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

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The findings and conclusions in this document are those of the author and do not necessarily represent the views of the National Oceanic and Atmospheric Administration (NOAA).

My Background

- PhD Fisheries. Effects pollution on salmon
- Leader, Biology Division, Southern California Coastal Water Research Project (SCCWRP) – 9 years assessing major wastewater discharges
- Ecologist, Puget Sound MESA Program – Effects of pollution in the Sound
- National Status and Trends Program – helped initiate national pollution monitoring
- Member, Co-author, NRC Committee on Managing Wastewater Discharges in Coastal Areas
- Ecologist and Senior Staff Scientist – NOAA Emergency Response Division. Support USCG during spills.
  - Exxon Valdez – 22 years of recovery studies
  - Bioremediation
  - Dispersants and dispersant use
  - Deepwater Horizon – Dispersion white paper and Congress

Process of 2001-02 Science Advisory Panel

- What did Panel do to work together and successfully produce and publish findings?
- How did they organize report writing?
- What resources did they have? Need?
- How did they work together?
- How did they resolve conflicts?

Quick Look at the 5 Questions

1. What did Panel do to work together and successfully produce and publish findings?

- Met (see details below)
- Conflict of Interest Disclosures
- Agreed on a risk-based framework
- Topics divided up
- Homework, lead authors interactw/ co-
- Worked well w/ Agencies (DEC, EPA), Industry

2. How did they organize report writing?

- Panel divided into chapter teams
- Each team had a lead author and several co-authors
- Each panelist was lead author or co-author of one or more chapters
- Draft chapters were reviewed by all panel members
- Facilitator lead discussion of overall outline
- ADEC staff contribute sections

3. What resources did they have? Need?

- Effluent data (from Colonell et al 1999 forward
  - Effluent monitoring data by DEC
- Ongoing (new) data on effluent chemistry by ADEC
- Literature, peer-reviewed and gray
- Facilitator (USCG ret'd) was a technical expert
- Facilities of panel member's agencies for writing, printing, email
- Research vessel (arranged by facilitator)
- Access to cruise ships in Juneau, Seattle. On board 2-day cruise and cruise ship conference room
- EPA IX Laboratory for WET Testing
- Presence at EPA-sponsored dye dilution study in Miami

4. How did they work together?

- Face-to-face 2-3 day meetings, conference calls
- Conflict of interest disclosures
- Discussion and adoption of Risk Assessment framework
- Responded to public questions and concerns:
  - Microlayer (sea surface pollution)
  - Effluent toxicity testing (Appendix 8)
  - Sediment contamination
  - Mass loading and overlapping ship tracks
  - Cumulative effects /sensitive species (eg., humpback whales)
- Panel-added concerns/added values:
  - Contaminants of Concern
  - Mussel Watch data from NOAA shoreline monitoring
  - Pharmaceuticals
  - Mortality from shear
  - 7 Scientific papers (including EPA Miami)

5. How did they resolve conflicts?

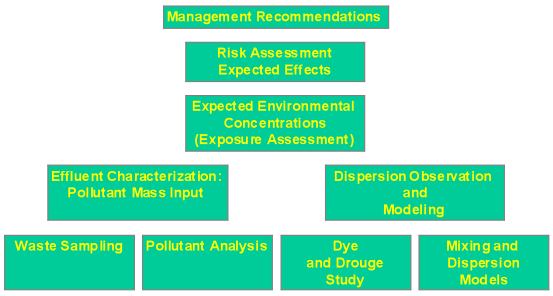
- Conflict of Interest Disclosures
- Agreement on a framework (risk assessment)
- Agreement on Contaminants of Concern
- Scientific debates….excellent scientific exchanges
- Multiple approaches to key issues (ie, dispersion and transport)
- Lot of homework, literature review, modeling, etc.
- Do not recall significant conflict other than at the beginning… what the framework would be (above)
- At least one panel member changed level of concern based on seeing actual data on dilution

Details

Members and Disciplines of the 2001-2002 Science Advisory Panel

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

Risk Assessment Framework



Simple Assessment Questions and Flow

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

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)
- Participated in 3 cruises, field studies inc. EPA Miami
- 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 or below engine room
- Treatment (in 2000-2002)
  - None
  - MSD
  - "Advanced" - various new technologies
  - Disinfection - chlorine, UV

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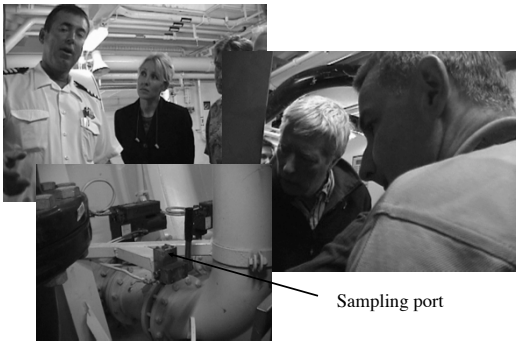
Contaminants of Concern

- 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



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

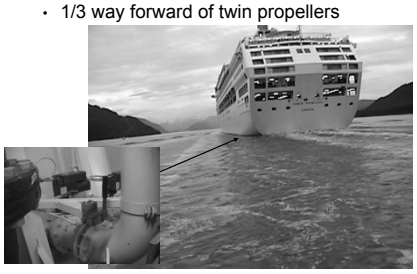
Assessment Questions

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

Large Ships

(250 - >2000 passengers)

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



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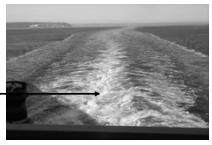
Large Ships
(250 - >2000 passengers)

- Designed to discharge up to 200 cu m (49,000 gallons) per hour underway
- Discharged effluent entrained in prop wash within seconds
- 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, Aug 2002
- 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 255,499 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

EPA Dye Dilution

- Results indicate that discharges behind cruise ships moving at between 9 and 17 knots are rapidly diluted by a factor of 260,000:1 to 580,000:1. These results are larger than dilution factors estimated by previous modeling efforts. This suggests that previous studies underestimate the impact of turbulence caused by the propellers and displacement of the ship's hull.

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

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

- The injection of effluent occurs in a stronly mixing wake; contaminant concentrations in the low parts per trillion range in seconds to minutes … and meet all water quality criteria
- Metals from effluent result in increases in low parts per trillion range and meet all water quality criteria. Even the highest copper effluent value was not a problem after dilution.

Assessment Questions

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

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

Assessment Questions

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

People: Fecal Coliform Bacteria

- Exceedance of the applicable bacteria standard would not result from cruise ships discharging any effluent underway at a speed of 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.

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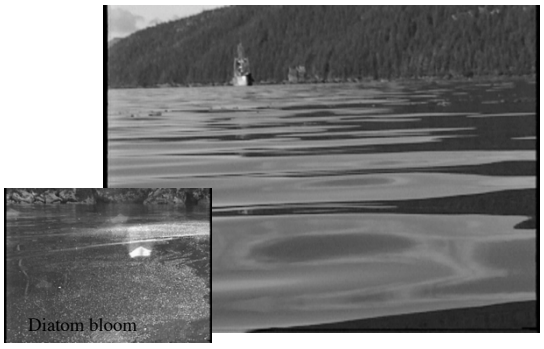
EPA Whole Effluent Toxicity (WET) - 2002

- 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 micro-layer
- At issue is non-moving (anchored) vessel discharge in protected bays, inlets
- Mechanical shear likely source of injury to marine plankton

Marine Sediments

- Resulting from cumulative (mass loading) 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

Assessment Questions

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

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
- Minimize chlorination

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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.
- 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 context.
- *Marine Pollution Bulletin* article in 2006 and *Oceans 2003* Conference Proceedings summarizing the Panel's work.

Thoughts Ten Years Later

- What is (are) objective(s) of end-of-pipe requirement?
  - Minimize toxicity to marine life? (fresh water will be toxic regardless)
  - Reduce mass emission loading to zero?
    - Compare contaminant mass emissions to local sourcs?
- What are the environmental tradeoffs
  - Subsequent waste handling
  - Carbon emissions (full life cycle)

Publications by SAP and EPA Collaborators
(first 7 in Proceedings, IEE/MTS Oceans '03)

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More Information?

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

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