**Royal Caribbean International**
**Advanced Wastewater Purification Systems**

Royal Caribbean International is installing advanced wastewater purification (AWP) systems on all of its ships. These technologically advanced systems clean the wastewater generated onboard our ships. At the end of the cleaning process, the wastewater is so clean that it far exceeds all international ship wastewater discharge standards.

Royal Caribbean's commitment to advanced wastewater purification systems is an example of our company's policy of continual environmental improvement.

Over the next several years, each of our ships will be equipped with an AWP system. This represents a total investment of well over $100 million for our company.

## THE INSTALLATION PROCESS

We install the new systems either when a ship goes into its normally scheduled dry dock, or while the ship is in service. Our new ships will be delivered with AWP systems already installed.

Ideally, it takes approximately four to five months to manufacture a system and four months to install one onboard. Then it takes approximately two months to commission the system, which includes a sampling period to ensure the system's performance meets standards comparable to the U.S. federal standards for ships operating in the State of Alaska (regardless of where the ship is operating.)

Below, you will find a list of our ships currently equipped with AWP systems, and our schedule for future installations. We also list the type of system being used or scheduled for installations, where decisions have been finalized.

Due to the highly technical and experimental nature of AWP systems, installation and completion timeframes are subject to change, based on the availability of AWP systems, installation processes and commissioning procedures. Further below, you will find a list of three advanced wastewater purification systems we use, along with brief explanations of how they are designed to work and a diagram of each system.

## AWP INSTALLATION STATUS

**Ships with AWP Systems Installed:**
Vision of the Seas – Hydroxyl (partial system, slated for replacement)
Serenade of the Seas – Scanship
Enchantment of the Seas – Hydroxyl
Freedom of the Seas – Scanship
Liberty of the Seas – Scanship
Radiance of the Seas – Hydroxyl
Brilliance of the Seas – Hydroxyl
Independence of the Seas - Scanship
Jewel of the Seas – Hydroxyl
Oasis of the Seas – Hydroxyl/Headworks
Rhapsody of the Seas - Navalis
Allure of the Seas (Newbuild-Hydroxyl/Headworks)
Voyager of the Seas – Scanship
Mariner of the Seas – Scanship
Explorer of the Seas – Scanship
Adventure of the Seas -- Scanship
Navigator of the Seas – Scanship
Splendour of the Seas – Scanship
Grandeur of the Seas – Scanship

**Installations Expected To Be Substantially Completed in 2013:**
Legend of the Seas

## AWP SYSTEMS WE USE

We currently have three types of advanced wastewater purification systems on our ships, the Scanship, Hydroxyl/Headworks and Navalis systems. The Scanship and Hydroxyl systems use a similar process and are based on biological treatment. The Navalis is primarily a filtration and advanced oxidation process, but does use biological treatment to a lesser extent .

The first two systems use beneficial bacterial to consume waste particles, and a chemical – mechanical process to remove the remaining solids similar to a land-based wastewater treatment facility.

How it works:

- On most Scanship systems, coarse mechanical screens remove wastewater solids, such as paper and 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.

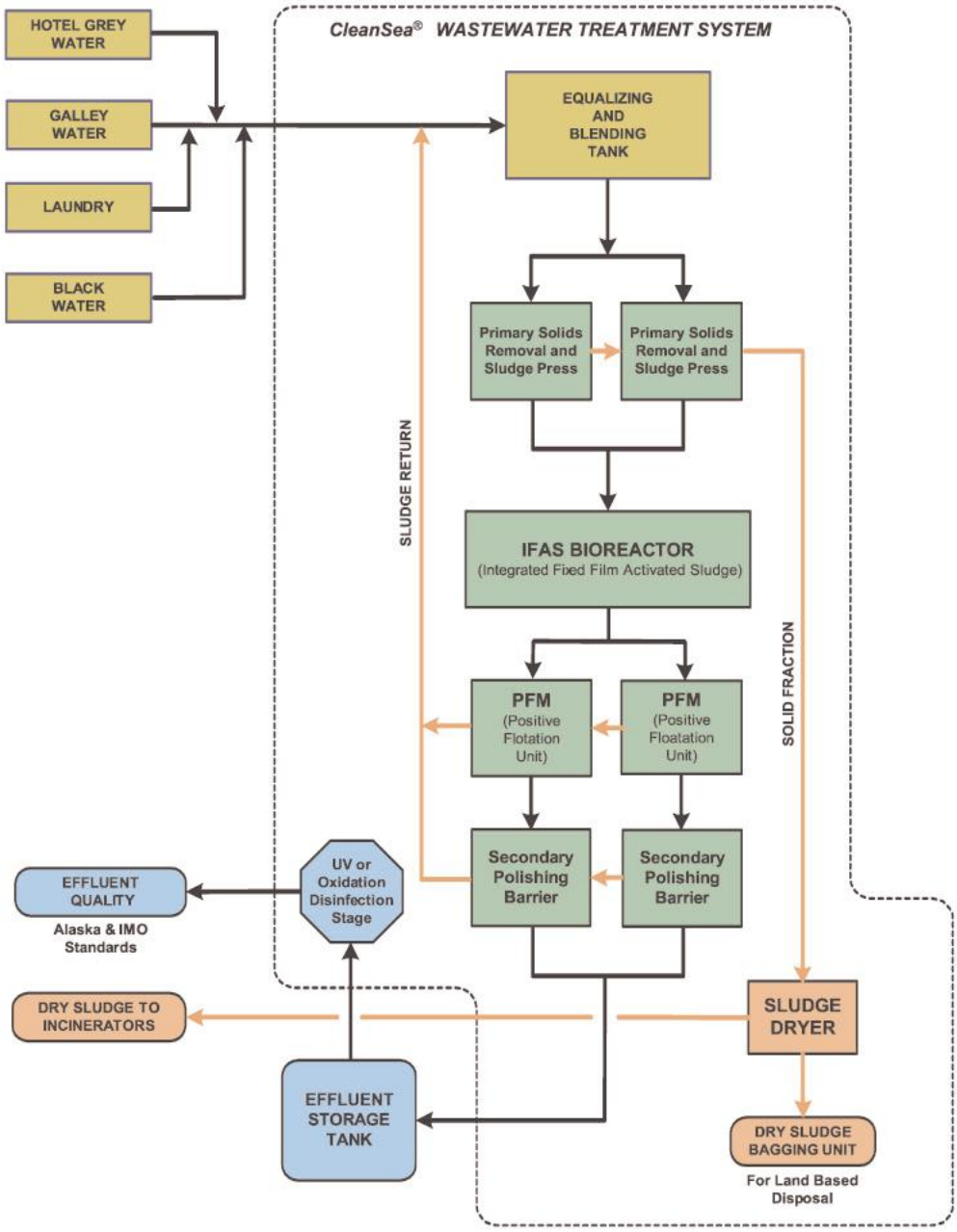
- The resulting very clean water is then pumped through polishing filters.

- Next, an ultraviolet light reactor provides the final disinfection.

- The 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**

## *Hydroxyl CleanSea® Cruise Ship System*
### *Black and Grey Water Treatment System*

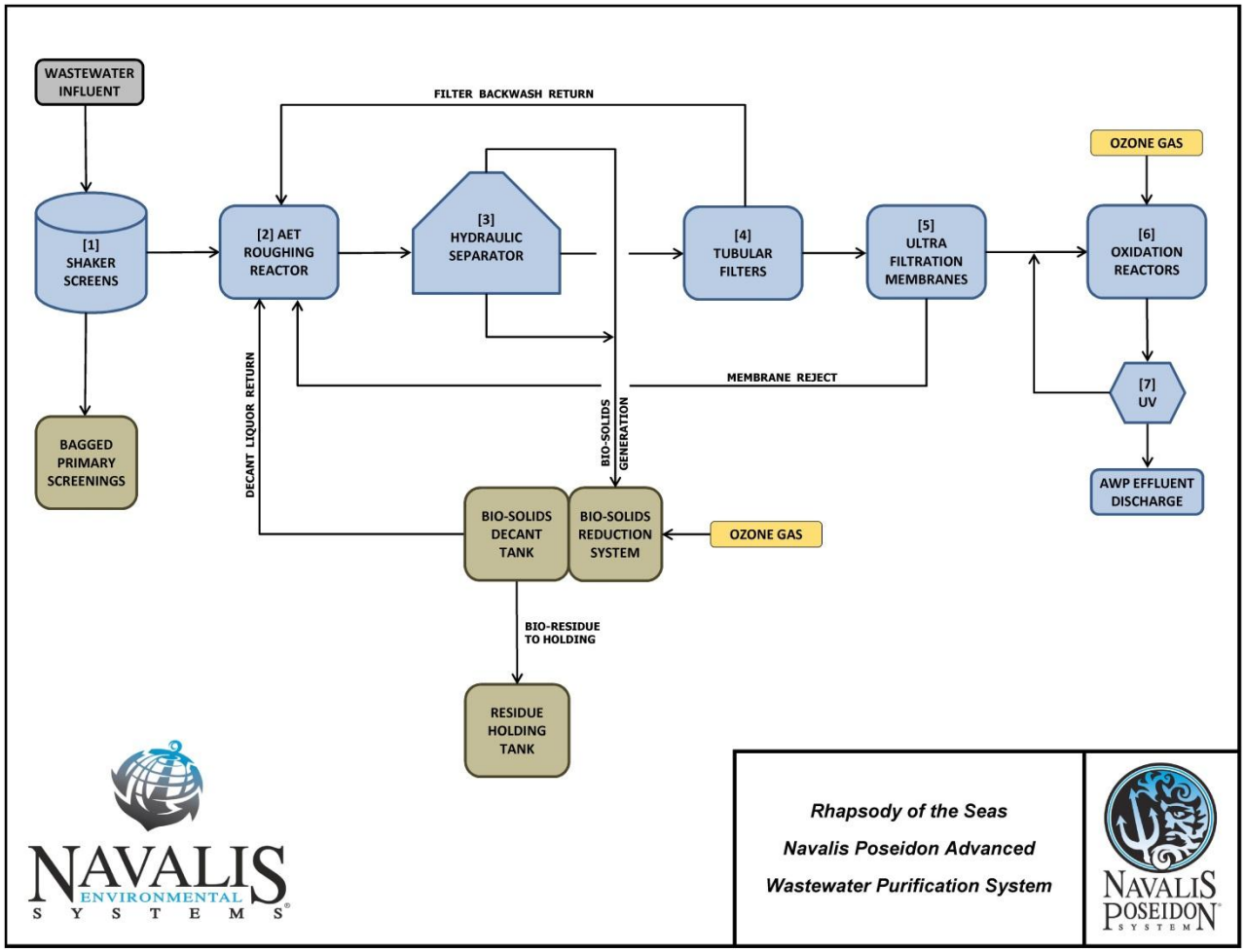


**NAVALIS**

Solids are first removed from the wastewater stream using multi-decked vibratory shaker screens [1]. The screened water is collected in the combined Aerated Equalization Tank (AET) and Roughing Reactor [2]. The AET provides for chemical equalization while the compact Roughing Reactor biologically reduces the influent loading for the downstream oxidation process.
Following the AET, further particle removal is achieved by a series of processes which include chemical flocculation, Hydraulic Separation [3], Tubular Filtration [4] and finally Ultrafiltration [5] with ceramic membranes.

The clarified water from the membranes (permeate) is directed to a two stage oxidation process where the wastewater is continuously circulated through a reactor tank, and a re-circulated stream containing dissolved ozone is introduced. 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 [7] where residual ozone is broken down into highly reactive oxygen compounds that further polish the water.

Solids produced by this system are oxidized with ozone reducing their volume and mineralizing them into a safer bio-residue, suitable for drying, ready for land based disposal or at sea discharge.


WASTEWATER INFLUENT
FILTER BACKWASH RETURN
OZONE GAS
[1] SHAKER SCREENS
[2] AET ROUGHING REACTOR
[3] HYDRAULIC SEPARATOR
[4] TUBULAR FILTERS
[5] ULTRA FILTRATION MEMBRANES
[6] OXIDATION REACTORS
[7] UV
MEMBRANE REJECT
DECANT LIQUOR RETURN
BIO-SOLIDS GENERATION
BAGGED PRIMARY SCREENINGS
AWP EFFLUENT DISCHARGE
BIO-SOLIDS DECANT TANK
BIO-SOLIDS REDUCTION SYSTEM
OZONE GAS
BIO-RESIDUE TO HOLDING
RESIDUE HOLDING TANK
NAVALIS ENVIRONMENTAL SYSTEMS
Rhapsody of the Seas
Navalis Poseidon Advanced
Wastewater Purification System
NAVALIS POSEIDON SYSTEM