Challenges and Lessons Learned from the Development of Standard Protocols for the Evaluation of Ballast Water Treatment Systems

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California State Lands Commission
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United States Coast Guard
Developing Test Procedures

(One Person’s In-Progress Perspective)

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Lessons Learned

- Run like h...
- Make useful friends
- Trust but verify
- Don’t bust your @$ if you can burn some gas
- Don’t color outside the lines
- Ignore the chatter (politicians and press)
- It’s not a horse race
- More $$ = More lawyers
- Murphy!
Outline

- U.S. Coast Guard authority
- Higher level requirements
- Key partnerships
- Integrated procedures
- Validation
- Harmonization
USCG interest in testing BW treatment systems

- USCG authorized by Congress to approve BWM methods
  - NANPCA 90/NISA 96
    - Sec 1101 (b)(2)(B)(iii) and (c)(2)(D)(iii)
    - “…if the Secretary determines that such alternative methods are at least as effective as ballast water exchange…”
  - Need to develop procedures by which to assess efficacy
USCG Approval of Equipment

- 46 CFR 159 (Subchapter Q)
  - Approval of Equipment and Materials
    - Application requirements
    - Application review procedures
    - Test Requirements
      - Efficacy
      - Design, materials and construction appropriate for shipboard
      - Environmental tests
        - Vibration
        - Heat & Humidity
        - Incline
        - Other, as appropriate for equipment and use
  - Independent laboratories
    - Recognition by USCG
    - Qualifications
Ballast Water Treatment
General Requirements

- Effective for full range of organisms including:
  - Bacteria (0.2 - 2 um)
  - Large Plankton (200 um - 20 mm)
  - All life stages
  - Sexual and asexual
  - Aerobic and anaerobic

- Effective under wide range of conditions:
  - Salinity
  - Turbidity
  - Organic content (Particulate and dissolved)
Approving BWM Systems

- Type Approval of systems
  - Rigorous land-based tests
  - Shipboard performance assessments

- Requires standard test protocols and methods
  - Validated methods and apparatuses
  - Controlled and repeatable conditions.

- Results need to be
  - Comparable between tests
    - Different treatment equipment at same location
    - Different test facilities
  - Scientifically rigorous
  - Legally defensible
That’s it for “Approval” (in this talk)

- Requirements for approval of ballast water management systems will be part of published regulations.
  - APA: No ex parte communication prior to publication

- Comments today will focus on generic assessment of efficacy / performance
  - Ideally, stakeholders would be interested in high quality credible data on performance
How Effective?

- Back in the day…
  - Numerous independent efforts to develop BWMS
  - Wide range of testing approaches and metrics
    - USCG R&D Center 2002 evaluation:
      - Testing efforts inadequate
        - Design
        - Methods
        - Documentation

- Independent of “approval” – need to identify appropriate procedures
  - Understand state of technology
  - Identify areas for improvement
Partnerships

EPA Environmental Technology Verification Program

United States Coast Guard

NSF International

NRL Center for Corrosion Science and Engineering
Lesson

Make useful friends…and then use* them

* Well, actually…work ‘em like galley slaves…

ETV: “The Usual Suspects” A key cadre of technical experts willing to work week ends for little more than food, coffee, and the chance to enjoy the adventure and romance of travel…on federal per diem....
USCG-EPA Partnership
Testing Ballast Water Treatment Systems

- Environmental Technology Verification Program (ETV)
  - USCG-EPA MOU 2002
  - Develop Standardized Test Protocols
    - Transparent procedures
    - Rigorous tests
    - Credible results
ETV Tech Panel

Ocean Engineers
Physical Oceanographer
Mechanical Engineers
Naval Architects
Marine Engineer
Control & Automation Engineer
Instrumentation Engineers
Independent Consultants
Microbiologist
Marine Biologists
Ocean Engineers
Draft Testing Protocols

ETV Protocols
V 1.0
April 2004

- ETV Technical Panel & Battelle produced draft protocols in April 2004
- BPJ
- Fairly high level guidance
- Not validated
Lesson #

Trust, but Validate

Or

Show me the Data…

(…and the methods, the statistical models, the assumptions, the QA/QC procedures, etc)
A side note on the importance of validation

IMO Guidelines for Approval of Ballast Water Management Systems (G8)

Draft ETV Protocol used as a model

Consensus document

Science & Engineering

International politics

Short time-line

Unvalidated after adoption

Problems with rec’s

Ad hoc adjustments

Great Uncertainty
Validation

- **USCG Broad Area Announcement**
  - Interest/ability/capacity?

- **USCG and NRL Interagency Agreement**
  - NRL
    - Long history of ballast tank/system work
    - Significant physical infrastructure
    - Experienced in T&E of shipboard systems

- **Task: Validate ETV Protocol**
  - Independent review of document
  - Model test pad
  - Pilot test
Test Facility Components

Pumps

Tanks

Test Pad
Validation of protocols requires solving many challenging problems

Fundamental questions and challenges regarding “HOW-TO” perform testing
Control and automation essential
- Consistency, reliability and economy
- Scientifically defensible

Approach: industrial process control system
- Simultaneous operation and feedback control
  - Valves, pumps and sensors
- Data acquisition and archiving
- Automated data analysis and reduction
- Alarm conditions for operation outside of specifications
  - Facility
  - BWT manufacturer

High degree of control
- Guaranteed operating conditions
- Verifiable record
- Reduced human error
- Reduced induced-organism mortality at sampling locations.
Instrumentation

- Over 100 instrumented sensors.
  - Flow rate
  - Pressure & Differential Pressure
  - Temperature
  - Dissolved Oxygen
  - Turbidity (NTU)
  - pH
  - Particle Counts & Size Distribution

- 96 valves
  - Flow rate control
  - Isolation & Flow distribution
  - Sample acquisition
  - Most pneumatic and electrically actuated
  - Manual valves wired with a magneto-sensor for open/closed information and supervisory monitoring (QA/QC purposes)

- Sample acquisition ports pre-BWT, post-BWT, post-tank
  - Organisms
  - Chlorophyll, POC, DOC, CHNP
Lesson

Don’t bust…

Or

Let the electrons work the 14 hour days…

…but keep some smart people around…

…and VALIDATE
Automation: Rapid and Consistent Analysis

The expert at the ‘scope is neither sustainable nor desirable

Counting and Classifying 300 Zooplankton Organisms As Dead or Alive Takes (Poke Method) a Human Operator at Least 3.5 Hours.

Very Difficult to Maintain Observational Consistency

Sample Degradation within 6 hours

Automation results:

Greatly reduced analysis time

Image and Video Archive

Cost Over Time is Less - Fewer Technicians
Automation of Sample Analysis

- **FlowCAM by Fluid Imaging Technologies Inc.**
  - 1 um to 3 mm optical flow cytometer

- **In-house Image Analysis**
  - Larger plankton

*Not an endorsement!
Automated Sample Analysis
Initial Results

- Data Archive
  - Particularly image files
- Reduced time
- Increased consistency
- Reduced cost (eventually...)
Consistency and Comparability

- Harmonization is critical among test organizations/facilities
  - Domestic
    - NRL Key West FL
    - GSI Superior WI
    - MERC Baltimore MD
    - PNNL Sequim WA
  - International
    - NIVA Norway
    - NIOZ Netherlands
    - Korea?
    - Japan?
    - South Africa?
Lesson

Don’t color outside the lines

Or

Standardization, comparability, and consistency are critical
Comparability and Consistency Paramount

- Test rigor and QA/QC need to be comparable across tests
  - Within sites
  - Across sites

- Significant variability will hurt
  - Buyers need to know system will perform as needed
    - Certificate alone not enough
      - Approved systems may be required (IMO, U.S.?*)
      - Discharge standard may also apply (IMO, CA, U.S.?*)
  - Regulatory agencies need to have confidence

* Based on pending legislation
Achieving Consistency and Comparability

- **Standard procedures**
  - Validation
- **Intersite “calibration”**
  - Analytic methods
    - Spiked blind samples
  - Site comparisons
    - Parallel tests
- **Transparency**
  - Public reports
    - Results
    - Methods

**Standard Test Organisms**

- **Pros**
  - Common biological link between tests
  - Eventually – simplification of analyses??
- **Cons**
  - Added complexity
    - Culturing, injection, stock consistency
  - NIS concerns
Things to Consider

- Process control and automated analysis are paramount.
  - Production time scales
  - Large quantities
  - High statistical confidence and rigor
  - High quality assurance

- Surrogate identification & optimization work required.
  - Comparability among tests…
  - Significant drawbacks

- Multiple test sites are likely necessary for reliable and consistent testing in the future.
  - Test facility designs and procedures require validation
  - Need to ensure a satisfactory level of inter-site comparability