



Capabilities of Shipboard Ballast Water Treatment Technology

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Regulatory Applicability

- In the United States, ballast water discharges from vessels are primarily regulated by two federal regimes:
 - Under the Clean Water Act, implemented under the Vessel General Permit (VGP) by the EPA
 - Under the National Invasive Species Act, implemented under regulations promulgated by the Coast Guard



Who is covered by the VGP?

- Vessels which discharge into waters of the United States need to have an NPDES permit for their discharge(s), unless they are one of the following types of vessels:
 - Recreational Vessels, regardless of size (as defined in CWA section 502(25))
 - Vessels of the Armed Forces, as defined in Section 40 C.F.R. § 1700.3.
 - Vessels less than 79 feet (unless discharging ballast water)
 - Commercial fishing vessels of any size (unless discharging ballast water)



VGP Applicability

available at: www.epa.gov/npdes/vessels

- Estimated to cover approx. 61,000 US flagged commercial vessels and 8,000 foreign flagged
- As of July 27, 2010, more than 50,000 Notices of Intent (NOIs) were submitted to EPA – nearly 44,000 of which are active.





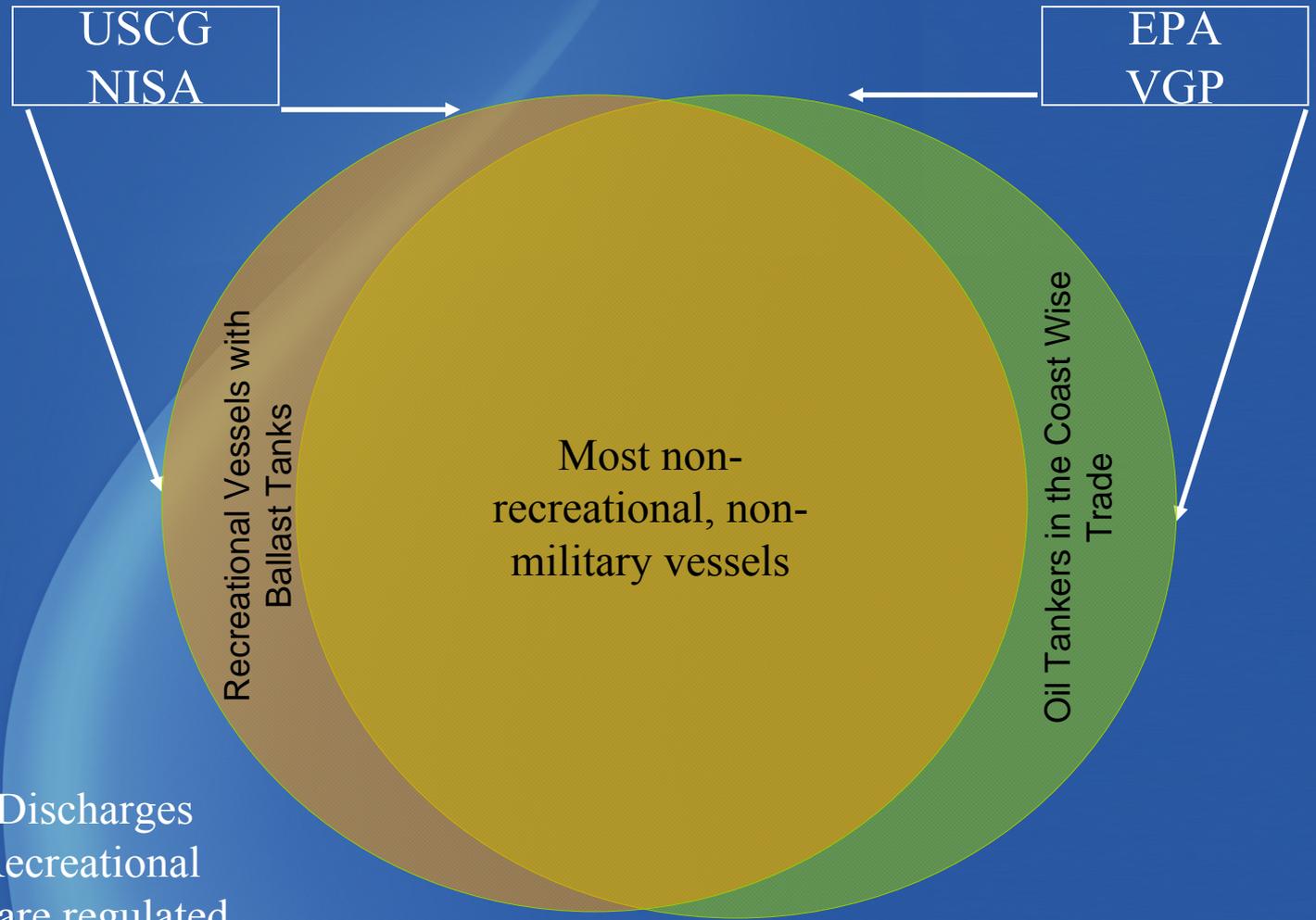
US Coast Guard Ballast Water Regulatory Applicability



- Applies to all vessels with ballast tanks, except a few statutory exceptions, including:
 - Crude oil tankers engaged in the coastwise trade
 - Department of Defense and Coast Guard Vessels



Regulatory Overlap of Ballast Water Discharges for NPDES program and NISA



Note: Discharges from Recreational Vessels are regulated by Section 312 of the CWA

DOD and Coast Guard Vessels



Vessel Characteristics (based on VGP NOIs submitted)



- Vessels range from inland barges and tugs to ocean going container ships and tankers
 - Ballast water capacity ranges from 0 to more than 100,000 m³
 - Of the 29,000 NOIs which contain both tonnage and ballast water information, more than 10,000 vessels have less than 100 cubic meters – most of these vessels are less than 2,000 Gross Tons (GT), but some as large as 40,000 GT
- Of the 50,000 vessels having submitted NOIs, approximately 16,500 report leaving the US Exclusive Economic Zone and 4,400 report being engaged in Pacific nearshore voyages
 - More than 29,000 total vessels are barges – many are unmanned and unpowered and travel either inland or coastal routes



The average ballast capacities of vessels as determined by a USCG analysis

For a comparison, the volume in an Olympic Size swimming pool is about minimum 2,500 m³

Category Description	Average Ballast Capacity (m ³)
Capesize Bulker	63,000
Chemical Carrier	10,700
Combination Vessel	7,300
Feeder Container Ship	2,900
Feedermax Container Ship	3,700
Gas Carrier	11,600
General Cargo Vessel	4,500
Handy Bulker	17,700
Handy Container Ship	8,000
Handy Tank Ship	6,400
Handymax Tank Ship	31,500
Panamax Bulker	35,600
Panamax Container Ship	17,200
Panamax Tank Ship	54,100
Passenger Ship	2,600
Postpanamax Container Ship	19,100
RORO	7,700
Subpanamax Container Ship	13,900
ULCC Tank Ship	93,000
VLCC Tank Ship	89,200
Minimum	2,600
Maximum	93,000
Average (not weighted)	24,985



Existing VGP Ballast Water Limits



- The permit:
 - Incorporates Coast Guard mandatory management and exchange requirements
 - In addition, vessels engaged in Pacific nearshore voyages must conduct exchange greater than 50 nm from the coast
 - Mandatory saltwater flushing for all vessels with residual ballast water and sediment (NOBOBs) coming from outside the USEEZ



Existing VGP Ballast Water Limits (cont.)

- Must use shore-based treatment if available and economically practicable and achievable
- Must conduct exchange as early as practicable
- Exchange/flushing requirements have a safety exemption and do not mandate diversion



Technology-Based Numeric Ballast Water Limits



- EPA did not require numeric ballast water limits in the 2008 VGP. Why not?
 - At the time of permit issuance (12/18/2008), EPA found treatment technologies that could form the basis for such limits were not:
 - “Available” and
 - Economically achievable
 - Lack of data meeting these tests as of permit issuance
- Some states added numeric ballast water limits for their state waters pursuant to CWA 401 certification



BWM Technology

Unit Processes

- **Mechanical**
 - Filtration (screen, media*)
 - Separation (cyclonic, Ionic*)
 - Shear
- **Chemical**
 - Deoxygenation (pressure, N₂, inert gas generators)
 - Oxidizing biocides (OCl⁻, ClO₂, O₃, AOT)
 - Non-oxidizing biocides (SeaKlean, gluteraldehyde*, acrolein)
- **Energy**
 - Radiation (UV, heat, ultrasonic)
 - Micro-Cavitation



Living Organism Standards

- Most existing standards express limits as an acceptable value of living organisms
- Classes typically include:
 - $>50 \mu\text{m}$: $<10/\text{m}^3$ - $< 1/100 \text{ m}^3$
 - $10 \mu\text{m}$ – $50 \mu\text{m}$: $<10/\text{ml}$ - $< .01/\text{ml}$
 - Microbiologicals (Indicator bacteria, total bacteria, and viruses or virus-like particles)



Two other approaches

- “No detectable living organisms” (CA)
- Requirements prescribing certain treatment approaches (Michigan Approach)





Examples of standards suggested or used by the international community or domestic regulatory agencies

 NARRATIVE DESCRIPTION	Size: $\geq 50 \mu\text{m}$	Size: $< 50 \mu\text{m}$, but $\geq 10 \mu\text{m}$	Bacteria	Viruses
"IMO"	< 10 living organisms per m^3	< 10 living organisms per ml	<u><i>Vibrio cholera</i></u> < 1 CFU per 100 ml <u><i>E. coli</i></u> < 250 CFU per 100 ml <u><i>Intestinal enterococci</i></u> < 100 CFU per 100 ml	-----
"100 x IMO" ¹	< 0.1 living organisms per m^3	< 0.1 living organism per ml	<u><i>Vibrio cholera</i></u> < 1 CFU per 100 ml <u><i>E. coli</i></u> < 126 CFU per 100 ml <u><i>Intestinal enterococci</i></u> < 33 CFU per 100 ml	-----
"1000 x IMO" ¹	< 0.01 living organisms per m^3	< 0.01 living organism per ml	<u><i>Vibrio cholera</i></u> < 1 CFU per 100 ml <u><i>E. coli</i></u> < 126 CFU per 100 ml <u><i>Intestinal enterococci</i></u> < 33 CFU per 100 ml	-----
"CA Interim Standards"	0 detectable living organisms	< 0.01 living organism per ml	<u><i>Vibrio cholera</i></u> < 1 CFU per 100 ml <u><i>E. coli</i></u> < 126 CFU per 100 ml <u><i>Intestinal enterococci</i></u> < 33 CFU per 100 ml $< 10^3$ bacteria per 100 ml	$< 10^4$ viruses per 100 ml
"CA Final Standards"	0 detectable living organisms	0 detectable living organisms	0 detectable living organisms	0 detectable living organisms

¹ Note – the "100 x" and "1,000 x" refer only to the " $\geq 50 \mu\text{m}$ " and the " $< 50 \mu\text{m}$, but $\geq 10 \mu\text{m}$ " size groupings. See Table 1 in the White Paper for more detail



Questions/Discussion





The Study Charge

 Question 1: Designed to evaluate the performance of shipboard systems with available effluent testing data

- 1a. For the shipboard systems with available test data, which have been evaluated with sufficient rigor to permit a credible assessment of performance capabilities in terms of effluent concentrations achieved (living organisms/unit of ballast water discharged or other metric)?
- 1b. For those systems identified in (1a), what are the discharge standards that the available data credibly demonstrate can be reliably achieved (e.g., any or all of the standards shown in Table 1 of the White Paper? Furthermore, do data indicate that certain systems (as tested) will not be able to reliably reach any or all of the discharge standards shown in that table?
- 1c. For those systems identified in (1a), if any of the system tests detected “no living organisms” in any or all of their replicates, is it reasonable to assume the systems are able to reliably meet or closely approach a “no living organism” standard or other standards identified in Table 1 of the White Paper, based on their engineering design and treatment processes?



The Study Charge



- Question 2: Designed to evaluate potential performance of shipboard systems without reliable testing data
 - Based on engineering design and treatment processes used, and shipboard conditions/constraints, what types of ballast water treatment systems (which may include any or all of the systems listed in Table 4 of the White Paper) can reasonably be expected to reliably achieve any of the standards shown in Table 1 of the White Paper, and if so, by what dates? Based on engineering design and treatment processes used, are there systems which conceptually would have difficulty meeting any or all of the discharge standards in Table 1 of the White Paper?



The Study Charge

Question 3: Designed to evaluate future system potential performance

- 3a. For those systems identified in questions 1a and 2, are there reasonable changes or additions to their treatment processes which can be made to the systems to improve performance?
- 3b. What are the principal technological constraints or other impediments to the development of ballast water treatment technologies for use onboard vessels to reliably meet any or all of the discharge standards presented in Table 1 of the White Paper and what recommendations does the SAB have for addressing these impediments/constraints? Are these impediments more significant for certain size classes or types of organisms (e.g., zooplankton versus viruses)? Can currently available treatment processes reliably achieve sterilization (no living organisms or viable viruses) of ballast water onboard vessels or, at a minimum, achieve zero or near zero discharge for certain organism size classes or types?



The Study Charge

- Question 4: Designed to identify limitations in data and how we overcome those limitations
 - What are the principal limitations of the available studies and reports on the status of ballast water treatment technologies and system performance and how can these limitations be overcome or corrected in future assessments of the availability of technology for treating ballast water onboard vessels?



The Study Charge



- Related sub-questions of interest:
 - What is current ballast water treatment technology capable of under best industrial-scale circumstances? Are there technological limits?
 - What might current ballast water treatment technologies be able to achieve under real-world circumstances of operating ships?
 - Issues:
 - Space
 - Power
 - Time
 - Conditions (source water, vessel design & materials)



Questions/Discussion





Overview

Treatment Technologies

- Treatment technologies/processes summarized in reports by Lloyd's and ABS
 - Most based on existing ballast water treatment
 - Separation (mostly screen filters, 25-50 um, and hydrocyclones, some flocculation)
 - Non-chemical biocides (ultraviolet, ultrasonic, shear, pressure, heat)
 - Chemical biocides (hypochlorite, ClO₂, O₃, AO, other REDOX reactants, non-REDOX organics)



Overview



Treatment Conditions

- Full range of natural salinities – including hyper-saline
- Full range of organic and inorganic WQ constituents – including urbanized harbors, w & wo WQ protections
- Tropical to polar temperatures
- Wide range of:
 - Capacities ($10^1 - 10^5 \text{ m}^3$)
 - Flow rates ($10^1 - 10^4 \text{ m}^3/\text{h}$)
 - Available time (hours – months)

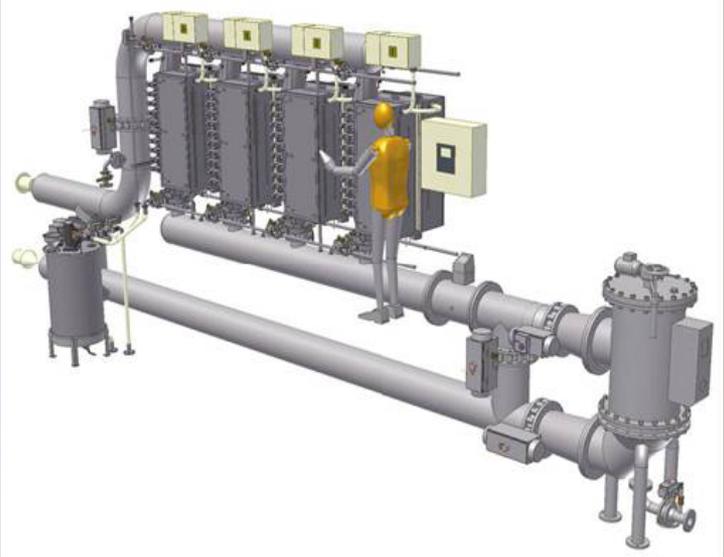


Challenge: Space is Limited





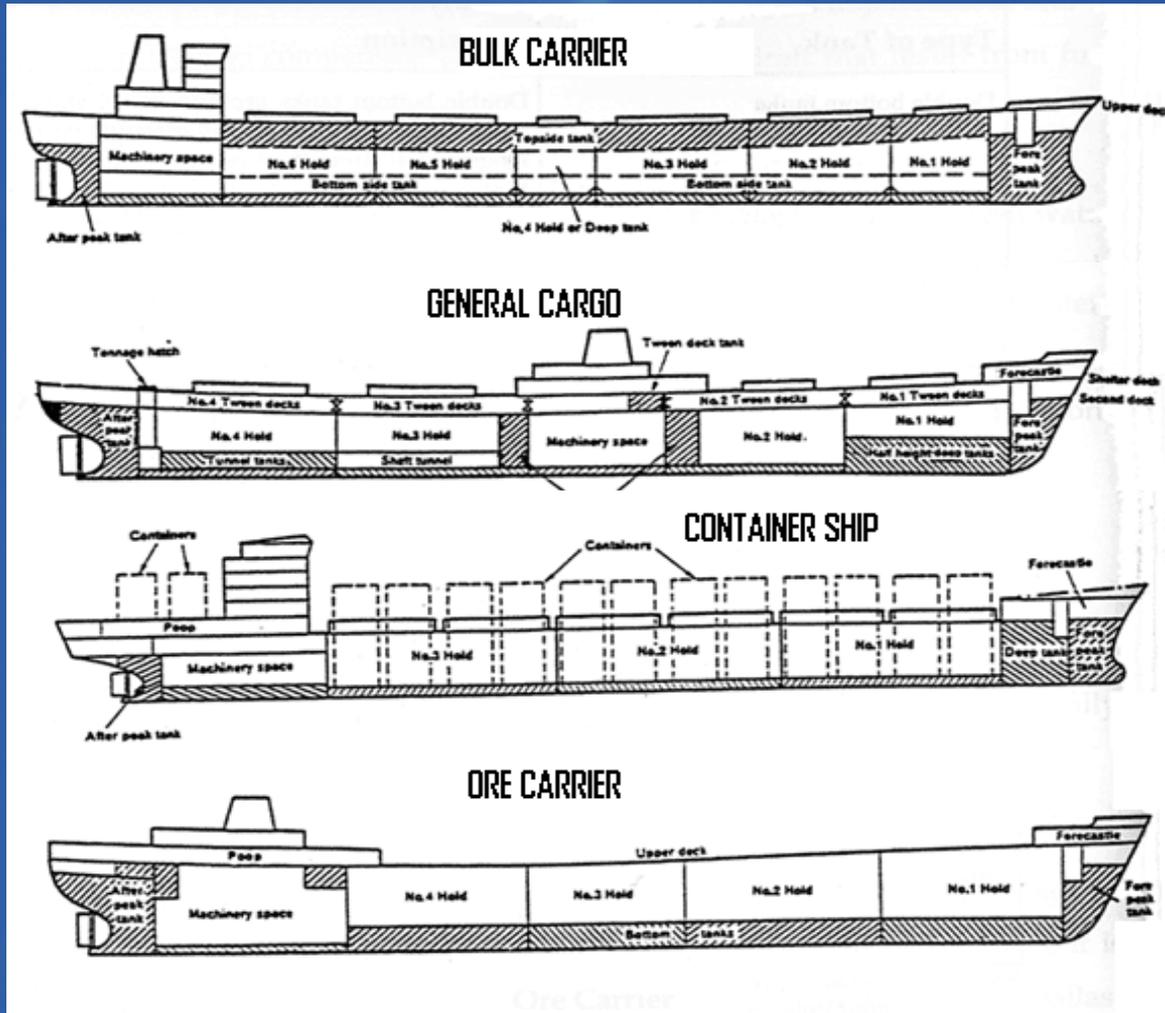
Treatment Systems are Complex





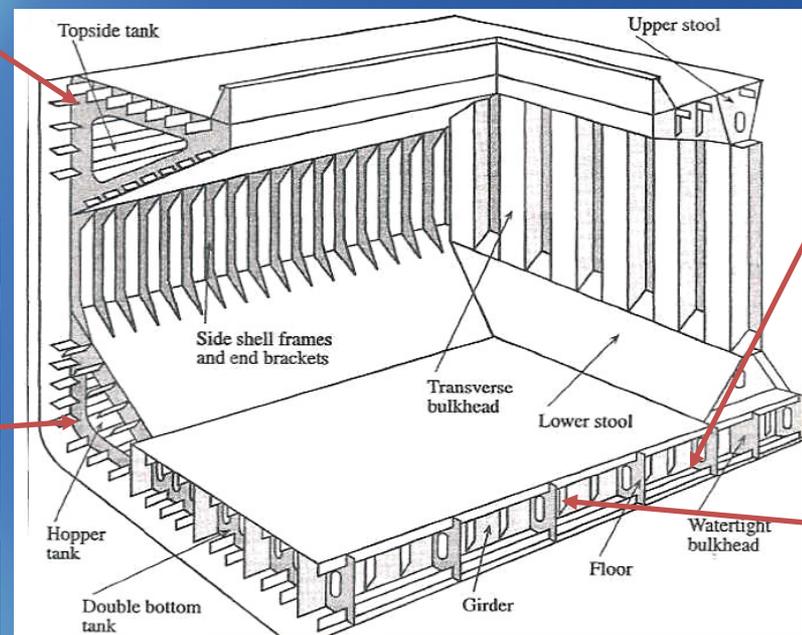
Operational Issues

BW TANK CONFIGURATIONS





Ballast Systems Are Complex



Scientist collecting residual sediment from a side level near the bottom of a forepeak tank. Note scoop (white) in right hand.



Large ballast pipe (left side of picture) in a double bottom tank. Note cellular structure of the tank, consisting of a series of interconnected bays with longitudinals, lightening holes, and other structural cutouts for drainage and access.



IMO Type Approval



- Convention requires that ballast water management systems (= treatment systems) used to meet the Regulation D-2 discharge standard be approved by the Administration (government) under whose flag a vessel operates.
- Recommended approval procedure is described in the *Guidelines for Approval of Ballast Water Management Systems (G8)*



G-8 Approval Guidelines



- **Type approval**
 - A “type unit” of a treatment system model tested under “standardized” test protocols in both land-based and shipboard circumstances
 - Ability to consistently achieve the discharge standard evaluated
 - Electronic control and monitoring components subjected to standardized environmental testing (vibration, incline, temp and humidity)
 - Design and construction specifications reviewed
 - Appropriate for shipboard
 - Manufacturing arrangements reviewed
 - Ability to manufacture to “type” specifications
 - Administration issues type approval certificate



G-8 Treatment Efficacy Test Protocols



- Caveats
 - Negotiated compromise
 - Reflects many technical, economic, and political agendas
 - Relatively short preparation time
 - Key sections left vague
 - Never validated prior to implementation
 - Different fixes at different facilities



G-8 Treatment Efficacy Test Protocols

- Land-based tests
 - Treatment and control
 - 200 m³ volume minimum
 - 200 m³/h flow-rate minimum
 - Sample sizes
 - >50 μm : 1 m³
 - 10-50 μm : 1 L
 - Bacteria: 500 ml
 - 3 “replicate” samples at each time/location
 - Before treatment, after treatment, at discharge



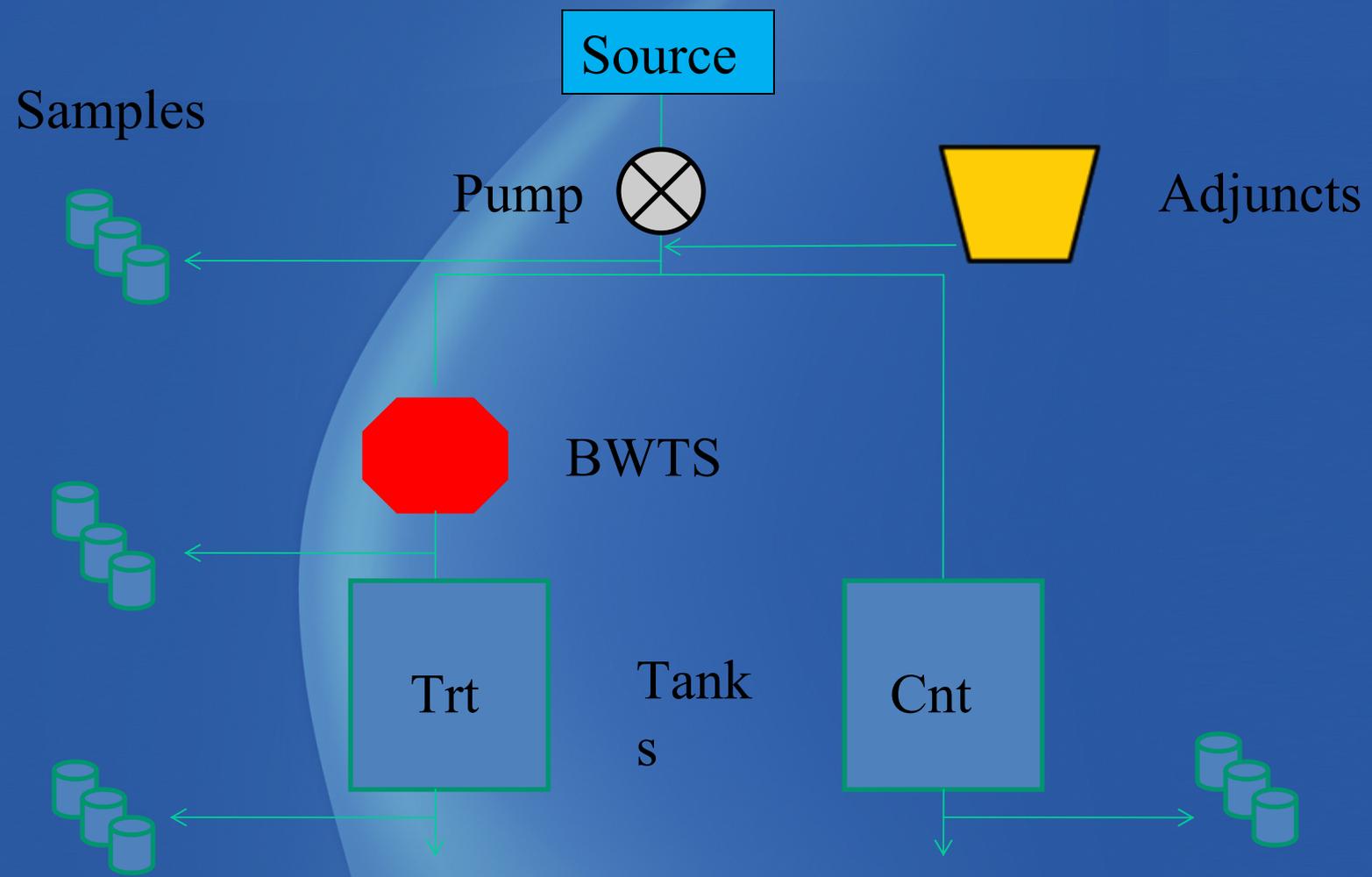
G-8 Treatment Efficacy Test Protocols



- Shipboard tests
 - Treatment tank(s) (multiple??)
 - Control tank
 - Volumes and flows consistent with normal operation of vessel
 - 3 consecutive valid test runs required
 - Uptake organism concentrations $>10x$ D-2 std
 - Discharge organism concentrations $>$ D-2 std

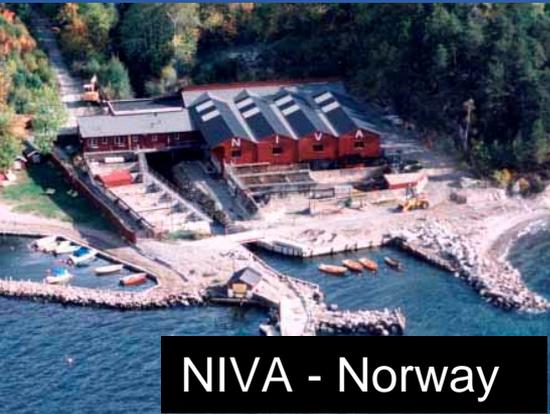


G-8 Land-based Schematic





CONSISTENCY & RELIABILITY AMONGST TEST FACILITIES, DOMESTICALLY & INTERNATIONALLY



NIVA - Norway



NIOZ - Netherlands



GSI - Superior, WI



MERC - Baltimore, MD

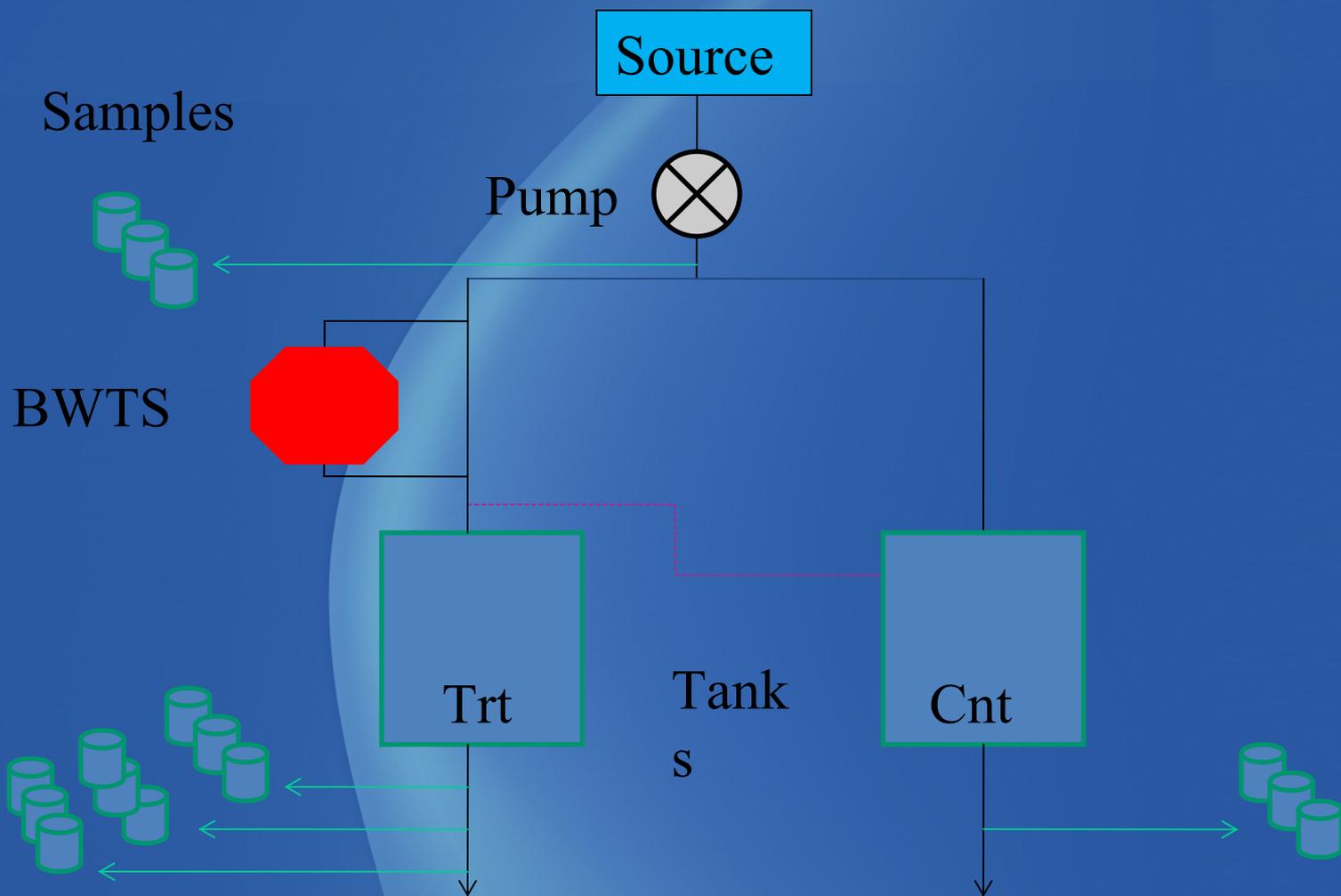


Tokyo, Japan

Also South Africa, Republic of Korea



G-8 Shipboard Schematic





Questions/Discussion





Data Presented to the Committee

- Information divided into three major groups:
 - Summary reports produced by parties evaluating the availability of existing ballast water treatment systems or their potential efficacy
 - Primary performance data reports and other key information available to EPA and USCG
 - Reference library for the committee (IMO G-9 documents and one class society advisory)



Data Presented to the Committee

Summary Reports



- Reports include:
 - Lloyd’s Register Review
 - American Bureau of Shipping (ABS) advisory
 - California State Lands Commission Reports
 - IMO circular
 - Excerpts from Lee et al. white paper “Density Matters”
- Reports provide (some or all of the following)
 - summary information on specific systems
 - general information on how systems work
 - presentation and evaluation of summary data
 - conclusions about potential commercial availability of systems



Data Presented to the Committee

Primary Performance Data and other Information

- Most data collected with intent of ultimately seeking type approval. Data are from:
 - data reports from the testing of ballast water treatment systems provided to foreign Administrations in granting type approval under the BW Treaty or
 - data reports gathered by vendors in preparation to apply for type approval by a flag Administration, or
 - application packets prepared by the vendor and submitted to the USCG under the Shipboard Technology Evaluation Program ([STEP](#))



Data Presented to the Committee Reference Library



- G9 Papers
 - Submitted for systems seeking active substance approval
 - Primary purpose for papers is to explore potential active substance impact on receiving waters
 - Outline how a given ballast water treatment system functions
 - May discuss mechanism for neutralizing organisms
- ClassNK class society advisory document



Other Regulatory Evaluations

(concurrently being conducted or likely to be conducted in the near future)

- California
 - Biennial basis
 - Staff evaluate data, seek input from an advisory panel, determine whether systems are potentially available to meet their limits, and seek report approval by commissioners
 - Updated report may be finalized this summer
- Wisconsin
 - Required by state legislation
 - Evaluation being conducted with advice from Great Lakes “Ballast Water Collaborative”
- US Coast Guard practicability reviews
- US EPA BAT evaluation for next VGP



Acquiring credible third party data from flag administrations or vendors

- EPA and USCG have not been able to gather all available data for the SAB's use
 - Some flag states have been unable/unwilling to share all data with US government, represented by the Coast Guard
 - EPA and Coast Guard unable to contact broad group vendors
 - Some vendors unresponsive regarding sharing data reports for this project



Use of Additional Information



- EPA and USCG are strongly supportive of the committee using additional, third-party data submitted via public comment or introduced by any committee member, provided it is:
 - Peer reviewed published data or
 - Third-Party laboratory data or shipboard testing data in final or similar report



Questions/Discussion





Testing Data Concerns: General



- Non-standard methods among test facilities
- Lack of available facility validation documentation
 - Ability to control spec'd conditions
 - Ability to measure with acceptable precision and accuracy
- Lack of available QA/QC documentation for tests
- Independence of testers and vendors



Testing Data Concerns: Sampling

- Representative samples?
 - Sample port design
 - Installation
- Sample volume
 - “replicates” are not independent
 - Volume = 1 m³, 3 m³, or 9 m³ depending
 - Not sufficient for measuring very low concentrations (1/10 m³, 1/100 m³)
- Sampling artifacts
 - Source of mortality



Testing Data Concerns: Sampling

- Sample analysis
 - Viability assays
 - Accuracy and precision in detection and enumeration
 - Safe window for processing



Questions/Discussion

