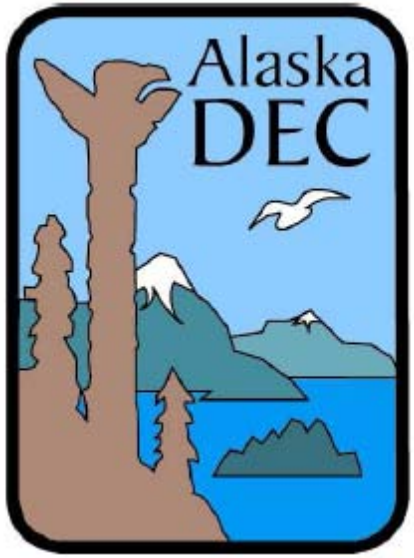


Alaska Cruise Ship Wastewater Science Advisory Panel

Vendor Information Inquiry Responses

Distributed at the 09/21-23/11 SAP Meeting

Vendor	Preliminary Email Date	Date of Response	Responder	Date Specs Sent (Email & FedEx)	Date Report Received
Evac Zodiac Kubota	5/25/2011	6/26/2011	Jari Jokela	6/2/2011	9/14/2011*
Gertsen and Olufsen AS	5/25/2011	6/6/2011	Jakob Olsson	6/2/2011	8/8/2011**
Hamworthy Water Systems, Ltd.	5/26/2011	5/28/2011	Dr. Wei Chen	6/2/2011	7/1/2011**
RWO GmbH Marine Water Technology	5/26/2011	6/7/2011	Martyn Ayris	6/2/2011	6/28/2011***
Headworks USA	5/26/2011	6/2/2011	Jack Gardiner	6/2/2011	
			Graeme Dempster	6/8/2011	Pending
Lenntech BV	5/26/2011	5/27/2011	Andrea Tancredi	N/A	N/A
Oy WatMan Ab	5/26/2011	6/27/2011	Juha Lintujärvi	6/2/2011	N/A
Scanship	5/26/2011	5/30/2011	Bettina Nowak	6/2/2011	N/A

Color Codes:
Information Received
Information Pending
No Interest/No Information Provided

*No AWTS specifications or cost data; no ammonia removal technology; metals removal testing description and cost estimate only
**AWTS specifications only; no cost data; no metals or ammonia removal technology
***AWTS specifications and cost data only; no metals or ammonia removal technology

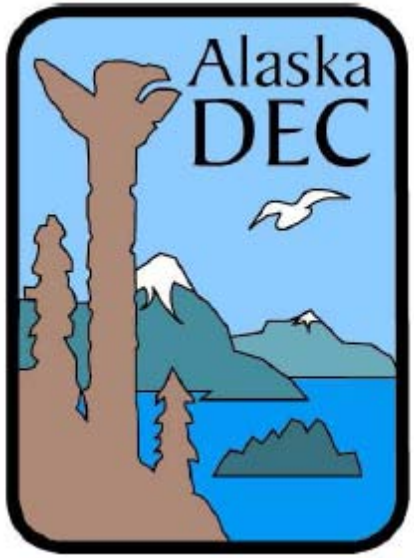
Overview of Information Received

	AWTS Technical Specification	AWTS Cost Data	Ammonia Removal	Metals Removal
Evac Zodiac Kubota				X
Gertsen and Olufsen AS	X			
Hamworthy Water Systems, Ltd.	X			
RWO GmbH Marine Water Technology	X	X		

Last updated: 09/20/11

Vendor	Follow-ups / Notes
Evac Zodiac Kubota	06/26/11 email from Mr. Jokela indicated metals testing ongoing; would send report when concluded.
Gertsen and Olufsen AS	07/1/11 email from Mr. Olsson indicated a reply would be available at end of July.
Hamworthy Water Systems, Lt	06/25/11 email from Dr. Chen indicated no commercial information forthcoming.
RWO GmbH Marine Water Tec	Report received from Pekka Pohjanen.
Headworks USA	ADEC was referred to Victoria, B.C. office contact, Graeme Dempster. 08/19/11 email from Mr. Dempster indicated report would be sent following week; not yet received.
Lenntech BV	N/A - Not involved in any kind of waste water treatment.
Oy WatMan Ab	06/27/11 email from Mr. Lintujärvi indicated they have nothing readily available.
Scanship	06/10/11 phone call from Peter Randall - stated Scanship can't help unless State of Alaska buying a unit.

Last updated: 09/20/11



Alaska Technology Project
2009 Alaska Cruise Ship Wastewater Science Advisory Panel

Technology Information Request

Project Background:

The specification descriptions and technical information requested in this document were developed by members of the 2009 Alaska Cruise Ship Wastewater Science Advisory Panel (SAP.) The waste water technology referred to in this document is for use on board of sea-going large cruise vessels, and is intended to treat sewage, gray water, black water (organic waste), ammonia, and dissolved metals, specifically Copper, Nickel, and Zinc (Cu, Ni, and Zn).

Section 1 of this document includes an outline of the effluent limits for each pollutant/parameter of interest. Section 2 includes the estimated volumes and pollutant concentrations before treatment. We are aware that the available technology may not be a "seamless match" with all the specification requirements below; if that is the case please feel free to provide your alternatives and other possibilities.

Section 1. General Description

The Project objective is to obtain technical and budget costs quotations for the following waste water treatment options:

A: **Complete wastewater treatment processing (AWP) without removal of ammonia or dissolved metals.**
WW treatment system for treatment of pollutants listed in Table A, below, but not including ammonia or dissolved metals. If ammonia removal is already integrated into your technology to the levels as set out in this Section, please identify.

B: **Complete wastewater treatment processing (AWP) including removal of ammonia.**
WW treatment system for treatment of pollutants listed in Table A, below, including ammonia. If ammonia removal is already integrated into your technology to the levels as set out in this Section, please identify.

C: **Complete wastewater treatment process (AWP) including removal of both ammonia and dissolved metals.**
Please identify which technologies could be used for the removal of dissolved metals and ammonia to comply with the limits outlined in Table A. If ammonia and dissolved metals removal are already integrated into your technology to the levels as set out in this Section, please identify.

D: **AWP Effluent polishing unit for Ammonia.** This unit would be an Add-on control on an existing installation (after initial WW treatment.)

E: **AWP Effluent polishing unit for Dissolved Metals**. This unit would be an Add-on control on an existing installation (after initial WW treatment.)

If combinations of the above technologies are possible, please include those options.

Please note: If your company has experience installing AWP processes onboard Cruise Ships, we would also like to receive a retrofit installation budget cost estimate for the quoted options.

The system should be designed for a capacity of **3500 people** (Pax and Crew) and is able to treat the complete volume of wastewater per day incl. specified peak loads. This wastewater consists of:

- Black water
- Gray water from accommodation
- Laundry waste water
- Galley waste water
- Pulper/food waste water

Please note: When quoting complete AWP processes, please quote processes including all water streams.

The proposed system(s) should meet Alaska water quality regulations under normal operation conditions. This will give the following quality of treated waste water (effluent), which should be met by your proposed technology:

Table A.

Parameter	Limits	Daily Max. Limits (if applicable)
TSS	< 150 mg/L	
BOD5	< 30 mg/L monthly average	<60mg/L daily max.
Fecal coliforms	< 14FC average /100 mL	<43FC/100 mL daily max.
Total residual Chlorine	< 0,0075 mg/L	
pH	6.5 - 9.0	
Ammonia	< 1 mg/L	
Dissolved Copper	< 3.1 µg/L	
Dissolved Nickel	< 8.2 µg/L	
Dissolved Zinc	< 81 µg/L	

Section 2. Water specifications for AWP

The project requires that two different influent water criteria be used for the optional treatment processes outlined in Section 1.

- When providing technology and budget cost quotes that include complete AWP processes (**options A, B or C**), please base your technology budget cost quotations on the **AWP influent** water criteria described in Section 2(a).
- When providing quotes for AWP effluent polishing units (**options D and/or E**), please base your technology budget cost quotations on the **AWP effluent** criteria described in Section 2b.

Both the AWP influent data as well as the AWP effluent data is based on data collected from various U.S. EPA and Alaska DEC shipboard sampling, as well as data presented to the SAP by various parties.

Section 2(a). Water specification for complete AWP processing (AWP influent)

Hydraulic loading: 855 m^3/day

Please note: Despite waste water onboard has sufficient holding and mixing capacities, the treatment process need to be sized to handle 1.5 times the average hydraulic loading

Peak hour hydraulic loading 55 m^3/h

Organic loading:	BOD	1166 mg/l
	COD	1915 mg/l
	TSS	755 mg/l
Ammonia	NH4-N	60mg/l
Heavy metals	Copper	300 µg/l
	Nickel	30 µg/l
	Zinc	300 µg/l

Please note: Influent water concentrations vary slightly by ship, day, sailing location etc.
Concentrations differences are caused by:

- *Source water (made on board, how, bunkering location, pH)*
- *Piping materials (CuNiFer, AISI316L, Copper, Galv. steel, plastic etc.)*
- *Chemicals used onboard (Laundry, pipe cleaning, galley super chlorination etc.)*
- *Daily variations of waste water mixing ratios*
- *Ship schedule etc.*

The waste water influent concentrations and the peak loading are assumed to take care of the variations. You are free to use safety factors on your processes based on your own expertise. Please include the maximum potential value the system can treat.

2(b). Water specification for Ammonia and Dissolved Metals polishing processes (AWP Effluent)

Most of the existing cruise ships operating in Alaskan waters already have an advanced waste water treatment plant (AWP) installed onboard based on a biological treatment process step and either membrane or DAF separation of solids and biomass. The polishing unit "influent" water specification is based on data received from the AWP unit effluents.

Hydraulic loading: 855 m^3/day

Please note: Despite waste water onboard has sufficient holding and mixing capacities, the treatment process needs to be sized to handle 1.5 times the average hydraulic loading.

Peak hour hydraulic loading 55 m^3/h

Organic loading:	BOD	< 10 mg/l
	COD	< 50 mg/l
	TSS	< 10 mg/l
Ammonia	NH4-N	30mg/l (limit < 1 mg/l)
Heavy metals	Copper	10 µg/l (limit <3,1 µg/l)
	Nickel	15 µg/l (limit < 8,2 µg/l)
	Zinc	100 µg/l (limit < 81 µg/l)

Section 3. Budget Cost and Proposal Information

All budget costs quotations should be quoted ex works factory. Please provide an estimated delivery time.

Please note: Any retrofit installation costs estimates should include material, freight, installation, crew travel, and other expenses. If not all elements are known or "rough estimates" are included, please identify.

Preferably, we would like your response to include the following technical information:

- Short description and diagram of each process step and operation of the whole process
- % reduction of contaminants per process steps with estimated total performance data (e.g., are additional chemicals or reagents used?)
- Sludge generated. Please specify the sludge quantity and dryness. Are there other process by-products?
- Wet and Dry Weights (kg) of system
- Dimensions length x width x height (m)
- The minimum size opening (width x height (m)) through which the equipment could be transported for retrofit applications
- Power requirements (voltage (volts), frequency (Hz), power (kWe)). Specify kWe used per m3 waste water treated (Electrical equipment to be IP54)
- Compressed air requirements (if applicable) including quantity (nm3/hr), pressure (bar).
- Estimated heat dissipation, smell or noise which will be accrue during normal process conditions
- Any shipboard environmental limitations regarding vibration, humidity, etc.
- Material specifications of key components
- Start up, stand by and stop procedures and time needed. Please provide information can the system be started and stopped only when needed or is the process designed only for continuous operation (continuous use / intermittent operations.)
- Description of the operation of the system including details about control and monitoring
- Description of redundancy requirements
- Estimates of initial starting up and commissioning of the proposed process, including crew training
- List of technology / latest references

For the Life Cycle estimated Budget Costs please estimate:

- The maintenance required and frequency of that maintenance for 5 year operation
- Spare part consumption for 5 year operation
- Consumption of chemicals etc. and the cost of these consumables for 5 year operation with approximate costs of chemicals, consumables and spare parts

Performance Verification:
Please provide a performance assessment, calculation or test results that demonstrate as to whether or not the system as designed would comply with this specification.

Liability Clause:
The issuance of these specifications and the receipt of information in response to this document will not cause the SAP to incur any liability or obligation to the Vendor, financial or otherwise.

Use and Disclosure of Information
The SAP reserves the right to use information submitted by you or on your behalf in response to this technology request in any manner we may deem appropriate in evaluating the Products and/or Services proposed. This may include sharing the proposal information with contracted third party consultants under a non-disclosure agreement with us and our professional advisors. However, proposals submitted by the Vendor will be considered confidential. Additional glossy brochures, samples and product/service information submitted by the Vendor that are considered confidential must be clearly marked as such. In the event that confidentiality cannot or will not be afforded, the Vendor will be notified and will be permitted to withdraw the proposal and the information will be returned.

The fact that this technology request has been issued and the information contained in within is confidential and proprietary to the SAP. Vendor agrees to treat all the information contained in this request as confidential. The information is to be used by Vendor only for preparing a proposal in response to this request. The information in this technology request may not be used for any other purpose or, subject to requirements of applicable law, shared with any other parties without first obtaining our prior written consent. If the Vendor needs to disclose any provided information to a third party in order to prepare the proposal, please contact the Project Manager (Section 5.)

Section 4. Requested enclosures

- Process & Instrumentation (P&I) Diagram. Please provide a complete P&I Diagram for the proposed waste water treatment process step. The diagram should be made in accordance with the requirements of DIN/ISO standards.

- Please provide a preliminary General Arrangement (floor plan) drawing of the proposed waste water treatment process, including main dimensions and required service space.

- Any data sheets with relevant information regarding the proposed system are welcomed.

Section 5. Contact Information. Please direct responses and questions to:

Melissa Goldstein, Project Manager
Alaska Department of Environmental Conservation
Commercial Passenger Vessel Compliance Program
Technology Project / Science Advisory Panel
410 Willoughby Ave., Ste. 303
Juneau, Alaska 99801

Tel: 907-465-5278
FAX: 907-465-5274

Email: melissa.goldstein@alaska.gov

EVAC ZODIAC KUBOTA

Request specification Reference: Letter Alaska Technology Project 2009 Alaska Cruise Ship Wastewater Science Advisory Panel Attachment: *"SAP Technology Information Request 06/06/11" 7 (seven) pages (including front page).*

Spec reference	*"SAP Technology Information Request 06/06/11" 7 (seven) pages (including front page).*
Sent by	ADEC CPVEC / PM
Originated	SAP Vendor List
Vendor Manufacturer	Evac Zodiac Kubota
Date Spec sent	6/2/11
Response date [first]	9/14/11
Other Responses	Yes / E-mail Zodiac /ADEC 9 15 11 11:32 PM <RE: Alaska Technology Project-Information attached> Included Attachment 2011-09-02-00743 JPG [photo of test bench]. E-mail Zodiac / ADEC 9 16 11 12:30 PM <RE: Alaska Technology Project-Information attached> Included Attachment Evac Metal removal unit [Revised "Heavy Metal removal From wastewater Process Removal Proposal"]

Overview Review Notes ADEC CPVEC:

Description of response documents provided by Vendor / Manufacturer:

E-mail Jari Jokela (Evac) / Melissa Goldstein (ADEC CPVEC) dated: 9/14/2011 10:41 AM <AW: Alaska Technology Project- Information attached> Attachments:

- Technical Description and cost estimate document Revised version "Heavy Metal Removal from Wastewater Process Proposal" State of Alaska Department of Environmental Conservation Division of Water Cruise Ship Program. EVAC AWP system description Metal Removal Unit Rev. C01 dated 15 09 2011 Jari Jokela; total of 6 (six) pages. Revised version 9 16 11 Attachment E-mail 9 16 11, hand marked coversheet.
- E-mail Zodiac /ADEC 9 15 11 11:32 PM <RE: Alaska Technology Project-Information attached> Included Attachment 2011-09-02-00743 JPG [photo of test / test bench].

- E-mail Zodiac / ADEC 9 16 11 12:30 PM <RE: Alaska Technology Project-Information attached> Included Attachment Evac Metal removal unit [Revised "Heavy Metal removal From wastewater Process Removal Proposal"]

Note: Copies of E-mail correspondence and related Attachments are included in Appendix A of this overview.

Response Summary:

Item	Status	Comments
Reviewed by ADEC CPVEC	Yes	Metals removal study report.
AWTS technology included	No	
Performance data included	Yes	Performance tests conducted on metals removal system in a laboratory setting.
Metals and ammonia control technology included	Yes, metals only.	Laboratory setting only.
Additional information provided by Vendor	No	

Performance Data:

EVAC provided performance data for their proposed metal removal system in the form of laboratory study results. Figure 1 is a photograph of the laboratory testing set-up.

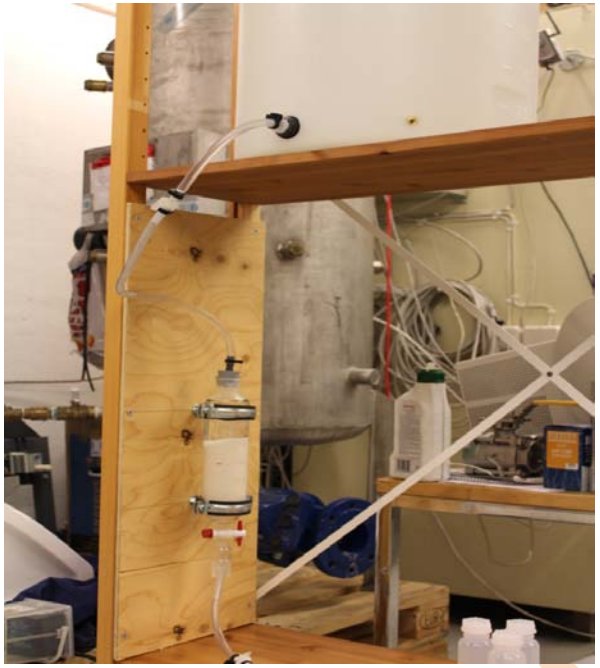


Figure 1. Laboratory set-up used for testing of EVAC's proposed metal removal system.

Influent for the test runs was a matrix of metals in de-ionized water. Test results are listed in Table 1. Testing of the metal removal system using matrices of metals in permeate from a small (16 person) membrane bioreactor is ongoing.

Table 1. EVAC Metals Removal Laboratory Study – Performance Data

Parameter	Spec / ADEC Limits	Inlet Load[2]	EVAC			Meet Spec. Limits?
Total daily Flow	855 m3/day		855 m3/day[1]			
			Sample 1	Sample 2	Sample 3	
Dis. Cu	< 3.1 µg/L	560 µg/L	8 µg/L	6 µg/L	<5 µg/L	No
Dis. Ni	< 8.2 µg/L	86 µg/L	<5 µg/L	<5 µg/L	<5 µg/L	Yes
Dis. Zn	< 81 µg/L	620 µg/L	<20 µg/L	<20 µg/L	<20 µg/L	Yes

Notes:

1) Study was conducted on a small-scale, using low volumes.
2) Laboratory influent concentration of metal solution.

Technology:

The metal removal system as proposed by EVAC is based on selective ion exchange technology. The system does not include rotating parts.

General Process Description and Scope:

The documentation includes a brief description of the resin containers, bioreactors, and piping arrangements.

Cleaning Operations:

The units are equipped with automatic valve arrangements for by-pass and cleaning operations.

Cost Elements

Equipment Costs & Installation-related Costs:

EVAC included in their response budget prices for select equipment items. These costs could be categorized as "onetime costs," and are related to the equipment itself and the installation of the equipment. EVAC's budget quote included:

- 2011 Costs for the Vessel and piping
- 2011 Costs for the 5,500 liter resin
- Automation system
- EVAC did not identify costs associated with start up, commissioning, and equipment training. Delivery conditions and location were not identified.
- The estimated annual cost for resin replacement was provided.

Initial supply and 1 year operational cost quotes provided by EVAC for the proposed metals removal technology are presented in Table 2. EVAC provided the costs in Euros (€) only; Table 2 includes an exchange rate to convert the Euro (€) to U.S. Dollars ($). EVAC mentioned that pH, metal concentrations, and organic matter, among other factors, would potentially affect the metal removal system performance. The requested removal limit for ammonia (1.0 mg/L) and related technology (AWTS) was NOT included. Table 2 also includes a preliminary estimate for the total metals treatment cost per m3 wastewater for one year. These estimated costs are based on an AWTS installation that meets the effluent performance requirements.

Table 2. EVAC Initial Supply and Annual Operational Costs for Metals Removal Unit

System Components Included	Cost Euros (€)	Cost U.S. Dollars ($)[1]
Vessels and piping		
Automation		
Resin - 5,500 liters		
Price Quotation	**375,000 – 425,000**	**513,750 – 582,250**
Estimated Annual Resin Replacement Cost	105,000 - 140,000	143,850 – 191,800

Based on SAP Specifications:		
Treated WW volume	855 m^3/day	312075 m^3/yr
	Cost Euros (€)	**Cost U.S. Dollars ($)[1]**
EVAC Total Cost (metal removal) per treated m^3 WW for 1 year period[2]	0.45	0.62

[1]Exchange Rate used: 1 Euro = 1.37 U.S. Dollar (rate as of 09/19/11)

[2]The highest annual cost (based on price range provided by EVAC) was used to generate estimates.

Costs related to Operations / Consumables:

EVAC included some operational and consumable costs in the response. The costs appear to be based on year-round service and equipment parts life cycles. Labor supervision costs are not provided. Consumable costs are those items that are needed to support the process. Please note these costs are only for the AWTS effluent treatment for metals removal.

EVAC Vendor View Points:

EVAC did not provide any additional information regarding dissolved metals removal technology. However, EVAC did include some "uncertainty" items that could affect the performance of the system, especially when existing parameters are not considered for specific AWTS system (vessel) operations.

The metals removal performance study was conducted in a laboratory setting; therefore the Vendor identified that the results of the study could be affected by:

- Organic matter effects of the influent (polisher) on the polisher removal rate.
- Role of changing pH and metal precipitation.
- This results are obtained from scale laboratory setting, real world performances (residual concentrations) not known.
- Possible uncertainties when used in ship board application.

Conclusions / Engineer's Views:

EVAC took the time and effort to respond to the SAP specification with a budget quotation for a metal removal system, including budget costs. EVAC also took the time and effort to conduct laboratory tests. It appears that the laboratory testing is at the time of this writing not yet concluded. EVAC's response included the statement that the test results with ion exchange technology is promising, and provides useful information.

<u>A few notes for consideration:</u>

It should be noted that the EVAC scope and quoted costs did not include the ammonia reduction technology as requested in the SAP specification. Nor were AWTS system scope and costs included.

EVAC's laboratory testing results indicate that dissolved metal removal is possible using ion-exchange technology. EVAC provided sizing of the reactor vessels including the arrangements. Possible use of multiple vessels in different arrangements can reduce the overall installation dimensions.

Lifetime of the resin is dependent on the operations and the "metal load." Lastly, the information provided by EVAC (metal removal study results and budget costs) should be viewed in context with the requested SAP specifications.

RWO GmbH MARINE WATER TECHNOLOGY

Request specification Reference: Letter Alaska Technology Project 2009 Alaska Cruise Ship Wastewater Science Advisory Panel Attachment: *"SAP Technology Information Request 06/06/11" 7 (seven) pages (including front page).*

Spec reference	*"SAP Technology Information Request 06/06/11" 7 (seven) pages (including front page).*
Sent by	ADEC CPVEC / PM
Originated	SAP Vendor List
Vendor Manufacturer	RWO Veolia Water
Date Spec sent	6/2/11
Response date [first]	6/28/11
Other Responses	Yes / E-mail RWO ADEC 8/18/11 11:58PM Response on Ammonia effluent performance.

Overview Review Notes ADEC CPVEC:

Description of response documents provided by Vendor:

E-mail Pekka Pohjanen (RWO/Veolia Water) / Melissa Goldstein (ADEC CPVEC) dated: 6/28/2011 4:02 AM <AW: Alaska Technology Project-Status Inquiry> Attachments:

- Budget offer ADEC_Memrod3500.pdf
- AWP Sketch.pdf
- RWO-PP-Operational cost over 10 years-Rev.C.pdf
- RWO_AC_Condensate_2011.pdf
- RWO_Memrod 2010.pdf

Note: Copies of E-mail correspondence and related Attachments are included in Appendix A of this overview.

Response Summary:

Item	Status	Comments
Reviewed by ADEC CPVEC	Yes	See notes/review of effluent performance.
AWTS technology included	Yes	For standard pollutants (IMO.)
Performance data included	Yes, except no description of RWO achievable limits of dissolved metals and ammonia.	Memrod technology not designed for dissolved metal or ammonia removal.
Metals and ammonia control technology included	Not included in Budget Quotation for AWTS. Identified for removing Cu from technical water - RWO "AccuRem Technology."	Scope focused on Murkowski / IMO installation.
Additional information provided by Vendor	Included in ADEC review.	See "Vendor View Points" section of this review, pg. 10.

Vendor Response Elements:

The Vendor included in their response a budget quotation for an AWTS system based on membrane technology. The response did not include options for the removal/reduction of dissolved metals. RWO did provide up to date information. Please note that a RWO Veolia AWTS system for Graywater treatment was installed in 2011 on the vessel Westerdam. This installation has no metal treatment option. RWO included estimated wastewater volumes for treatment.

Performance Data:

The Vendor stated that when the AWTS plant is operated according to design requirements (flows, etc.) and the plant's operating manual, the requested ADEC discharge limits can be met (Table 1.) It should be noted that for meeting the ADEC discharge limit, RWO included a 30-day geometric mean "requirement" for ammonia. RWO confirmed on 8/19/11 that the ammonia limit of < 1

mg/L is too stringent, and that Memrod technology can meet a fixed limit of ammonia of 3 mg/L (correspondence attached.) Metals removal technology was not included in the RWO response.

Table 1. RWO AWTS Memrod Technology – Performance Data

RWO Veolia Water Memrod system Performance based on Spec requirements.			
Parameter	Spec / ADEC Limits	RWO Veolia Water Memrod	Meet Spec Limits
Total daily Flow	855 m3/day	855 m3/day[1]	Yes
TSS	<150 mg/L	< 150 mg/L	Yes
BOD_5	< 30 mg/L month avg. < 60 mg/L daily max.	< 30 mg/l month avg. < 60 mg/L daily max.	Yes
FC	<14FC avg. / 100 mL < 43 FC / 100 mL daily max.	<14FC avg. / 100 mL < 43 FC / 100 mL daily max.[2]	Yes
Total residual Cl	< 0,0075 mg/L	Not applicable[3]	Yes
pH	6.5 – 9.0	6.5 – 9.0	Yes
Ammonia	< 1 mg/L	< 1 mg/L 30 day geometric mean	No[4]
Dis. Cu	< 3.1 µg/L	Reduction technology not included. Reduction technology for TW (technical water) included (description only; no cost information provided.)	
Dis. Ni	< 8.2 µg/L		
Dis. Zn	< 81 µg/L		

Notes:

1) Peak hydraulic load not clearly identified in response.
2) Only when UV after treatment system is utilized.
3) Not applicable - Memrod process does not use chlorine for disinfection.
4) Ammonia discharge limit compliance (State of Alaska DEC) is not developed by 30 day geometric mean. E-mail of 8/19/11 (RWO/ADEC) documents guarantee by GWO that a fixed ammonia limit of 3 mg/L is acceptable for the Memrod technology.

Technology:

RWO Selected the Memrod system for the treatment options. Memrod stands for Membrane Reactor Operation Device. This process is based on the well established Membrane Bio Reactor (MBR) technology.

RWO identified that Memrod is proven technology, and has very low energy needs of about 3 kWhr per m^3 wastewater treated, or 1 kWhr per passenger per day. RWO did not identify the energy consumption in relation to the technical scope. The core of the process is membrane filtration. The membrane surface provides a barrier separating clean effluent water from the solid material. The membranes are arranged in flat sheet modules, which are submerged in sludge. The clean permeate is extracted under slight pressure. RWO provided detailed descriptions and illustrations of the process; these are included in the Appendices of this review. The identified technology is capable of removing the "standard waste water pollutants" but not dissolved metals.

General Process Description and Scope:

The RWO response included optional components for the waste water treatment system. In particular tanks, inter-piping and associated fittings, wiring, tie-in to existing on board systems, etc. were addressed. These items were assumed to already be onboard the vessel and were to be integrated with the new system. A summary of the RWO Memrod process elements in relation to the proposed scope are listed in Table 2.

Table 2. RWO Memrod Process and Scope

Treatment phase / Functional Description	Necessary Process Requirements not included in RWO scope	Costs provided
1. Wastewater collection: GW laundry screening / GW galley food oil grease separator / BW screening tank	Construction of tanks / inter piping / pumps not included in scope. Screening not included. RWO recommends collecting GW and BW in holding tanks / equalizer tank to control peak loads (ammonia). From there the BW is fed to the AWTS system. Surplus surge tankage, screening, surplus sludge removal not included.	No

2. Pre-cleaning: GW galley food treated by two separators, each with capacity of 50% flow.	Included in scope as optional.	Yes / Optional
3. Screening Unit: GW BW pre-cleaned GW Galley by two drum screen units. Each 100% capacity.	The scope is based on the idea that screening units can convey the solids / residues straight to a sludge tank. Sludge tank not included.	Yes / Units only / Optional
4. Bioreactor: GW BW process function activates microbial degradation. Also serves as equalization tank. Tank size 400 m3 (gross) operating level 80%. Storage buffer of approx. 50 m3 peak flow. Two chamber design; 50% treatment of design flow. Sundries Air distribution/injection, three system blowers, oxygen sensors, de-foaming system /controls. The preferred height of the bioreactor (tank) is 5.0 m.	The scope is not entirely clear. It appears the main process items are included. Not included are the vessel engineering, fabrication, erection, coating and testing of the Bioreactor tank(s). Sludge pumps, fittings, drains, etc. not included. Interface of aeration system / anti-foam system in tank not identified. Installation of supplied parts to be done by vessel. Inter- tank piping and pumps appear to not be included. Figure 4 of the RWO response provides a 3-D diagram of the bio reactor.	Yes / bioreactor tank parts not tank itself / Optional
5. Membrane Filtration: Filtration process placed in the Membrane tank. Tank is two chamber design. Tank size is 150 m3 (gross 0.40 membrane modules are installed in the two chambers, with 60% capacity design flow. Suction lines per chamber and 3 self-priming pumps for permeate draw. Aeration system located under the	The scope is not entirely clear. It appears the main process items are included. Not included are the design, fabrication, erection, coating and testing of the Membrane tank. Sludge pumps, fittings, drains, etc. not included. Interface of aeration system in tank not identified. Inter-tank piping and controls appear not to be included. Figure 5 of the RWO response provides a 3-D diagram of the Membrane bio reactor with the flat sheet membrane modules.	Yes / membrane tank parts not tank itself / Optional

membrane packs, with two blowers. Waste water pump stations. The preferred height of the membrane (tank) is 4.7 m. Hoisting gear / maintenance gear included.		
6. Electrical / Measuring Control: Instrumentation according to the RWO metering point list. Control panels for two trains. Instrumentation according to Class / approval certificates. Controls by integrated touch panel / process panels. Error messages recording. Connection IMCS available for one common alarm.	Measuring Instrumentation devices, inter-wiring interface not included. Installation control panels, mounting hardware not included.	Yes / in parts sections / Optional
7. Operations/ Cleaning in Place: Sections of the membranes are cleaned semi-automatically.	System scope (CIP) is not detailed. Tank for solution make up is provided. Inter piping / wiring and connections to the tanks and installation appears to not be included.	Yes / in part sections / Optional
8. Sludge Treatment Unit: Excess sludge form membrane tank, screening, food waste reject water in sludge tank. Excess water from this tank to BW tanks. Gross Volume 100 m3.	Tanks not included in scope. Vessel tank to be used. Inter-piping / wiring controls not include in scope.	No
9. UV disinfection Unit: Unit needs to be used to meet the effluent performance (Table 1.)	Included as Optional Cost	Yes / Optional

RWO provided information on how the Memrod Process elements could be laid out for onboard use. The following AWTS system layouts were suggested:

- Integrated / Consolidated Bioreactor tank and Membrane tank. This is according to RWO the most economical way of arranging the process tank. The bioreactor and membrane reactor are placed in the same tank (divided into two chambers) and internal recirculation pumps are replaced by overflow lines between the chambers. This arrangement is successfully utilized in the Alaska trade for other AWTS systems. An advantage of this arrangement is a more compact, space-efficient installation (*i.e.*, smaller footprint.)
- Separate Bioreactor tank and Membrane tank. Bioreactor and membrane tanks are separate and not consolidated. According to RWO this arrangement would potentially require re-circulation pumps and tanks of different sizes.

Cleaning Operations:

RWO included instructions for cleaning the membranes periodically - usually 3 times a year. The cleaning solution is prepared in a standalone tank. This tank is included in the scope provided. The cleaning solution is hydrogen peroxide (HP) (500 ppm) or citric acid (CA) (500 ppm); the solution is moved through the permeate pipe. Choice of cleaning agent is based on the reason of clogging. Cleaning agent is delivered in drums and diluted with permeate water. The cleaning process is relatively fast, as it is semi-automatic and takes less than one hour. Cleaning is performed when an increase of trans-membrane pressure is detected. Membrane replacement under normal operational conditions is not needed. RWO did not provide the regular recommended daily supervision needed for the AWTS system, nor a description of the required training level of system operators.

Cost Elements

Equipment Costs & Installation-related Costs:

RWO included in their response standard prices (costs) for the quoted equipment items. These costs could be categorized as "onetime costs," and are related to the equipment itself and the installation of the equipment. RWO's costs quote includes:

- Fixed cost for AWTS equipment according to the scope is provided, including start up, commissioning, and training. Cost for boarding commissioning engineer for vessel is provided. Delivery conditions and location are not identified.
- Optional costs for sundries are provided.
- Optional costs (approximate) for retrofit / conversion projects within the same scope are provided.
- **Note:** Costs for supplies and services by others (vessel) are not included. All pipelines, valves, etc. are considered outside of the RWO scope. Equipment installation costs, utilities, waste water sampling, and work on ship components in preparation of installation are not provided.

Optional costs for equipment are offered for projects that have potentially useable existing installation parts. Particularly in the case of a retrofit project, some of the equipment can be re-used and reduce the overall installation costs. However, sometimes the existing equipment has reached the end of its useful life, or does not match the new requirements. In general, ADEC staff has observed that retrofits done so far onboard Alaska trade vessels often reuse existing equipment. In order to meet effluent performance requirements reused equipment must fully meet the ATWS system specifications, have sufficient technical life time left, and be in good working order.

The delivery time of the equipment offered in the RWO response was approximately 6 – 8 months after order confirmation and clarification of all technical details.

A summary of RWO cost quotes for the proposed AWTS solution is presented in Table 3. RWO provided the costs in Euros (€) only; Table 3 includes an exchange rate to convert the Euro (€) to U.S Dollars ($). The summary also includes a preliminary approach in treatment cost per person on board (estimate provided by ADEC staff.) It should be mentioned that the costs are based on an AWTS installation that meets the effluent performance as set out in Table 1 (Performance Data RWO AWTS Memrod Technology.) Both the requested removal limit for ammonia (1.0 mg/L) and metal reduction treatment technology are NOT included.

TABLE 3. Summary of RWO cost quotes for the proposed AWTS and options.

Description		Price (Euro)	Price (U.S. Dollar)[1]
Primary screening			
Bioreactor (excluding Tanks)			
Waste Water Pump stations			
Memrod Unit (excluding Tanks)			
Sludge tank (excluding Tank)			
Electrical / Measurement and Control equipment			
Pipe lines and valves			
Engineering			
Start up, commissioning and training			
	Total	**€ 1,750,000.00**	**$ 2,581,250.00**
Optional			
Oil and Grease separators for galley/food waste reject water		€ 200,000.00	
UV Unit		€ 55,000.00	
Total Price New built ship without Options		€ 1,750,000.00	
Total Price New built ship with Options		€ 2,005,000.00	
Approximate extra costs for retro-fit conversion project with same scope of supply		**€ 500,000.00**	**$ 737,500.00**
Total Cost AWTS RWO basic		€ 1,750,000.00	
Including UV to meet performance spec		**€ 1,805,000.00**	**$ 2,662,375.00**
Total Costs AWTS RWO basis plus UV			$ 2,662,375.00
Retro fit project			$ 737,500.00
	Total		**$ 3,399,875.00**

[1]Exchange Rate: 1 Euro = 1.37 U.S. $

Table 3 (cont.)

RWO Operational Costs

Consumables	Use		Price E		10 yrs OPEX	**Cost (Euro)**	**Cost (US $)**
Chemicals							
Sodium Hypochloride / CIP cleaning	5	m3/yr	€ 0.60	kg	€ 30,000.00	€ 30,000.00	$ 41,100.00
Defoamer / Defoaming (start ups)	500	kg/yr	€ 1.50	kg	€ 7,500.00	€ 7,500.00	$ 10,275.00
Flocculation / filterability agent (emergency only)	100	kg/yr	€ 19.00	kg	€ 19,000.00	€ 19,000.00	$ 26,030.00
Sodium Hypochloride 50% pH adjustment	140	kg/day*	€ 0.30	kg	€ 153,300.00	€ 153,300.00	$ 210,021.00
* approx 100 ltr/day							
Energy Costs							
avg. daily power consumption	4000	kWh	€ 0.10	kWhr*	€ 1,500,000.00	€ 1,500,000.00	$ 2,055,000.00
* RWO estimate vessel power generation costs							
Membrane Replacement Cost							
40 modules total Price excludes shipping.				Approx.	€ 200,000.00	€ 200,000.00	$ 274,000.00
Estimated life time 5-7 years.							
					Total Operational Costs	**€ 1,909,800.00**	**$ 2,616,426.00**

From SAP Specification:		
Treated WW volume:	855	m3/day
	312075	m3/year
	3120750	m3 / 10 year
	3500	persons
Treated WW per person day	0.244286	m3/day

RWO Total Cost per treated m3 waste water 10 Year period	**€ 0.61**	**$ 0.84**

Costs related to Operations / Consumables:

RWO included some operational and consumable costs in the response. The costs appear to be based on year-round service and equipment parts life cycles. Labor supervision costs are not provided. Consumable costs are those items that are needed to support the process. RWO estimates that the technical life time of the membranes is 5-7 years depending on maintenance. The cost of membranes is included in the 10 years OPEX column of Table 3.

Table 3 also includes a summary of the RWO estimated operating costs of the AWTS solution. RWO used in their operational costs estimate some conservative factors to develop the approximate operation costs. Again, note the operational costs are based on year-round AWTS operation for meeting the effluent performance as set out in Table 1 (Performance Data RWO AWTS Memrod Technology) or lower effluent performance standards as needed. In either case, the operational costs do NOT include effluent treatment for metals reduction.

RWO Vendor View Points:

RWO did not include dissolved metal control technology for waste water in their response. However, RWO did include the new metal reduction technology for vessel condensate or technical water (TW,) called ACCuRem (Air conditioning Condensate Copper Removal.) A copy of the RWO brochure that describes this technology is included in Appendix A.

RWO did provide some useful viewpoints (based on vessel experiences) from an AWTS manufacturer's perspective:

On metal removal controls: *"Dissolved nickel, zinc, and copper should not be contractual effluent limit. More over they should be considered as source reduction issue, i.e. they originate evaporator, on shore supplies and piping. It should be noted that generally all new cruise ship comply with ADEC limits without any of sort of metal removal technology"* [sic] (page 5 RWO response 6 28 11).

RWO did not include detailed information to explain the statement that "generally all new cruise ships comply with ADEC limits…;" without an explanation, ADEC could not evaluate this statement. Effluent sampling results do not necessarily show that older

vessels have relatively higher loads of metal in the effluent than newer vessels in the Alaska trade. Studies performed by the vessels (SREs) included sample results with elevated level of metals (*e.g.*, copper) from evaporator (treatment), heater, and laundry operations. Water supplied from on shore facilities (potable water) were analyzed for metals; sample results from Alaskan communities did not demonstrate elevated levels of Cu, Ni, and Zn.

On operator training: RWO also touched on the subject of operator crew education and training for modern AWTSs. With regard to the complexity of the modern AWTS installations, RWO states that training of the operators has become more and more specialized, and requires trained and specialized crew members. *"Still, however, many cruise ship owners do not see the need to invest in the training of the crew" [sic] (E-Mail RWO / ADEC 6 28 11 4:02 AM).*

On AWTS equipment size: According to RWO, in their experience "*there is not enough space/tank height for removal of ammonia. New built vessels are of course different case, but again very few ship owners/ship yards are willing to allocate enough room to accommodate AWPs". [sic] (E-Mail RWO / ADEC 6 28 11 4:02 AM).*

Conclusions / Engineer's Views:

RWO took the time and effort to respond to the SAP specification with a budget quotation, and the estimate includes potentially useful information.

A few notes for consideration:

It should be noted that the RWO scope and quoted costs do not include the ammonia performance level and the metal reduction technology as requested in the SAP specification. In general an AWTS for onboard use needs to be compact and be easily accessible for maintenance and repairs. The RWO Memrod system includes preliminary size dimensions; it seems that the Memrod system has large dimensions when the Membrane tank is not integrated in the Membrane bioreactor tank. Possible total dimension reductions

can be obtained when a consolidated tank system is used. The bioreactor dimensions quoted also appear to be large; using existing onboard tanks as bioreactor tanks (activated sludge tanks) may allow overall size reduction of the system.

In their report, RWO identified tank size and height limitations as potential inhibitors for onboard use. A look at the dimensions of vessels with similar ATWS installations and space capacity may provide references for possible installation sizing. The provided height dimensions do not appear to be entirely comparable with existing vessel AWTS installations with similar membrane technology. In addition, modular (sectional) AWTS components can result in reduced equipment dimensions and more efficient use of space.

In an e-mail dated 6/28/11, RWO mentioned that the removal of ammonia requires very efficient aeration of the biomass, and that tank height can limit this process and thus affect ammonia removal performance. Proper design of tanks with effective aeration systems can offset the risk of poor ammonia removal performance. New engineering approaches and lessons learned appear beneficial to adequately retrofitting vessels with AWTSs to effectively control ammonia. Adopting new aeration plans, using tank flow modeling, and improved ventilation for the aeration process may improve the issue of inadequate aeration. Another contributor to a poorly performing aeration process is inadequate maintenance of the aeration systems. Some current designs do not allow quick and efficient maintenance, and clogging of aeration system components (*e.g.* nozzles) by grease oils, etc. can still be an issue. Tank aeration system performance may also be affected by the intermittent use of some AWTS installations (*i.e.*, when systems are used only during the Alaska season, or just for the Alaska portion of a voyage.) In these cases, proper maintenance of the aeration system during system “off time” may not be performed.

Correctly designed and maintained tank aeration systems should be used to minimize the potential risk of poor aeration and subsequently poor ammonia removal performance.

The proposed RWO Memrod system does not include installation details for materials needed for inter-piping, and the AWTS process tanks, electrical wiring, and utilities connections are not included in the scope. RWO did provide in their budget quote approximate extra costs for retrofit within the performance scope. These costs are included in the RWO quotation and in Table 3.

Notes on RWO new copper removal technology:

RWO include a detailed description of ACCuRem, a technology intended to remove copper from technical water (condensate from air conditioners.) High copper concentrations in technical water used in the laundry process are not acceptable because of the possible green staining of laundry. The RWO copper removal technology appears to be based on a "special filtration process" (most likely Ion Exchange.) The informational brochure provided by RWO did not include concentrations treated, volumes, or the removal rate of the process. It was not clearly identified by RWO whether this technology would be useable for the needed capacities of waste water treatment. Appendix A includes a full description of RWO ACCuRem technology.