of inflows to determine the potential for meaningful reductions of constituents in the waste water stream, followed by possible reduction actions
2. Technology Evaluation / Implementation to identify, modify and install (as necessary) technology to reduce effluent concentrations.
3. Determining operational modifications to allow the ships to withhold all discharges while in Alaska State waters.

It should be noted that technology solutions have not yet been fully evaluated and may not yet be commercially available for application on a large cruise ship. Therefore at present, there remains much uncertainty in the evaluation and potential implementation of such technologies.

Activities under each of these categories is described further below:

<u>Influent Source Reduction Evaluation</u>

A Source Reduction Evaluation has commenced and includes:

1. Identification of cleaning or disinfecting (chlorine or chemical disinfectants) products, pesticides, or other industrial products that may be the direct or indirect source of the loading;
2. Identification of other sources such as shore-based drinking water supply or the possible introduction of contaminants through leaching or corrosion of plumbing, storage or waste handling systems;
3. Adoption of operational practices to reduce pollutant sources such as use of alternative cleaning products, potable water treatment, piping material modifications, selective source water bunkering or distillation;
4. Substitution of non-chemical methods for processes that involve chemicals.

The purpose is to identify potential sources of copper, zinc, nickel or ammonia as they may enter the waste water stream, and to investigate and implement means to reduce their presence in the influent to the Advanced Wastewater Purification (AWP) systems on board. The major phases of this evaluation are:

1. **Document influent to waste streams as potential sources**:

a. Most significant cleaning or other chemicals in terms of volume and/or concentration of constituents.

Our approved chemical list has over 1,000 products listed, however, most should never enter the gray or black water systems directly. The identification of the exact contents of the large number of chemicals that may directly or indirectly enter the waste water stream is the first step. We have conducted a survey of our cleaning products and found only two minor sources of some of the contaminants in small quantities. Some of our floor cleaners, specifically Vectra and Plaza Plus contain zinc, as zinc is commonly used in floor finishes as a cross linker. It is unlikely that the small amount of product used in relation to the amount of gray water generated could have a detectable impact, but we will evaluate options for changing our practices to prevent this from being placed into the gray water. As with the floor finishes, we have identified that our Johnson Diversey products Heavy Duty Pre-spray and Extraction Rinse carpet cleaners contain ammonium hydroxide(less than 1%) for neutralization (pH adjustment) in concentrate. These products are further diluted upon use so the percentage decreases even more. Again, the relatively small amount of this diluted product is unlikely to have even a negligible impact on contaminant levels in the gray water. As we do not control the vast number of personal care products that our guests bring on and potentially add to the gray or black water, this will likely remain an uncontrollable variable. We are working with our business partners, such as our spa provider, to identify their products that could enter the waste water stream to determine if any of these products contain any of the contaminants of interest. We use only non-toxic pest management products that are unlikely to enter the waste water stream. They are either mechanical traps or utilize bait gels that are consumed by the pests to prevent infestation of all kinds.

2009 Update: We have completed the ship surveys to determine which products could even remotely/possibly enter the gray or black water systems. We have sent out the comprehensive list (a population of 293 possible products) to all of our suppliers to have them research each one to determine if they contain any of the compounds of interest, and if so at what concentration. After we know this we can better determine actual impact based on anticipated use of the concentrate and dilution factors. As we are awaiting replies from our suppliers, we now anticipate completing the full influent product evaluation before the beginning of the 2009 Alaska season. Given the large numbers of potential products, this proved to be a more difficult task than initially thought. However, given our initial review and the unlikely possibility that any product would have a significant amount of any of the contaminants of interest, our initial thoughts are that this input is immaterial.

b. Source water evaluation.

The industry is currently conducting a bunker water sampling program that includes all ports from San Francisco to Seward and every watering point on each dock. The contract is through an Alaska based water quality sampling company and they are testing for copper, zinc and nickel. The goal is to test each water point each week and to capture at least 5 to 9 samples per site. Whenever possible, they will test during the bunkering of water by a cruise ship. The testing began in mid July 2008, and we estimate it will take at least three samples to start to get some patterns. We will provide sample results in the course of our periodic reporting. After we identify any ports with high levels of the contaminants, we will evaluate if another source should be used. If a decision is made to produce more water onboard, this will likely result in higher air emissions being generated regardless of whether Reverse Osmosis or flash evaporators are used as both consume fuel directly or indirectly.

2009 Update: The industry-initiated potable water testing program has been completed and the results can be found in the updated Appendix 3. Some patterns have emerged that we will take into consideration when planning for our potable water production and bunkering. According to the results, there are bunkering ports where the metals contained in the potable water are extremely high. Royal Caribbean will work with other industry members to determine the feasibility of having the port cities make changes to the bunker water infrastructure in those ports. The final report was published and sent to the industry on the 9th of November, 2008, which delayed our analysis.

We have surveyed our ships and have determined that they have replaced varying amounts of metallic piping with non-metallic varieties. We will also confirm that all Alaska deployed ships are currently carrying out potable water production and conditioning operations in accordance with the latest advice from our water treatment experts in our Newbuilding Technical branch.

c. **Other potential contributors**.

The unknown variables will require significant sampling and operational observation to determine whether or not there are improvements to be made from heretofore unknown products or practices. Our advanced wastewater purification systems treat all domestic waste water on the ship. We collect and treat all gray, including galley, laundry, pulper and salon, as well as all black water. Our source water is a combination of bunkered and produced potable water and a very small amount, if any, of condensate from HVAC systems. After the initial potable water and chemical input evaluations are completed and we know their contribution, we will then be better informed as to how much research will be needed regarding other contributors. As most of the ships will be in the Caribbean operating out of Florida during the 2008 - 2009 winter season, this will facilitate this evaluation. We anticipate needing approximately 3 months after the first two evaluations are completed and should finish this portion by **March 31st 2009**.

To be completed by March 31st, 2009

2009 Update: As the potable water and chemical inventory took longer than expected, we anticipate completing this by the end of June 2009.

2. **Evaluate plumbing/piping and storage systems as potential sources:**

If the previous influent evaluation and reduction actions do not result in the necessary levels being reached, we anticipate evaluating the plumbing, storage, or conveyance systems as possible sources of contaminants through leaching or corrosion of metals or coatings associated with these systems. Although we will be conducting this analysis concurrently with the above, this evaluation and possible intervention will commence in earnest **around April 2009**. What we know today is that our older vessels' potable water piping is constructed of copper (2 Alaska based ships, but only one listed above), while our newer vessels (4 ships listed above) were constructed with a combination of metallic and polybuten/plastic. In addition, in the engine spaces (most often), potable water piping is stainless with some plastic pipe sections included. These metallic types of pipes may be a source of some of the metals. We will begin the process of identifying the types and the degree of corrosion found in the piping immediately. We will also evaluate the various types of piping and identify the specific water treatment/preparation options to minimize leaching. There will also be a review of the types of maintenance that is done to eliminate or reduce piping or tank corrosion. There has already been a significant amount of metallic piping replaced with plastic pipe throughout the fleet, but it will take some time to conduct an inventory of the amount already converted. There may also be components found in the advanced wastewater purification systems that may be metal sources. We will begin to evaluate the possible contribution of any of the contaminants either in corrosion or actually in the coating systems of the various tanks used in the storage and treatment of waste water. The manufacturers and types of coatings used varies from ship class to class and is also dependent upon the normal maintenance intervals of a specific tank due to service related wear and tear. However, many of the waste water tanks have been specially coated with products designed to stand up to the rigors of waste water storage, such as Jotun Marathon 2:1 in the gray water tanks and in the treated effluent tanks. The potable water tanks on many ships have been painted with Jotun Naviguard NM. Many of these coatings are very durable epoxy systems designed to resist the aggressive nature of waste or soft water. The approximate mixing ratio of the black water and grey water is approximately from 1 : 12 or as high as 1 : 20. This should not affect the quality of the effluent with the possible exception of the amount of ammonia found in human waste. If it is found that our onboard piping systems are a major source of the pollutants, then we will have to determine the best course of action. The options available will be to try to control the corrosion through water treatment methods, replace the piping with non-metallic types, withhold discharges in Alaskan waters or focus on end of pipe metals removal technologies.

To be completed by July 31st, 2009

2009 Update:

Potable water and gray and black water system piping is being replaced as necessary. Below is a summary of the piping work done in the recent past:

Serenade of the Seas had all potable water risers changed during 2008 - approx 20% of total piping.

Radiance of the Seas has had 10% of the interior piping changed to non-metallic piping. Teams are scheduled to replace more at the end of 2009. Also, the riser pipes (from Engine spaces to Deck 10) have been replaced with non-metallic pipes. Copper piping in the hotel areas will be renewed in some areas in the near future.

Rhapsody of the Seas has had 100% of her potable water risers (cold and hot), including the recirculating lines, 60% of the lower loop cold, 40% of the lower loop hot and 40% of the lower loop recirculating lines converted to non-metallic piping.

Celebrity Millennium has replaced approximately 65% of its potable water piping with non-metallic piping. There are plans to do more during future dry dock, tools/parts have been received.

Celebrity Infinity has replaced approximately 70% of its potable water piping with non-metallic piping.

3. Identification of potential product / source water substitution or operational practices to reduce constituent concentrations or environmental loading.

Condensate water generated through the HVAC system and often used in the laundry and for other technical purposes, such as deck and window washing, is often very hard, and due to copper components, such as the heat exchanging coils, in the AC handling units, the copper content in the condensate may be high. At this time, no treatment is done to condensate water before it enters the gray water stream. This will be investigated in the near future, but given the lack or extremely limited amount of condensate generated by our ships while in Alaska, this is not expected to be a material source of any of the targeted metals. Potable water produced with evaporators or through reverse osmosis systems may contain one or all of the metal contaminants. Additives used during production are approved food grade acid for pH balancing and chlorine for disinfection. Reverse Osmosis systems will use sodium metabisulfite and cleaning chemicals, that contain no metals. The generation or treatment of potable water, specifically the mandatory use of chemical halogenation, on our ships is closely regulated by the United States Public Health Service's Vessel Sanitation Program (VSP) in the US Centers for Disease Control (CDC). On some vessels, we use a sodium silicate product to reduce corrosion in the potable water. Recently, Royal Caribbean undertook an extensive water testing and evaluation project to determine best practices. Thus, corrosion protection measures (pH balancing and chloride control) that are already in place should help reduce the amount of metals in the water. We will by the end of the 2008 cruise season determine the level of compliance with the project's proposed methods and if variations exist, will direct correction. We will also devise a testing plan to determine the effectiveness of any future modifications to current operational practices. The potable water production and bunkering amounts during a typical cruise in Alaska are below. These amounts are approximate and vary from cruise to cruise.

Vessel	**Evaporator Maker and average production (M3/day)**	**Reverse Osmosis Maker and average production (M3/day)**	**Bunker Ports and average loading (M3/week)**	**Average Condensate water production (M3/day)**
Celebrity Infinity	SERCK COMO GMGH/760m3	Desal GMBH/0m3	N/A	10-15
Serenade of the Seas	Alfa Laval/650m3	Desal/350m3	Skag 75m3 Vanc 250m3	0m3
Radiance of the Seas	Alfa Laval/600m3	Desal/400m3	Jun 133m3 Ket 504m3 Skag 411m3 Van 730m3	0m3
Celebrity Millennium	SERCK COMO GMGH/225m3	Desal GMBH/0m3	3670m3 total, amount per port varies	0m3

			weekly	
Rhapsody of the Seas	SERCK COMO /322m3	N/A	Seattle, Juneau, Skagway, Prince Rupert, average 1434 m3/week, total amount per port varies weekly	0m3

To be completed by October 31st, 2009.

2009 Update: A potable water forecast is being developed for the ships and efforts will be made to avoid those ports where the presence of the metals of interest exceed the limits in the permit. However, given the operational needs of the ship (potable water supply, voyage speed, availability in other cities, etc.), there may be instances where the ships will have to bunker public drinking water from the various Alaska city systems in spite of the level of metals that exceed the permit limits.

A forecast for potable water sourcing for 2009, is being developed by the ships, however with the installation of the diesel generators on our Gas Turbine ships, potable water production will likely change as the ships adjust to current operational conditions:

Serenade of the Seas:
Total daily consumption estimated to be 650-750m3/day.
The approximate percentage of total technical and potable water used that is generated during the Alaska Season by each of the four sources estimated to be: 1) 80% Steam/Flash Evaporators; 2) 0% Reverse Osmosis; and 3) 20% Bunkered Water.

Radiance of the Seas:
Total daily consumption estimated to be 650-750m3/day.
The approximate percentage of total technical and potable water used that is generated during the Alaska Season by each of the four sources estimated to be: 1) 65% Steam/Flash Evaporators; 2) 0% Reverse Osmosis; and 3) 35% Bunkered Water.

Rhapsody of the Seas:
The approximate percentage of total technical and potable water used that is generated during the Alaska Season by each of the four sources estimated to be: 1) 65% Steam/Flash Evaporators; 2) No Reverse Osmosis onboard; and 3) 35% Bunkered Water.

Celebrity Millennium:
The approximate percentage of total technical and potable water used that is generated during the Alaska Season by each of the four sources estimated to be: 1) 8% Steam/Flash Evaporators; 2) 2% Reverse Osmosis onboard; and 3) 90% Bunkered Water.

Celebrity Infinity:
Historically Infinity produced all of its water in during the Alaska season, however that was prior to the installation of the Diesel engine, Until the diesel operating information is captured, unable to determine actual potable water production.

Treatment Technology Evaluation

Identification of potential treatment technologies for reducing the target constituents is expected to be more complex than the initial source identification phase. Much of the information needed to select the proper system(s), in both size and type, will come from the influent source evaluation, the operational reviews described above and the progress made as evidenced by effluent sampling. While the ships were sailing in Alaska during 2008, some were sampled for the legacy standards in addition to the new General Permit limits for ammonia and the 3 metals. The results from the first year of sampling for the 4 contaminants are included in appendix 4. These results represent the capabilities of the ships before any operational or technology related interventions. During the next approximate 1.5 years, Royal Caribbean Cruises Ltd will work with our AWP system and other vendors and evaluate additional treatment technologies as may be appropriate for reducing these pollutants that are practicable for implementation in a cruise ship environment. The EPA Cruise Ship Assessment (below) identified several treatment techniques and technologies as having the potential to improve effluent quality for ammonia: biological nitrification, reverse osmosis and ion exchange. Royal Caribbean has and will continue in the future, to evaluate the potential effectiveness and practicability of these technologies. Below is an excerpt form the recent US EPA Cruise Ship Discharge Assessment Report regarding these technologies.

Excerpt from EPA Cruise Ship Assessment:

Nutrient Removal Technologies

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

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

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

All activated sludge processes, including those sampled on the cruise ships, have nitrifying bacteria present, although their numbers are much lower than the typical microorganisms that use organic carbon (measured as BOD_5*) as their food source. To enhance ammonia removal in the combined carbon oxidation and nitrification process, land-based sewage treatment plants (publicly owned treatment works (POTWs)) have made both equipment modications and operational changes. These enhancements have allowed POTWs to achieve ammonia nitrogen levels much less than one mg/L, with a corresponding increase in effluent nitrate concentration. Cruise ships would require equipment modifications and operational changes to enhance existing AWTs. Possible equipment modifications would include increased hydraulic retention time and additional aeration equipment to increase the amount of oxygen transferred to the activated sludge process. Possible operational modifications would include longer sludge retention times and optimized temperature, pH, and alkalinity control.*

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

<u>Total Nitrogen Removal by Ion Exchange</u>

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

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

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

As mentioned, Royal Caribbean is currently in discussions with several vendors and wastewater treatment experts as to which of these technologies are best suited for the marine environment and present the best chance for success.

Depending upon hydraulic retention time and levels of dissolved oxygen, some of our AWP systems have achieved varying levels of nitrification, however, it has not consistently been observed to meet the 2010 ammonia limits set in the permit. It may be possible to modify our existing systems to maximize this effect and this will be one strategy we will pursue. We have already communicated with our AWP vendors, waste water treatment experts and other treatment companies to gauge feasibility, safety, and costs of the above options. This evaluation will be made more complex due to the severe space limitations on the ships and the unknown impacts that end of pipe metals and or ammonia removal technology will have on the existing conventional pollutant treatment. For instance, if chemical precipitation (lime is a common element) is used to remove the metals, then what impact will that have on pH, and Total Suspended Solids. There are frequently other resultant waste streams generated that will have to be managed as well.

We will have more data with which to work after the piping and chemical analysis are completed. Although unlikely, it remains to be seen if the operational and piping program in and of themselves will be enough to reduce the metals in the effluents to below the limits. After our evaluation is done, **around July of 2009,** we will be better prepared to engage vendors in going beyond the current feasibility studies. The EPA Cruise Ship Assessment (excerpt below) identified two treatment technologies for consideration in the removal of metals: ion exchange and reverse osmosis. In the interim, Royal Caribbean has substantial in-house technical expertise with which to research these and any other promising technologies. This includes a large and technically diverse Newbuilding and Fleet Design department that routinely evaluates the suitability of various technologies, including potable water and wastewater treatment. Royal Caribbean also works continuously with our AWP vendors in response to a whole host of waste water topics. We will continue the dialogue with them in order to learn and research the issues related to reducing the ammonia and metals in our effluent.

In addition to recommendations on ammonia removal, the EPA Cruise Ship Assessment (below) identified several treatment technologies as having the potential to improve effluent quality for metals: ion exchange and reverse osmosis.

Excerpt from EPA Cruise Ship Discharge Assessment Report:

Metals Removal Technologies

<u>"Metals Removal by Ion Exchange</u>

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

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

Metals Removal by Reverse Osmosis

Reverse osmosis is a process in which dissolved ions would be removed from AWT effluent using pressure to force the water through a semipermeable membrane element, which would pass the water but reject most of the dissolved materials. This membrane separation process is expected to remove more than 90% of copper, nickel, zinc, and mercury from AWT effluent (FILMTEC, 1998). Reverse osmosis also would remove other metals and other analytes in cruise ship effluent, including other chlorinated solvents, phenol- and benzene-based organic compounds, and possibly pharmaceuticals and personal care products. Reverse osmosis is expected to generate a concentrate stream that is approximately 15% of the total influent flow. This concentrate stream would have to be appropriately managed, including an assessment against the RCRA hazardous waste regulations at 40 CFR 262.11 (see Section 6 for further discussion). The costs and potential environmental concerns associated with management of this waste would need to be considered as part of the assessment of this technology.

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

In addition to the theoretical options presented above, presently, Royal Caribbean is completing the plans and specifications for the *Rhapsody of the Seas* and is installing a system by a manufacturer that is new to cruise ships. The *Rhapsody of the Seas,* will receive the first shipboard system built to date. We anticipate the system being installed and beginning initial operation in early 2009. **Immediately upon successful commissioning,** we hope to have initial results of the plant's effectiveness against all relevant criteria and will know more if this system is also capable of removing the ammonia. If so, it may be possible to install a partial system on the existing ships to specifically treat the ammonia. In a land-based prototype installation, this process has shown promising results in the removal of ammonia and other nutrients through an advanced oxidation process. For ammonia and other nitrogen family compounds, advanced oxidation is an industry-accepted process for the nitrification of ammonia to nitrate, and the denitrification of nitrogen compounds (ammonia, nitrate, nitrite, etc…) to nitrogen gas. Due to the chemistry at work within the Navalis Poseidon, we feel it is potentially well suited for removal of these nutrients. Although Navalis has not extensively sampled for the wide variety of nutrients possible in cruise ship wastewater, two sampling episodes for ammonia were conducted as follows:

- 16 March 2006 – Influent 36.1 mg/l, effluent 3.6 mg/l; Reduction = 90%
- 01 March 2007 – Influent 27.8 mg/l, effluent 1.0 mg/l; Reduction = 95%

It is important to remember, that although a prototype of this technology has been used in a land-based sewage and laundry facility, it is yet unproven in a large marine/cruise ship application.

The Navalis system currently being commissioned on *Rhapsody of the Seas* has not yet been evaluated for the removal of dissolved metals. The hydraulic separation process will be marginally effective at removal of dissolved metals, but excellent at removal of suspended metals (i.e. metal oxides). The filtration step at 20-nm is actually in the nano-filtration range and will catch all but the smallest of material. A quick look at the molecular size of copper, zinc and nickel indicates that ionic forms will pass through the membrane. The wet oxidation step with ozone followed by an advanced oxidation step might have a positive effect on conversion of dissolved metals, but the exact results from this process are unknown. To assist in the removal of dissolved forms of the metals, it may be possible to adjust the pH of the influent (prior to the Hydraulic Separator to above 9.5 (with sodium hydroxide). At that pH, the dissolved metals would precipitate together with other dissolved salts into floatable and filterable solids for removal. This would require pH reduction to allowable levels after the advanced oxidation step.

We will continue to coordinate our actions with those of other cruise lines operating in Alaska and thus subject to the general permit. It is possible that pilot studies undertaken on various treatment technologies will be coordinated in order to facilitate review of as many different types of technologies as possible. We anticipate possibly beginning a pilot study of promising technologies in **the Spring of 2009** and completing the evaluation by the **end of 2009**. Based on the results of the studies, we would look to install on those ships planned to discharge in Alaska in early 2010 in time for the 2010 Alaska season.

Regarding “end of pipe” treatment solutions, Royal Caribbean has contacted wastewater treatment experts in Europe and North America as well as several manufacturers of both ionic exchange and reverse osmosis systems. At this point, reverse osmosis appears to be the most promising method of removing the metals down to the required parts per billion levels. The reverse osmosis process will however, create a reject stream that may amount to 25% of the original treated volume. This reject stream will contain the metals in an enriched form and this waste stream will also need to be managed. We are also in discussions with an Ionic Exchange vendor, however, independent experts are uncertain whether or not Ionic Exchange technology can actually achieve these extremely low levels. We look forward to any information gained from the state’s technology search workshop.

Onboard Storage of all effluent while in Alaska waters

If no suitable systems can be found, Royal Caribbean Cruises Ltd. will then plan to avoid discharging while in Alaskan waters. This option was exercised in the 2008 season with minimal itinerary impacts.

We will update this plan and report on our overall progress in the scheduled annual report approximately early January 2010’ but no later than 14 January’ **2010**.

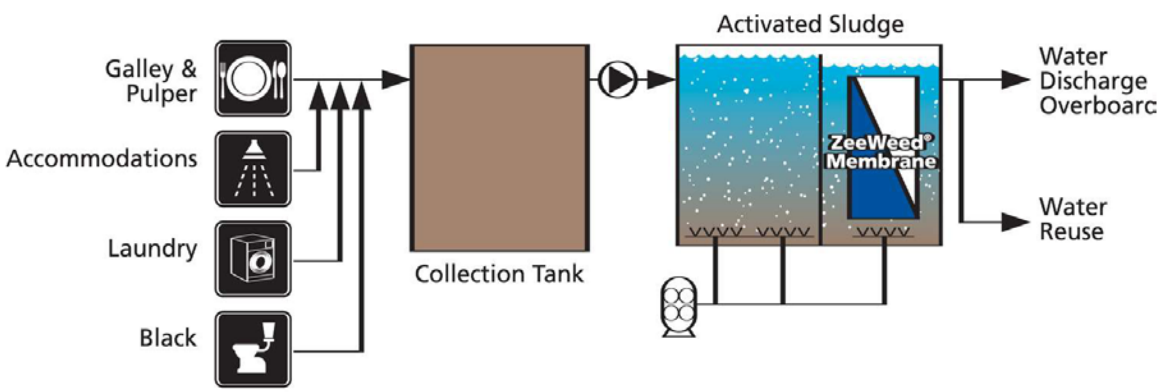
Appendix 1: Advanced Wastewater Purification System Descriptions

Celebrity Infinity

Zenon

The Zenon system uses a combination of biological treatment and membrane filtration processes:

- Coarse mechanical screens remove wastewater solids, such as plastics, before they enter the treatment system.
- Submerged within the biological reactor are filtration membrane fibers resembling spaghetti strands. The fibers create a physical barrier between the water and tiny solid materials.
- Using a very slight vacuum, the water is pulled through membranes that are so fine they even filter out most bacteria.
- In additional to the below diagram, the resulting clean water is then pumped to an ultraviolet light reactor for final disinfection. The treated effluent can then be pumped directly overboard or held in a tank for future discharge. After being held in a tank, it is again treated by the UV system to disinfect.
- The solids that remain from this entire process are pumped to a holding tank for subsequent drying and incineration, for disposal at an approved land-based facility, or at sea in accordance with international standards.



Celebrity Millennium and Radiance of the Seas

Hydroxyl

- Coarse mechanical screens remove wastewater solids, such as plastics, before they enter the treatment system.

- The biological reactor uses a fixed-film media, which looks like small plastic gears or wheels, which give beneficial bacteria a surface on which to attach themselves to aid in breaking down any solids.

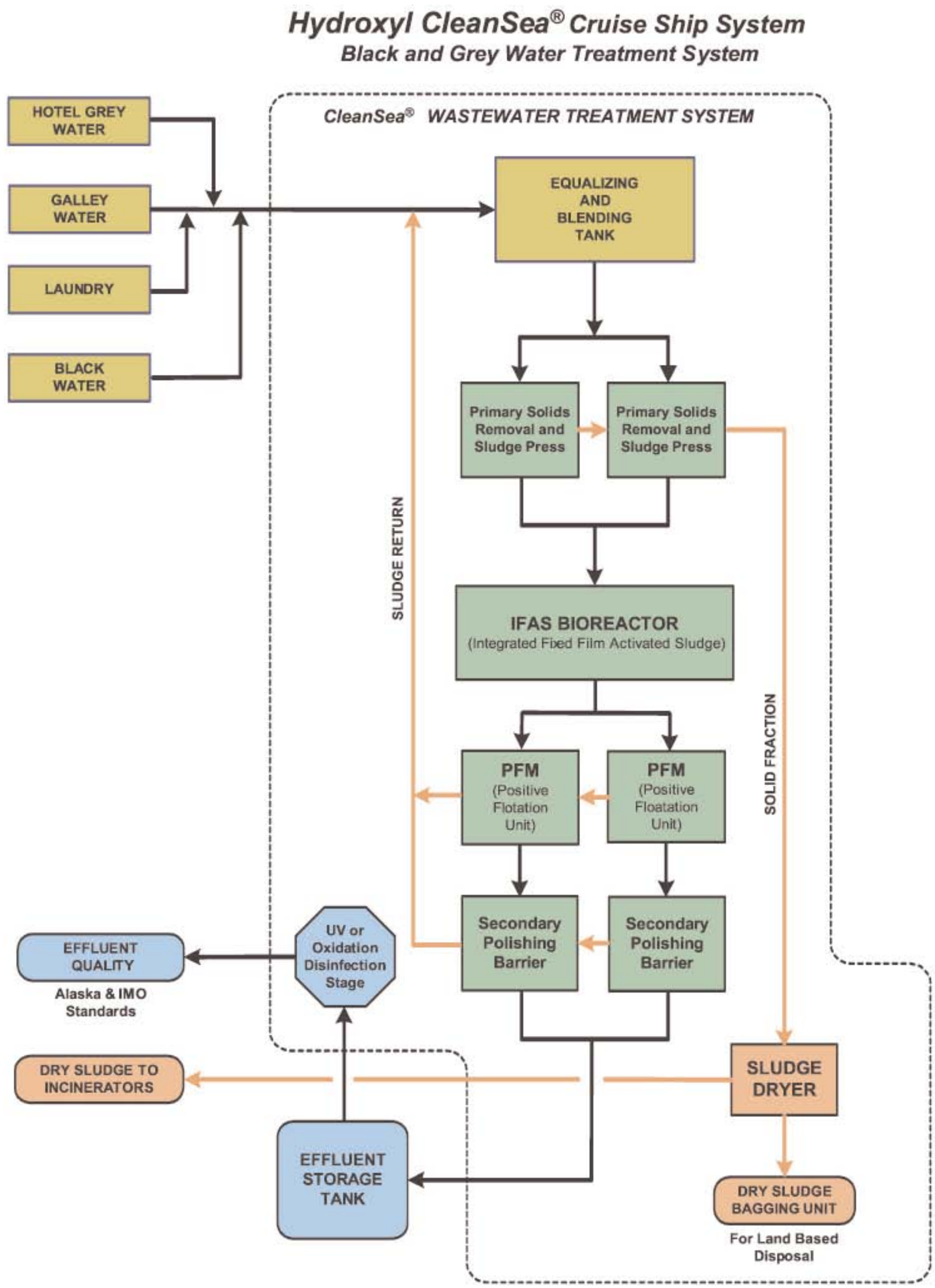
- From the biological reactor, the water and any tiny solids are pumped to machines that mechanically and chemically remove the remaining solids from the water.

- The resulting very clean water is then pumped through polishing filters.

- Next, an ultraviolet light reactor provides the final disinfection. The treated effluent can then be pumped directly overboard or held in a tank for future discharge. After being held in a tank, it is again treated by the UV system to disinfect.

-

- The solids that remain from this entire process are pumped to a holding tank for subsequent drying and incineration, disposal at an approved land-based facility, or at sea in accordance with international standards.



Hydroxyl CleanSea® Cruise Ship System
Black and Grey Water Treatment System
CleanSea® WASTEWATER TREATMENT SYSTEM
HOTEL GREY WATER
GALLEY WATER
LAUNDRY
BLACK WATER
EQUALIZING AND BLENDING TANK
Primary Solids Removal and Sludge Press
Primary Solids Removal and Sludge Press
SLUDGE RETURN
SOLID FRACTION
IFAS BIOREACTOR
(Integrated Fixed Film Activated Sludge)
PFM (Positive Flotation Unit)
PFM (Positive Floatation Unit)
Secondary Polishing Barrier
Secondary Polishing Barrier
UV or Oxidation Disinfection Stage
EFFLUENT QUALITY
Alaska & IMO Standards
DRY SLUDGE TO INCINERATORS
SLUDGE DRYER
EFFLUENT STORAGE TANK
DRY SLUDGE BAGGING UNIT
For Land Based Disposal

<u>Serenade of the Seas</u>

SCANSHIP

- Coarse mechanical screens remove wastewater solids, such as plastics, before they enter the treatment system.

- The biological reactor uses a fixed-film media, which looks like small plastic gears or wheels, which give beneficial bacteria a surface on which to attach themselves to aid in breaking down any solids.

- From the biological reactor, the water and any tiny solids are pumped to machines that mechanically and chemically remove the remaining solids from the water.

- The resulting very clean water is then pumped through polishing filters.

- Next, an ultraviolet light reactor provides the final disinfection. The treated effluent can then be pumped directly overboard or held in a tank for future discharge. After being held in a tank, it is again treated by the UV system to disinfect.

- The solids that remain from this entire process are pumped to a holding tank for either subsequent drying and incineration, disposal at an approved land-based facility or at sea discharge in accordance with international standards.

AWP SYSTEM DIAGRAMS

Rhapsody of the Seas

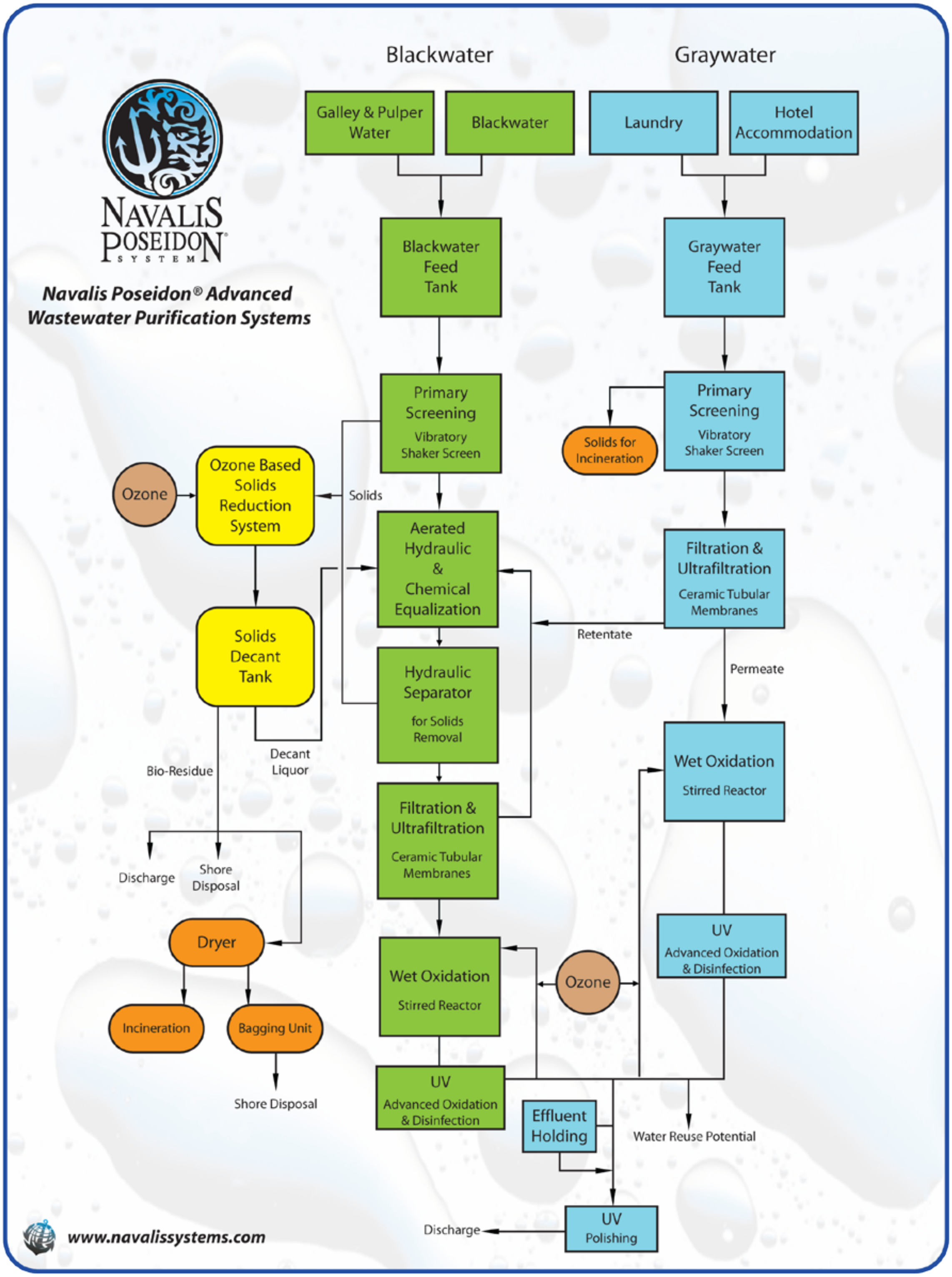
NAVALIS

The Navalis system treats the gray and black water streams separately. Navalis combines hotel accommodation and laundry water together as graywater and sewage, pulper and galley water together as blackwater.

In both treatment trains, solids are first removed from the wastewater stream. In the black water system this is accomplished through use of a plastic strainer and fine mesh-vibrating screen, followed by filtration and finally ultrafiltration with ceramic membranes. The graywater system traps plastic at the vibrating shaker screen step where the small amount of solids are bagged and disposed of by incineration.

The clarified water from the membranes (permeate) is directed to a stirred reactor where the wastewater is continuously circulated through a fluidized bed of glass coated plastic media, and a re-circulated stream containing dissolved ozone is introduced. This media provides substantial surface area for the interaction of ozone gas with dissolved impurities in the wastewater. The net result is complete oxidation of pollutants and the production of carbon dioxide gas and water. The ozonated water is next passed through a powerful ultra-violet light reactor where residual ozone is broken down into highly reactive oxygen compounds that further polish the water.

The gray water and black water systems use identical system components. Prior to discharge, the two highly oxygenated streams are combined. Prior to discharge, the treated effluent passes through an additional ultra-violet light reactor for final effluent polishing.


Blackwater
Graywater
Galley & Pulper Water
Blackwater
Laundry
Hotel Accommodation
Navalis Poseidon System
Navalis Poseidon® Advanced Wastewater Purification Systems
Blackwater Feed Tank
Graywater Feed Tank
Primary Screening
Vibratory Shaker Screen
Solids for Incineration
Primary Screening
Vibratory Shaker Screen
Ozone
Ozone Based Solids Reduction System
Solids
Aerated Hydraulic & Chemical Equalization
Filtration & Ultrafiltration
Ceramic Tubular Membranes
Retentate
Solids Decant Tank
Hydraulic Separator
for Solids Removal
Permeate
Decant Liquor
Bio-Residue
Wet Oxidation
Stirred Reactor
Filtration & Ultrafiltration
Ceramic Tubular Membranes
Discharge
Shore Disposal
Dryer
UV
Advanced Oxidation & Disinfection
Wet Oxidation
Stirred Reactor
Ozone
Incineration
Bagging Unit
Shore Disposal
UV
Advanced Oxidation & Disinfection
Effluent Holding
Water Reuse Potential
UV Polishing
Discharge
www.navalissystems.com

Appendix 2 Timeline:

Event	**Approximate Date**
Begin Influent Source Reduction Evaluation	July 2008
Begin initial Treatment Technology Evaluation	July 2008
Complete documenting chemicals in influent to waste streams as potential sources	**March 2009**
Complete sampling of Source Potable Water (bunkered)	**November 2008**
Begin initial operational testing of new AWP system with potential to reduce ammonia	**January 2009**
Annual progress report to ADEC	**January 2009**
Complete evaluation of other potential contributors including technical water	**May 2009**
Obtain initial sample results from new AWP system that has potential to reduce ammonia	Early to Mid 2009
Begin evaluating the impact of plumbing/piping systems on pollutant levels (if necessary)	April 2009
Focus on most promising Treatment Technologies	July 2009
Complete the evaluation of the impact of plumbing/piping systems on pollutant levels (if necessary)	31 July 2009
Identify potential product, source water or operational practices substitutes (if necessary)	August 2009
Begin pilot study of promising technology(ies)	Fall 2009
Complete the identification of potential product, source water or operational practices substitutes (if necessary)	31 October 2009
Complete treatment technology evaluation	End of 2009
Annual progress report to ADEC	January 2010
Install treatment technology on those ships planned to discharge in Alaska.	April 2010

Admiralty ENVIRONMENTAL 431 N.Franklin St., Suite 101 Juneau, AK 99801 (907) 463-4415 (480) 247-4476 (fax)

Mr. John Binkley
Alaska Cruise Association
360 K Street, Suite 300
Anchorage, AK 99501

November 7, 2008

<u>Bunker Water Metals Investigation</u>

Summary

Samples of water from dockside potable water connections at various ports of call of ACA member cruise ships were collected between July 16, 2008 and September 18, 2008 for the analysis of dissolved copper, dissolved nickel, and dissolved zinc in order to identify potential sources of these trace metals in water bunkered by the ships. A text summary of limit compliances and exceedances of the compliance levels in the ADEC General Cruise Ship Permit can be found below for each port sampled, organized alphabetically. A synopsis of the analytical results of the 162 total sampling events in this project is attached to this cover letter. Results that are in excess of the 2010 ADEC general cruise ship wastewater discharge permit regulatory limits (3.1 ug/L for dissolved copper, 8.2 ug/L for dissolved nickel, and 81 ug/L for dissolved zinc) are shown in bold. Please note that the regulatory limits in the ADEC cruise ship wastewater permit are significantly lower than drinking water regulatory limits for the State of Alaska, and this data should not be evaluated in the context of human safety for drinking water consumption. For each sampling event, the sample port was flushed for several minutes prior to collection and clean sampling techniques were used. Samples were filtered after collection using trace clean 0.45 micron filters and stored in bottles preserved with trace metal grade nitric acid in preparation for analysis. All sampling and sample handling procedures were conducted in accordance with the NWCA 2008 Operating Season Quality Assurance/Quality Control Plan For Sampling and Analysis of Treated Sewage and Graywater From Commercial Passenger Vessels (QA/QCP), dated January 4, 2008. An overview of the results from each individual port is as follows. Haines, Alaska there was only one sample obtained for the Haines Dock during the study. Results for that sample were below the ADEC 2010 regulatory limits for all three dissolved metals of interest. Juneau, Alaska At all three Juneau docks, tested nickel levels were consistently below the ADEC 2010 limit of 8.2 ug/L. Dissolved zinc was consistently below the 2010

limit of 81 ug/L at the AJ and South Franklin docks, while two of the eight analyses of Steamship dock bunker water yielded notably high levels of dissolved zinc (362 and 680 ug/L). This may have been a result of less flushing prior to sampling, as samples taken from this dock were always taken from the same valve (#6), and did not ever have a ship bunkering directly from the valve sampled. One of the elevated samples (07/21/08) was the first sample taken during the season, and the valve was not allowed to flush for an extended period of time at that sampling event. Dissolved copper levels were consistently above the 2010 limit of 3.1 ug/L at all three Juneau docks, with one or two exceptions for each dock on differing sample days. Ketchikan, Alaska Water samples at three of the four Ketchikan berths (#1, #2, and #3) were consistently below regulatory limits for all three dissolved metals analyzed, with the exception of one above-limit value for dissolved copper (3.21 ug/L) at Berth #1. Berth #4 was consistently below the limit for dissolved zinc. However, four of nine samples from Berth #4 had values that were above the 2010 limit for dissolved copper and three of nine were above the limit for dissolved zinc. San Francisco, California In San Francisco, samples were obtained from two different docks. Pier 35 was sampled five times, and had dissolved nickel levels that were consistently below the ADEC 2010 limit. Dissolved copper levels were above the regulatory limit for two of the five samples taken, and dissolved zinc was above the 2010 limit for all samples obtained. The two samples taken from Pier 36 were both below the regulatory limits for all three dissolved metals analyzed. Seattle, Washington In Seattle, all three docks sampled were consistently below the 2010 limit for dissolved nickel. Pier 66 was also below the limit for dissolved zinc each time it was sampled, but had dissolved copper levels above the regulatory limit for 100% of the sampling events. Conversely, Pier 30 2125R had only one of eight sampling events with a dissolved copper level above the 2010 limit, while that dock had dissolved zinc levels above the limit for three out of eight sampling events. Pier 30 1850R had dissolved zinc levels consistently above the ADEC 2010 limit, with the exception of one out of eight sampling events falling below the limit for zinc. Seward, Alaska Samples taken from the Seward Dock had dissolved nickel and dissolved zinc levels below the ADEC 2010 limits for all sampling events. Dissolved copper was above the 2010 limit for half of the sampling events, with a maximum value of 9.5 ug/L. Skagway, Alaska In Skagway, the Broadway and Ore Station docks consistently had dissolved nickel and dissolved zinc levels below the 2010 limits, with the exception of one elevated zinc value at the Ore Station dock. Dissolved copper at these two docks was also relatively low, with only two and one value during the testing period above the ADEC limit for the Broadway and Ore Station docks, respectively. The Railway Dock had dissolved copper and dissolved nickel levels above the 2010 limits for every sampling event. However, dissolved zinc levels at that dock were below the 2010 limits for five of the eight sampling events. Vancouver, British Columbia Sampling in Vancouver involved a variety of sampling points at two separate piers, therefore data from each pier were grouped together. At the Ballentyne pier, dissolved copper was above the 2010 limit for four of the five sampling events, and dissolved nickel and zinc were both below the 2010 limits for all sampling events. At the Canada Place pier, dissolved copper was above the 2010 limit for 17 of the 22 sampling events, dissolved nickel was consistently below the limit, and dissolved zinc was above the 2010 limit for only two of the 22 sampling events. Victoria, British Columbia Results for the three docks sampled in Victoria were consistent with each other, and revealed dissolved copper levels above the 2010 limit for each sampling event. Values were below the 2010 limits for both dissolved nickel and dissolved zinc at all three docks. Whittier, Alaska All eight samples taken at the dock in Whittier were below the ADEC 2010 limits for all three dissolved metals measured. Wrangell, Alaska There was only one sample obtained for the Wrangell Dock. That sample had a dissolved copper value above the 2010 limit, while dissolved nickel and dissolved zinc were both below regulatory limits. In summary, the following conclusions may be drawn: • Dissolved copper, is consistently found in several shore side water sources at levels above the ADEC 2010 limit; • Several samples had dissolved zinc levels notably higher than the 2010 ADEC permit limits. Based on the data shown here, the high dissolved zinc values observed in some of the samples may have been a result of too little flushing out of the line prior to sampling. If this is the case, then a ship bunkering water from sources with high zinc may take on an initially large amount of zinc, but those levels would become diluted as the volume of water taken on increased. However, there is a notable discrepancy in zinc levels between the Seattle docks sampled, and this may need further investigation. • Dissolved nickel levels were below the regulatory limit for 2010 at all docks sampled, with the exception of the Skagway Railway Dock, which had dissolved nickel levels over the ADEC 2010 limit each time it was sampled. • It is likely that the levels of dissolved metals measured at these dock locations is directly related to the age, composition, and condition of the metal piping material in the shoreside supply lines, as well as natural levels of dissolved metals in the source water. • Dissolved metals levels in water eventually discharged as wastewater by the cruise ships may therefore be affected by their specific sources of bunkered potable water. A tabular summary of each dock location is included below. Complete reports of the final lab results for each sampling event are available upon request.

Kindest Regards,

David Wetzel
Admiralty Environmental

Port of Haines

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
HAINES DOCK	Wed	17-Sep	2.1	<1	5.9	Volendam

Port of Juneau

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Juneau AJ Dock	Mon	21-Jul	**58.4**	0.771	26.8	Oosterdam
Juneau AJ Dock	Mon	28-Jul	**75.4**	0.8	47.3	Oosterdam
Juneau AJ Dock	Mon	4-Aug	**93.2**	0.811	53.3	Oosterdam
Juneau AJ Dock	Mon	11-Aug	**120**	0.21	55	Oosterdam
Juneau AJ Dock	Mon	18-Aug	**100**	0.51	35	Oosterdam
Juneau AJ Dock	Tue	26-Aug	1.8	<1	8.1	Norwegian Star
Juneau AJ Dock	Thu	4-Sep	**34**	<1	28	Serenade of Seas
Juneau AJ Dock	Thu	11-Sep	**33**	<1	15	Serenade of Seas
JNU AK Steamship Dock	Mon	21-Jul	**8.8**	1.88	**362**	Statendam
JNU AK Steamship Dock	Mon	28-Jul	1.23	0.683	71.9	Statendam
JNU AK Steamship Dock	Mon	4-Aug	**17.1**	0.891	14.7	Statendam
JNU AK Steamship Dock	Mon	11-Aug	**24**	0.61	41	Statendam
JNU AK Steamship Dock	Mon	18-Aug	**7.5**	0.14	20	Statendam
JNU AK Steamship Dock	Tue	26-Aug	**3.7**	<1	13	Celebrity Infinity
JNU AK Steamship Dock	Thu	4-Sep	**34**	1.2	75	Celebrity Mercury
JNU AK Steamship Dock	Thu	11-Sep	**89**	<1	**680**	Zaandam
Juneau S. Franklin Dock	Mon	21-Jul	**1.51**	0.753	4.83	Golden Princess
Juneau S. Franklin Dock	Mon	28-Jul	**58.1**	1.61	31	Golden Princess
Juneau S. Franklin Dock	Mon	4-Aug	**95.2**	2.61	55.7	Golden Princess
Juneau S. Franklin Dock	Mon	11-Aug	2.3	0.46	13	Golden Princess
Juneau S. Franklin Dock	Mon	18-Aug	**280**	2.9	77	Golden Princess
Juneau S. Franklin Dock	Tue	26-Aug	**20**	<1	32	Sapphire Princess
Juneau S. Franklin Dock	Thu	4-Sep	**62**	1.5	28	Coral Princess
Juneau S. Franklin Dock	Thu	11-Sep	**85**	<1	28	Island Princess

Port of Ketchikan

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Ketchikan Dock Berth#1	Fri	25-Jul	0.953	0.152	3.98	Westerdam
Ketchikan Dock Berth#1	Fri	1-Aug	**3.21**	<0.15	3.74	Westerdam
Ketchikan Dock Berth#1	Thu	7-Aug	0.22	0.21	6.5	Golden Princess
Ketchikan Dock Berth#1	Fri	15-Aug	1.3	0.73	17	Sun Princess
Ketchikan Dock Berth#2	Fri	18-Jul	2.46	<0.1	3.2	Carnival Spirit
Ketchikan Dock Berth#2	Thu	21-Aug	0.73	<1	4.0	Statendam
Ketchikan Dock Berth#2	Fri	29-Aug	<1	<1	3.4	Carnival Spirit
Ketchikan Dock Berth#2	Thu	4-Sep	1.4	<1	7.7	Statendam
Ketchikan Dock Berth#2	Fri	12-Sep	1.3	<1	<1	Westerdam
Ketchikan Dock Berth#3	Fri	18-Jul	1.42	<0.5	<5.0	Norwegian Pearl
Ketchikan Dock Berth#3	Fri	25-Jul	2.97	0.151	11.5	Norwegian Pearl
Ketchikan Dock Berth#3	Fri	1-Aug	0.845	<0.15	6.12	Norwegian Pearl
Ketchikan Dock Berth#3	Thu	7-Aug	<1	0.16	5.6	Oosterdam
Ketchikan Dock Berth#3	Fri	15-Aug	0.72	0.25	8.9	Norwegian Pearl
Ketchikan Dock Berth#3	Thu	21-Aug	0.88	<1	9.5	Oosterdam
Ketchikan Dock Berth#3	Fri	29-Aug	1.3	<1	16	Norwegian Pearl
Ketchikan Dock Berth#3	Thu	4-Sep	1.7	<1	13	Oosterdam
Ketchikan Dock Berth#3	Fri	12-Sep	2.2	<1	14	Norwegian Pearl
Ketchikan Dock Berth#4	Fri	18-Jul	**5.87**	0.307	**538**	Zaandam
Ketchikan Dock Berth#4	Fri	25-Jul	2.48	0.535	**1340**	Silver Shadow
Ketchikan Dock Berth#4	Fri	1-Aug	0.376	<0.15	3.96	Zaandam
Ketchikan Dock Berth#4	Thu	7-Aug	<1	0.11	4.7	Sapphire Princess
Ketchikan Dock Berth#4	Fri	15-Aug	1.3	0.22	9.7	Westerdam
Ketchikan Dock Berth#4	Thu	21-Aug	**9.1**	0.14	19	Sapphire Princess
Ketchikan Dock Berth#4	Fri	29-Aug	2.2	<1	10	Zaandam
Ketchikan Dock Berth#4	Thu	4-Sep	**6.7**	<1	**3300**	Sapphire Princess
Ketchikan Dock Berth#4	Fri	12-Sep	**3.4**	<1	3.8	No ship bunkering

Port of San Francisco

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
San Francisco Pier 35	Wed	13-Aug	0.74	<0.5	**770**	No ship bunkering
San Francisco Pier 35	Thu	21-Aug	0.85	<1	**1800**	No ship bunkering
San Francisco Pier 35	Tue	26-Aug	**3.4**	<0.5	**250**	No ship bunkering
San Francisco Pier 35	Fri	5-Sep	**3.6**	<0.5	**210**	No ship bunkering
San Francisco Pier 35	Thu	11-Sep	1.8	<1	**1600**	No ship bunkering
San Francisco Pier 36	Wed	16-Jul	0.83	<0.5	<5.0	Dawn Princess
San Francisco Pier 36	Tue	5-Aug	<0.5	<0.5	<5.0	Dawn Princess

Port of Seattle

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Seattle Pier 30 1850R	Wed	16-Jul	**3.9**	2	**710**	No ship bunkering
Seattle Pier 30 1850R	Thu	7-Aug	2.8	<1	**1100**	No ship bunkering
Seattle Pier 30 1850R	Thu	14-Aug	<2	<1	**820**	No ship bunkering
Seattle Pier 30 1850R	Thu	21-Aug	2.5	<1	**830**	No ship bunkering
Seattle Pier 30 1850R	Thu	28-Aug	<2.0	<1.0	**890**	No ship bunkering
Seattle Pier 30 1850R	Thu	4-Sep	2.3	<1	**1500**	No ship bunkering
Seattle Pier 30 1850R	Fri	12-Sep	<2	<1	**590**	No ship bunkering
Seattle Pier 30 1850R	Thu	18-Sep	2.5	<1	56	No ship bunkering
Seattle Pier 30 2125R	Wed	16-Jul	**14**	1.5	**630**	No ship bunkering
Seattle Pier 30 2125R	Thu	7-Aug	<2	<1	<20	No ship bunkering
Seattle Pier 30 2125R	Thu	14-Aug	<2	<1	**120**	No ship bunkering
Seattle Pier 30 2125R	Thu	21-Aug	<2	<1	33	No ship bunkering
Seattle Pier 30 2125R	Thu	28-Aug	2.0	<1	21	No ship bunkering
Seattle Pier 30 2125R	Thu	4-Sep	<2	<1	**140**	No ship bunkering
Seattle Pier 30 2125R	Fri	12-Sep	<2	<1	27	No ship bunkering
Seattle Pier 30 2125R	Thu	18-Sep	2.0	<1	21	No ship bunkering
Seattle Pier 66	Wed	16-Jul	**52**	1.7	<20	No ship bunkering
Seattle Pier 66	Thu	7-Aug	**17**	<1	<20	No ship bunkering
Seattle Pier 66	Thu	14-Aug	**14**	<1	<20	No ship bunkering
Seattle Pier 66	Thu	21-Aug	**10**	<1	<20	No ship bunkering
Seattle Pier 66	Thu	28-Aug	**12**	<1	<20	No ship bunkering
Seattle Pier 66	Thu	4-Sep	**10**	<1	<20	No ship bunkering
Seattle Pier 66	Thu	18-Sep	**7.1**	<1	<20	No ship bunkering

Port of Seward

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Seward Dock	Fri	25-Jul	2.54	1.15	8.71	Radiance of Seas
Seward Dock	Wed	30-Jul	0.904	1.46	6.91	SevenSeas Mariner
Seward Dock	Thu	7-Aug	2.0	<1	3.3	No ship bunkering
Seward Dock	Fri	15-Aug	**9.5**	0.26	6.1	Veendam
Seward Dock	Thu	21-Aug	**9.5**	0.42	9.8	No ship bunkering
Seward Dock	Thu	28-Aug	2.5	<1	11	Tahitian Princess
Seward Dock	Thu	4-Sep	**6.4**	<1	9.5	No ship bunkering
Seward Dock	Thu	11-Sep	**7.1**	<1	29	Tahitian Princess

Port of Skagway

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Skagway Broadway Dock	Thu	17-Jul	**6.75**	5.57	38.7	Volendam
Skagway Broadway Dock	Thu	24-Jul	0.531	0.65	4.93	Zaandam
Skagway Broadway Dock	Wed	6-Aug	1.37	0.645	4.92	Norwegian Pearl
Skagway Broadway Dock	Thu	14-Aug	**3.9**	1.3	9.5	Volendam
Skagway Broadway Dock	Tue	19-Aug	0.92	0.96	7.2	Statendam
Skagway Broadway Dock	Tue	26-Aug	1.0	<1	8.1	Statendam
Skagway Broadway Dock	Tue	2-Sep	2.9	1.8	15	Statendam
Skagway Broadway Dock	Thu	9-Sep	1.3	5.2	9.1	Statendam
Skagway Ore Station Dock	Thu	17-Jul	**3.88**	2.23	39.8	Norwegian Sun
Skagway Ore Station Dock	Thu	24-Jul	0.618	0.732	4.82	Norwegian Sun
Skagway Ore Station Dock	Wed	6-Aug	0.459	0.791	4.54	Norwegian Star
Skagway Ore Station Dock	Thu	14-Aug	1.3	0.68	17	Norwegian Sun
Skagway Ore Station Dock	Tue	19-Aug	1.1	0.95	**140**	Radiance of Seas
Skagway Ore Station Dock	Tue	26-Aug	2.3	2.2	13	Millennium of Seas
Skagway Ore Station Dock	Tue	2-Sep	1.3	4.6	10	Radiance of Seas
Skagway Ore Station Dock	Thu	9-Sep	1.4	5.4	4.6	Millennium of Seas
Skagway Railway Dock	Thu	17-Jul	**5.68**	**12.7**	**84.6**	Coral/Star Princess
Skagway Railway Dock	Thu	24-Jul	**5.2**	**8.11**	27.9	Islnd/Star Princess
Skagway Railway Dock	Wed	6-Aug	**5.55**	**8.63**	74	Diamond Princess
Skagway Railway Dock	Thu	14-Aug	**150**	**470**	**500**	Coral/Star Princess
Skagway Railway Dock	Tue	19-Aug	**8.4**	**12**	29	Sapph/Golden Pr.
Skagway Railway Dock	Tue	26-Aug	**20**	**22**	54	Goldn/Diamond Pr.
Skagway Railway Dock	Tue	2-Sep	**32**	**46**	**89**	Sapph/Golden Pr.
Skagway Railway Dock	Thu	9-Sep	**19**	**39**	69	Goldn/Diamond Pr.

Port of Vancouver

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
100M Ballentyne East	Thu	21-Aug	2.0	<1.0	<5	No ship bunkering
100M Ballentyne East	Thu	28-Aug	7.0	<1.0	5.0	No ship bunkering
170M Ballentyne East	Thu	21-Aug	5.0	<1.0	6.0	No ship bunkering
250M Ballentyne East	Fri	5-Sep	4.0	<1.0	5.0	Millennium of Seas
250M Ballentyne East	Fri	12-Sep	7.0	<1.0	18	Radiance of Seas
Canada Place East	Thu	21-Aug	28	<1.0	35	No ship bunkering
Canada Place East	Wed	27-Aug	110	<1.0	<5	Carnival Spirit
Canada Place East	Fri	5-Sep	2.0	<1.0	<5	No ship bunkering
Canada Place East	Fri	12-Sep	120	<1.0	18	No ship bunkering
Canada Place E. (Central)	Thu	24-Jul	15	<0.2	280	No ship bunkering
Canada Place E. (Central)	Tue	29-Jul	3.1	0.2	13	No ship bunkering
Canada Place E. (Central)	Tue	5-Aug	31	<1.0	29	No ship bunkering
Canada Place E. (Central)	Tue	12-Aug	9.0	<1.0	16	No ship bunkering
Canada Place East (North)	Thu	24-Jul	1.5	<0.2	9.0	No ship bunkering
Canada Place East (North)	Tue	29-Jul	6.4	<0.2	5.0	No ship bunkering
Canada Place East (North)	Tue	5-Aug	3.0	<1.0	7.0	No ship bunkering
Canada Place East (North)	Tue	12-Aug	9.0	<1.0	13	No ship bunkering
Canada Place East (South)	Thu	24-Jul	7.8	<0.2	6.0	No ship bunkering
Canada Place East (South)	Tue	29-Jul	13	0.2	2.0	No ship bunkering
Canada Place East (South)	Tue	5-Aug	33	<1.0	22	No ship bunkering
Canada Place East (South)	Tue	12-Aug	9.0	<1.0	14	No ship bunkering
Canada Place North	Thu	21-Aug	3.0	<1.0	<5	No ship bunkering
Canada Place West	Thu	21-Aug	12	<1.0	<5	No ship bunkering
Canada Place West	Wed	27-Aug	4.0	<1.0	12	Ryndam
Canada Place West	Fri	5-Sep	11	<1.0	<5	Silver Shadow
Canada Place West	Fri	5-Sep	2.0	<1.0	17	Veendam
Canada Place West	Fri	12-Sep	16	<1.0	270	No ship bunkering

Port of Victoria

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Ogden Point Pier A South	Tue	26-Aug	7.0	<1	<5	No ship bunkering
Ogden Point Pier A South	Tue	2-Sep	4.0	<1	<5	No bunkering
Ogden Point Pier A South	Tue	9-Sep	5.7	<5	<10	No ship bunkering
Ogden Point Pier A South	Tue	16-Sep	3.7	<1	6	No ship bunkering
Ogden Point Pier B North	Tue	26-Aug	7.0	<1	16	No ship bunkering
Ogden Point Pier B North	Tue	2-Sep	5.0	<1	9.0	No ship bunkering
Ogden Point Pier B North	Tue	9-Sep	5.9	<5	<10	No ship bunkering
Ogden Point Pier B North	Tue	16-Sep	3.4	<1	18	No ship bunkering
Ogden Point Pier B South	Tue	26-Aug	4.0	<1	<5	No ship bunkering
Ogden Point Pier B South	Tue	2-Sep	4.0	<1	<5	No ship bunkering
Ogden Point Pier B South	Tue	9-Sep	4.3	<5	<10	No ship bunkering
Ogden Point Pier B South	Tue	16-Sep	3.4	<1	2	No ship bunkering

Port of Whittier

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Whittier Dock	Thu	24-Jul	1.3	0.345	17.5	No ship bunkering
Whittier Dock	Thu	31-Jul	1.76	0.309	25.2	No ship bunkering
Whittier Dock	Thu	7-Aug	2.3	<1	17	No ship bunkering
Whittier Dock	Thu	14-Aug	2.3	0.27	23	No ship bunkering
Whittier Dock	Thu	21-Aug	1.4	<1	14	No ship bunkering
Whittier Dock	Mon	25-Aug	2.8	<1	18	Coral Princess
Whittier Dock	Wed	8-Sep	1.2	<1	<1	Coral Princess
Whittier Dock	Thu	11-Sep	1.2	<1	7.6	Carnival Spirit

Port of Wrangell

Sampling Location	Day	Date	Dissolved Copper ug/L	Dissolved Nickel ug/L	Dissolved Zinc ug/L	Ship Bunkering
Wrangell Dock	Sun	7-Sep	11	4.4	31	Silver Shadow

Appendix 4. 2008 Wastewater Effluent Sampling Results

Celebrity Cruises Inc. ships

Celebrity Infinity

Date	cBOD (mg/L)	TSS (mg/L)	pH -	Cl (free) (mg/L)	Cl (Total) (mg/L)	Fecal Coliform Col. or MPN/100mL	Ammonia (mg/L)	Dissolved Metals: Copper (mg/L)	Dissolved Metals: Nickel (mg/L)	Dissolved Metals: Zinc (mg/L)	Port	Comments
	Tested Parameters (red = exceedance)											
Permit 7-day	< 40	< 45	6.5 to 8.5	-	< 0.1	< 43	< 80.4	< 0.066	< 0.180	< 0.230		ADEC next year: NH3-2.9 Cu-0.0031 Ni-0.0031 Zn-0.0081
Permit 30-day	< 25	< 30				< 14						
23-May-08	38	5	7.4	0.1	< 0.1	500	67	0.025	0.040	0.117	SEA	
30-May-08	30	21	7.2	0.1	< 0.1	30	100	0.025	0.040	0.170	SEA	
6-Jun-08	32	8	7.4	0.1	< 0.1	300	74	0.025	0.040	0.880	SEA	
24-Jun-08	< 3	44	7	-	0.16	47.9	40	0.015	0.021	0.251	JNU	Juneau Sampling
8-Jul-08	3.7	4	6.8	-	0.02	21	64	0.074	0.026	0.090	JNU	Begins
22-Jul-08	2.5	< 4	7	-	< 0.1	7.04	49	0.051	0.030	0.342	JNU	
16-Sep-08	< 2	< 4	7.4		< 0.1	6.8	48	0.083	0.025	0.325	JNU	
27-Sep-08	< 3	< 4	7.2		< 0.1	16.9	37	0.089	0.025	0.431	JNU	

Celebrity Millennium

Date	BOD (mg/L)	TSS (mg/L)	pH -	Cl (Total) (mg/L)	Fecal Coliform Col. or MPN/100mL	Ammonia (mg/L)	Dissolved Metals: Copper (mg/L)	Dissolved Metals: Nickel (mg/L)	Dissolved Metals: Zinc (mg/L)	Port	Comments
	Tested Parameters (red = exceedance)										
Permit 7-day	< 40	< 45	6.5 to 8.5	< 0.1	< 43	< 80.4	< 0.066	< 0.180	< 0.230		ADEC next year: NH3-2.9 Cu-0.0031 Ni-0.0031 Zn-0.0081
Permit 30-day	< 25	< 30			< 14						
11-Jun-08	< 10	4	7.2	< 0.1	12	-	-	-	-		
12-Jun-08	< 10	10	6.8	< 0.1	< 1	-	-	-	-		
13-Jun-08	< 10	18	6.7	< 0.1	< 2	-	-	-	-		
	< 10	20	6.7	< 0.1	4	18	0.022	0.011	0.100		
14-Jun-08	2	10	7.3	< 0.1	< 1	48	0.006	0.063	0.013		Initial USGC test
	2	12	7.2	< 0.1	< 1	48	0.007	0.058	0.014		
15-Jun-08	3	12	7	< 0.1	< 1	33	0.011	0.074	0.015		
	9	13	7	< 0.1	< 1	35	0.013	0.083	0.015		
16-Jun-08	< 3	6	7	< 0.1	< 1.4	43	0.005	0.057	0.015		
	2	6	7.1	< 0.1	< 1.4	42	0.006	0.061	0.016		
30-Jun-08	2.8	13	6.8	0.03	< 1	7	0.017	0.015	0.084	JNU	Juneau Sampling
14-Jul-08	6.9	24	7.5	0.05	390	6.4	0.011	0.031	0.067	JNU	Begins
28-Jul-08	3.7	23	7.5	< 0.1	210	4.5	0.002	0.016	0.065	JNU	
28-Jul-08	3.4	25	7.5	< 0.1	100	4.6	0.002	0.014	0.061	JNU	
11-Aug-08	6	9	7.4	< 0.1	4.29	25	0.006	0.021	0.094	JNU	
25-Aug-08	4.1	14	7.3	< 0.1	19.7	22	0.010	0.016	0.091	JNU	
8-Sep-08	6.7	14	7.3	< 0.1	1740	6	0.004	0.019	0.082	JNU	
26-Sep-08	4.6	18	6.4	< 0.1	77	9	0.030	0.020	0.134	JNU	
27-Nov-08	84	24	7	< 0.1	8					WLG	

Royal Caribbean International ships

RCL Serenade of the Seas

Date	cBOD (mg/L)	TSS (mg/L)	pH -	Cl (free) (mg/L)	Cl (Total) (mg/L)	Fecal Coliform Col. or MPN/100mL	Ammonia (mg/L)	Dissolved Metals: Copper (mg/L)	Dissolved Metals: Nickel (mg/L)	Dissolved Metals: Zinc (mg/L)	Port	Comments
Permit 7-day	< 40	< 45	6.5 to 8.5	-	< 0.1	< 43	< 80.4	< 0.066	< 0.180	< 0.230		**ADEC next year:** NH3-2.9 Cu-0.0031 Ni-0.0031 Zn-0.0081
Permit 30-day	< 25	< 30				< 14						
12-Apr-08	42	13	7.17	< 0.01	0.04	11					SJU	
24-May-08	24	3	6.51	< 0.1	< 0.1	< 1	5.04	0.002	0.012	0.096	YVR	
31-May-08	< 10	4	5.86	< 0.1	< 0.1	< 1	0.19	0.010	0.010	0.067	YVR	
7-Jun-08	< 10	< 3	6.19	< 0.1	< 0.1	< 1	0.21	0.005	0.012	0.081	YVR	
14-Jun-08	29	21	6.44	< 0.1	< 0.1	7	14	0.005	0.023	0.093	YVR	
26-Jun-08	15	< 4	6.9	-	< 0.1	18	9.2	0.005	0.023	0.051	JNU	Juneau Sampling
10-Jul-08	13	13	6.8	-	< 0.1	21000	13	0.006	0.015	0.088	JNU	Begins
17-Jul-08	3.4	4	7	-	< 0.1	1.41	6.4	0.006	0.014	0.101	JNU	
7-Aug-08	3.2	6	6.6	-	< 0.1	8.45	11	0.004	0.019	0.071	JNU	
14-Aug-08	< 2	6	6.8	-	< 0.1	< 2	12	0.005	0.013	0.073	JNU	
11-Sep-08	4.9	5	6.7		< 0.1	1.41	2.4	0.002	0.011	0.079	JNU	
18-Sep-08	7.5	12	6.8		< 0.1	1	16	0.003	0.012	0.054	JNU	
8-Nov-08	14	9	7.05	0.03	< 0.01	< 2					SJU	
15-Nov-08	6	< 5	7.16	< 0.01	< 0.01	2					SJU	
22-Nov-08	31	27	7.2	< 0.01	0.03	30					SJU	

Tested Parameters (red = exceedance)

Radiance of the Seas due to system modifications and ongoing improvements has had no Final Effluent Limit testing done to date.

Rhapsody of the Seas has a newly installed Advanced Wastewater Purification system and as such has had no Final Effluent Limit testing done to date.