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Reliable Instruments for an Unreliable World

Rapid Compliance Monitoring using Indicative Tools

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Vice President of Marketing and Sales, Turner Designs
May 25, 2016

Regulation States

Organism size	Amount allowable in discharge
≥ 50 micrometers	<10 viable/living organisms per cubic meter
10 – 50 micrometers	<10 viable/living organisms per milliliter
Toxicogenic Vibrio cholerae	< 1 colony forming unit per 100 milliliters
Escherichia coli	< 250 colony forming unit per 100 milliliters
Intestinal enterococci	< 100 colony forming unit per 100 milliliters

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Monitoring – Tiered Approach

- **Level 1 – Initial Inspection**
  - Documentation, crew knowledge
- **Level 2 – More Detailed Inspection**
  - Equipment operation, self-monitoring indicators
- **Level 3 – Indicative Measure of Gross Non-Compliance**
  - Quickly, easily assess risk of non-compliance
- **Level 4 – Direct Measure of Compliance**
  - Lowest risk, highest certainty, longest time

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Why do Rapid Compliance Monitoring?

- A way to give port state officials and ship operators a quick and easy determination of whether treated ballast water is in risk of non-compliance with the standard
- Provides an indicative measure to avoid having to undertake a direct measure of compliance

Indicative Measurements: Why Sample 10-50um cells?

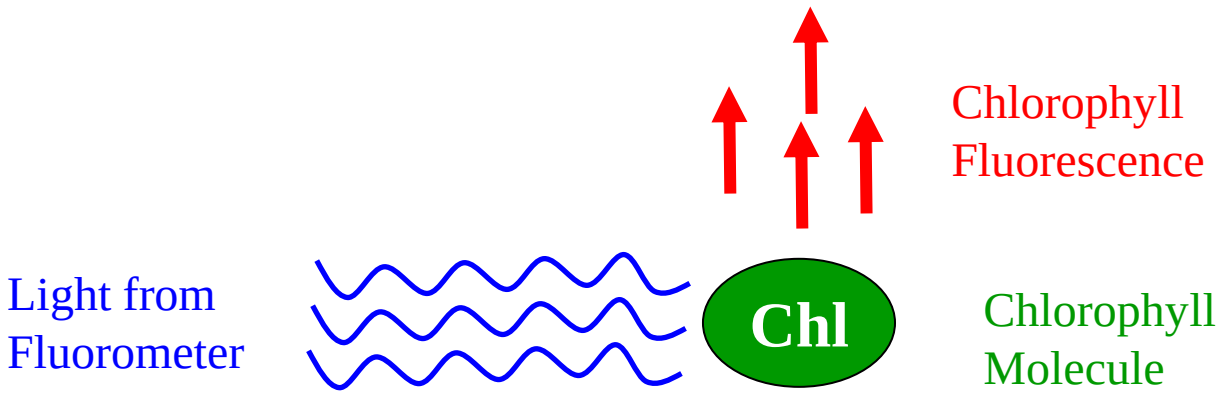
- Sample volume ideal
- Algal abundance proportional to bulk fluorescence
- Cell viability calculated using variable fluorescence
- Methods are simple, quick, no reagents required
- Respond to all treatment technologies

Indicative !

Algal Abundance

Algal abundance ~~ fluorescence detected from chlorophyll within algae

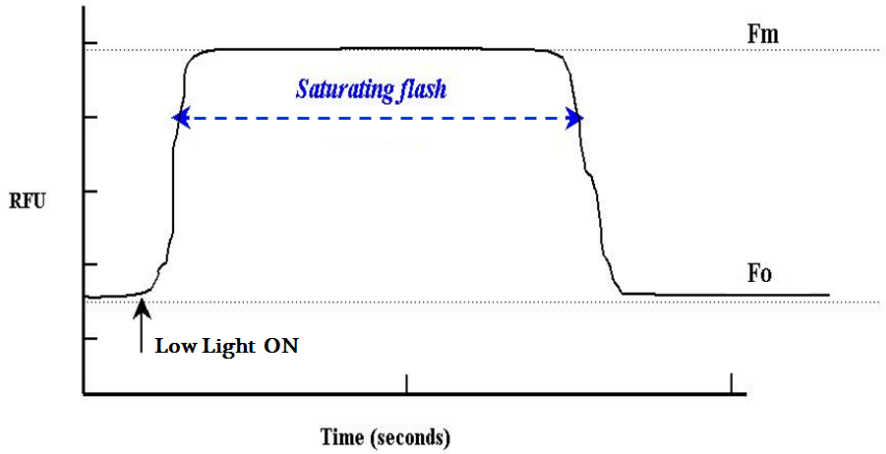
- Sample illuminated and light is absorbed by the cells
- Sample emits light (fluorescence)
- Fluorescence is quantified and displayed as a digital number estimating the algal abundance



Algal Activity

PAM measures photosynthetic efficiency (activity)

- Sample probed by low light level to determine background fluorescence (minimum fluorescence Fo)
- While monitoring background fluorescence, sample is blasted (saturated) with a high intensity light giving a maximum fluorescence value (Fm)
- These 2 values, Fo and Fm, are used to calculate an activity ratio that gives a good measure of how active algae are in the sample
  - Typical values for active algal cultures range from 0.25 – 0.70



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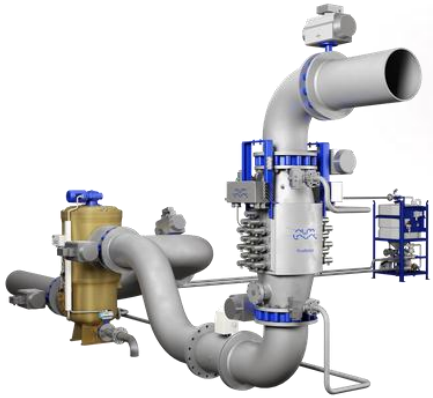
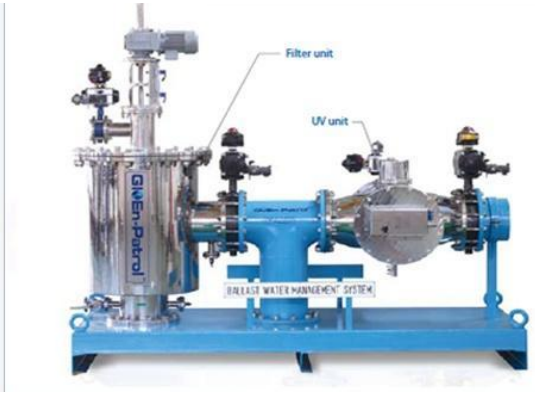
Indicative Tools respond to all Treatment Types





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Indicative Data: Chlorination System

Water Type	Cell Count (10 – 50 µm)	Ballast-Check 2	
		Total Chl	Activity
Raw	163.7	2.20 ± 0.03	0.36 ± 0.02
Treated	NA	0.30 ± 0.06	ND
After 24 hour hold at 11 ppm Chlorine Concentration			
Treated (T_i)	0	0.30 ± 0.00	ND
Treated (T_m)	2.5	0.20 ± 0.05	ND
Treated (T_f)	7.6	0.80 ± 0.10	0.19 ± 0.04

Data taken Dec. 1st and 2nd, 2014 aboard the Golden Bear during a ballast water treatment test using chlorination method.

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Indicative Data: UV System

Sample numbers	Ballast tank #	Uptake Fv/Fm	Treated Discharge Fv/Fm
Untreated #1 (Treated #4)	1	0.65	0.10
Untreated #2 (Treated #5)	2P/2S	0.58	0.06
Untreated #3 (Treated #6)	4S/4P/5	0.64	0.12
Mean ± Standard Deviation		**0.62±0.04**	**0.09±0.03**
Untreated #7 (Treated #10)	1	0.52	0.15
Untreated # 8 (Treated #11)	2P	0.57	0.15
Untreated # 9 (Treated #12)	2S	0.57	0.13
Mean ± Standard Deviation		**0.55±0.03**	**0.14±0.01**
Untreated # 13 (Treated #16)	1	0.58	0.1
Untreated # 14 (Treated #17)	2P	0.57	0.13
Untreated # 15 (Treated #18)	2S	0.59	0.15
Mean ± Standard Deviation		**0.58±0.01**	**0.13±0.02**
Grand mean ± Standard Deviation		**0.59±0.04**	**0.12±0.03**

Data collected by David Wright, August 2014, for a Hyde Guardian treatment system in a fresh water test.

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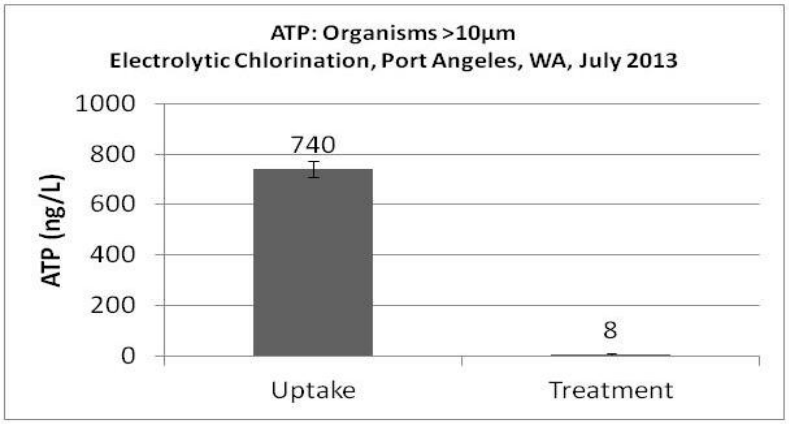
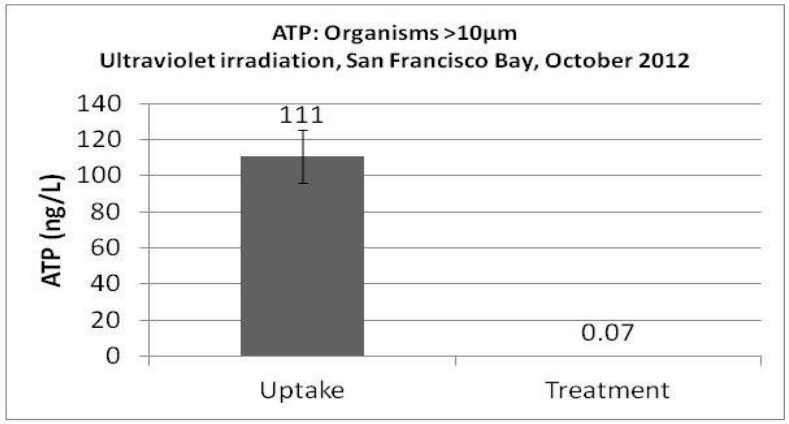
Indicative Data: ATP Method

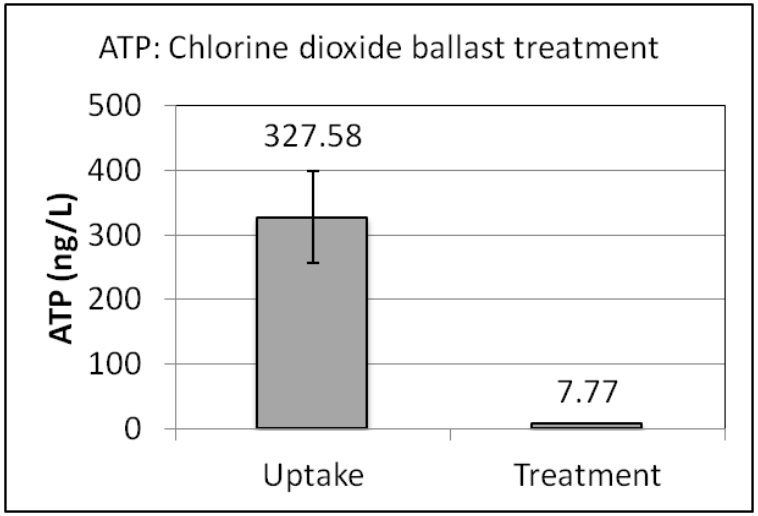
A. Hypochlorite treatment



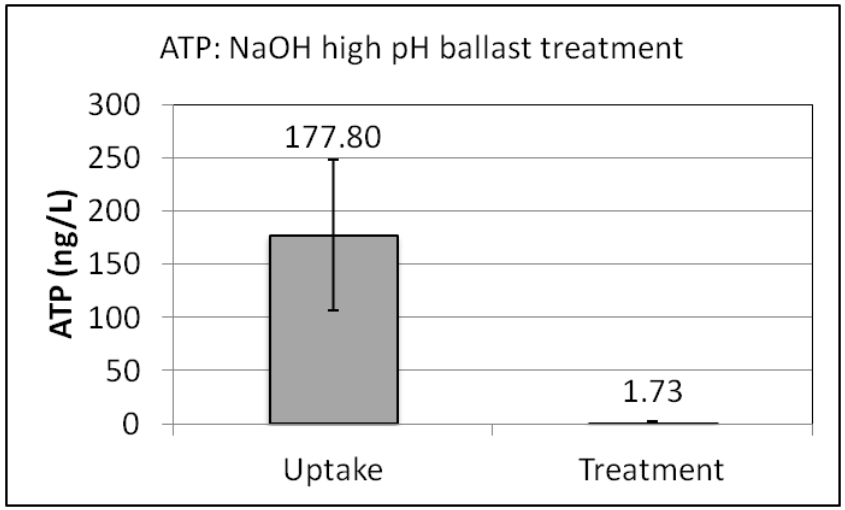
B. UV treatment



C. Chlorine dioxide treatment



D. NaOH treatment (freshwater)



Data courtesy Nick Welschmeyer

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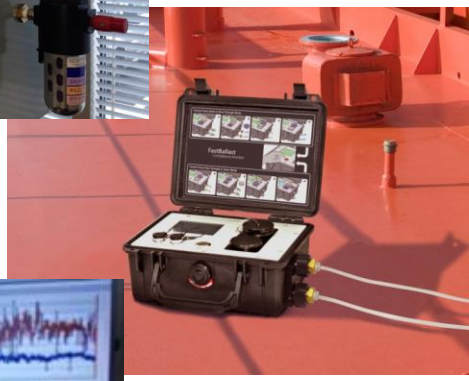
Indicative Monitoring Continuous or Discrete?

- Continuous
  - Installed & sampling all the time
  - Check large sample of water
- Discrete
  - Simple & quick
  - Independent verification
  - Low/no maintenance required



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Who is Validating Rapid Compliance Monitoring?

- USCG
- IMO
- Regulators
- Researchers

United States Coast Guard
U.S. Department of Homeland Security

IMO
INTERNATIONAL MARITIME ORGANIZATION

ALLIANCE FOR COASTAL TECHNOLOGIES
SUPPORTING INNOVATION TO BETTER UNDERSTAND, PREDICT AND MANAGE COASTAL, OCEAN AND GREAT LAKES ENVIRONMENTS.

California STATE LANDS Commission

David Consult

MEA-NL
MARINE ECO ANALYTICS

PML | Plymouth Marine Laboratory

NAVAL RESEARCH LABORATORY
WASHINGTON, DC

NRL/ACT leading USCG Validation

- Validation Round 1
  - June – September 2015
  - 2 discrete tools, 1 inline tool
  - 1 set of laboratory-based experiments
  - 3 sets of field-based experiments
  - Side by side comparison with standard method
- Validation Round 2
  - Started March 2016
  - 3 discrete variable fluorescence tools
  - 1 discrete ATP tool demonstrated
  - Expected completion Summer 2016


Photo: M. First; NRL; June 2015

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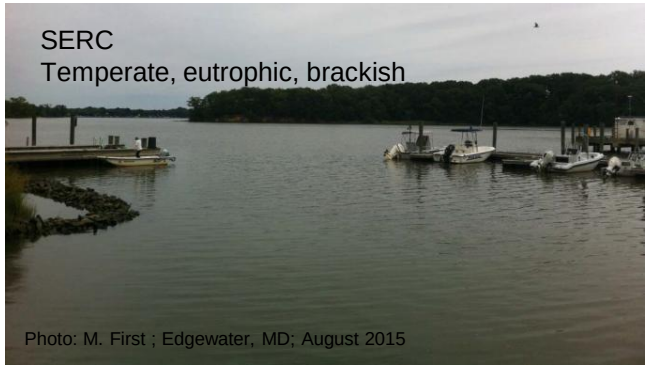
Initial Results Look Good

- Data show general agreement between indicative tools & microscope counts
- Results are preliminary & do not yet include all data
- Presentation given January 21, 2106 at ICMB-IX in Sydney
- Reports for individual tools will eventually be available through Alliance for Coastal Technologies (www.act-us.org)



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RV Meteor German Vessel

- Evaluate ballast sampling devices and analytic tools
- Mindelo, Cape Verde to Hamburg, Germany
- 2 weeks
- 19 researchers from 10 countries
- 28 experiments
- Several sampling devices
- Analytic devices: >=50 µm
- Analytic devices: 10 µm ≥ X < 50 µm
- Analytic devices: Indicator microbes

Project Leads: BSH and DFO

Analytic Devices(10 µm ≥ x < 50 µm)

- PAM methods (4)
  - bbe 10cells, Turner Designs Ballast-Check2, Hach BW680, Walz-Water PAM
- Microscopy (staining)
- ATP methods (2)
  - SGS method (aqua-tools), Welschmeyer method
- Bulk FDA
- FDA pulse counting
  - Satake Pulse Counter
- Flow cytometry

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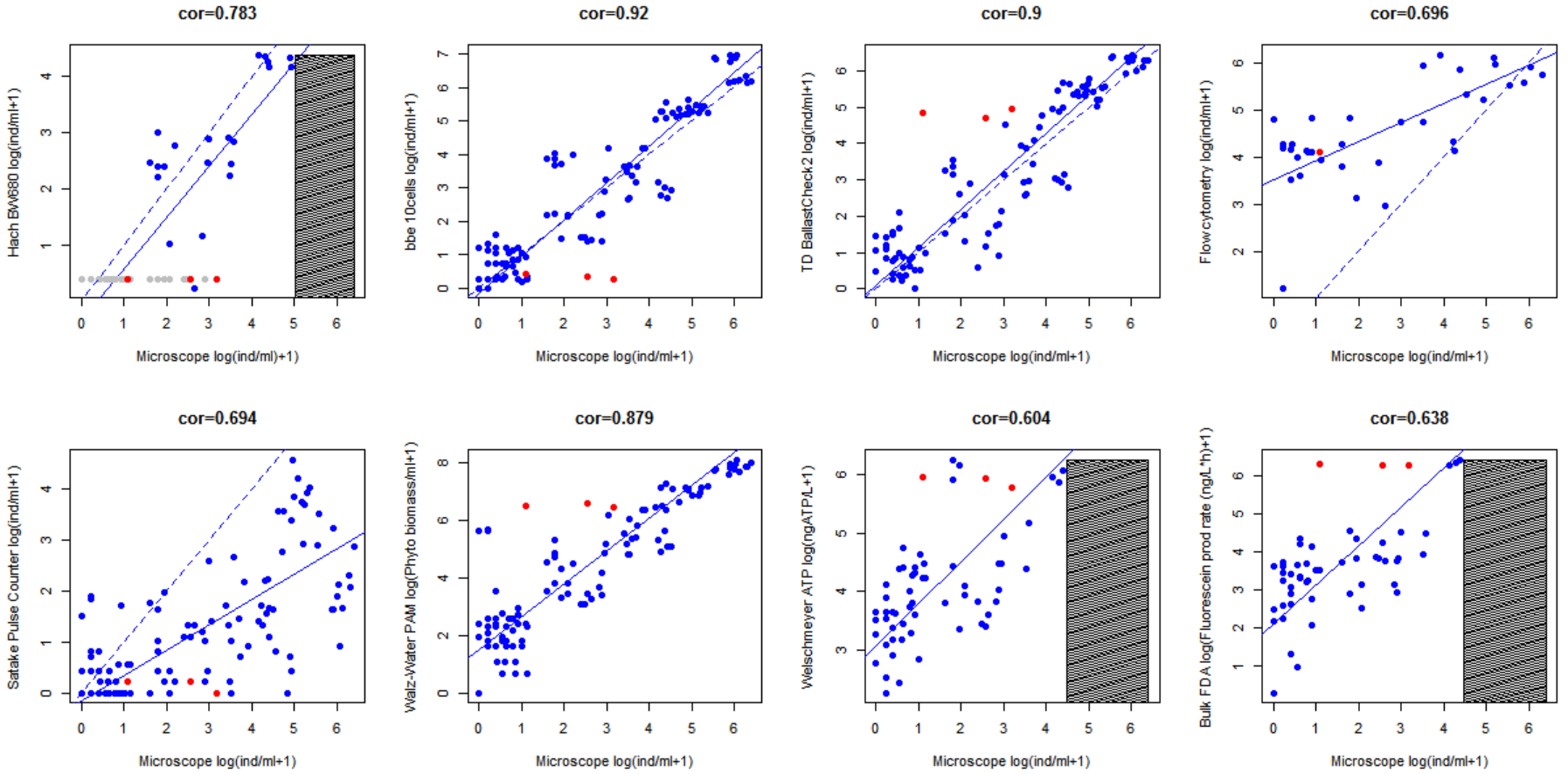
Meteor evaluated Indicative methods vs. Microscopy: 10-50µm



- Solid line is line of best fit based on Deming regression.
- Dashed line is 1:1 line for methods reporting results in individuals/ml.
- Red dots indicate data from experiments where BWMS was active. Grey dots indicate data below detection threshold.
- Shaded grey area shows region where data was not available.

Data belongs to METEOR participants. Funding by BSH and DFO

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CSLC Testing Indicative Tools

- Collected treated water samples from 3 ships
  - Planning to do 2-3 more
- Comparing results from 3 indicative tools to microscopic cell counts
- Conclusions should be available early summer
- Still developing compliance assessment protocol regulations
  - Rulemaking expected later this year

California STATE LANDS Commission

David Consult Testing Indicative Tools

- Port of Koper (Slovenia)
  - Simulate PSC sampling process
  - Test with several indicative tools onboard vessels
  - Samples taken to laboratory, results compared with microscope counts of 10-50µm cells using microscopy & FDA stain
- 10 vessels sampled & tested

Dr. Matej David
matej.david@siol.net

David Consult

MEA-NL Testing Indicative Tools

- Part of MEA-NL's ongoing intercalibration of instruments
- Comparing abundance with flow cytometry/ FDA staining
- Comparing viability with high end scientific instruments
- Performing land-based and shipboard tests of different type of BWMS

MEA-NL
MARINE ECO ANALYTICS

info@mea-nl.com

PML & Marinha do Brasil are Testing Indicative Tools

- How they work in real situations
  - During shipboard tests on ballast water management systems already installed /in use
- How their results correlate to laboratory-based tests
  - Flow cytometry and staining microscopy / cell counts;
- To what extent results are reliable and correspond to international standards
  - IMO & USCG
- A continuous series of measurements with the same indicative tools and laboratory-based techniques are being applied for L4 samples (Western English Channel).

PML | Plymouth Marine Laboratory

MARINHA DO BRASIL

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Who is Using Rapid Compliance Monitoring?

- BWTS Testing Labs
- Treatment System manufacturers
- Sampling System manufacturers
- Port States

DHI
The expert in WATER ENVIRONMENTS

ERMA FIRST
Powered by EPE
The Essential Ballast Solution

Glosten

Hyde Marine
Ballast Water Management Technology
A CALGON CARBON COMPANY

TRITON MARINE SCIENCE & CONSULT

http://tritonmsc.de/

e-CME BALLAST WATER
Compliance Monitoring & Enforcement

Glosten Using Indicative Tools

Ballast-Check 2 was used by the Glosten team to gain quick feedback on the efficacy of the USGS developed sodium hydroxide treatment system efficacy during 2015 shipboard trials, and now during 2016 trials. The table below aligns the obtained abundance and activity readings with those gained by CMFDA/FDA readings taken as per EPA ETV protocol.

FDA/cmFDA epiflourescent microscopy results (EPA ETV protocol) vs Turner Ballast-Check2

Test	Sample	Time (hrs)	cells/mL (#1)*	cells/mL (#2)*	Pass/Fail	Abundance	Activity	Risk
1	Uptake	0	21.0	-	Fail	1.7	0.21	**Low**
1	Control	48	7.6	30.3	Pass/Fail	2.9	0.18	Low
1	Low	48	0.9	0	Pass	0.7	0.14	Low
1	High	48	0.0	0	Pass	2.7	0.27	Low
2	Uptake	0	30.0	-	Fail	25.2	0.25	High
2	Control	48	6.3	26.3	Pass/Fail	5.6	0.23	Low
2	Low	48	0.0	0	Pass	2.3	0.09	Low
2	High	48	0.0	0	Pass	5.7	0.11	Low
3	Uptake	0	119.7	-	Fail	69.4	0.39	High
3	Control	48	52.2	242	Fail	13.0	0.37	High
3	Low	48	7.1	0.3	Pass	1.2	0.10	Low
3	High	48	5.1	0	Pass	8.2	0.14	Low
4	Uptake	0	211.7	-	Fail	59.9	0.47	High
4	Control	48	256.9	336.7	Fail	9.7	0.27	**Low**
4	Low	48	7.1	1.7	Pass	0.9	0.10	Low
4	High	48	7.2	0	Pass	7.0	0.09	Low

*#1 refers to results from the shipboard science team, #2 refers to results from a 2nd science team that analyzed samples sent by mail

High Risk:	High Algal Abundance	AND	High Algal Activity
Low Risk:	Low Algal Abundance	OR	Low Algal Activity

Abundance

# of live algal cells in 10-50 size fraction, <10 cells is a "PASS"

Measuring chlorophyll fluorescence from live algal cells expressed as (RFUBraw-RFUB10) * cal. Coeff.

Activity

Range is 0.01-0.75 with >0.3 being normal for uptake

Measureing photosynthetic yield expressed as (Fm-F0)/Fm

American Spirit while underway with 80,000 tons of cargo.

Mesocosm tank set-up on ship during trials, checking high and low dose efficacy.

Data courtesy Kevin Reynolds, Glosten

Hyde Marine Using Indicative Tools

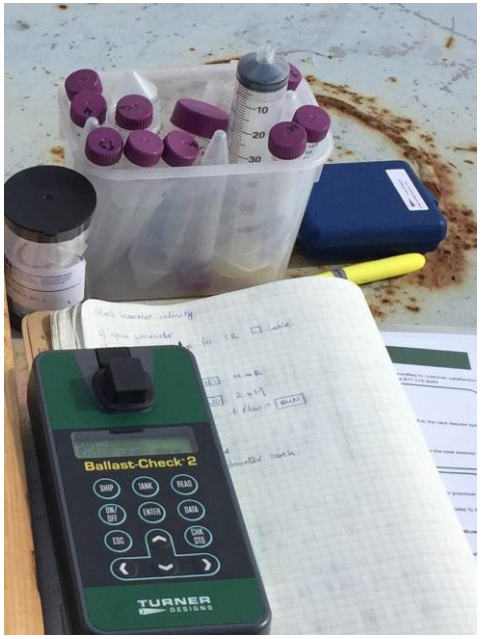
- Verify presence of organisms when preparing to conduct shipboard tests
- During tests, immediately verify during discharge effectiveness of Guardian

- Found it to be “Easy to use, convenient, and very accurate at predicting the results of full-scale shipboard tests." Mark Riggio, Hyde Guardian Product Manager

Hyde Marine
Ballast Water Management Technology
A CALGON CARBON COMPANY

ERMA FIRST Using Indicative Tools

- Verifying treatment system performance in R&D
  - Lab & shipboard tests
- Samples from all regimes tested before and after treatment
  - Marine, Fresh, Brackish water



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DHI-Singapore Using Indicative Tools

- Verify challenge water conditions before system tests
- Saves several hours vs cell counting

DHI
The expert in WATER ENVIRONMENTS

Hans Eikaas
hae@dhigroup.com

Triton MSC Using Indicative Tools

- Developed a small, closed system for BW sampling which can be permanently installed onboard ships
  - Footprint 30x50x40cm
- Using sampling system with indicative tools for
  - Rapid compliance testing onboard ships
  - Testing BW treatment system prior to their approval
- Together generates reliable, indicative results after less than 30 minutes

Triton MSC NP 6007 TG 18 system

TRITON MARINE SCIENCE & CONSULT

http://tritonmsc.de/

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e-CME Training Available

- Online Compliance, Monitoring, Enforcement Training
  - Background – why is BWMC needed
  - Ballast water sampling
  - Measuring compliance with D-2 (detailed and indicative (CME) analysis)
- Joint program
  - World Maritime University (Josefin Madjidian)
  - NIOZ (Louis Peperzak)
  - GoConsult (Stephen Gollasch)
  - DavidConsult (Matej David)
- http://elearning.e-cmeballastwater.eu/

- Hands-on course at NIOZ Test Facility

e-CME
BALLAST WATER
Compliance Monitoring & Enforcement

More General eTraining Available

- GEF-UNDP-IMO GloBallast Partnerships Programme created an online learning portal which includes the e-learning course Operational Aspects of BWM.
  - Introduction
  - Operational Aspects
  - Survey and Certification
  - Compliance Monitoring and Enforcement (CME).
- Free through registering at http://globallastlearning.com/login/index.php

GloBallast Partnerships

Who would use an Indicative Tool?

- Ship Operators
  - Easy, inexpensive way to quickly verify treatment system performance and provide documentation
- Port State Control
  - Easy, portable way to quickly verify treatment system performance
- Treatment System Manufacturers
  - Inexpensive way to give ship owners independent verification of treatment system operation

Turner Designs

- Established in 1972
- Focused on filter fluorometers for environmental & industrial markets
- Customers in >50 countries
  - University Researchers
    - Oceanographers, Limnologists, & Marine Biologists
  - Environmental Agencies & Consultants
  - System Integrators
  - Drinking Water & Waste Water Plants
  - Fisheries
  - Industries tracking Treatment Chemicals