Great Lakes Ballast Water Collaborative Meeting

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Trojan Technologies
Company Background

- Leading supplier of UV for municipal, industrial, commercial, and consumer applications
- Largest global installed base of UV disinfection systems
- Over 7,800 municipal UV installations on 6 continents treating over 44 billion gallons/day
- 35 years of research, innovation and commercialization of water treatment technologies
- Staff of over 800 in 12 countries
- Winner of the 2009 Stockholm Water Industry Award

Trojan Marinex™ is a division of Trojan Technologies, dedicated to the development, sale and support of Ballast Water Treatment solutions

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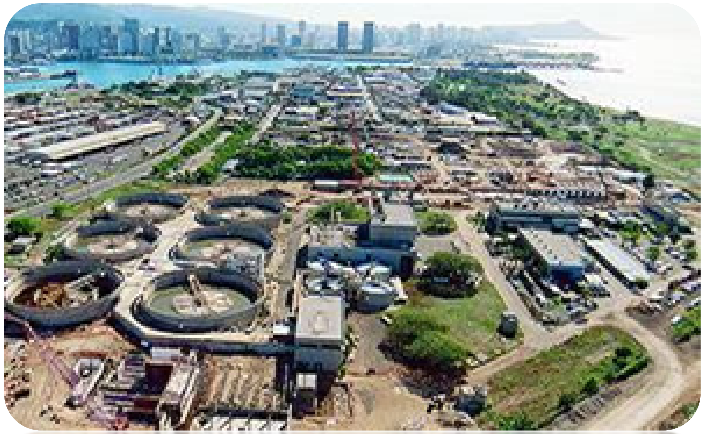
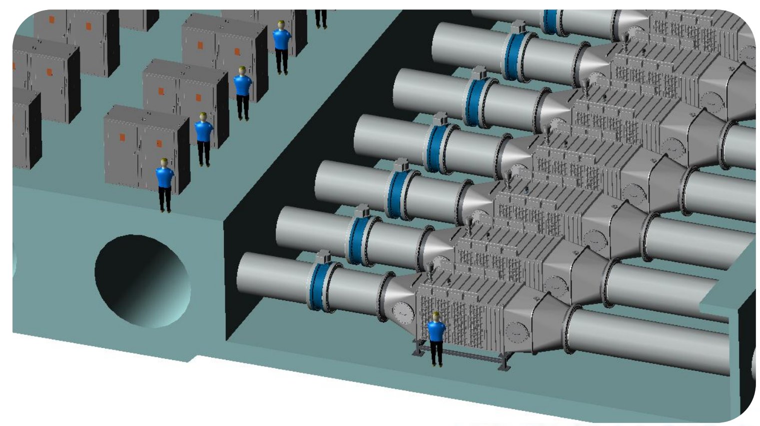
Experience Treating Large Flows and Challenging Waters with UV



Honolulu Wastewater Treatment (Primary Effluent) treating 82 MGD (12,934 m³/h)

New York City – 2 Drinking Water Plants Treating 2.5 Billion Gallons per day (395,000 m³/h)



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Trojan Marinex Ballast Water Treatment System

Integrated Filtration and UV Disinfection reduces Footprint and Power Draw

- **Footprint -** 50% less space than competing systems, minimizing space requirements & ease of installation, particularly for retrofit applications
- **Power -** one-third the power draw of other Filtration/UV systems, enabling use in higher flow applications
- **Explosion Proof –** All models also available in explosion-proof version
- **Broad System Range –** 7 discrete flow models treating flows ranging from 150 m^3/h to 1500 m^3/h

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Ballast Water System Development Experience

Testing Has Occurred at Multiple Facilities Globally

Ballast-Tech NIVA Test Facility,

DHI Test Facility, Denmark

Golden Bear Test Facility, California

Aquatron Test Facility, Nova Scotia

Ballast Water System Development Experience

Shipboard Testing

Land and Ship Based Testing aboard Golden Bear

Ship Based Testing aboard CMA CGM Utrillo

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Complex & Shifting Regulatory Landscape

Converging Discharge Standards - More Stringent US Validation/Type Approval Standards

Meeting / exceeding Regulatory requirements key to long-term winning strategy:

- Ratification of IMO Ballast Water Convention delayed and still pending (2013-15?)
- US Coast Guard Ballast Water regulations published in March 2012, become effective June 21, 2012
  - Market focus will shift to US Ballast Water Requirements
  - US discharge standards **essentially same** as IMO
  - US Validation/Type Approval standards are **more stringent** (e.g. Quality Control, test protocols & procedures)
  - Five Year compliance timeline – **non-compliance risk** for owner

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Water Treatment Issues for the Great Lakes

Unique Water Quality Conditions, Short Voyages, and High Flow Rates

1. **Water Quality Conditions:**
   - Fresh water
   - Cold water
2. **High Flow Rates:** – Over 75 percent of the vessels on the Great Lakes have 2 x 1500 tons per hour ballast pumps
3. **Short Voyages** - some a few hours
4. **Filtration challenges** - many vessels loaded within 6 inches of bottom
5. **US Coast Guard Type Approval**

Filter Testing, Port Stanley, Lake Erie, Ontario

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Water Treatment Issues

- 6,000 m^3/hr equivalent to a city with 200,000 people
- Water treatment plant for 200,000 people would occupy > a city block
- Equivalent BWT system space requirements < 250 ft^2
- Water treatment plants have a predictable source with minor seasonal variations
- Water treatment plants have professional operators
- Validation of equipment for usually involves a surrogate organism (e.g. MS-2 bacteriophage)
- Water treatment plants have known targets for certain target organisms (e.g. 4 log virus removal)

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Testing Challenges

Ambient Water Conditions Vary at Each Test Facility

Table 1. Summary of ambient water parameters in at different test sites.

Parameter	NIOZ Netherlands	MERC USA	GSI USA	NRL USA	DHI Denmark	DHI Singapore	KOMERI Korea	KORDI Korea	SWBWTCS China	NIVA Norway	MRDTC Japan
Temp (°C)	variable	4 – 30	9 – 22	20 – 32	variable	28 – 31	4.7 – 22.9	3.1 – 29.0	16 – 22	2 – 15	8 – 25
Salinity (PSU)	20 - 34	5 – 25	0 – 1	35 – 41	0 – 33	<0.3 – 32.2	30.3 – 34.3	21.1 – 33.8	32 – 33	0 – 34	31 – 34
TSS (mg l^{-1})	5 – 400	1 – 60	2 – 21	1 - 5 [1]	variable	1.6 – 54	variable	20 – 90	1 – 5	variable	5 – 11
POC (mg l^{-1})	5 – 20	0.5 – 8	< 1	2 – 4	> 5	variable	1.1 – 28.8	0.4 – 5.9	ca. 5	variable	<0.1 – 1.7
DOC (mg l^{-1})	1 – 5	2 - 10	6 – 22	2 – 4	> 10	variable	5.7 – 12.0	0.3 – 32.8	ca. 2	variable	1.0 – 1.5
Organisms ≥ 50 µm m^{-3}	10,000 – 1,000,000	10,000 - 300,000	100,000 - 3,000,000	50,000 – 180,000	variable	$10^3 – 10^6$	3,220 – 78,720	1 – 100 x 10^5	standard met	variable	5.8 x 10^3 – 5.3 x 10^5
Organisms < 50 µm and ≥ 10 µm ml^{-1}	100 – 100,000	500 - 15,000	25 - 1,200	ca. 10 – 200	variable	$10^2 – 10^4$	1 - > 800	120 - > 209,100	50 % of standard	variable	variable
Heterotrophic bacteria ml^{-1}	10,000 – 10,000,000	10,000 - 10,000,000	> 1,000	10^3 - 10^7	variable	10^4 - 10^6	variable	0.2 – 12.7 x 10^6	standard met	variable	variable

Source: Global Expert Workshop On Harmonization Of Methodologies For Test Facilities Of Ballast Water Management Systems, 24-25 January 2010, Page 5

Testing Challenges

Harbours With Low Salinity

Table 15: Globallast inventory (Clarke et al. 2003a): harbours with low salinity.

Port	Summer Tempera-ture (°C)	Winter Tempera-ture (°C)	Wet Season Salinity (ppt)	Dry Season Salinity (ppt)
Campana (AR)	24.0	15.0	0.0	0.0
Antwerpen (BE)	17.0	5.0	0.0	0.0
Ghent (Gent) (BE)	17.0	5.0	0.0	0.0
Amsterdam (NL)	18.0	6.0	0.0	0.0
Davant (US)	27.0	12.0	0.0	0.0
New Orleans (US)	27.0	17.5	0.0	0.0
Portland Oregon (US)	12.0	1.0	0.0	0.0
Vancouver Washington (US)	12.0	1.0	0.0	0.0
Calcutta (IN)	29.0	25.0	0.0	0.0
Nicolaev (UA)	21.4	1.3	0.1	0.2
Philadeplhia Pennsylvania (Port Richmond) (US)	18.0	2.0	0.0	1.0
Wilmington Delaware (US)	18.0	2.0	0.0	3.0
Port Harcourt (NG)	29.0	26.0	0.0	4.0
Baltimore Maryland (US)	20.0	2.5	0.0	4.0
Beaumont (US)	28.5	16.0	0.0	5.0
Shanghai Baoshan (CN)	25.5	7.0	0.5	5.0
Shanghai (CN)	26.4	6.5	0.8	4.9
Lake Charles Louisana (US)	27.0	20.0	0.0	7.0

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Testing Challenges

Cold water ports

Table 10: List of coldest ports (10% of 357 harbours in the Globallast inventory, Clarke et al. 2003).

Port	Winter Temp. (°C)	Port	Winter Temp. (°C)
Sept-Iles (Pointe Noire) Quebec (CA)	-1.0	Ilyichevsk (UA)	2.6
Tianjin (CN)	-0.1	Vancouver (British Columbia) (CA)	3.0
Boston Massachusetts (US)	0.5	Roberts Bank (British Columbia) (CA)	3.0
Anchorage Alaska (US)	1.0	Yantai Shandong (CN)	3.0
Portland Oregon (US)	1.0	Hamburg (DE)	3.0
Vancouver Washington (US)	1.0	Hafnarfjörður (IS)	3.0
Dnepro-Bugsky (Ochakov) (UA)	1.3	Straumsvik (IS)	3.0
Nicolayev (UA)	1.3	Enstedvaerkets Havn (DK)	3.5
Come By Chance (CA)	2.0	Fredericia (DK)	3.5
Halifax Nova Scotia (CA)	2.0	Wilhelmshaven (DE)	4.0
La Havre (FR)	2.0	Qinggdao Shandong (CN)	4.2
New York New York (New Jersey) (US)	2.0	Midia (RO)	4.5
Philadeplhia Pennsylvania (US)	2.0	Constanta (RO)	4.9
Wilmington Delaware (US)	2.0	Antwerpen (BE)	5.0
Dalian Liaoning (CN)	2.2	Ghent (Gent) (BE)	5.0
Vladivostok (RU)	2.5	Mangalia (RO)	5.7
Baltimore Maryland (US)	2.5	Varna, Bulgaria (BG)	5.9
Odessa (UA)	2.6	Amsterdam (NL)	6.0

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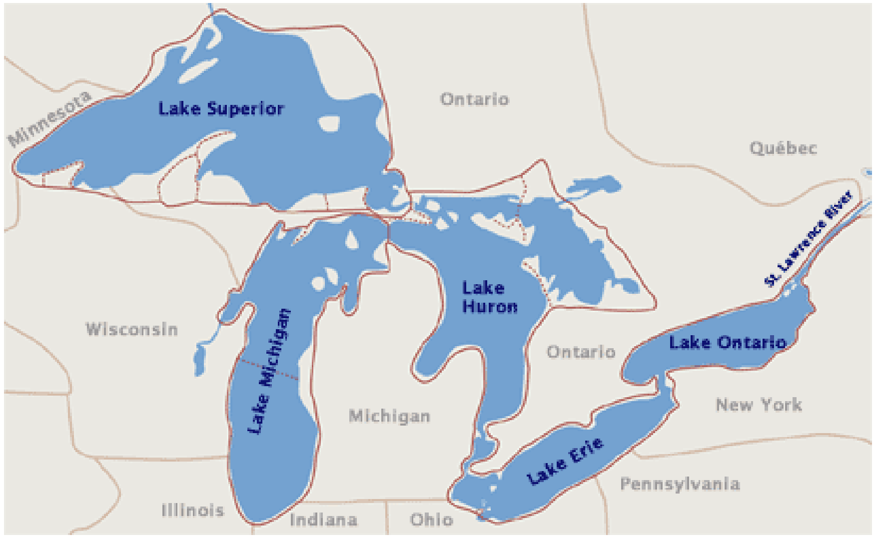
Great Lakes Ballast Water Quality Conditions

Seasonally Cold Temperatures, No Salinity



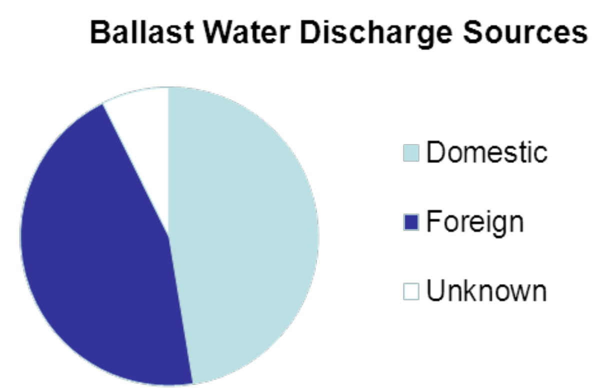
Source: NBIC Database - 1 Jan 2009 – 31 Dec 2010 US Ballast Water Discharge Records. Top 10 Domestic and Foreign Sources

Domestic Sources

Port	Min Temp	Max Temp	Avg Salinity
Cleveland	0.45	23.65	0
Sault Ste. Marie (Canada)	0.23	18.85	0
Detroit	0.28	22.88	0
Hamilton (Canada)	1.17	20.97	0
Gary	0.28	22.32	0
Saint Clair	0.18	21.68	0
Toledo	0.15	24.48	0
Indiana Harbor	0.23	22.45	0
Nanticoke (Canada)	0.53	22.78	0
Ashtabula	0.67	23.3	0

Foreign Sources

Port	Min Temp	Max Temp	Avg Salinity
Rotterdam (Netherlands)	4.55	19.25	1.78
Jorf Lasfar (Malasyia)	14.83	25.03	36.46
Antwerp (Belgium)	5.32	19.61	0.31
Oxelosund (Sweden)	0.87	16.23	6.36
Szczecin (Poland)	2.42	19.99	7.8
Ardalstangen (Norway)	0.01	12.32	0
Annaba (Algeria)	12.72	25.68	37.03
Foynes (Ireland)	7.49	17.14	8.6
Iceland	2.28	10.42	32.33
Djen-Djen (Algeria)	14.5	25.6	36.95



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Seasonally Cold Temperatures, No Salinity

Land Based Test in Colder Water Temperatures and in Fresh Water

- Land based test in fresh water at Dalhousie University Aquatron Ballast Water Testing Facility
- Test in colder water temperatures at Dalhousie University Aquatron Ballast Water Testing Facility

Scaling UV Systems- 3 Fundamental Approaches

Two Existing Approaches in Market to Scale Up UV Systems

250 m^3/h

Land based test of only one discrete flow model and utilize same unit in parallel for larger flows

250 m^3/h | 250 m^3/h | 250 m^3/h | 250 m^3/h

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250 m^3/h

Land based test of only one discrete flow model and utilize mathematical models or Computational Fluid Dynamics to scale up to larger flows

250 m^3/h | 1000 m^3/h | 1500 m^3/h | 2500 m^3/h

Land based test of each discrete flow model and utilize empirically validated units or land based test smallest and largest unit and extrapolate in between

250 m^3/h | 1000 m^3/h | 1500 m^3/h | 2500 m^3/h

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Type Approved Systems Incorporating UV Disinfection

Two Existing Approaches in Market to Scale Up UV Systems

System	Total Rated Capacity m^3/h	Discrete Flow Models - BWT	Discrete Flow Models - UV	Flow model tested – land and ship
Manufacturer A	60 –6000	~ 24	~ 8	250 m^3/h land 250 m^3/h ship
Manufacturer B	50-6000	~ 13	Unknown	250 m^3/h land 260 m^3/h ship
Manufacturer C	Up to 3000	Unknown	1 (250 m^3/h)	500 m3/h land
Manufacturer D	Up to 3000	Unknown	1 (167 m^3/h)	330 m^3/h land

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Scaling UV Systems

Reduce Sizing Risk By Land Based Testing Larger Flow Systems that will be Utilized by Lakers

250 m^3/h

1250 m^3/h

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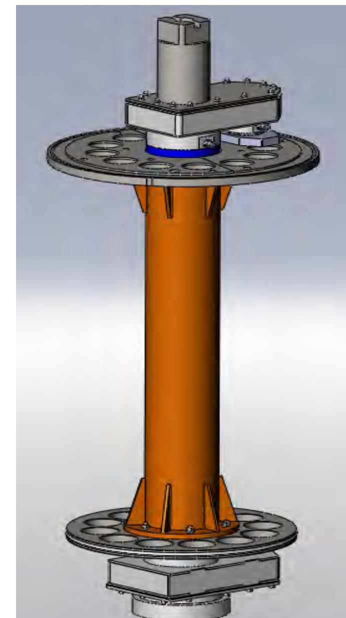
System Operability: Filter Optimization

Filter optimization is critical:

- Filtration is a critical step in treating organisms: must remove or damage organisms – not let them "squeeze" through.
- Filters can plug if improperly operated: operating at improper flux rates or poorly designed backwash systems can hinder operation.
- Frequent filter backwashing: constant backwashing can lead to reduced flow rate and extend time in port, jeopardizing ship schedules and revenue

Filter element



Filter insert & cleaning arm

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