An Assessment of Alaska Cruise Ship Wastewater Discharges by the First Cruise Ship Science Advisory Panel in 2002

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Member 2001-2002 Science Advisory Panel

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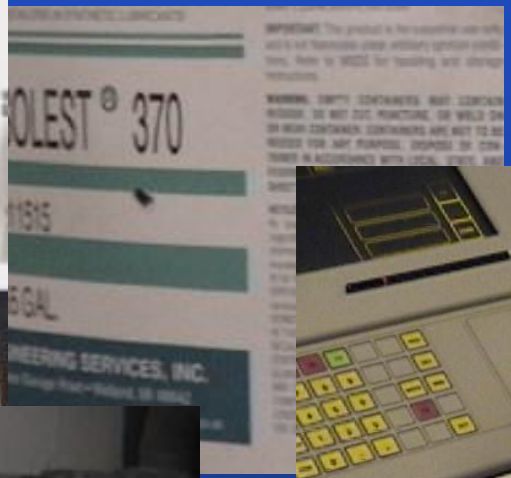
Members of the 2001-2002 Science Advisory Panel

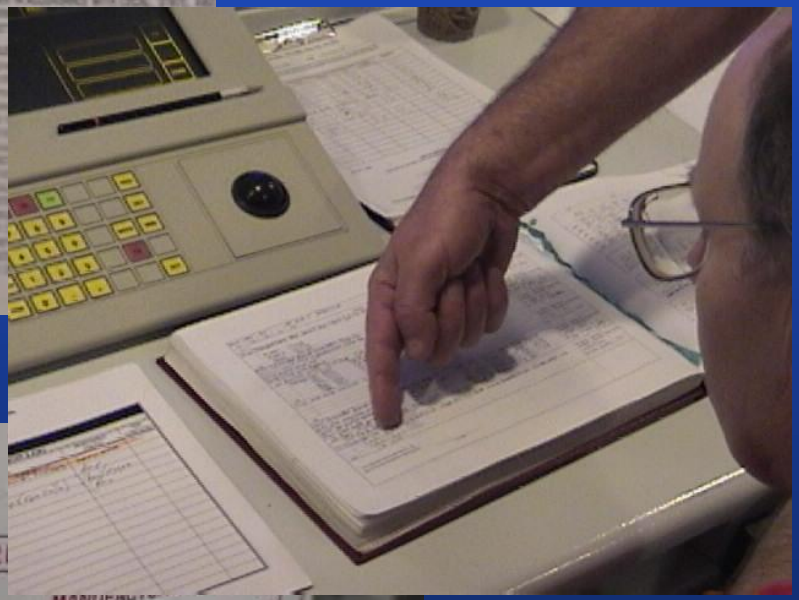
- Marlin Atkinson, University of Hawaii, Biological Oceanography
- CJ Beegle-Krause, NOAA HazMat, Oceanography and Modeling
- Kenwyn George, ADEC, Civil Engineering
- Ken Hall, University of British Columbia, Civil Engineering
- Lincoln Loehr, Stoel Rives, LLP, Oceanography
- Charles McGee, Orange Co. Sanitation Districts, Microbiology
- Alan Mearns, NOAA HazMat, Fisheries and Marine Ecology
- Michael Stekoll, University of Alaska, Chemistry
- Michael Watson,EPA, Region X, Environmental Toxicology
- David Eley, US Coast Guard (Retired), Facilitator
- Carolyn Morehouse, ADEC, Technical Support and Monitoring

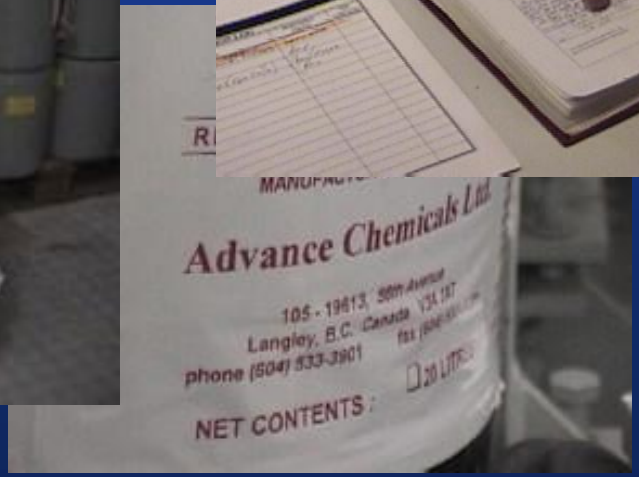
Science Panel Actions 2001-02

- Inspected Vessels, including stores, solid waste
- Reviewed past effluent chemistry and bacteria data
- Recommended changes, additions for data collection
- Reviewed new data (quality, values)
- Calculated receiving water concentrations after mixing and compared to WATER QUALITY criteria

Panel inspecting ships' storage, discharge records







Assessment Questions

- What's discharged?
  - Where does it go?
    - "Who" is exposed?
      - What are the effects?
        - How should we manage it?

What is Discharged?

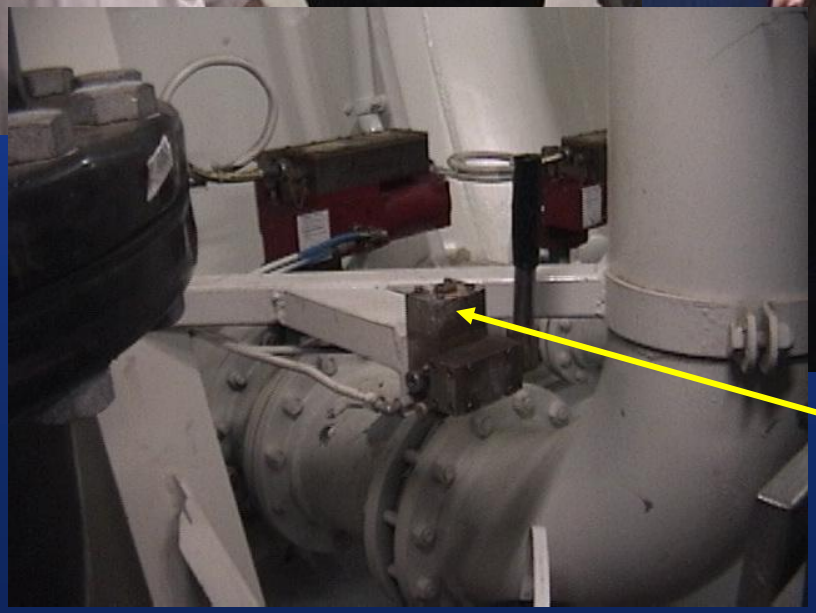
- Black water Effluent from toilets
- Grey Water From showers, sinks, laundry
- Holding Tanks In, below engine room
- Treatment (in 2000-2002)
  - None
  - MSD
  - “Advanced” - various new technologies
  - Disinfection - chlorine, UV

Contaminants of Concern

- Fecal coliform bacteria
- Persistent Organics (pesticides, PCB's)
- Volatile Organic Compounds (eg, benzene)
- Polycyclic Aromatic Hydrocarbons (PAH's)
- Base Neutral/Acid Compounds (phenols)
- Trace Metals (eg, mercury, copper) and Cyanide
- Nutrients (Nitrogen, Phosphorus)

Wastewater Sampling 2000-02

- >200 samples gray and blackwater
- Bacteria, conventional pollutants, pesticides, metals, hydrocarbons, chlorine, etc
- Representative sampling very difficult
- “Advanced” Treatment systems not functioning well in 2000, much better in 2001 and 2002



Sampling port

Effluent Concentrations 2000

- Fecal Coliform 0 to 24,000,000 MPN in BOTH black and grey water (highly variable)
- Of 72 chemicals only 17 above detection limits
- Pesticides and PCBs not detected
- Nine inorganics (metals, cyanide) detected. Copper unusually high (maximum was 7100 ppb)
- Chlorine: <0.3 to 78 parts per million

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Large Ships

(250 - >2000 passengers)

- Discharge ports located:
  - 2 - 6 meters below water line
  - 1/3 way forward of twin propellers

Large Ships
(250 - >2000 passengers)

- Designed to discharge up to 200 cu m (49,000 gallons) per hour underway
- Discharged effluent entrained in prop wash
- Effluent mixed in wake by both displacement water and propeller mixing

Mixing cross section 1 mile behind ship moving at 9 knots

Dilution and Dispersion Studies

- US EPA Dye Plume Study, Miami
- Science Panel Modeling and Simulation
- Dilution (Mixing) Formula Derived and Verified:
  - 4 x (ship width x ship draft x ship speed)/volume discharge rate

Comparison of Dilution Rates

- EPA Dye Study (4 ships, 9.1 to 19 Knots)
  - EPA Measured 288,412 to 643,810
  - EPA Calculated 255499 to 907,574
  - "Panel" Model 227,992 to 854,309
- Large Ships "nominal" * 50,000
- Wastewater Outfall diffuser 20 to 500

*Conservative dilution used by the Panel

Dilution (wake) Concentrations: Fecal Coliform Bacteria (based on summer 2000 data)

- Worst Case scenario (50,000:1) diluted to within a factor of 2 of criterion (200 MPN) by moving vessels
- With actual mixing (>>100,000:1) no ship effluent would have exceeded the criterion (200 MPN) regardless of level of treatment

Dilution (wake) Concentrations: Chemicals (based on 2000 data)

- The addition of effluent chemicals result in increases in the low parts per trillion range … and easily meet all water quality criteria
- Metals from effluent result in increases in low parts per trillion range and easily meet all water quality criteria. Even the highest copper effluent value was not a problem after dilution.

Assessment Questions

- What's discharged?
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Exposure Pathways and Resources at Risk

- Recreational activity (kayakers, divers)
- Marine life
  - In the water column
  - On shore
  - On the Sea Surface (microlayer)
  - On the sea floor

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People: Fecal Coliform Bacteria

- Exceedance of the applicable bacteria standard would not result from cruise ships discharging any effluent at six knots or more and a mile from shore.
- Based on the Summer 2000 data.

Nutrients and Eutrophication

- Mean total nitrogen in wastewater 0.07 mg/L
- Below regional background after dilution >50,000:1
- Results in excess primary production 0.03 ug chlorophyll/L
- Can result in one one-hundredth or less increase of natural background production
- Considered to be trivial.

Whole Effluent Toxicity (WET) - 2002

- Six effluents tested for toxicity to 4 sensitive marine organisms
- Maximum dilution required for No Observable Effects Concentrations (NOEC's) was 2000:1 for a chlorinated grey water sample
- Median NOEC dilution was 20:1
- Least toxic were an untreated (raw) blackwater sample, and a highly treated reverse osmosis effluent.
- Highest toxicity was due to chlorination

Sea surface microlayer

Sea Surface Microlayer

- 200-300 uM thick natural film
- Plankton, eggs and larvae of fishes and invertebrates
- Diluted wastewater (moving ships) will not increase contamination of microlayer
- At issue may be non-moving (anchored) vessel discharge in protected bays, inlets

Marine Sediments

- Resulting from cumulative effects (multiple discharges over season)
- Copper is “worst case” material
- The rate of flow of Copper on suspended solids from cumulative seasonal discharges would not increase sediment concentrations above natural background

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Best Management Practices

- Use Green products
- Avoid stationary discharges in low tidal exchange areas
- No discharge should occur within 0.5 nMi of shellfish harvest areas
- Discharge at >6 knots, >1 mile from shore is good management practice
- Minimize chlorination

Impact of Science Panel Studies?

- State and federal legislation imposed treatment requirements on the cruise ships before the Panel's analysis and made no changes after the Panel's analysis. I think of that sequence as READY, FIRE!, AIM.
- EPA's 2008 Cruise Ship Discharge Assessment Report made effective use of the Panel's dilution analysis to put their analysis of effluent results in proper context.
- *Marine Pollution Bulletin* article in 2006 summarizing the Panel's work.

More Information?

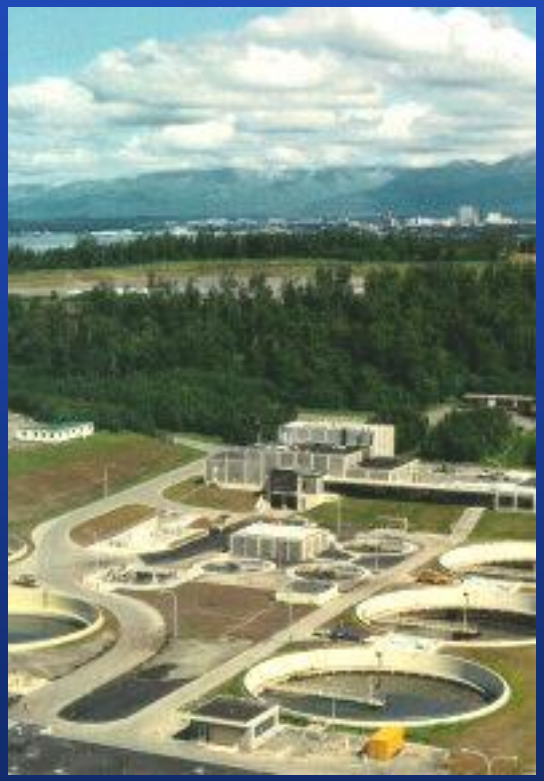
http://www.state.ak.us/dec/water/cruise_ships/

Proceedings, Oceans 2003, MTS/IEEE, Columbia, Maryland

Advances in Maritime Waste Water Treatment

July, 2007

Primary Treatment Process



John M. Asplund
Wastewater Treatment
Facility in Anchorage

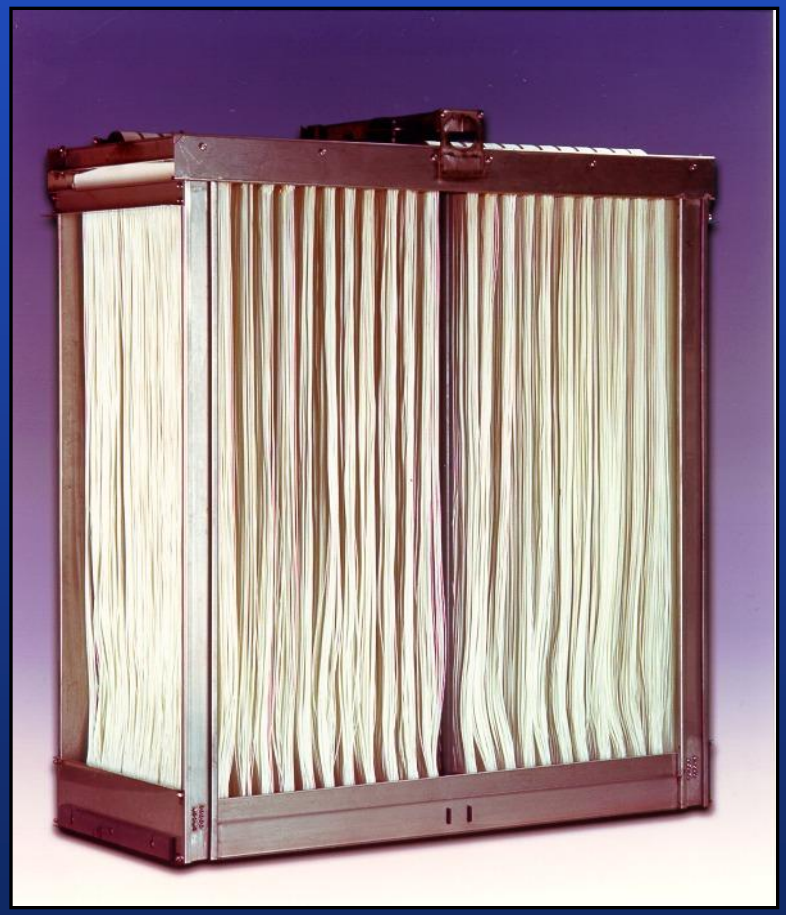
- Principal Stages:
  - Screening / Maceration
  - Sand/Grit removal
  - Settling
  - Sedimentation
- Removal
  - 35% BOD
  - 45-65% Suspended Solids
- Employed in:
  - Anchorage
  - Ketchikan
  - Sitka
  - Skagway
  - Vancouver, B.C.
  - San Diego (advanced primary)

Secondary Treatment Process

West Point Treatment Facility
Seattle Washington

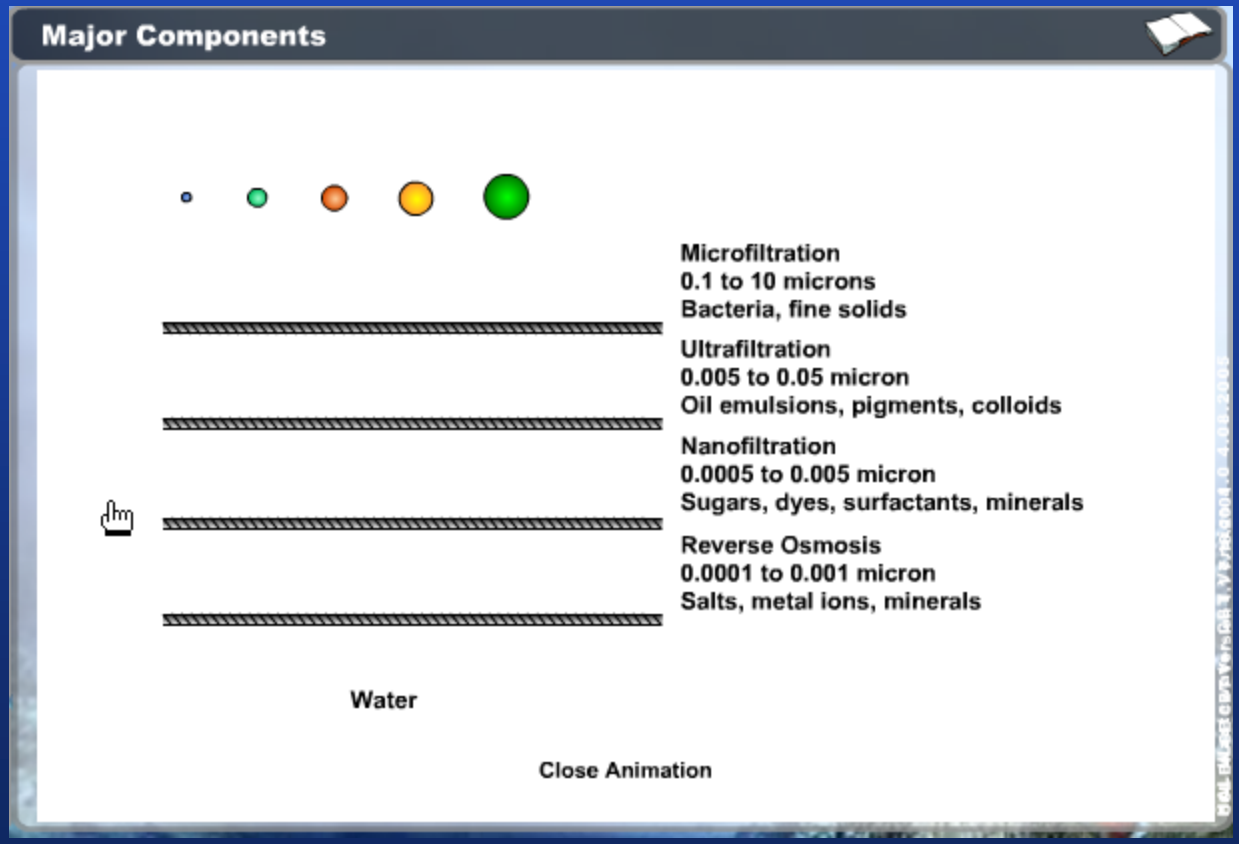
- Principal Stages:
  Primary
  + Biological treatment
    - Activated sludge
    - Aeration
    - Trickling filters
    - Secondary sedimentation
- Removal
  - 85-90% BOD
  - 85-90% Suspended Solids
- Employed in:
  - Juneau
  - Seward
  - Seattle

Advanced Waste Water Purification Systems (AWWPS)

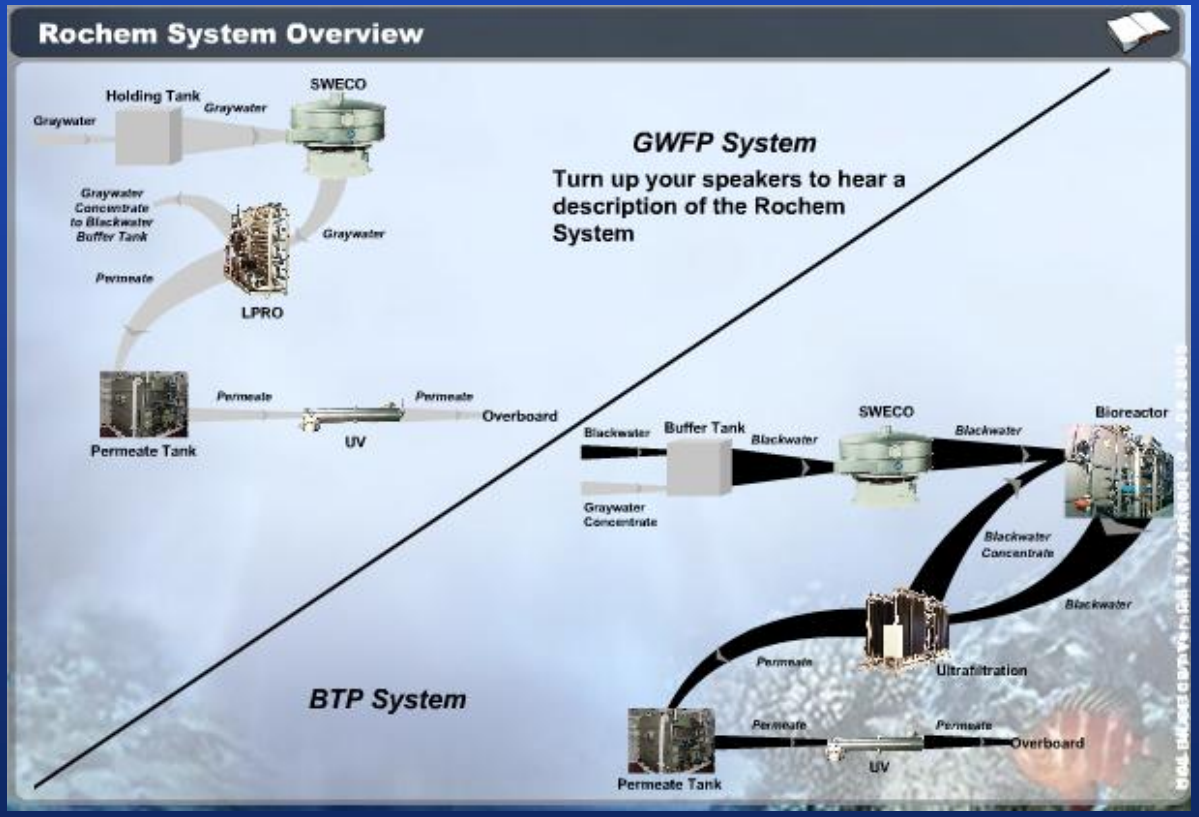


- Principal Stages:
  - Primary
  - + Secondary
  - + Filtration
  - + Disinfection
- Removal
  - Near total elimination of BOD
  - Near total elimination of Suspended Solids
  - Near total elimination of bacteria
- Employed in ?
- ***Large Cruise Ships sailing in the Northwest***

The Defining Characteristic of AWWPS Systems is Filtration



Rochem System Overview: Gray and Blackwater Treated



1. Waste initially accumulated in buffer tanks
2. Sweco filter removes debris, other solids.
3. Bio Waste volume is reduced by microbial digestion
4. Ultra-filtration removes suspended solids (re-circulated to bio-digester)
5. Clean Permeate dosed with UV light to kill remaining bacteria

Summation

- Cruise lines have pioneered technology and work practices that exceed legal requirements and protect water quality
- AWWPS systems are “state of the art” and produce an outstanding quality of discharge
- Working together, we can achieve outstanding results

Risk Assessment Framework