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· The Maritime Environment ·

Welcome to the Conference on

Ballast Water and Waste Water Treatment Aboard Ships and in Ports

Conference Schedule

The Conference is sponsored by

Der Senator für Wirtschaft und Häfen — Freie Hansestadt Bremen

Free Hanse City of Bremen, Germany

DEERBERG SYSTEMS

DEERBERG-SYSTEMS, Oldenburg, Germany

Office of Naval Research International Field Office London, UK

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Wednesday, 11th June 2003

10.00	Welcome by the Mayor of Bremerhaven, ***Oberbürgermeister Jörg Schulz*** Keynote Address by ***Staatsrätin Sybille Winther,*** Senator for Economy and Ports, Freie Hansestadt Bremen Introduction by the Conference Organiser
Session 1	**POLICIES, REGULATIONS, MANAGEMENT and ORGANISATION**
10.45 - 11.30	"Blue Angel" for Environment-Conscious Ship-Operation - Theory and Practice ***Capt. Christian Bahlke,*** GAUSS, GE ***Capt. Roerd Braren,*** Braren Shipping Co., GE
Session 2	**BALLAST WATER**
	Session Chairman Dr. Matthias Voigt, Consultant, GE
11.30 - 12.00	Chances for Strangers in Ballast Water ***Capt. Cornelius de Keyzer,*** Rotterdam Port Management, NL
12.00 - 13.30	**LUNCH**
13.30 - 14.00	Using Surrogate Organisms for Testing of Ballast Water Treatment Options ***Dr. Matthias Voigt,*** Dr. Voigt Consulting, GE
14.00 - 14.30	Peraclean(R) Ocean - a Promising Ballast Water Treatment Option ***Dr. Rainer Fuchs,*** Degussa AG, GE
14.30 - 15.00	OptiMarin Combining Technologies into New Devices ***Birgir Nilsen,*** OptiMarin, NO
15.00 - 15.30	**COFFEE**
15.30 - 16.00	Electro-Ionization Treatment of Ballast Water ***Jon Stewart,*** Marine Environmental Partners Inc. (MEP), US
16.00 - 16.30	Maritime Solutions Ballast Water Treatment System ***Richard E. Fredricks,*** Maritime Solutions Inc., US
16.30 - 17.00	Hamann New Modular Ballast Water Treatment System ***Holger Hamann,*** Hamann Wassertechnik GmbH, GE
18.30	**Reception by the Senator for Economy and Ports, Freie Hansestadt Bremen aboard the Sailing Vessel SEUTE DEERN**
19.30	**Dinner sponsored by DEERBERG-SYSTEMS, Oldenburg, GE**

Thursday, 12th June 2003

Session Chairman Capt. Cornelius de Keyzer, Rotterdam Port Management, NL

09.00 - 09.30 The Bremen Ballast Water Project - Development of the Treatment Plant
Oliver Kerschek, GAUSS, GE

09.30 - 10.00 Ballast Water Treatment - on Board Tests and Market Prospects
Han van Niekerk, Royal Haskoning B.V., NL

10.00 - 10.30 **COFFEE**

10.30 - 11.00 Marine Testing Board for Certification of Ballast Water Treatment Technologies
Dr. Mike Champ, ATRP Corp., US

11.00 - 11.30 Past and Current Ballast Water Research in North-Western Europe
Dr. Stephan Gollasch, GoConsult, GE

11.30 - 12.00 **Discussion**

Session 3 <u>**BLACK and GREY WATER, OILY WATER, SEWAGE and SLUDGES**</u>

Session Chairman Jochen Deerberg, **DEERBERG-SYSTEMS, GE**

12.00 - 12.30 **Closing the Gap between Solid and Liquid Waste Treatment**
Final Report on the Second Environmental Workshop
Introduction and Summary of the Liquid Waste Treatment Working Group Results
Jochen Deerberg, DEERBERG-SYSTEMS, DE

12.30 - 14.00 **LUNCH**

14.00 - Results from the Shipowners Point of View (Represented by CCS)
Renato Storari, Carnival Corporate Shipbuilding, IT
Richard Vie, P&O Princess Cruises, UK

Results from the Shipyards Point of View (Represented by Meyer Werft)
Hermann Josef Mammes, Meyer Werft, GE.
Massimiliano Giuffrida, Fincantieri, IT

\- 15.30 Results from the Producers Point of View (Represented by Triqua bv)
Lex van Dijk, Triqua bv, NL

15.30 - 16.00 **COFFEE**

16.00 - 16.30 Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor
Dr. Thomas Peters, on behalf of Rochem UF, GE

16.30 - 17.00 Grey Water Recycling: Solutions for the Marine Industry
Jeff Lebedin, Aquarecycle, US

17.00 - 17.30 Retrofitting, Startup and Running of the New Grey and Black Water Treatment Plants Onboard Norwegian WIND, Norwegian SKY and Norwegian SUN, Approved for Sailing in Alaska Water
Henrik Badin and ***Asgeir Wien,*** Scanship Environmental as, NO

Friday, 30th June 2000

09.00 - 09.30	Using of Bio-Degradable, Biological Waste Treatment & Cleaning Products. Report from over 50 Ships. ***Margaret Hepburn,*** DEERBERG-SYSTEMS, Hepburn Bio Ship Care, MC
09.30 - 10.00	Environmental Compliance for the Future Warship - Wastewater Treatment for RN Type 23 Frigates ***Dr. Geoff Smith,*** QinetiQ Haslar, UK
10.00 - 10.30	**COFFEE**
10.30 - 11.00	Waste Water Treatment: New Technology for Rules Fulfilling ***Vittorio Antonelli,*** I.S.I.R. S.p.A, IT
11.00 - 11.30	Long Term Experiences and New Developments in Wastewater Treatment Aboard of Ships with Membrane Bioreactor Technology ***Lex van Dijk,*** Triqua bv, NL
11.30 - 12.00	Discussion Summary and Conference Conclusions by Mr. Klaus Eule
12.00	**LUNCH**

Exhibitions

Marine Environmental Partners Inc. (MEP), US,
Jon Stewart

Royal Netherlands Institute for Sea Research (NIOZ), NL
Dr. Jan P. Boon. Margot Bik. Dr. Marcel Veldhuis

Dr. Voigt Consulting, DE
Dr. Matthias Voigt

DEERBERG - SYSTEMS, DE,
Jochen Deerberg

IMO, UK

Welcome address by the Conference Organizer, Mr. Klaus D. Eule, to the Conference on "Ballast Water and Waste Water Treatment aboard Ships and in Ports"

Frau Staatsrätin Winther, Ladies and Gentlemen!

Welcome to Bremerhaven!

and - Welcome to our Conference on "Ballast Water and Waste Water Treatment aboard Ships and in Ports"

I would like to extend special thanks to the Mayor of Bremerhaven, Mr. Jörg Schulz for his warm welcome to the seaport city of Bremerhaven and also to Frau Staatsrätin Sybille Winther from our Sponsor the Senator for Economy and Ports of the Hanse City of Bremen for her introduction to the conference. Furthermore our thanks go to our sponsors Mr. Jochen Deerberg, the CEO of the Total Waste Management Systems company DEERBERG-SYSTEMS based in Oldenburg, not far from here and the US Navy Office of Naval Research International Field Office.

Bremerhaven is one of the major German seaports belonging to the Hanse City of Bremen. All different trades of the maritime industry are located here, whether it is the Shipping Industry with several shipping lines, the shipyard of NDL, or the fishery industry. We are certainly very proud that we are holding the conference here already for the third time, as we know that Bremen and Bremerhaven for many years have undertaken major efforts in the area of environmental protection of our ports, the sea and the shores.

The Senator of Economy and Ports of the Hanse City of Bremen will be our host tonight for the reception aboard the Sailing Vessel "Seute Deern". The reception will start at 18.30. The reception will be followed by a dinner aboard the "Seute Deern" at 19.30 sponsored by DEERBERG-SYSTEMS.

In the world of maritime application of waste management systems Deerberg-Systems is a well-known company and the worldwide leading supplier for Total Waste Management Systems for the Cruise Industry. Deerberg-Systems now has been supplying over 100 systems to large passenger vessels. We will hear more about an initiative undertaken by DEERBERG-SYSTEMS in bringing together Shipyards, the Cruise Industry and Suppliers to work out the way ahead in the area of Liquid Waste Treatment. To include their report on the results of this effort seemed quite appropriate in his conference.

Our other sponsor, the US Navy Office of Naval Research International Field Office based in London is committed to fostering and facilitating collaboration in Science, Technology, Research and Development between the United States and their professional counterparts in Europe, Africa and the Middle East. The US Navy Office of Naval Research International Field Office is linked with international scientists and engineers through conferences, workshops, visits and personal research to identify key opportunities in Science & Technology, to assess Science & Technology activities and accomplishments and to exchange information and ideas in areas of mutual interest.

We all are aware of the current discussions in IMO and the European Commission on the regulations for ballast water and wastewater treatment on the high seas as well as in special areas. We are also aware of the more restrictive regulations that have been established by many coastal regions and even local authorities. This impacts on the shipping industry in general but particularly on the Cruise Industry that visits environmentally sensitive sea areas quite frequently.

We have selected the papers for our conference with the intention to contribute knowledge and examples to these discussions and to provide an expert forum for discussion of these matters involving the regulatory authorities as well as the concerned industry.

Therefore the objectives of this conference are:

1. Provision of a forum for representatives from industry, ship owners, academia, governments, maritime and harbour authorities and shipyards for discussion and exchange of information on policies, trends and development of regulations for the treatment of ballast water, waste water and sewage on ships and in ports.
2. Presentation and discussion of technologies and equipment for the treatment of black, grey and oily water as well as ballast water and sewage generated on board of ships.
3. Presentation and discussion of advanced waste water treatment technologies, future research and adaptation of current and future technologies for ship systems
4. Discussion of management aspects related to waste water and ballast water treatment.
5. Recommendations for latest technology applications on ships and in ports.
6. Recommendations to industries and governments for policies and international collaboration.

As you have noticed already we have, like during the past conferences, some exhibits of products and projects, which are worth wile studying. Our exhibitors are Deerberg-Systems from Germany, Maritime Environmental Partners Inc. from the United States, Dr. Voigt Consulting from Germany our Session Chairman for the first part of the Ballast Water Session, the IMO as well as the Royal Netherlands Institute for Sea Research (NIOZ).

I recommend that you take the opportunity to get yourself informed on the products and visit the stands.
The exhibitor's teams will certainly answer all your questions and provide you with the latest information on their products.

As you may have already noticed we have a number of changes to our programme in comparison with the original invitation to the conference. A few companies have withdrawn their presentations due to company internal circumstances; we have added some new presentations and for some papers the Speakers have changed. We apologize, if this is causing concern or disappointment to anybody but we seek your understanding that we have to accommodate those unforeseeable changes up to the last minute. It appears that in our industry we are going through difficult times, much as other industries do.

Finally, I would like to introduce to you Mrs. Elke Lonicer, our Conference Manager, who all of you have already met or talked to on the telephone.
Elke and I will be available to you during this conference and assist you in any matters, where you feel, that we could be of help. So, please do not hesitate to call on us for assistance.
Elke has asked me to announce that we are circulating the list for the reception and dinner tonight. Please indicate your participation. The other thing she wishes me to check is that everybody has chosen meat or fish for lunch on her checklist.
And now without further ado I will start with Session 1 of our conference.

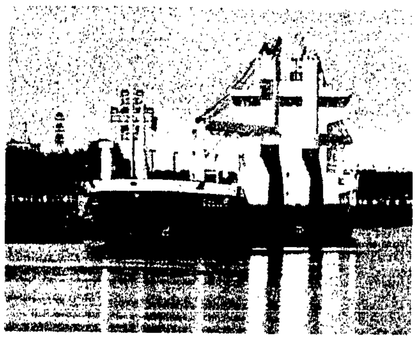
• The Maritime Environment •

" Ballast Water and Waste Water Treatment Aboard Ships and in Ports"

Session 1

Policies, Regulations, Management and Organisation

Blue Angel Award
for Environment-Conscious Ship Operation



In November 2002 the first *Blue Angel for environment-conscious ship operation* has been awarded by the Environmental Label Jury to the sister ships MV CELLUS und MV TIMBUS of the shipping-company R. Braren, Kollmar.

The Environmental Label is now available to all applicants all over the world who can prove to meet the ambitious requirements.

The MV „Cellus" has been awarded the Blue Angel for environment-conscious ship operation on Nov. 21, 2002, in Kiel

The initiative to make the Blue Angel applicable to environment-responsible shipping is bound to a research project GAUSS (Institute for Environmental Protection and Safety in Shipping, Bremen) was carried out for the Federal Environmental Agency[1]. One of the aims of the project was to determine quantities of emissions from ships and to indicate potentials for their reduction.

It became obvious that there are a number of commendable approaches to environmentally responsible shipping in parts as well as in the whole range of operations. In order to strengthen these positive starting points the engagement of ship owners for the environment had to be publicly and marketably awarded. Although international rules ideally are preferred in shipping, meaning that initiatives should normally rest with the IMO or the EU, the way to make use of the Blue Angel environmental label as an incentive for environmental-conscious ship operation has been chosen because of its possibilities of short-term and effective realization, the more so as the Blue Angel is a Label of UNEP (*United Nations Environment Programme*) and thus open to potential applicants the world over.

The criteria listed for the award of the Blue Angel Environmental Label are based on an analysis of various international assessment and certification systems for environmentally responsible shipping (incentive systems, classification societies, associations etc.). The consideration of existing initiatives is essential for ship owners especially with regard to their acceptance of the requirements. The proceedings and criteria of other initiatives have also been taken up to provide harmonization options for future times. The aim is to find consensus on a common denominator for ambitious and practicable environmental requirements in shipping.

The requirements have been modified and rated in view of the special problems connected with the awarding of the Blue Angel Environmental Label by a project-accompanying study group in which representatives of all relevant institutions concerned with shipping in Germany were assembled.

The requirements as now presented, comprising the whole range of ship management and operation while exceeding in many areas the conventional national and international obligatory targets, in parts even by far, reflect what is technically and economically feasible.

In effect the altogether twenty criteria clearly surpass all existing requirements. Applicants who successfully comply with these requirements must rightfully and on a worldwide scale be regarded as leading shipping-companies with respect to the protection of the environment.

[1] This project has been carried out under contract given by the Federal Environment Agency within the framework of the Environment Research Plan of the Federal Environment Ministry (BMU) – Project Promotion Number 299 25 266 – and has been financed by public funds.

The task to define requirements under these given conditions led to the following specifications for the project:

- Best possible and in practical operation realizable environmental protection of the sea.
- Proof of compliance with the criteria must be simple and reliable.
- Least possible administrative expenditure on land and on board.
- Possibility for realization by ship owners within the frame of commercial competition.

Economic and legal framework conditions

It follows from the fact that shipping is a worldwide activity since long that it also played a leading role in globalisation. Ships must not necessarily be registered and run under the flag of the state where the ship's owner has his place of business. Herein an incentive is generated to change to registers giving financial benefits. Such benefits result mainly from different standards which can be adhered to with lower costs.

The international legislation for merchant shipping is being promoted by the Special Organization of the United Nations, the International Maritime Organization (IMO). The standards developed there are normally strongly influenced by the interests of states with a high percentage of ships numbers and tonnage under their flag, namely also those, who benefit from outflagging. The so called flags of convenience have a tendency to reduced interest in higher safety and environmental protection standards. The standards resulting from such legislation initiatives are often reduced to the smallest common denominator under competing interests.

The (minimal) standards developed under these conditions at the IMO are seldom adequate in the judgment of ship owners and representatives of countries with deeper awareness of safety and the environment. The countries concerned wish and demand higher national and regional standards, which cannot, however, be legally enforced on ships under foreign flags.

Offering economic benefits is therefore increasingly viewed as appropriate means to succeed with ambitious technical and environmental standards in the own coastal waters.

Transport performances and capacities in merchant shipping

At the beginning of 2001 the worldwide merchant fleet consisted of about 39,000 ships of 300 grt or more, with major categories general cargo ships (ca. 17,115), tankers (ca. 9,620), bulk carriers (ca. 5,984), container ships (ca. 2,564) and ferries/ passenger ships (ca. 3,725).

There are about 1,750 ships under German flag registered in the national or in a second ship register. Germany thus ranges 24th with regard to transport capacity of ships in the world. The number of ships with German management but under foreign flags is much higher, however. It is assumed that in the container ship sector 80% of all ships are controlled by German management.

Merchant shipping is undoubtedly the largest transport and logistics industry in world trade. UNCTAD, the United Nations Conference on Trade and Development, has stated a steady increase in maritime transport performance over the past 15 years, and a new, all-time record in 2001 with 5.880 million tons.

The European Union is one of the market leaders in world trade, with exports taking the major part. The EU with its part of more than 14 % of all exports takes the first place over the U.S.A. with 12 % and Japan with 7.5 %. About 90 % of the inter-continental trade and about 40 % of the intra-European trade are dependent on transport by ship.

In order to demonstrate the enormous capacities of the ships in question it should be mentioned that a container ship of the 4. generation carries as many containers as a train of 50 km length, and that 15 % of these containers come under dangerous goods. The biggest tankers in the world (550,000 tdw) transport per voyage the amounts needed for the yearly supply of about 155,000 one-family houses. The values of ship and cargo often surpass 500 million EUR.

Sea-going ships nowadays operate around the clock and about 355 days in a year, while on board these ships rarely more than 20 persons, for the most part of different nationalities, are employed.

Although the figures mentioned above reflect impressively the efficiency and importance of commercial shipping, marine traffic for a number of decades now has not been perceived in its relevance by the public but rather in its connection with accidents, and here especially with accidents that led to pollution.

By awarding the eco-label *Blue Angel for environment-conscious ship operation* a positive signal shall be given for responsible and engaged commitment to marine environment protection and safety in shipping.

The requirements for eco-friendly ship operation

The requirements to be met for the award of the "Blue Angel environmental label for environment-conscious ship operation" are split into three groups representing different aspects of environmental protection in maritime traffic:

- Ship owners' policy and shipping-company management
- Ship design and equipment
- Management of ship operation and ship technology.

The various requirements allocated to these groups complement one another or rather can be achieved in combination only because they are interdependent (e.g. ship owners' policy with regard to training of crews in connection with the operational provisions to reduce emissions).

Ship owners' policy and shipping-company management

Safety and environmental protection at sea can only be effectively organized and succeeded with if also the ship management on land acknowledges these targets as a fundamental obligation. Not like in past times, when the owners knew the crews of their ships, when they could appraise them and assemble them under quality aspects, these tasks are nowadays undertaken by third parties in an impersonal manner. In modern shipping there is often no "owner" any more nor "the crew", because the ships are in the hands of fond managers and the personnel on board is provided by more or less engaged crewing agents. The deficits stemming from this lack of *commitment from the top* on one side and the absence of identification of the crew with the company or the ship on the other side led to a situation where lowered standards of safety and environmental protection became more and more apparent and where ways had to be found to counteract.

Systematized management instruments like the ISM-Code, **ISO 9001:2000**, **ISO 14000** as well as **personnel management** are put to test to solve these problems. While the ISM-Code is by now mandatory for all sea-going ships, the ISO 9001:2000 and ISO 14000 standards are not. But the latter are increasingly applied by committed owners, because either the business partners demand it in order to get better information on the shipping-company management, or certain components cannot be covered by the ISM-Code alone.

This is also a reason why these instruments as well as aspects of personnel management have been defined as requirements for the award of the "Blue Angel for environment-conscious ship operation".

Ship design and equipment

The requirements in this field demonstrate that effective marine environment protection is also always connected to the safety of the ship. The gravest marine pollution incidents confined by time and location result, as everybody knows, from ships' accidents which for their part have only very few causalities. Apart from the main causes *human element* and *human fatigue,* which must be answered with measures of personnel management, we find here collisions, strandings and the breaking-up of ships in high seas with consequent loss of lading.

These factors are covered by the requirements regarding collision protection and leakage safety and by the specifications for **redundant ship propulsion**. By appropriate measures loss of lading in less significant cases of collision, or stranding as well as machine failure with subsequent danger of collision, can effectively be avoided.

A **Hull Stress Monitoring System** for the indication of stresses in ship structures, which will help to avoid dangerous overloading of bearing structures, and **Emergency Towing Equipment** for quick towage of a ship in distress have been defined as requirements.

Also, when defining requirements for environmentally sound ship operation, it must not be forgotten that still today considerable pollution is being connected with repairs and the scrapping of ships. One of the reasons is lack of knowledge about the pollutants contained in materials built into the ship. Furthermore often, and partly knowingly, aspects of proper working conditions, accident prevention and environmental protection -especially in third world countries- are still not observed.

Environment-damaging substances and materials built into the ship must be identifiable for purposes of repairs or scrapping, meaning the location on board, the amounts or sizes, and the properties must be known. To achieve this a **register of all materials used on board** should be prepared and continuously be kept.

Ship operation management and ship technology

The criteria for environmentally safe ship operation in the area of regular operational emissions represent the biggest package of requirements. Specifications have been defined for gaseous, liquid and solid emissions, which partly exceed the presently valid limiting values in national and international regulations by far.

The gaseous emissions from ship operations must probably be regarded the most critical of all operational emissions. There have been successful efforts to reduce step by step the pollutant contents in fuels used for land traffic, so that meanwhile sulphur-free fuels are available for vehicles. This process has so far not been successfully established for marine fuels. Quite contrary sea-going ships are regarded as disposal facilities for refinery residues, with the effect that by using heavy fuel oils in ships everything that is no longer permitted in fuels on land is burnt on board. The major part of local sulphur emissions on the inshore waters and in harbours of heavily trafficked coastal states is meanwhile attributed to shipping.

Ships applying for the eco-label Blue Angel will have to carry out considerable reduction measures in this field. This applies to the reduction of sulphur oxides and nitrogen oxides in the exhaust gases of the ship as well as to the usage of coolants and the reduction of respective emissions from cooling and refrigeration plant. Reduction measures for soot and particle emissions have also been recognized as important, but limiting values have not been defined yet because practicable proofing methods are still lacking.

Since there are still ships being equipped with the extremely climate-damaging **fire-extinguishing agent Halon** the decision has been made that this agent has to be exchanged against some environment-friendly agent.

Out of the liquid emissions getting into the environment from ships black and grey sewage waters, bilge waters and ballast water have been selected for criteria when applying for the Blue Angel. Regarding the emission of **black and grey sewage waters,** higher standards will be set for passenger ships than for cargo ships. The volumes of sewage waters are higher in passenger ships -and they often cruise in sensible sea areas- as compared to cargo vessels with their small number of people on board. Here, as with the criteria bilge waters and waste disposal, the processing on land has been favoured as the most sensible solution.

Bilge waters, i.e. condensation and leak waters which collect in the engine-room and in the areas of cargo spaces, are normally contaminated with pollutants, among others with oil. In certain sea areas, as e.g. in the Baltic Sea, disposal to land facilities is offered almost everywhere. Where land disposal is not possible the international regulations allow disposal into the sea under clearly defined conditions. For the award of the Blue Angel eco-label the limiting values in these cases are reduced to 1/3 of the internationally accepted values.

The transport and introduction of non-indigenous species by ballast water is seen as an increasing threat to the marine environment. Considerable economical damage and partly also ecological damage is caused by the fast propagation of organisms having no natural enemies in their new habitats. The reduction in local fish stocks, damage to aqua-farming and to structures, e.g. marine growth on cooling pipes and destruction of wooden structures, can be named here. Measures for the mitigation or even the solution of this problem are being prepared on international basis. The criteria for the award of the Blue Angel eco-label take this into account already.

In the field of solid emissions generated on board the disposal of wastes and ashes from waste incineration, and the introduction into the environment of marine growth inhibiting substances from antifoulings will be considered. In industrialized countries with established recycling systems the **disposal of wastes** on land is the best environmental policy. In remote areas without adequate infrastructure this method may just the same lead to pollution of the environment, however. It made better sense, therefore, to allow **waste incineration** on passenger ships where much waste is accumulating. It must be carefully observed, however, that in order to avoid the generation of dioxins and furans neither special wastes nor PVC are incinerated.

The introduction of TBT-containing **antifoulings**, applied to the underwater hull against marine growth, has led to deformities in marine snails and other creatures living on the sea floor along the main traffic routes. By transfers in the food chain this strong poison is found also in sea mammals. That is why there was relatively soon a majority at the IMO voting for the phase-out of TBT application on ships within a very limited time. On vessels applying for award of the Blue Angel TBT is completely prohibited without any transition period.

Award system for an environment-conscious ship operation

By considering all technical aspects of running a ship when awarding the environmental label almost the whole bandwidth of emissions from ships is addressed. In consequence incentives for improvements take effect on all requirements. This approach reflects in addition the fact that effective environmental protection is always also dependent on the motivation and the training of the ships' crews. Because the ships of owners leading in environmental protection fulfil many of the essential technical requirements, while no ship covers the whole bandwidth of criteria classified as important, it has been decided to make fulfilment of the essential technical requirements obligatory while the compliance with a certain number of the other requirements remains optional. This proceeding has the following advantages:

- Obligatory requirements have to be met. They are a must for environmental protection. Amongst other the environmental training of the crews, the reduction of sulphur and nitrogen oxide emissions and those of climate-relevant coolants and refrigerants belong in this group. The use of specified substances like Halon and TBT must totally be banned on ships.
- The optional requirements are based on criteria commonly not regarded as unalterable (e.g. the application of ISO 14000, the reduction of soot and particle emissions, consideration of the ballast water problem, use of environmentally safe materials in the ship).
- There are options applicable differently to new and older ships, meaning that requirements can be selected which are to be fulfilled only by new ships or by ships still in the planning (e.g. the installation of redundant propulsion systems).
- Different options can be used for different types of vessels (e.g. the installation of *Hull Stress Monitoring Systems* for large ships).
- The shipping-companies can choose to commit themselves to the fulfilment of requirements especially suitable to their ships and their routes (e.g. take special precautions when handling ballast water).
- The award conditions remain dynamic because only a certain number of the optional requirements has to be met: the environmentally leading ship is the ship complying with most of the options.
- The system is flexible and simple (no ship types requiring extra rules etc).

Emission reduction potentials by Blue Angel ships

A definite statement about the attainable emission reduction potentials is at present only be possible for individual ships. Attempts to extrapolate from individual potentials to those in sea areas or fleets will always remain rough approximations because of insufficient data like the duration of operations in certain areas, the actual power output and size of ships etc. Generally speaking, the fact that in contrast to common opinion sea-going ships also often operate near to coasts will have the effect that by increasing acceptance of the environmental label the air quality will improve especially in areas where air pollution is felt the most: at the coasts, on inshore waters and in the harbours.

According to a survey by *Lloyd's Register of Shipping* the contribution of international shipping to the total sulphur emissions in the world is 7 %, i.e. about 10 million tonnes per year. Yearly emissions in the North Atlantic amount to about 1.37 million tonnes sulphur dioxide. Each Blue Angel ship emits only half of its previous emissions (by obligation) or even about 85% less (optional).

The NO_X-share of international shipping in global emissions is estimated at 11 to 13 %, i.e. about 9.3 million tonnes NO_X per year and thereof ca. 1.94 million tonnes in the Northeast Atlantic. Here individual emissions will be reduced by 20 % (obligatory) or by more than 50 % (optional).

On many ships substances evidently damaging the ozone layer are still in use. Estimations have shown that

- about 50 % of all refrigerant substances on board are emitted to the environment during the life times of cooling and refrigerating plant, and that another 15 % are emitted during maintenance and repairs of these installations.

Finally, large amounts of CFCs are being released when ships are scrapped. The use of halons is completely prohibited for ships awarded the Blue Angel. The substances allowed on board a Blue Angel ship therefore have an Ozone Depletion Potential (ODP) of 0.05 at the most (obligatory) or even zero (optional), and the Global Warming Potential factor (GWP) describing the greenhouse effect is limited to 1650.

Other emissions are treated in similar ways: bilge waters must have not more than 33 % of the oil content limit internationally prescribed (obligatory) or must be disposed of on land (optional). The same principles hold for disposal of other wastes. Because of the many ways to include optional requirements it is difficult for the time being to provide exact assessments of the reduction effects on the whole bandwidth of emissions.

The aim for awarding the environmental label "Blue Angel" for environment-conscious ship operation is to acknowledge the compliance with clearly defined and high standards by an internationally accepted label. Hereby an opportunity shall be opened to shipyards, ship owners and charterers to show commitment for our environment, and at the same time to use such commitment for the promotion of market and public relations. The worldwide scope and recognition of an environmental label acknowledged by the United Nations is of indisputable advantage for shipping and cannot be disregarded.

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Bremen
HRB 16766

Januar 2003

Traffic patterns worldwide

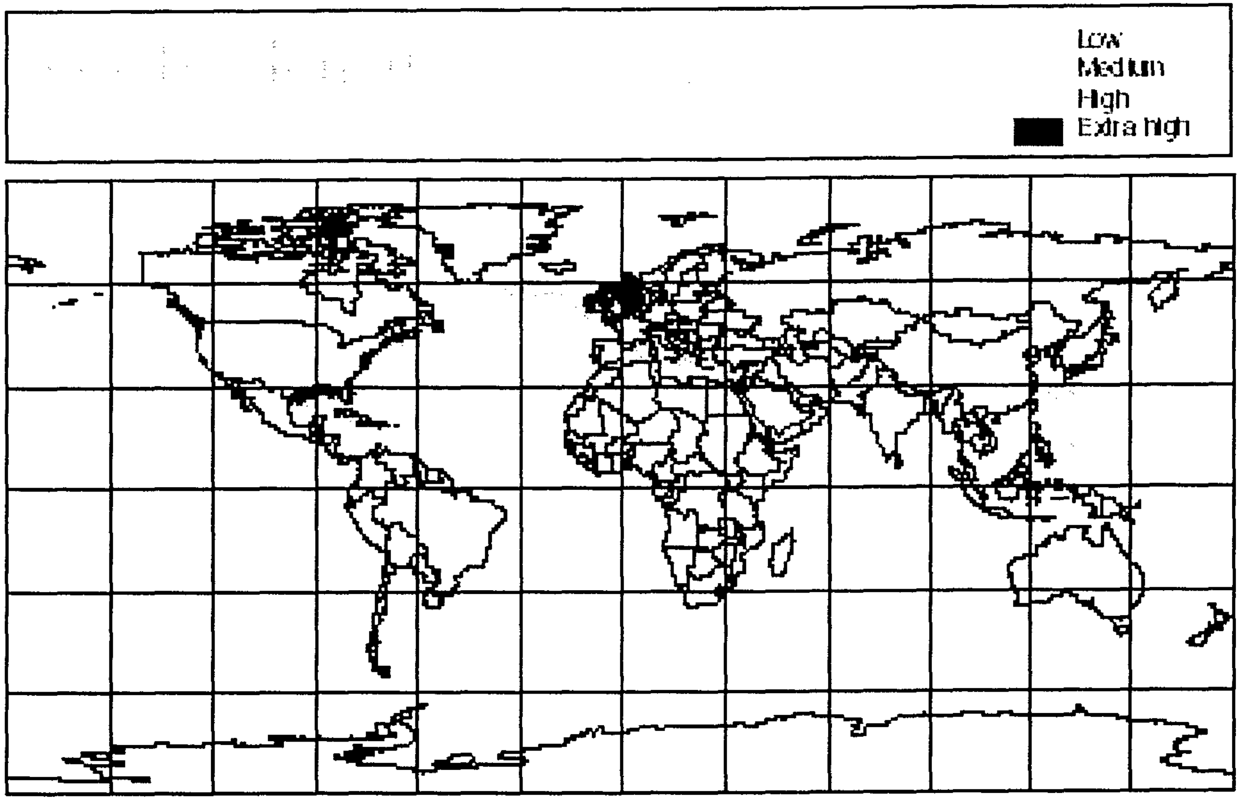
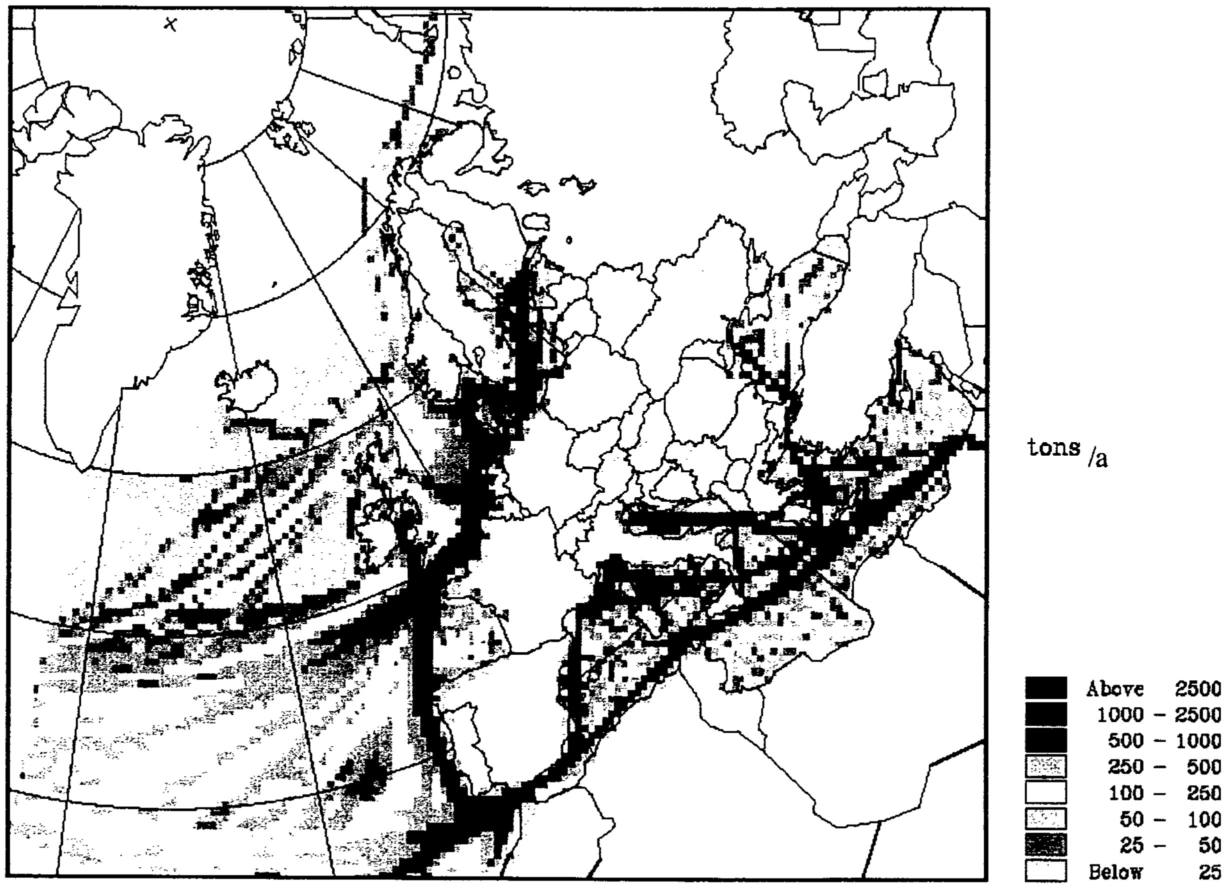


Figure 3-9 Estimated traffic density based on data from 1996.

Area's with large SOx - Emissions

SOx emission from International ship traffic in All Sea Areas



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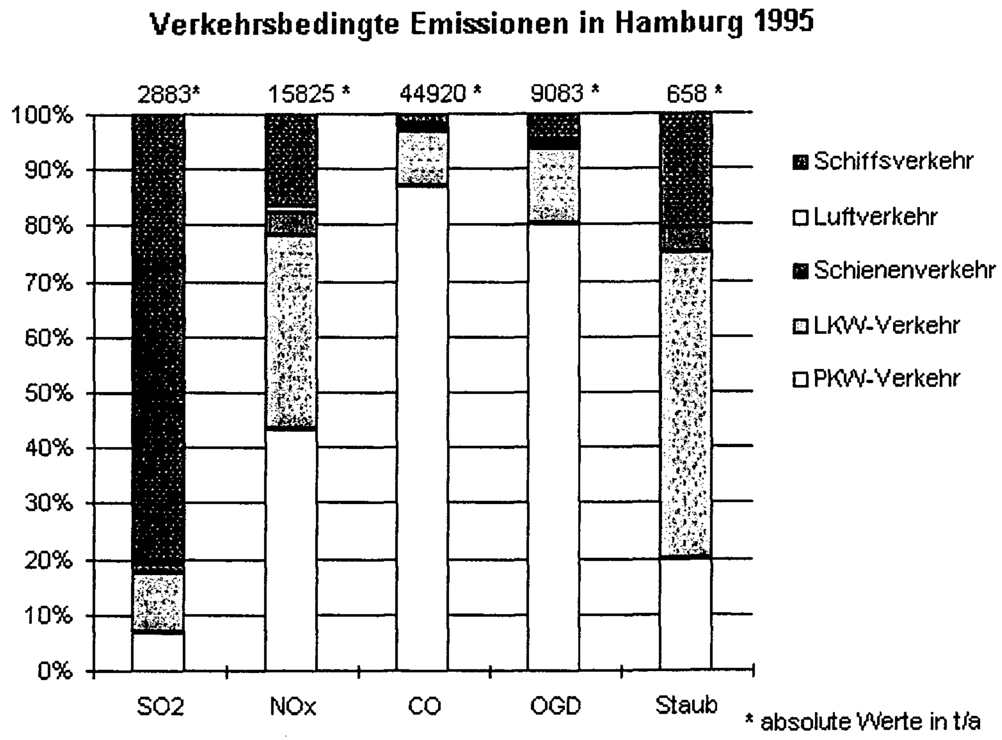
Emission Distribution in Ports



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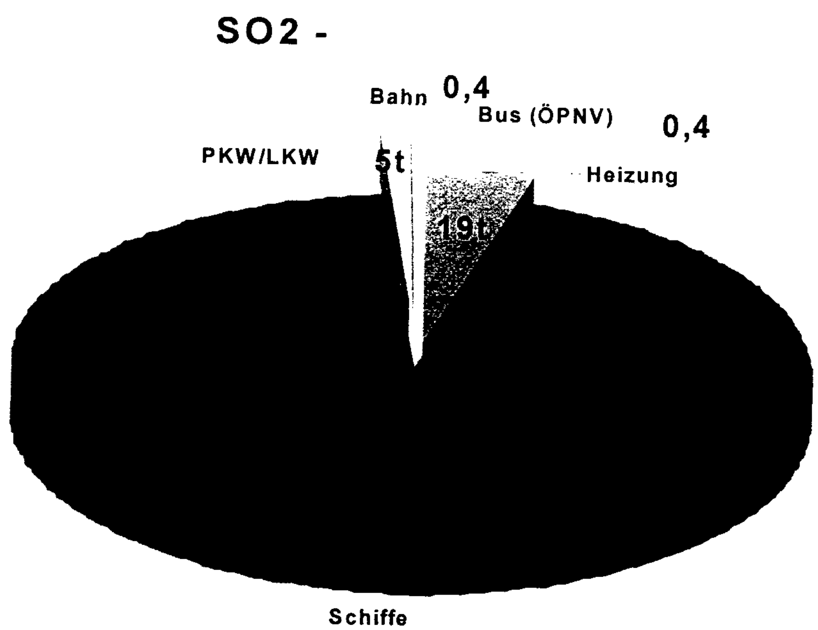
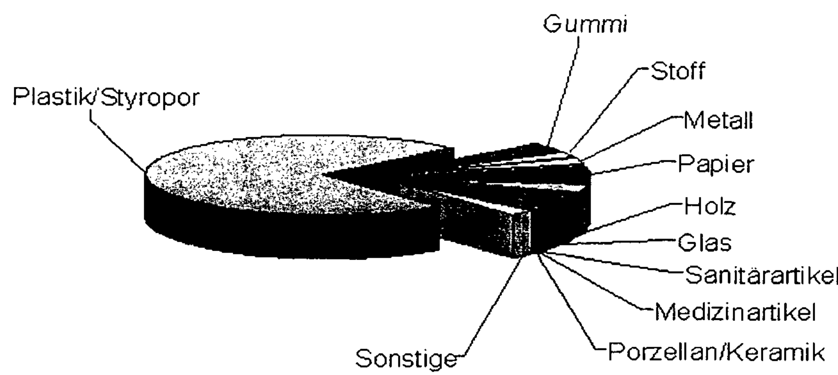
Emission Distribution in Ports

SO2 -Emissionsbilanz für Travemünde



Waste - Distribution on beaches

Zusammensetzung der Abfälle, die an den Stränden der Nordseeküste aufgefunden werden



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Impact from Ballast Water

(Entry of invaders)

- 100 in Baltic Sea
- 80 in North Sea
- 100 Atlantic coast of Europe
- 350 Mediterranean Sea
- 50 Black Sea

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Cruise Shipping and the Environment

Medium	Amount (3.000 persons / 1 week)
Black water	55.482 ltr.
Grey water	264.201 ltr.
Hazardous waste	29.1 ltr. photo chemicals, 1.3 ltr dry cleaner 2.6 ltr.used paints 1.3 ltr exp. chemicals
Solid waste	(non hazardous) 8 tons
Bilge water	6.666 ltr.

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International Legislation for Shipping

Medium	Timeframe for Legislation
Black water / Grey water	MARPOL Annex IV (27.09.2003)
Antifouling / TBT	01.01.2003 – 31.12.2008
Gaseous Emissions	MARPOL Annex VI (??)
Ballast water	Convention in 2004 (??)
Coolants, Halon (FF), Particles, ETS, Double Hull etc.	(??)

"Umwelttechnik-Transfer für die Seeschifffahrt"

- Sponsored by the Environmental Agency, Berlin
- Time period: 1999 – 2002
- Project execution:

  GAUSS, Institute for Environmental Protection and Safety in Shipping

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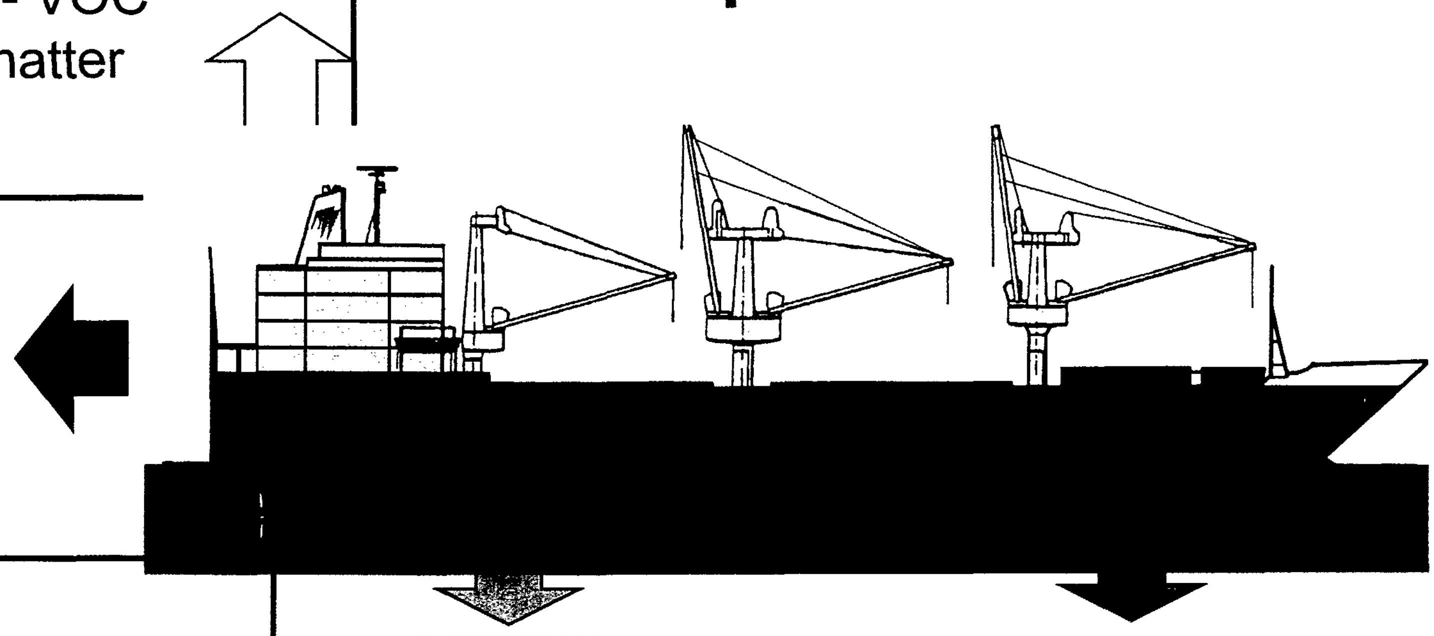
Ship Emissions

<u>Gaseous Emissions</u>
- SO_2
- NOx
- Particular matter
- Coolants
- VOC



<u>Solid Waste</u>
- Plastic / glas
- Metal / scrap
- Paint
- Ash
- Food waste
- Household waste
- Cargo waste

<u>Liquid Waste</u>
- Sludge / Bilgeoil
- Black- and Grey water
- Ballast water
- Slop

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“Umwelttechnik-Transfer für die Seeschifffahrt”

- Impact of shipping to the environment
- Potential of reduction with ships emissions
- Transfer of land-based techniques to protect the maritime environment
- Definition of Best Available Technique

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The Initiative to develop an Incentive System to protect the Maritime Environment

- Which system should be used ?

  a) ...

- What are the ship-types to be considered ?

  a) ...

- What are the requirements to be met ?

  a) ...

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Blue Angel Award for Environment Conscious Ship Operation

- Founded 1977 by Klaus Töpfer
- Environmental Sign of the United Nations
- Presently 150 Product Groups with 3700 Products
- Presently 780 Users of the Award

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Basic Conditions for the Blue Angel Award

- Best possible protection of the maritime environment
- Realisation under conditions of practise
- Documentation of compliance must be simple
- Documentation of compliance must be reliable
- Low expenditure on shore and on board
- Feasibility for companies in commercial competition

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The Initiative to develop an Incentive System to protect the Maritime Environment

- Which system should be used ?

  Blue Angel Award

- What are the ship-types to be considered ?

  Merchant Shipping with exemptions

- What are the requirements to be met ?

  a) ...

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Identification of Requirements

Assessment of existing approaches

- Classification societies
- Incentive schemes
- Industry standards and others

Workshops with stakeholders

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Three Main Focuses

- Policy and management of company and ship
- Shipbuilding and equipment
- Reduction of emissions from ship operation

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Company's Policy and Ship-Management

- Quality management
- Environmental management
- Personnel management
  - ITF – tariff / Environmental education
  - SMCP / Labour continuity

red: mandatory (10 requirements)
blue: optional (3 from 20 require.)

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Shipbuilding and Equipment

- Material used on board
- Collision protection
- Redundant machinery
- Hull Stress Monitoring
- Emergency Towing Equipment

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Reduction of Emissions from Ship Operation

- Sulphur content in fuel oil
- Nitrogen emissions
- Climate gases
- Particular matter
- Waste disposal
- Waste incineration

- Black water
- Grey water
- Bilge water
- Antifouling
- Ballast water
- Substances for ff

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Reduction of Emissions from Ship Operation

Medium	Mandatory	Voluntary
Black Water	50% of Marpol Annex IV, no Cl_2	D.o.s. or Coli < 30 / 100 ml
Grey Water	No requirements	50% of Marpol Annex IV, no Cl_2
Ballast Water	Application of IMO Res. A 868 (20)	BW Management / BW Treatment

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Systematic Approach

- In total 20 single requirements
  - 10 mandatory requirements (red)
  - 3 options from 20 additional requirements (blue)
    - 10 aggravated requirements
    - 10 special requirements

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Decision of the Environmental Labelling Jury

Based on the work of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Federal Environment Agency and a group of experts the

Blue Angel Award for Environment-Conscious Ship Operation

was launched in October 2002.

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Blue Angel Award for Environment - Conscious Ship Operation

The situation:

- Definition of a benchmark for *Quality Shipping*
- Independently acknowledged Standard
- Standard approved by the National Authority
- „Do good things and talk about it“

The future:

- Financial incentives for *Quality Shipping*

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The 1st vessel with the Blue Angel Award

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Normal Ship-Operation versus BE-Vessel

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Emissionreduction at the MS TIMBUS

Item	Normaler SB	Umweltfr. SB
Treibstoff	RMK	DMA
S-Gehalt (%)	0.028	0.006
Energiegehalt (kJ/g)	39.785	42.347
Treibstoffverbrauch (t/Reise)	33.816	32.044
CO_2 - Emissionen (t/Reise)	110.292	102.717
NO_x - Emissionen (t/Reise)	1.988	0.199
SO_2 - Emissionen (t/Reise)	1.894	0.385
CO - Emissionen (t/Reise)	0.096	0.096
Ölschlamm (t/Reise)	0.713	0.00
TBT (kg / Reise)	0.135	0.00
Öl im Bilgenwasser (t/Reise)	0.086	0.00
Festmüll (4 Reisen /t)	0.275	0.00

GAUSS 2002

The Situation on Board MS CELLUS

Requirement	M	V
ISO 9002		+
ISO 14000		+
Personnel management	+	+
Material pass		+
Collision protection		+
Redundant machinery		+
Hull stress monitoring		+
Emergency towing system		+

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The Situation on Board
MS CELLUS

Requirement	M	V
Sulphur dioxide	+	+
Nitrogene	+	+
Climate gases (ODP / GWP)	+	+
Particular matter		+
Waste handling / Waste incineration	+	+
Black water / Grey water	+	+
Bilge water	+	+
Ballast water	+	+
Antifouling	+	+
Fire fighting	+	+

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• The Maritime Environment •

" Ballast Water and Waste Water Treatment Aboard Ships and in Ports"

Session 2

Ballast Water

Session Chairman:
Dr. Matthias Voigt, (first day)
Dr.Voigt Consulting, GE
Capt. Cornelius de Keyzer, (second day)
Rotterdam Port Management,NL

Port of Rotterdam

CHANCES FOR STRANGERS IN BALLASTWATER

By Capt. Cornelius de Keyzer

Generally speaking the transportmodality known as "water" has brought much benefit and joy to mankind. Unfortunately however, this is not the case with ballastwater from ships.
The distortion of local and regional ecosystems by thuswise conveyed alien invaders has become a serious and ongoing concern. The increasing current international attention for the problem is emphasizing the importance of the subject.

So far the focus has mainly been on a possible menace of exotics, predominantly from a scientific point of view. As a non-scientist I like to strike a different note or even two notes, namely as port authority and as a ship-operator.

IMO approach and developments through the Marine Environment Protection Committee

Annex I of IMO's MEPC (draft) Ballastwater Management Code is, inter alia, mentioning practices for Deep Sea Ballastwater Exchange (BWE). Apart from that Port States shall:

(a) ensure that all ports having ship repair yards or tank cleaning facilities shall have adequate facilities available for the environmentally safe disposal of ballast tank sediments; and
(b) ensure that any port reception and / or treatment facilities for ballastwater are adequate, effective, practical, safe and environmentally sound and that they operate without causing undue delay.

On the one hand I must say that the IMO efforts to achieve a multilateral and harmonized solution are much more favourable than the unilateral approaches in already 14 different countries at present.
On the other hand I feel worried about the slow progress (MEPC 46 reports reaching the point where planning a diplomatic conference in 2003 should be considered) and the emphasis on Deep Sea BWE and possible treatment ashore. The latter is OK for sediments but certainly not for huge volumes of ballastwater together with investments and needed space ashore for - not causing undue delay - tankstorage provisions without a strict requirement for vessels to use the facilities.

Moreover both deballasting ashore and BWE are not considered to be an effective solution because a so called deballasted ship will never be 0% MT. Investigations from AQIS (Australian Quarantaine and Inspection Service) have shown that up to 5% of the original ballastwater may remain on board, containing up to 25% of the entire present organisms.
Apart from that it has been lined out that the different methods of BWE do not result in a complete removal of organisms (A.N. Cohen, San Francisco, 1997).

Just to compare volumes: (British numbers are used - source: Webster's New Lexicon Number Table)

-Annually some 10 – 12 Billion tons of ballastwater is transferred, only 1% left results in at least 100 Milliard tons.
-1% of the ballastwater capacity of a Double Hull VLCC (100.000 tons) still could result in 1000 tons.

Next to that, when taking containervessels into consideration, we have to face the fact that these ships are using ballastwater for proper trimming purposes and can carry a real "cocktail" for longer periods. Nowadays they are high speed vessels with a relative shorter interval between port calls. One and another is considered to be a real survival chance for "strangers".

Last but not least is the aspect of the burden on ships constructions during Deep Sea BWE, even under favourable weather conditions. Shear forces, bending moments, torsional forces, hull vibration, sloshing action, free surface effects, internal tankpressure, just to mention a few, are already threatening the safety of ships at present, specially with respect to (larger) bulkcarriers carrying high density cargoes.

Figures released by Intercargo show that during the 10-year period 1991 – 2000, a total of 134 bulkcarriers sank and 740 seafarers have gone down with their ships and apart from this mournful figure we should recognize that so far those vessels were not even subject to BWE procedures.

To a certain extent the MEPC recognized one and another, as reflected in MEPC document 44/4:

Safety related issues

2.10 Throughout the discussions within the Working Group two issues kept recurring:

- the need to emphasize throughout the text the paramount importance of maintaining the safety of vessels and of ship's crew
- the development of criteria for alternative treatment techniques and their performance standards

2.11 A number of experts considered these as being fundamental issues and that without such a basis it was difficult to develop draft provisions for a new convention and respective regulations. The Working Group agreed that the concerns regarding ship's safety should be set out in the Preambular text to the Convention.

Besides and on top of that I like to raise some questions:

- Do the three BWE methods, i.e. dilution, flow-through or sequential, have the same effect ?
- Is any of the three methods considered to be more favourable for the ship's construction ?
- Is it known whether a Deep Sea BWE area (at least 500 meters depth and at least 200 nautical miles from the nearest land) could or could not be effected by ecological distortion through ballastwater strangers disposed in such an area.?
- How strict and effective can BWE be controlled ?

With respect to the last question I can inform you that Intertanko circular 215 (November 1999) is already mentioning that there are a growing number of cases involving malpractice with BWE . (An example was given in which a vessel was not considered to have carried out BWE, even though the master had reported otherwise. The port insisted that a specialist should board the vessel and the ballast be treated with chlorine before discharge – the cost of which was levied upon the owner.)

Summarizing and taking all facts and figures into account my conclusion is that the real solution should strongly focus on ballastwater-treatment-methods <u>ON BOARD.</u>

At this very moment, in different parts of the world, a number of research projects have been initiated for <u>ON BOARD</u> ballastwater-treatment-methods. De-oxygenation, UV/US and ozonisation, Hydrogen peroxide, Thermal or Filtration techniques or a combination thereof are options. Also Gamma radiation might be a possibility. Hydrocyclone or cyclonic seperation are currently under assessment.

In this scope systems like the EVTN vortex centrifugal seperation technology with a second stage UV treatment or for larger flow rates a second stage chemical biocide treatment or the OptiMar Ballast Systems with an integrated cyclone / Microkill UV treatment are looking most promising. Lately a project with the MSI Microfugal Separator started aboard the USMA vessel Cape May in Baltimore.

Balancing the pros and cons and regarding the (dis)advantages of the three different options:

- Delivery and treatment ashore
- Deep Sea BWE and
- Treatment <u>ON BOARD</u>

I am convinced that the most effective and feasible approach and solution will be the last one

Chances for Strangers in Ballastwater

Cornelius de Keyzer, Master Mariner

Senior Policy Advisor

Nautical Environment and Safety

Strategy & Communication

Maritime Development

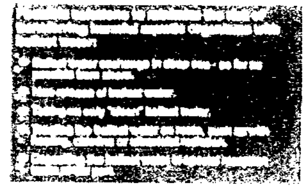
Rotterdam Municipal Port Management

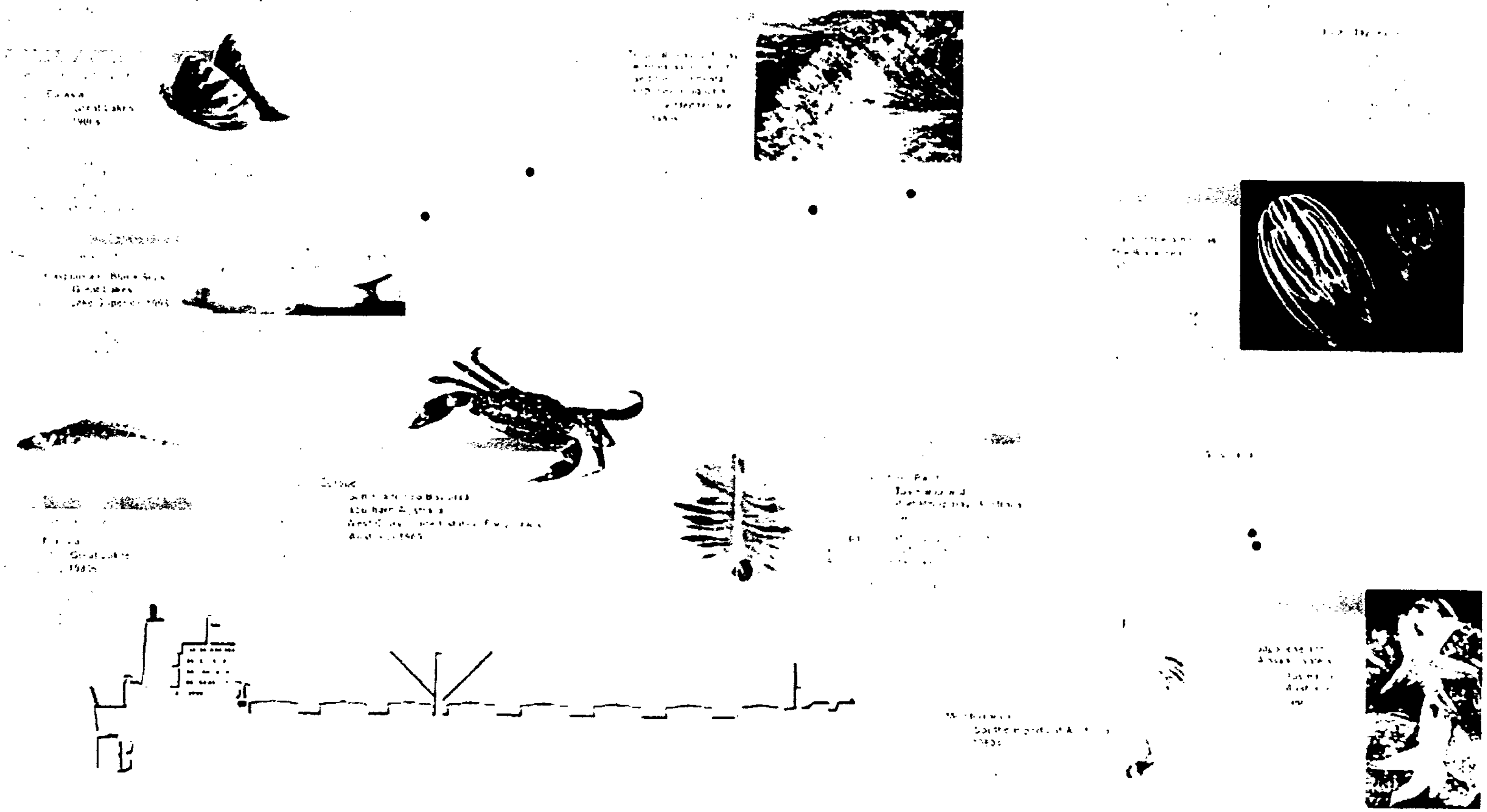
Alien Invaders

Alien invaders - putting a stop to the ballast water hitch-hikers

Alien life forms that hitch a ride across the oceans in the ballast water of ships have been creating significant problems for the marine environment, public property and human health. Unlike oil spills and other marine pollution caused by shipping, exotic organisms and marine species cannot be cleaned up or absorbed into the oceans. Once [illegible] they can be virtually impossible to eliminate and in the meantime may cause havoc.

The International Maritime Organization is working through its Member States to tackle the ballast water problem. *Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens* were adopted in 1997 (replacing earlier guidelines on the subject initially adopted in 1993) [illegible] IMO is now working towards adopting mandatory regulations on the management of ballast water.





3

With acknowledgement to IMO news

200105PP-034

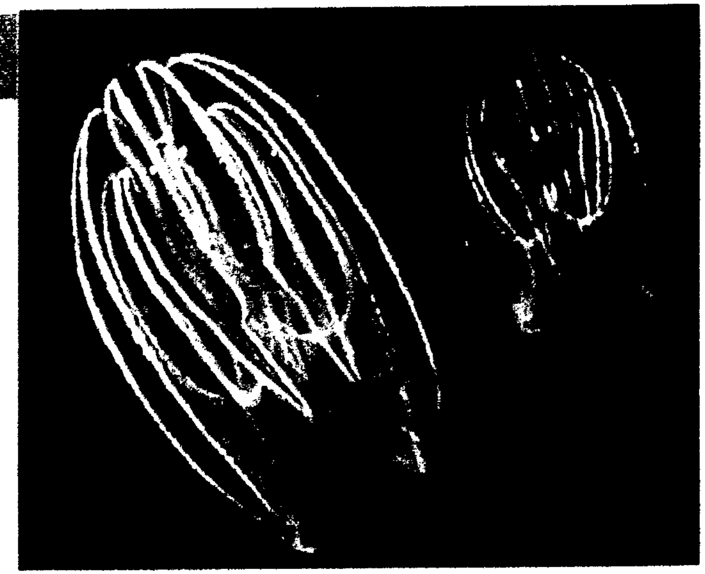
American Ctenophore (Comb Jelly)

AMERICAN CTENOPHORE (Comb Jelly)

(Mnemiopsis leidyi)

Origins: **East coast of the Americas**
Introduced to: **The Black Sea**
First sighting: **1970s**

The comb jelly (an organism with similarities to a jellyfish) is a voracious predator on zooplankton, fish eggs and larvae - thereby depriving other species of this source of food. It has been largely responsible for the collapse of the sprat and anchovy fishing industries in the Black Sea



With acknowledgement to IMO news

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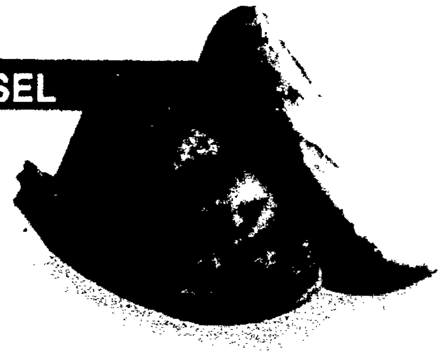
200105PP-034

European Zebra Mussel

Great Lakes

Invasion of alien species to the Great Lakes dates back to the opening of St Lawrence Seaway (1959) By 1996, more than 130 alien species had been identified, including the European zebra mussel and the goby fish.



EUROPEAN ZEBRA MUSSEL

(Dreissena polymorpha)

Origins: **Eurasia**
Introduced to: **Great Lakes**
First sighting: **1980s**

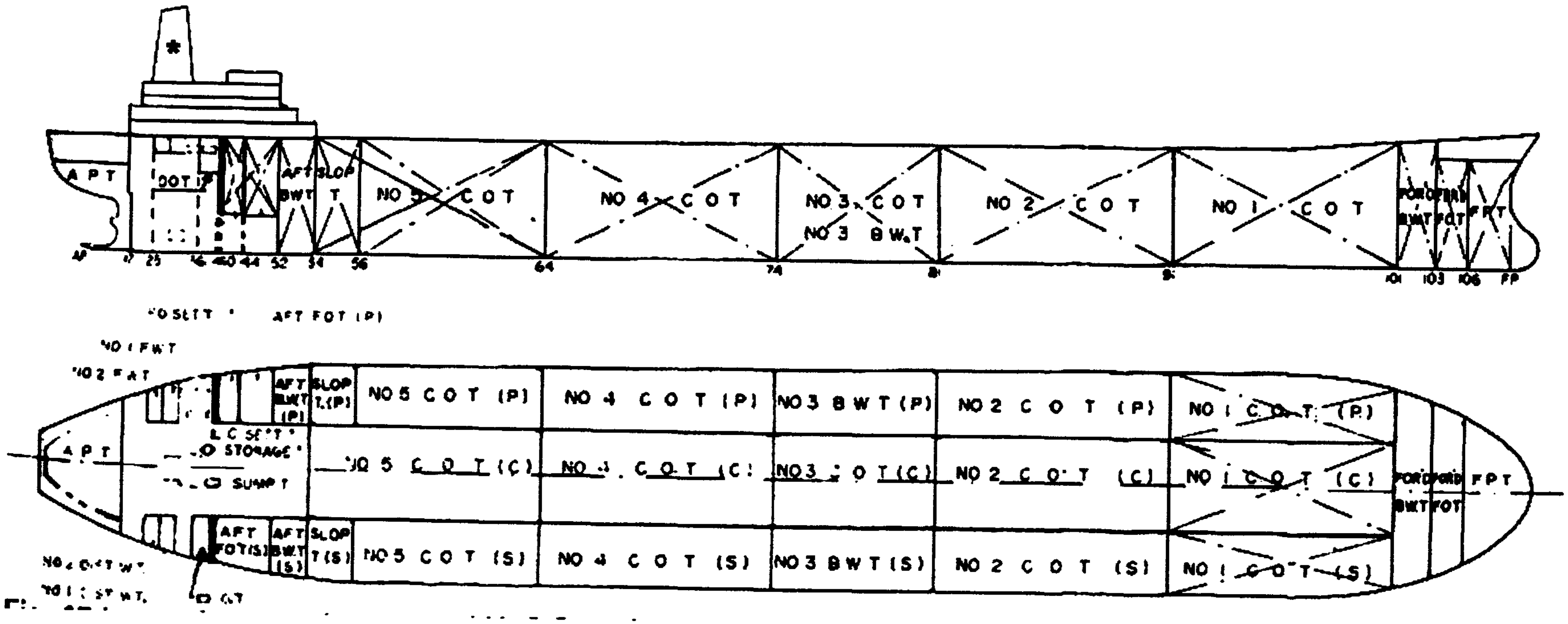
In 1990, the United States federal government pledged 11 million US dollars per year to fight the zebra mussels, which were causing problems by swarming near water intake pipes of power plants and factories, in some cases clogging them completely. The zebra mussel also competes with native fish for plankton, affecting native fish populations.

With acknowledgement to IMO news

Ballastwatercapacities in % of DWT

ULCC > 300.000	30%
VLCC > 200.000	30%
Suezmax Tankers (120.000 - 200.000)	30%
Aframax Tankers (80.000 - 120.000)	30%
Older and/or smaller tankers	20%
Chemical tankers	20%
LNG/LPG tankers	25 - 30%
OBO's and Ore/oil tankers	30%
Northsea Shuttletankers (60-120.000)	up to 40 - 50%
Bulkcarriers Capesize	20%
Bulkcarriers Panamax (60-80.000)	20%
Bulkcarriers Handysize (20-60.000)	20%
General Cargo	10 - 15%
RoRo's	20 - 25%
Vehicle carriers	20 - 25%
LASH vessels	30%
Containervessels	10 - 15%
Post Panamax containervessels	30%

Single Hull Tanker



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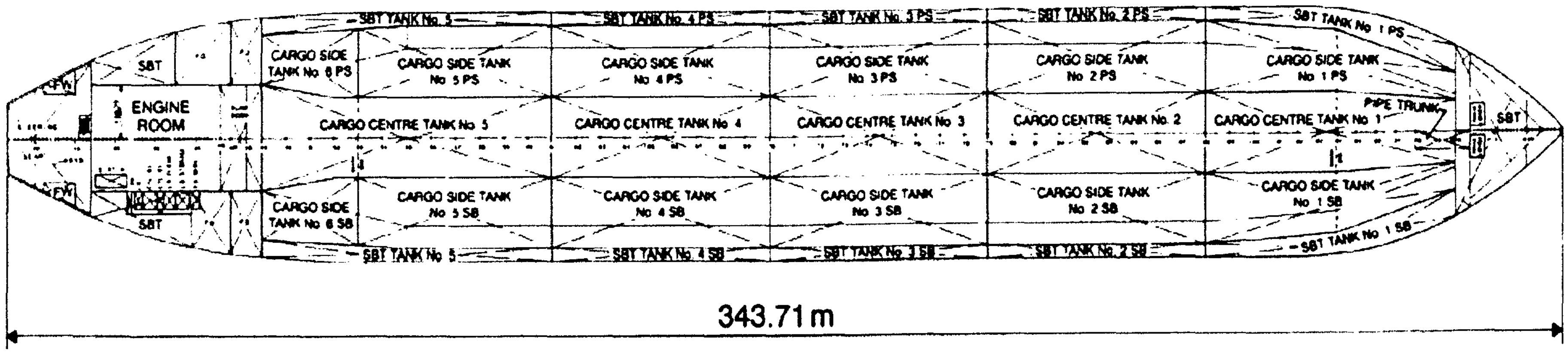
Double Hull Tanker



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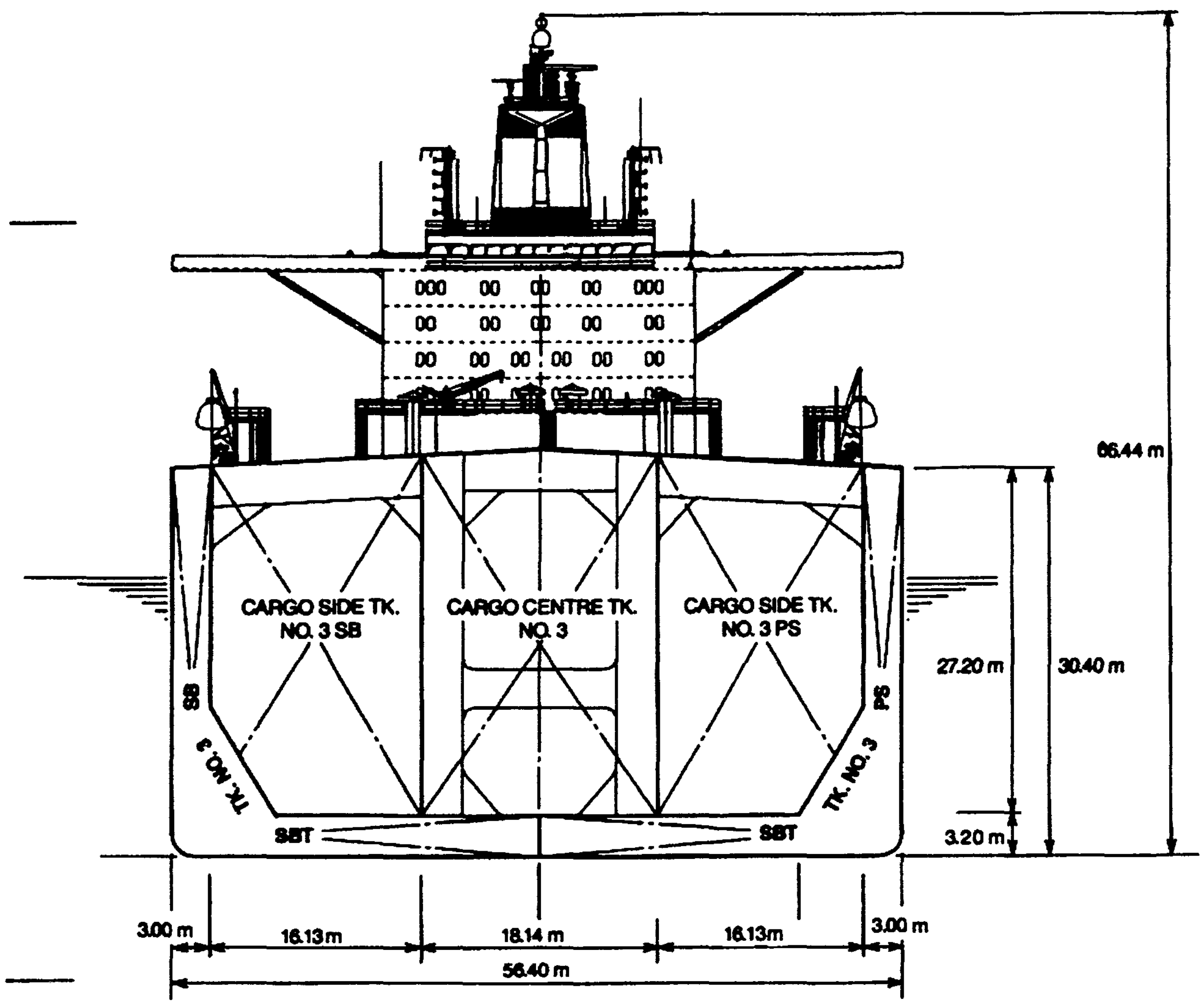
Double Hull Tanker



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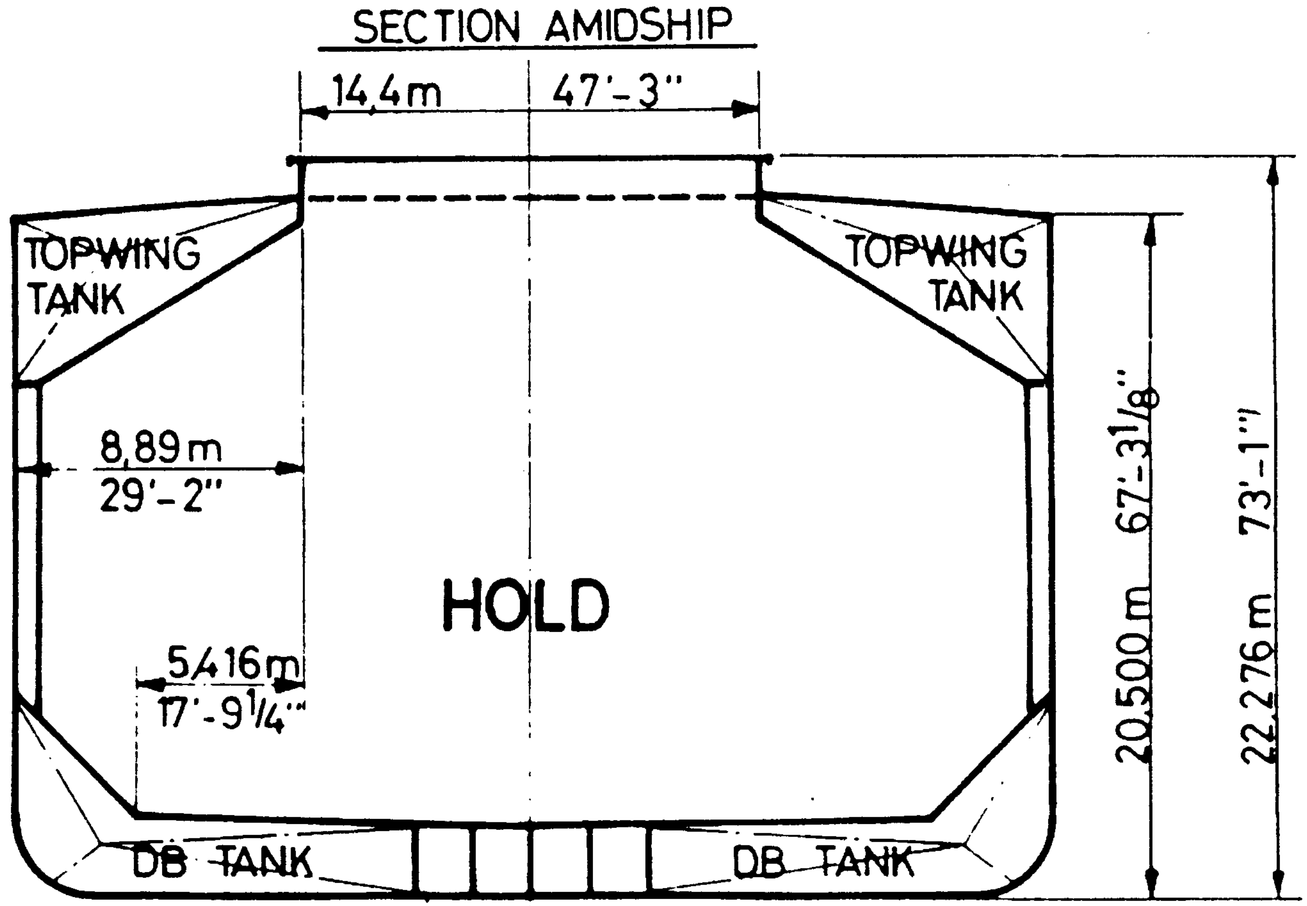
Bulkcarrier



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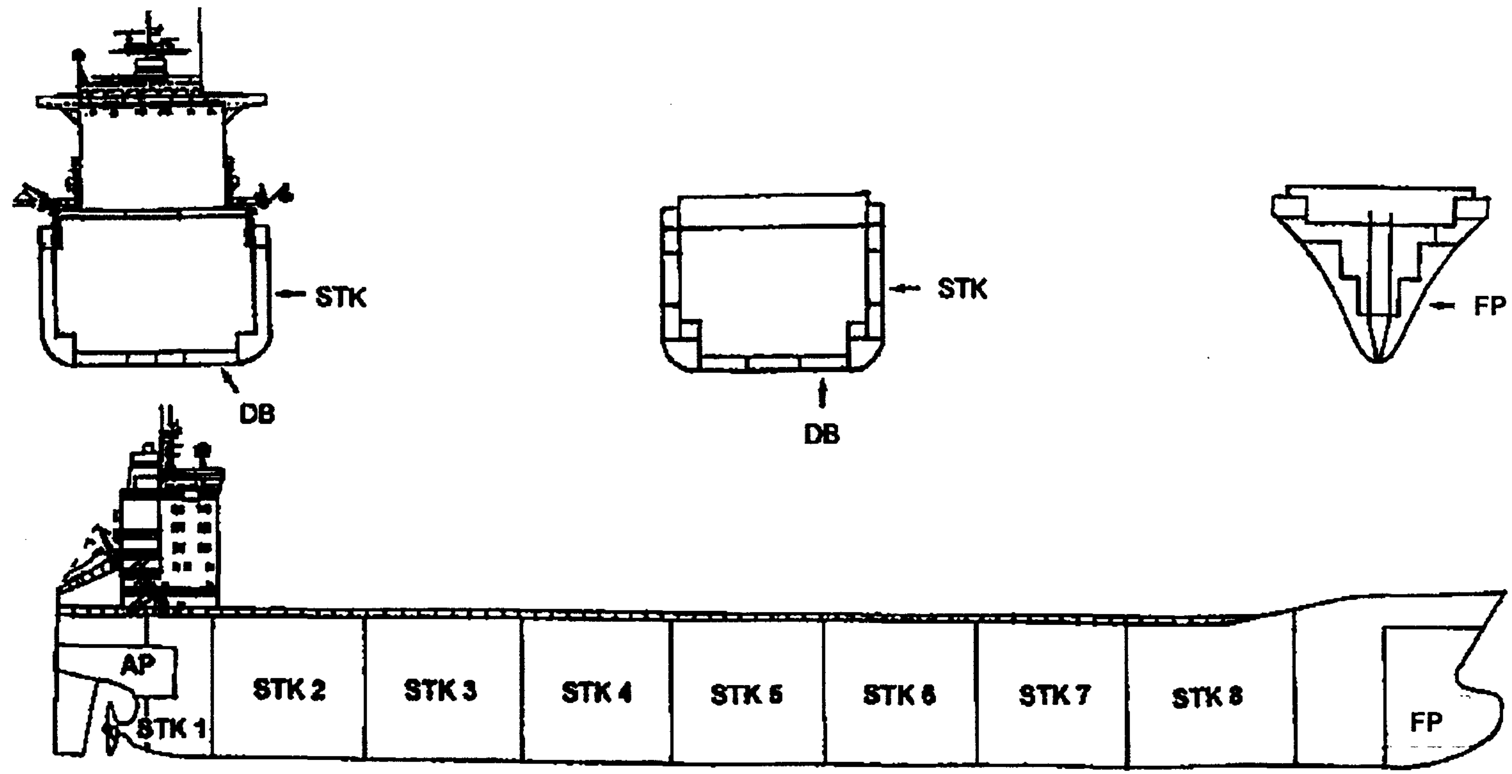
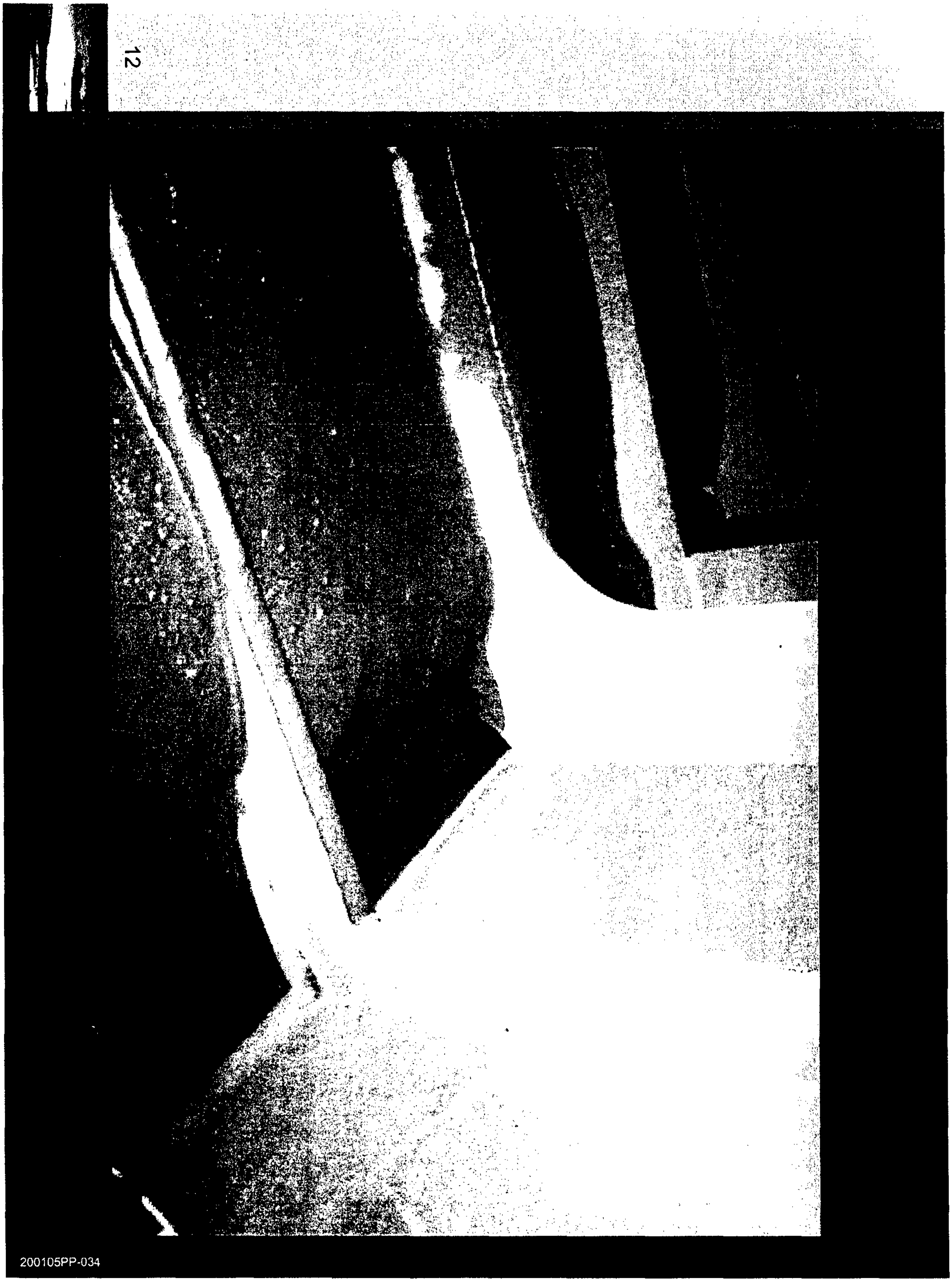
UCC



Profile view of a modern container vessel showing the position of ballast water tanks (AP = aft peak tank, FP = fore peak tank, STK = side tanks and DB = double bottom tanks).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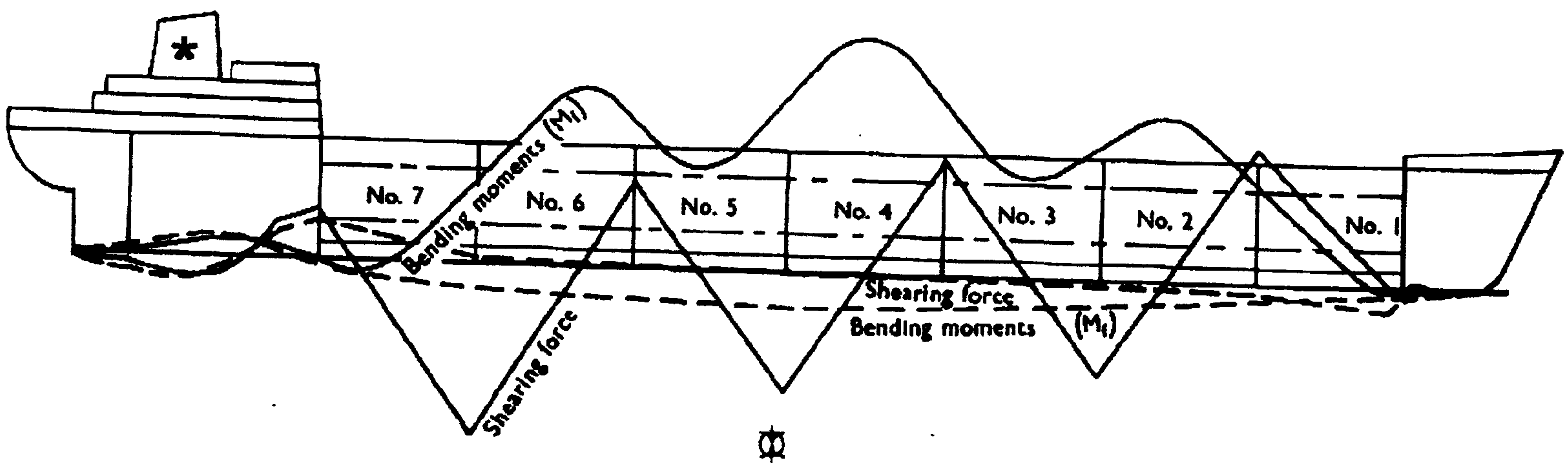

- - - = Homogeneous loaded ——— = "alternate loading". 1,3,5 and 7 Loaded

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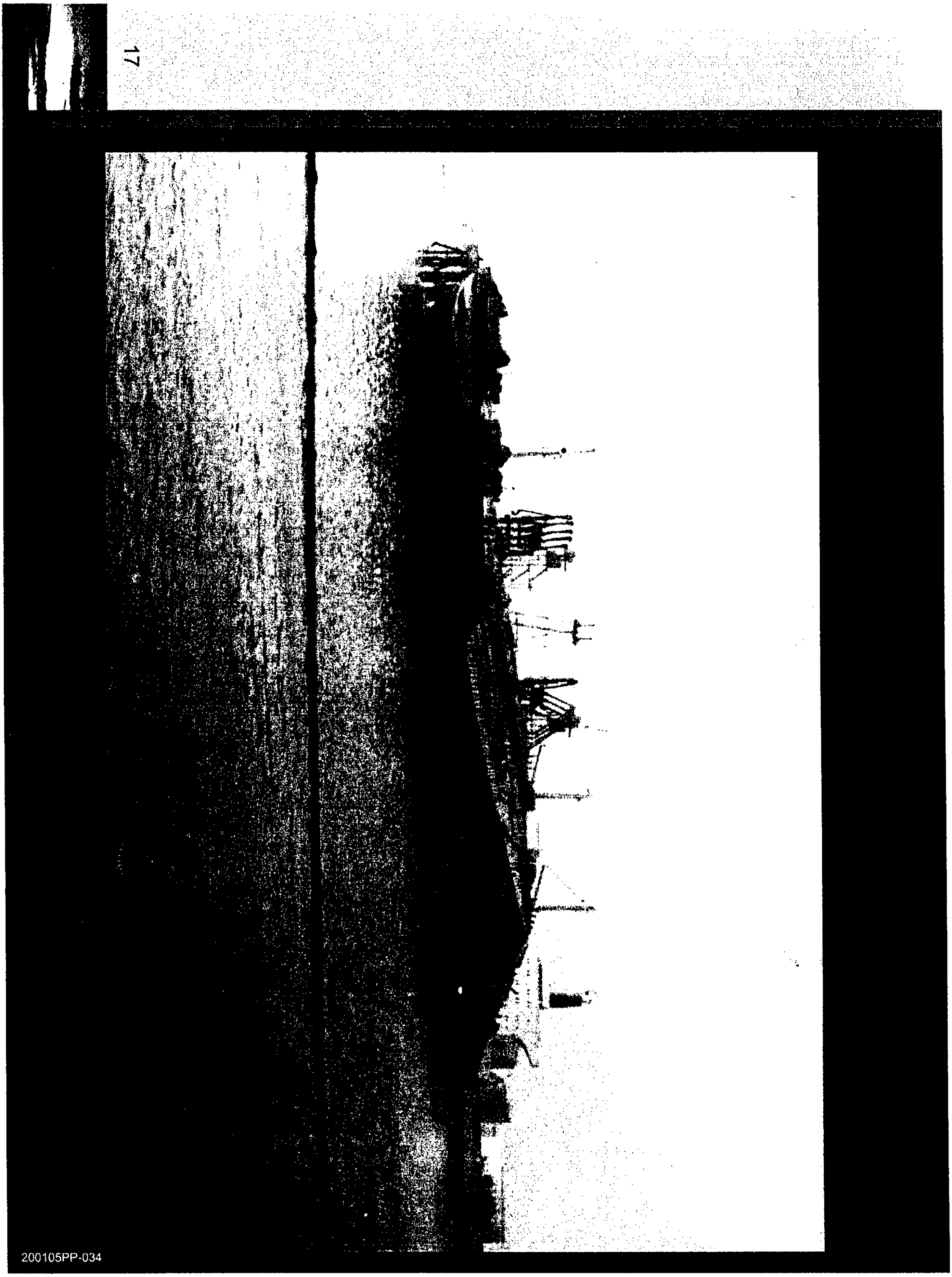
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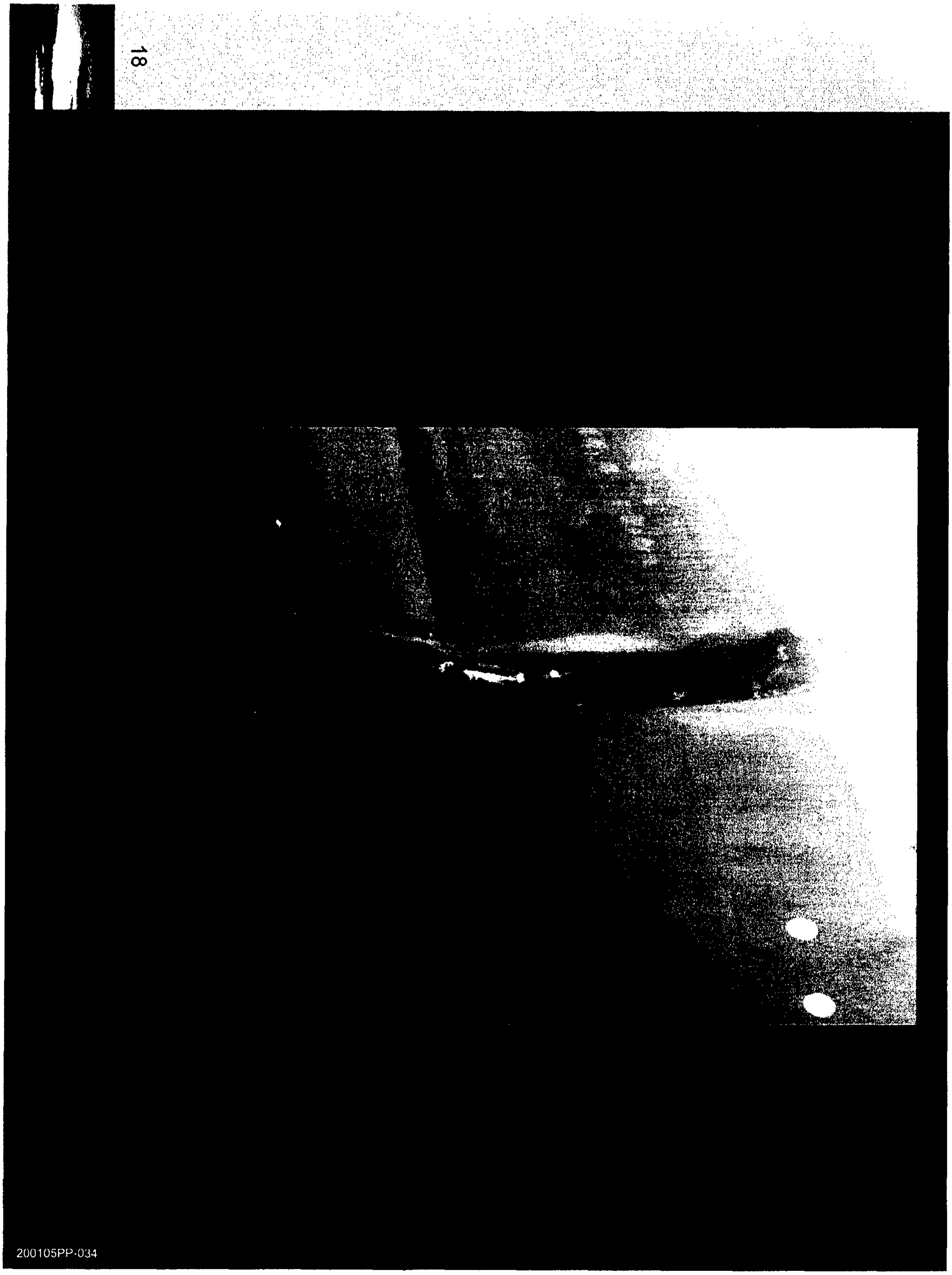
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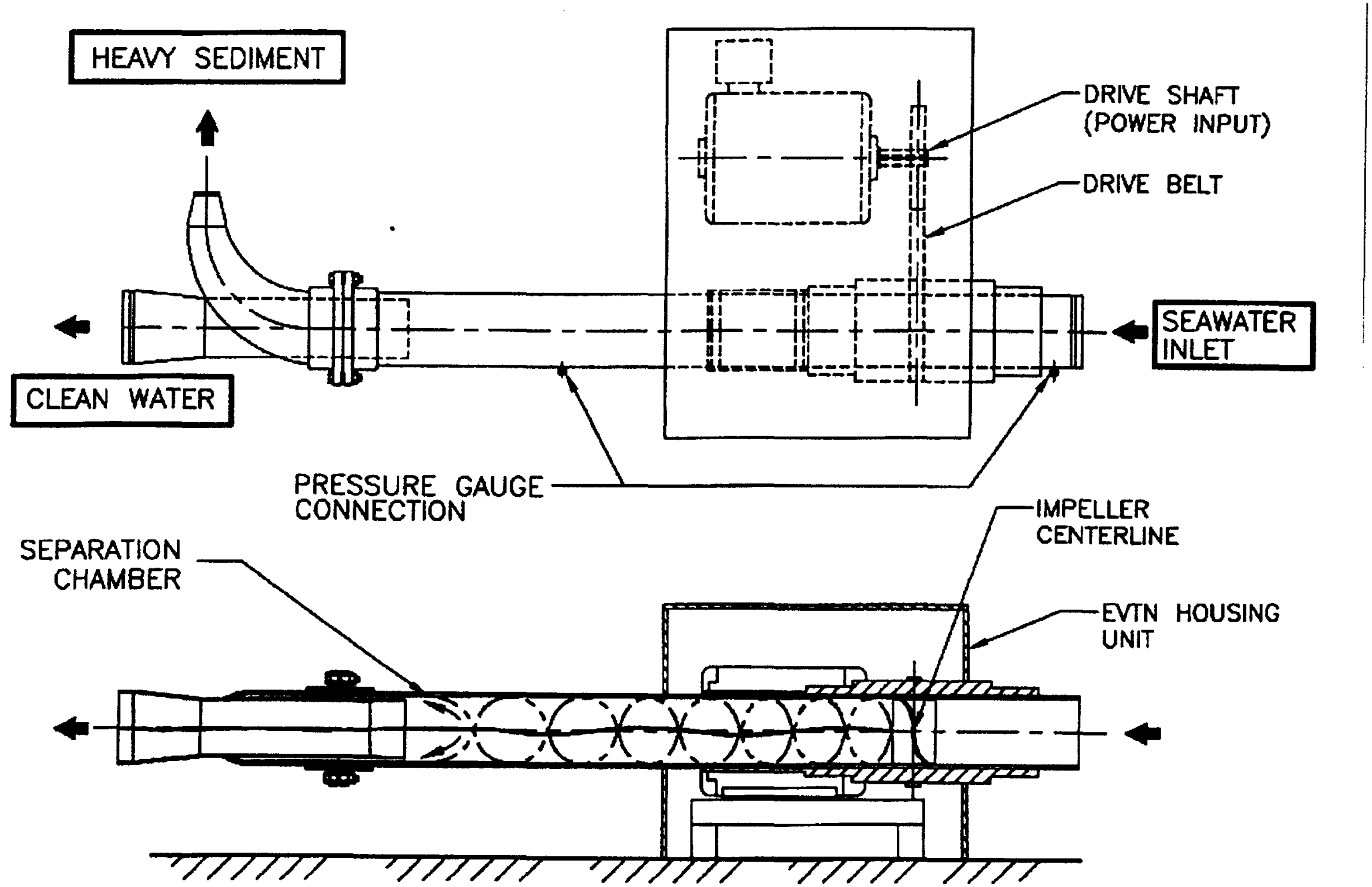
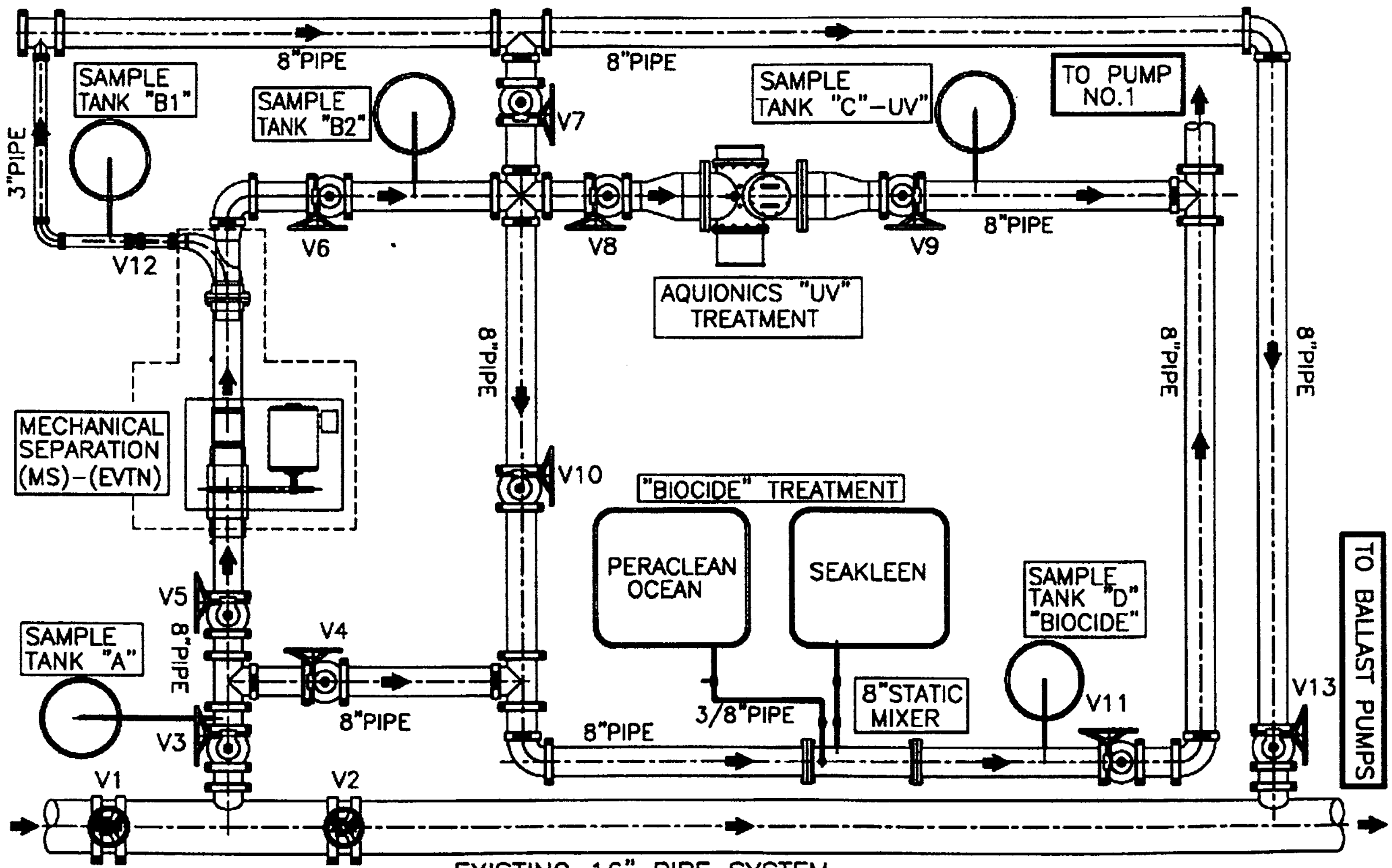


FIGURE 1
EVTN VORAXIAL SEPARATOR·
MARITIME SOLUTIONS, INC.

SIGMA DESIGN
Professional Engineers & Designers
43 COMMERCE STREET
SPRINGFIELD, NEW JERSEY 07081
(973) 912-7932, info@sigmadesign.net

200105PP-034



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GENERAL ARRANGEMENT

FIGURE 4
MSI SYSTEM-"CAPE MAY" GENERAL ARRANGEMENTS
MARITIME SOLUTIONS, INC.
SIGMA DESIGN
Professional Engineers & Designers
43 COMMERCE STREET
SPRINGFIELD, NEW JERSEY 07081
(973) 912-7922, info@sigmadesign.net

200105PP-034

Using Surrogate Organisms for Testing of Ballast Water Treatment Options

Matthias Voigt,
dr. voigt-consulting, Stolpe, Germany

- Introduction
- Background information
- The Artemia Testing System (ATS)
- Test Results
- Conclusions

The IMO is Preparing a Legal Regime to be Adopted by a Diplomatic conference in early 2004.

The new BW Convention is going to include several methods of Ballast Water Management:

Ballast Water Exchange

as well as

New Technologies which could include: Mechanical, Physical and Chemical and any combination of these.

The mid-ocean exchange of Ballast Water is currently the only readily available Ballast Water Management option on existing vessels.

However, this method can pose a structural risk to the ships.

Furthermore, the biological efficacy of Ballast Water Exchange is questionable.

There is an urgent need new Ballast Water Treatment options

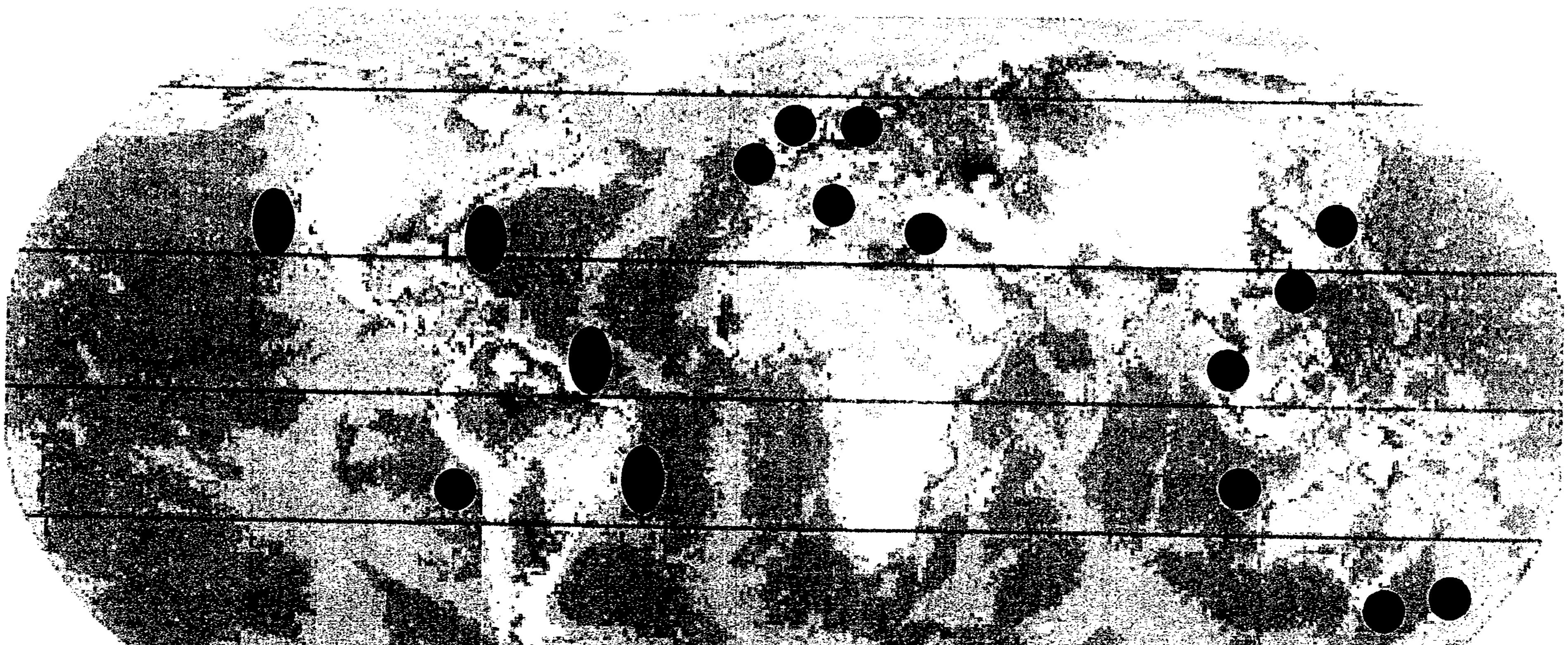
- That show a biological efficacy better than Ballast Water Exchange;
- That do not pose a risk to the ship and the crew or to the environment.

Why do we need surrogate organisms for the assessment of Treatment Options?

- The biological efficacy of any ballast water treatment option has to be assessed in full-scale tests.
- The tests have to be as independent as possible from seasons and location of the test plant in order to assure a cost efficient and rapid development of urgently needed new ballast water treatment technology.

Why do we need surrogate organisms for the assessment of Treatment Options?

➢ Research projects world wide



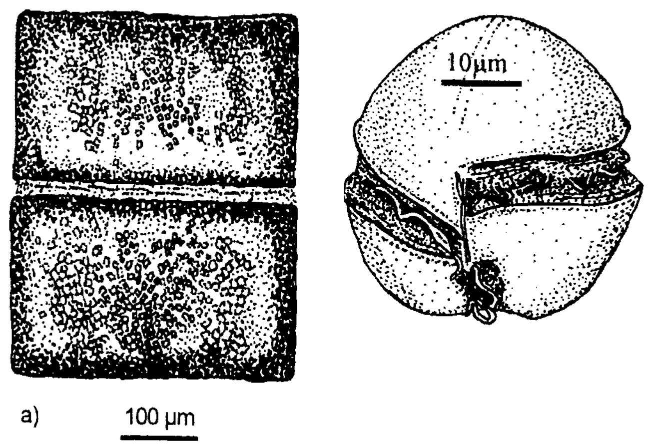
Tests are carried out at " the door step", using local species / species composition

Why do we need surrogate organisms for the assessment of Treatment Options?

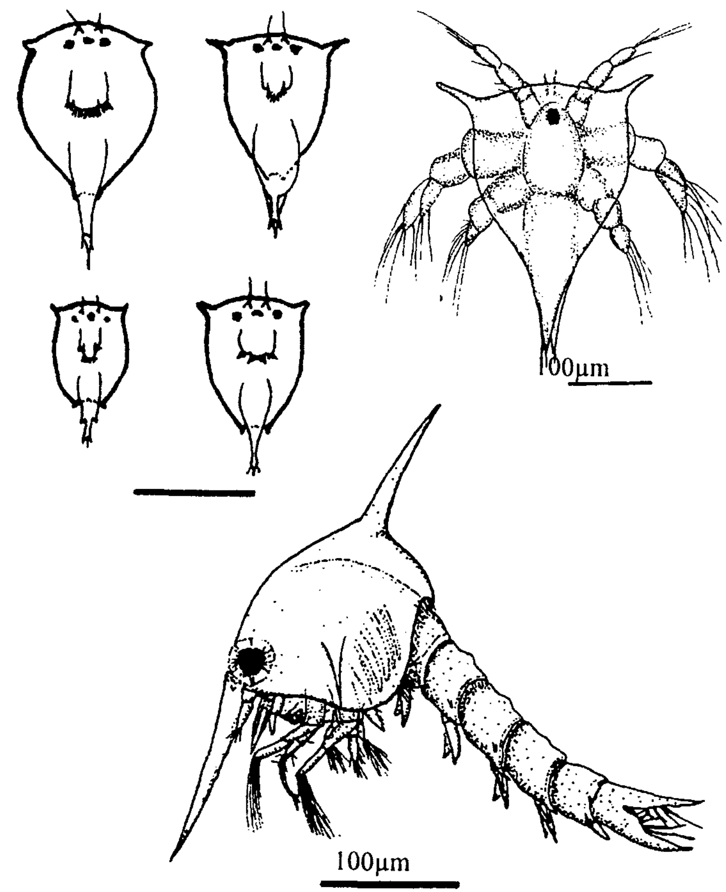
- The distribution and density of marine fauna and flora is not the same everywhere
- Even the most common and most widely distributed species are not found in comparable densities over their whole distribution area.

Some examples for organisms present in ballast water

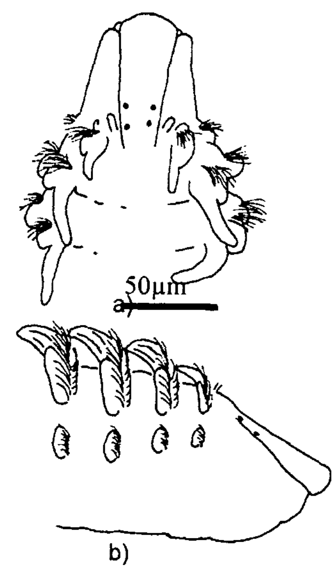
Algea



Larval stages of crustaceans



Larvae and juveniles of worms



- Changes in the species composition at the test site and in the densities of individual species have a negative impact on the statistical analysis of the experimental data.

- When surrogate species are used, the test system can be primed with a given number / density of the surrogate organisms.

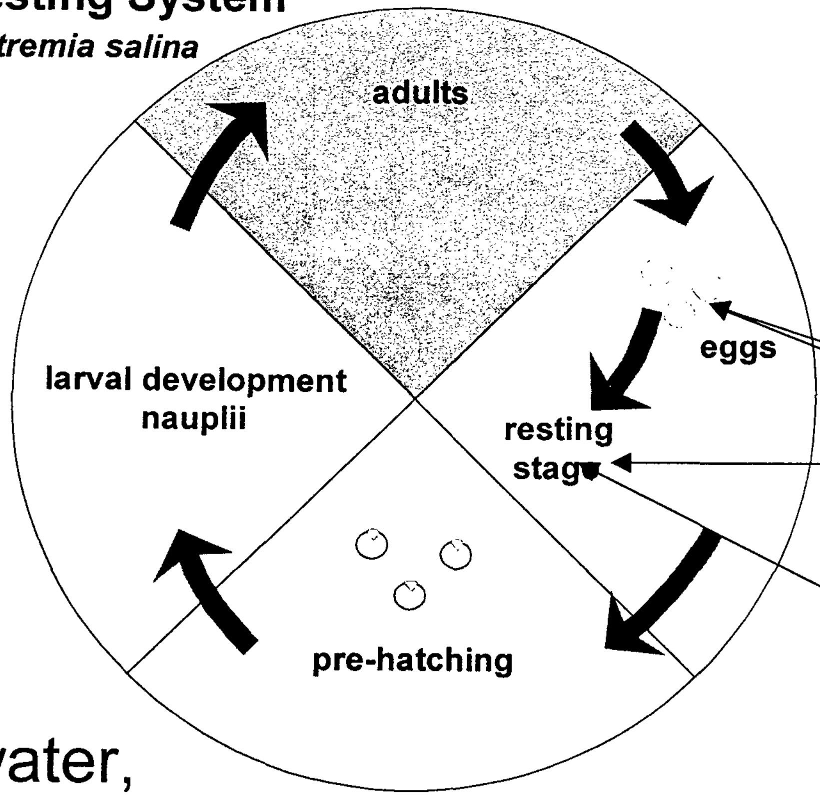
- Observed changes in numbers / survival rates are mainly attributed to the treatment.

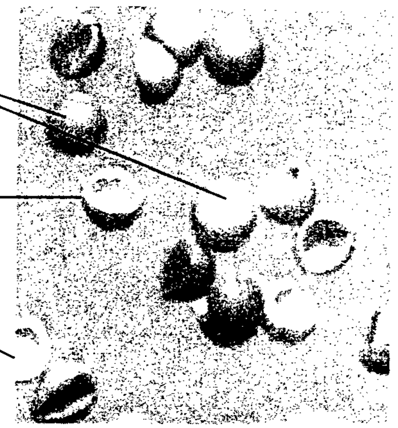
The Artemia Testing System - ATS

The test involves different larval and development stages of *Artemia* salina as surrogates for a variety of organisms commonly found in ballast water

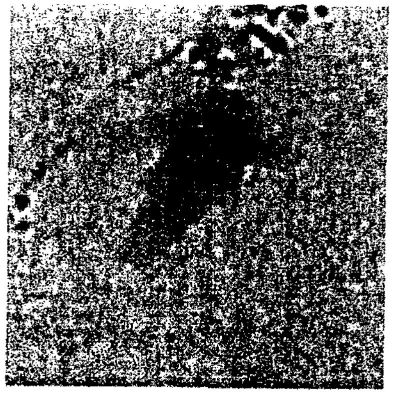
Artemia Testing System

I. lifecycle of *Atremia salina*

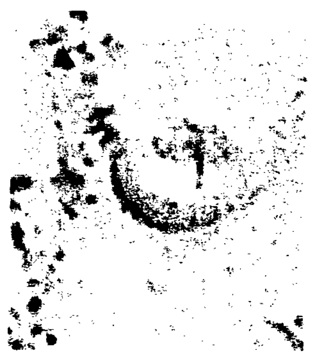




Hard shelled, specific gravity < or = water



Medium-soft body, specific gravity > water, active swimming



Medium-soft shelled, specific gravity > water

The Artemia Testing System - ATS

- The robust *Artemia* can be produced in any lab with only little effort.
- Furthermore, they can be easily added to the water prior to the treatment system.
- They are easy to recognise / identify even in samples with high numbers of other taxa and / or high turbidity.

The Artemia Testing System - ATS

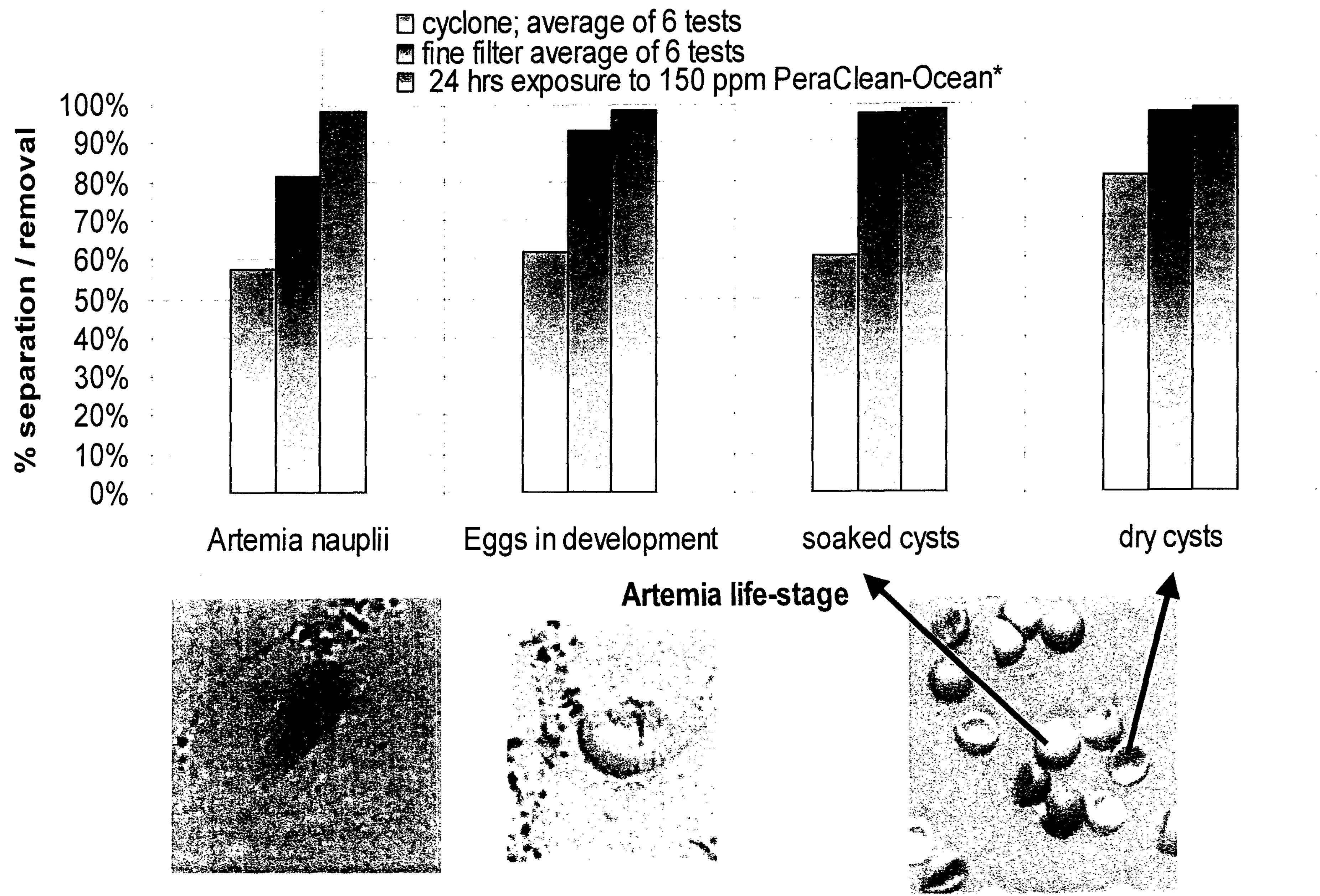
- All development stages of *Artemia* show rather low sensitivities to physical and chemical stressors, which makes them a good “worst-case-scenario” for any stand-alone treatment or any combination of treatment options.
- Because of the rapid development of the cysts and larvae (nauplii), the test results can be obtained already 24 hours after the experiment

Test results

Examples from a modular treatment system

The ATS (Artemia Testing System) has already been applied in various full scale tests at flow rates between 130 m^3/h to 200 m^3/h

ATS Test Results



Conclusions

The ATS is a very useful tool that can be applied as a surrogate for

- A wide range of organisms with
  - different specific gravities
  - different sizes and shapes
  - different behaviour
  - different sensitivities to stress

The ATS is a very useful tool that can be applied as a surrogate for

- The ATS can be used in any location at any time
- Low environmental risk from the surrogate species
- The robust *Artemia* can be calibrated against more sensitive species
- Reproducible results

The full ATS test protocol is available free of charge in PDF-format at

www.drvoigt-consulting.de

The ATS-benchmark for chemical treatment options

The efficacy of the chemical treatment option is measured as mortality of the adults and the nauplii, and the hatching rates of cysts and developing eggs, respectively. The experimental design includes 13 separate measurements (after 1h, 3, 5, 7, 10, 12, 24, 30, 36, 48, 54, 60, 72 hrs exposition time) for each of the 4 development stages in three replicates and control experiments (without treatment).

Preparation of experiments

Breeding of adult *Artemia*

1. Fill a 1-l-bottle with 600 ml of filtered sea water and aerate well.
2. Transfer 1 table spoon of premium grade *Artemia* eggs to the bottle. Incubate in a water bath at 24°C for 24 hours.
3. Decant the hatched nauplii through a sieve (mash 10µm) and transfer to 10 l to 20 l aquarium filled with sea water (24°C).
4. Aerate aquarium well. Start feeding the nauplii after 2 to 3 days with micro algae.
5. Monitor growth of larvae carefully.
6. Remove dead individuals and excess food daily.
7. After 14 to 16 days the Artemia are fully grown and can be used for the experiments.

Breeding of nauplii

Follow steps 1 to 3 as above

Breeding of developing eggs

1. Fill a 1-l-bottle with 600 ml of filtered sea water and aerate well.
2. Transfer 1 table spoon of premium grade *Artemia* eggs to the bottle. Incubate in a water bath at 24°C for 12 hours.
3. Take a sample of the eggs and examine under a stereo microscope at 20 x magnification. If the outer shell of the eggs has opened, the yellowish embryo is clearly visible and the eggs can be used for the experiments. If the embryo is not clearly visible, incubate the eggs for 4 to 6 more hours. Monitor the development closely.

Preparation of cysts

1. Fill a 1-l-bottle with 600 ml of filtered sea water.
2. Transfer 1 table spoon of premium grade *Artemia* eggs to the bottle. Allow the cysts to soak for 2 hours at room temperature.

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The ATS-benchmark Test procedure

Each test involves the 4 life-stages of *Artemia* in three replicates and control group (three replicates without treatment). Filtrated sea water is aerated to saturation. This water is used for each of the experimental groups.

Each replicate is treated as follows:

1. Transfer 50 adult *Artemia* to a 5 l aquarium with sea water and label clearly (e.g. Control 1, Control 2, ..., yx ppm 1, xy ppm 2....).

2. Transfer 50 *Artemia* nauplii to a 5 ml glass tube (screw top) with sea water and label clearly (e.g. Control 1, Control 2, ..., yx ppm 1, xy ppm 2....).

3. Transfer a maximum of 100 developing eggs to a 5 ml glass tube (screw top) with sea water and label clearly (e.g. Control 1, Control 2, ..., yx ppm 1, xy ppm 2....).

4. Transfer a maximum of 100 soaked cysts to a 5 ml glass tube (screw top) with sea water and label clearly (e.g. Control 1, Control 2, ..., yx ppm 1, xy ppm 2....).

5. Add test substance at the concentration wanted to each of the experimental groups.

6. Incubate the adult *Artemia* and *Artemia* nauplii at room temperature.

7. Incubate the developing eggs and soaked cysts at 24°C in a water bath.

8. Record starting time of the experiment

9. Observation of test organisms:
   The movements of the adult *Artemia* are observed with the naked eye. Immobile individuals are removed carefully and transferred to a Petri dish with sea water. The movements of gills and legs are monitored under a stereo microscope at 10x magnification. The individual is dead, if no movements of gills can be detected.

   The sealed glass tube with the *Artemia* nauplii is removed from the water bath and is transferred to a dish filled with water to reduce reflections on the glass tube during the observation. The movements of the antenna and legs are monitored under a stereo microscope at 10x magnification. The individual is dead, if no movements of the antenna can be detected. After the observation, the glass tube is returned into the water bath.

   The sealed glass tube with the developing eggs and with soaked cysts are observed as above. The number of hatched individuals is counted under a stereo microscope at 10x magnification. Furthermore, the numbers of dead nauplii is recorded. After the observation, the glass tubes are returned into the water bath.

10. Record the numbers of dead adult *Artemia* and *Artemia* nauplii and the numbers of hatched developing eggs and cysts after 1h, 3, 5, 7, 10, 12, 24, 30, 36, 48, 54, 60, 72 hrs exposition time (see attached lab protocol).

11. Calculate the mortality in percent for the adult Artemia and the nauplii as follows: [number of dead individuals / total number of individuals in the sample] * 100.

12. Calculate the hatching rate in percent for the developing eggs and soaked cysts [number of hatched individuals / total number of eggs/cysts in the sample] * 100

13. Calculate the mortality in percent for hatched nauplii [number of dead nauplii / total number of hatched nauplii in the sample] * 100

14. Plot mortality (%) vs the exposure time and the hatching rate (%) vs the exposure time.

ATS benchmark

Test substance: ____________________ **Date:** _______________ **Time started:** _____________

Test organism: ___________________________ **Lab. protocol no.:** _________

No. of experiment	Concentration [ppm]	No. of dead individuals / hatched nauplii after xx hours of exposure time												
		1h	3	5	7	10	12	24	36	48	52	60	72hrs	Total

The ATS full-scale test for ballast water treatment options

The efficacy of any ballast water treatment option has to be assed in full-scale tests. The ATS full-scale test is based on a modified version of the ATS-benchmark. The test involves different larval and development stages of *Artemia* salina as surrogates for a variety of organisms commonly found in ballast water (Tab .1). The robust *Artemia* can be produced in any lab with only little effort. Furthermore, they can be easily added to the water prior to the treatment system and are easy to recognise / identify even in samples with high numbers of other taxa and / or high turbidity.

Table 1: Development stages of *Artemia salina* used in the ATS full-scale tests.

Artemia development stage	Trophic level	Surrogate for
Resting stage	inactive cysts	Floating (pelagic cysts) <100µm
Soaked cysts	inactive cysts	Demersal (benthic) cysts > 100µm
Developing eggs	floating / demersal eggs	Larval organisms (plankton) 150 µm – 180 µm
Nauplii	larvae (not feeding)	Numerous planktonic organisms > 250µm

The different physical properties (specific weight, size) and the different behaviour (passive movement with currents and active swimming) make the above development stages ideal surrogates. Furthermore, they show rather low sensitivities to physical and chemical stressors, which makes them a good "worst-case-scenario" for any combination of treatment options as well as for stand-alone treatments.

Because of the rapid development of the cysts and larvae (nauplii), the test results can be obtained already 24 hours after the experiment.

Preparation of experiments

The numbers of individuals needed for the tests depend on the capacity of the treatment system. As a role of thumb, one each of the following cultures is needed for every 30 m³ /hour capacity.

Breeding of nauplii

1. Fill a 1-l-bottle with 600 ml of filtered sea water and aerate well.
2. Transfer 1 table spoon of premium grade *Artemia* eggs to the bottle. Incubate in a water bath at 24°C for 24 hours.
3. Decant the hatched nauplii through a sieve (mash 10µm) and transfer to 10 l to 20 l aquarium filled with sea water (24°C).

Breeding of developing eggs

1. Fill a 1-l-bottle with 600 ml of filtered sea water and aerate well.
2. Transfer 1 table spoon of premium grade *Artemia* eggs to the bottle. Incubate in a water bath at 24°C for 12 hours.
3. Take a sample of the eggs and examine under a stereo microscope at 20 x magnification. If the outer shell of the eggs has opened, the yellowish embryo is clearly visible and the eggs can be used for the experiments. If the embryo is not clearly visible, incubate the eggs for 4 to 6 more hours. Monitor the development closely

Preparation of soaked cysts

1. Fill a 1-l-bottle with 600 ml of filtered sea water.
2. Transfer 2 to 3 table spoons of premium grade *Artemia* eggs to the bottle. Allow the cysts to soak for 2 hours at room temperature

Preparation of resting stage

1. Fill a 1-l-bottle with 600 ml of filtered sea water.
2. Transfer 2 to 3 table spoons of premium grade *Artemia* eggs to the bottle directly prior the beginning of the tests

Preparation of the treatment system

1. Install a by-pass to the first pump of the treatment system in order to prime the system with the cultures of *Artemia* development stages.
2. Identify the capacity (flow rate) of the by-pass and calculate the passage time of the water through the system.
3. Adjust the flow rate of the by-pass to allow min. 5 minutes of test run.
4. Start the treatment system and allow to stabilize for at least 1 hour.

IMPORTANT: re-direct the water flow into tanks with sufficient capacity during the test run to avoid introduction of Artemia to the test side.

The ATS full-scale test procedure

1. Mix the cultures (resting stages, soaked cysts, developing eggs and nauplii) in a bucket or barrel (10 litre volume for every 30 m^3 of capacity of the treatment system). Top up with sea water and aerate well.

2. Transfer a sample of 1 litre to a 200 l barrel (control), top up with sea water and aerate.

3. Prime the system with the prepared cultures through the by-pass of the pump.

4. During the passage of the organisms through the treatment system, take samples of 200l each directly before and after each treatment step (e.g. filtration / separation, desinfection).

5. Mix the water in the 200 l barrels well and take sub-samples (three replicates) of 10 litres each .

6. Put the sub-sample through a sieve (10µm) and observe under a stereo microscope at magnification of 10 x.

7. Count the numbers for each of the development stages. Record numbers of damaged or dead individuals separately.

8. Observation of test organisms directly after the test run:

   a. The movements of the antenna and legs of the *Artemia* nauplii are monitored under a stereo microscope at 10x magnification. The individual is dead, if no movements of the antenna can be detected.

   b. The resting stages, the soaked cysts and the developing eggs are examined for mechanical damage under a stereo microscope at 10x magnification.

9. Cover the barrels and leave without aeration for 24 hours.

10. Repeat steps 6 to 9.

11. Calculate the mortality / removal in percent for the nauplii for each step of the treatment.

12. Calculate the removal /damage rate in percent for the resting stages, soaked casts and developing eggs.

If the numbers of developing eggs increases in all three replicates taken after 24 hours in comparison to the samples taken directly after the test run, the treatment was insufficient for the soaked cysts.

If the numbers of the alive nauplii increases in all three replicates taken after 24 hours in comparison to the samples taken directly after the test run, the treatment was insufficient for the developing eggs.

Conference on
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Peraclean® Ocean – A Potentially Environmentally Friendly and Effective Treatment Option For Ballast Water

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Introduction

The transfer of human pathogens and the introduction of non-indigenous species through the ballast water of ships has been recognized as a significant problem. The introduction can result in tremendous costs and may impose a threat on local ecosystems. Globally, approximately 3 billion tons of ballast water are transported per year. Various treatment options for ballast water have been suggested (Gollasch, 1997).

Chemical and environmentally friendly treatment with Peraclean® Ocean is one method to effectively remove unwanted organisms and pathogens in ballast water. This paper summarizes the laboratory results of a partially funded and already finished research project and covers experimental results of a shipboard test. It provides details on the efficacy and toxicological properties of Peraclean® Ocean.

Name of Project

Testing of Peraclean® Ocean as a chemical ballast water treatment option has been part of a research project in Germany (1998 – 2001), that was funded by the industry (Degussa AG) and the German Federal Ministery of Education and Research (BMBF) with the title 'Process for the removal of organisms from different waters'[1)].

Properties of Peraclean® Ocean

Peraclean® Ocean is a liquid biocide formulation based on peroxygen chemistry. One active component in the formulation Peraclean® Ocean is peracetic acid (PAA). PAA- containing formulations are widely used in the food and beverage industry as well as in sewage treatment plants and other water treatment processes. They are widely used in the treatment of cooling

[1)]:. This publication is based on the results of a research project funded and supported by the Ministry for Research and Technology of Germany under registration number 02/WA9912. The authors are soley responsible for the content of this publication.

water and as a pre-treatment of biologically contaminated waters prior to discharge into the environment. PAA is accepted in the USA as a secondary and indirect food additive at concentrations up to 100 mg/l.

Peraclean® Ocean is a fast-acting oxidizing biocide effective against a broad spectrum of micro-organisms: bacteria, spores, yeasts and moulds, protozoa, algae and viruses (Block, 1991; Schliesser, & Wiest, 1979; Baldry, 1983). Peroxyacetic acid products are effective over a wide range of conditions. Peraclean® Ocean is most active at pH values of 5-7 but also displays good activity even under mildly alkaline conditions up to pH 9. Peraclean® Ocean remains effective even at temperatures of 4 °C and below. The microbial activity of peroxyacetic acid based products is relatively unaffected by organic matter, compared to other oxidising biocides (Block, 1991).

The shelf-life of Peraclean® Ocean is more than 1 year, and: more than 90% of the original activity is still present after one year's storage at room temperature. Peraclean® Ocean is commercially available in 220-kg drums, 1 m^3-IBC or in 20-m^3 bulk containers. Peraclean® Ocean is readily biodegradable according to OECD Screening Test 301 E guidelines.

Peraclean® Ocean does not persist in the environment and breaks down into innocuous degradation products, being acetic acid, water and oxygen:

$$CH_3CO_3H + H_2O \rightarrow CH_3CO_2H + H_2O_2$$

$$2\,H_2O_2 \rightarrow O_2 + 2\,H_2O$$

The hydrolysis products of Peraclean® Ocean are also readily biodegradable.

The half-life of Peraclean® Ocean omounts to minutes to hours in seawater, depending on pH value, salinity and temperature. In fresh water, the half-life of Peraclean® Ocean is 2-24 hours. Enhanced decomposition of Peraclean® Ocean may occur in contact with sediments.

Efficacy tests – laboratory tests

Several studies showed that many organisms from different trophic levels can be found in ballast water tanks. For that reason the efficacy testing of a chemical treatment should include organisms from more than one trophic level (Voigt, 1999).

For a first evaluation of the performance of Peraclean® Ocean, the *Artemia* Testing Standard (ATS) was applied. This benchmark test uses the brine shrimp, *Artemia salina,* as indicator organism. The ATS involves 4 different development stages of the brine shrimp: adults, larvae, nauplius-stages, pre-incubated eggs and cysts. The results of the benchmark tests are summarized in Table 1.

Table 1: Results of Peraclean® Ocean on different development stages of the brine shrimp, *Artemia salina;* Values in brackets represent the highest mortality reached at the end of the experiment.

Testorganism Brine shrimp, *Artemia salina*	**Parameter observed**	**Concentration of Peraclean® Ocean (ppm)**	**Max. Hatching Rate after 72 hrs**	**Time (hrs.) needed to reach 100% mortality**
Cycts[1]	Hatching rate Survival of hatched Nauplii	350 700 1 400	3% 0% 0%	
Pre-incubated Eggs[2]	Hatching rate Survival of hatched Nauplii	350 700 1 400	9% 0% 0%	
Nauplii	Mortality	350 700 1 400		(97%; 72 h) 36 8
Adults	Mortality	350 700 1 400		(38%; 72 h) 12 8

1 = untreated control group: 52 +/- 8,4 %
2 = untreated control group: 47,4 +/- 2,2 %.

The ATS data showed that the addition of Peraclean® Ocean at levels of above 350 ppm resulted in 100 % mortality of all *Artemia* live stages. The pH of the treated seawater is slightly reduced from pH 8.2 to 6.1, due to the acidic properties of Peraclean® Ocean.

After the initial tests, further experiments were carried out with a number of indicator organisms. The experimental designs applied included different salinities and temperatures. In each case, the experimental conditions represented optimum environmental conditions for the test species.

Experiments with nauplii of the brine shrimp, *Artemia salina*, indicated, that only 400 ppm Peraclean® Ocean are required to reach 100% mortality under varying environmental conditions (Tab. 2).

Table 2: Experiments with Peraclean® Ocean in different water qualities. Testorganism: nauplii of brine shrimp (*Artemia salina*). Values represent average of 3 parallel experiments. Note: Observations were made after 1, 2, 4, 8, 12, 24, 36, 48 and 72 hours.

Testorganism Brine shrimp, *Artemia salina*	**Water Quality**	**Parameter observed**	**Concentration of Peraclean® Ocean (ppm)**	**Time (hrs.) needed to reach 100% mortality**
(Nauplii)	Salinity 13.5ppt Temp. 24°C	Mortality	400 800 1 200	16 8 4
(Nauplii)	Salinity 13.5ppt Temp. 32°C	Mortality	400 800 1 200	11 4 4
(Nauplii)	Salinity 31ppt Temp. 24°C	Mortality	400 800 1 200	36 19 5
(Nauplii)	Salinity 31ppt Temp. 32°C	Mortality	400 800 1 200	24 7 4

ppt= parts per thousand

Experiments with fertilized eggs of Atlantic herring (*Clupea harengus*) followed. The eggs were pre-incubated in clean water for one week to assure an undisturbed start of the larval development. In this case too, 400 ppm were sufficient to reach 100% mortality of the embryos. Concentrations as low as 200 ppm also resulted in high mortalities above 98%, with the lowest killing rate (98.3%) being observed under marine conditions (salinity = 31 ppt) and temperatures of 12°C (Tab. 3).

Organisms of the zooplankton showed even higher sensitivities. The dosing of only 400 ppm Peraclean® Ocean resulted nearly instantly in 100% mortality of the test organisms. After a maximum of 2 hours exposure time, all of the organisms were dead (see Tab. 4).

Experiments with phytoplankton cultures (indicator organism: *Chlorella* sp.) showed similar results: even 200 ppm Peraclean® Ocean killed the algae within 48 hours (See Tab. 5). However, higher concentrations of Peraclean® Ocean (concentration range from 400 ppm to 1600 ppm) did not result in significantly faster eradication of the algae.

Table 3: Experiments with Peraclean® Ocean in different water qualities. Testorganism: pre-incubated eggs of Atlantic Herring (*Clupea harengus*). Values represent average of 3 parallel experiments. Note: Observations were made after 1, 2, 4, 8, 12, 24, 36, 48 and 72 hours. Values in brackets represent the highest mortality reached at the end of the experiment.

Test organism Fertilized eggs of Atlantic Herring	**Water Quality**	**Parameter observed**	**Concentration of Peraclean® Ocean (ppm)**	**Time (hrs.) needed to reach 100% Mortality**
	Salinity 13.5ppt Temp. 5°C	Mortality of embryo	200	16
			400	8
			800	2
	Salinity 13.5ppt Temp. 12°C	Mortality of embryo	200	15
			400	3
			800	1
	Salinity 31ppt Temp. 5°C	Mortality of embryo	200	12
			400	4
			800	1
	Salinity 31ppt Temp. 12°C	Mortality of embryo	200	(98.3%; 72 h)
			400	1
			800	1

Table 4: Experiments with Peraclean® Ocean with plankton organisms. Testorganisms: crustaceans from freshwater and brackish water communities. Values represent average of 3 parallel experiments.

Testorganism	Water Quality	Parameter observed	Concentration of Peraclean® Ocean (ppm)	Time (hrs.) needed to reach 100% mortality
Freshwater Plankton (Cultures) *Cyclops* sp. (Copepod)	Freshwater, room temperature	Mortality	200	2
			400	1
			800	1
Bosmina sp. (Cladocera)	Freshwater, room Temperature	Mortality	200	1
			400	1
			800	1
Daphnia sp. (Cladocera)	Freshwater, room Temperature	Mortality	200	-
			400	2
			800	2
In situ Plankton Baltic Sea (wild catch) Copepods (30% of taxa)	Brackish water, about 13 ppt Sal. room temperature	Mortality	400	< 1
			800	< 1
Nauplii (66% of taxa)		Mortality	400	< 1
			800	< 1
Cladocera (4% of taxa)		Mortality	400	1
			800	< 1

6

Table 5: Experiments with algae. Testorganism: *Chlorella* sp.. Parameter: photometric measurement of extinction at 3 different wave lengths: 750 nm, 663 nm and 645 nm. The following results represent the average of three parallel experiments each.

Testorganism	**Water quality**	**Parameter observed**	**Concentration of Peraclean® Ocean (ppm)**	**Time needed to reach 100% mortality**
Chlorella sp.	Salinity: 31 ppt room temperature	Chlorophyll a and b	200	48
			400	48
			800	48
			1 200	48
			1 600	48

Efficacy tests – ship board trial

A ship board trial was organized from Maritime Solutions Inc. at the harbour of Baltimore, USA. On the vessel "CAPE MAY", a ship with roughly 30,000 dwt and 10,000 tons ballast water capacity. A field trial was done during summer 2001.

50 – 400 ppm of Peraclean® Ocean without any pre-separation of organisms or solids was dosed into ballast water (water out of the harbour of Baltimore) that went into the ship`s ballast tanks and into plastic containers.
Peraclean® Ocean effectively killed:

- Copepod Adults, Copepod Nauplii and Nematodes at 50 ppm Peraclean® Ocean concentration
- Polychaetes, Bivalves, Rotifiers and Nematodes at 100 ppm Peraclean® Ocean concentration
- Ostracods and Protozoans at 200 ppm Peraclean® Ocean concentration.

See: Table 6.

Table 6: Ship board trials: treatment with Peraclean® Ocean, without any pre-separation of species or solids

Testorganism	Mortality of untreated control group[a)] [%]	Mortality [%] of treated groups in different tanks		Applied Concentration of Peraclean® Ocean [ppm]	Exposure Time [hours]	100 % kill.
		Plastic tank (Mesocosm tank)	Ship's Ballast Tank			
Copepod Adults	3-42	**100**	98	**50**	24	
	6-40	**100**	**100**	**50**	48	**X**
Copepod Nauplii	3-68	**100**	**100**	**50**	24	**X**
Polychaetes	0-3	**100**	20	**50**	24	
	0-3	**100**	25	**50**	48	
		100	**100**	**100**	24	**X**
Bivalves	7-42	**100**	0-100	**50**	24	
	15-26	**100**	50	**50**	48	
		100	**100**	**100**	24	**X**
Rotifiers	0-100	**100**	**100**	**50**	24	
	18-71	**100**	89	**50**	48	
		100	**100**	**100**	24	**X**
Nematodes	0-NF[a)]	NF[a)]	**0**	**50**	24	
	0-NF	NF	NF[a)]	**50**	48	
		NF	**100**	**100**	24	**X**
		NF	NF	**100**	48	
Ostracods	0-12	NF	**0**	**50**	24	
		NF	0-50	**50**	48	
	0-11	0		**100**	24	
		NF		**100**	48	
		100	90	**200**	24	
		NF	**100**	**200**	48	**X**
		100	**100**	**400**	24	**X**
Protozoans	40-84	**100**	**100**	**50**	24	
	70-95	**100**	40	**50**	48	
		100	99	**100**	24	
		100	94	**100**	48	
		NF	**100**	**200**	24	**X**
		NF	**100**	**200**	48	**X**

a) values of different control groups; highest and lowest numbers are given.
b) NF = not found.

Conclusions

The results of all the experiments clearly indicate that Peraclean® Ocean is an effective biocide for the treatment of ship`s ballast water. 100% mortality of different test organisms from different trophic levels were found at Peraclean® Ocean concentrations between 50 ppm and 400 ppm.
The short half-life of Peraclean® Ocean in seawater assures that even the discharge of great quantities of ballast water in sheltered areas with limited water exchange (e.g. harbours and bays) would not have a negative impact on the environment. Furthermore, the physical properties of Peraclean® Ocean (easy storage and long shelf-life) favour it for both, on board and land based ballast water treatments as a stand-alone method, or in combination with filtration and/or gravity separation.

A lower dosage of Peraclean® Ocean could be sufficient if a separation of solids and bigger organisms takes place before Peraclean® Ocean is applied.

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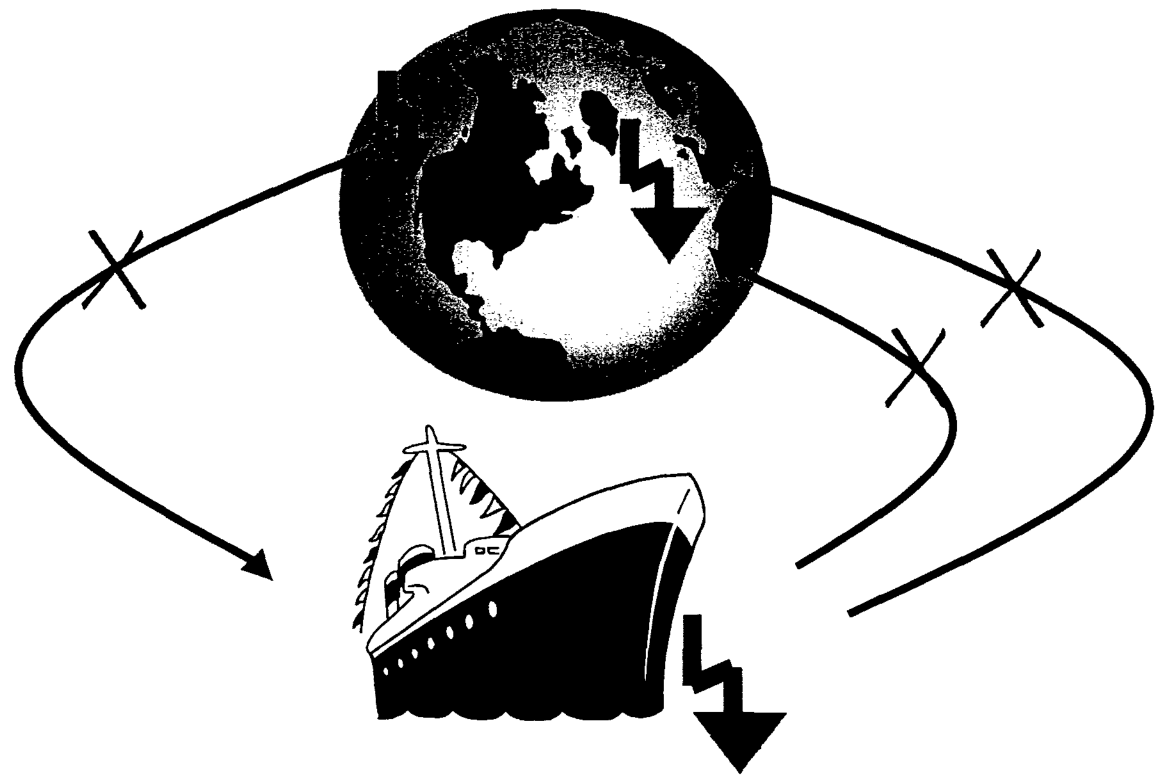
Peraclean® Ocean - A Promising Ballast Water Treatment Option

Global Transfer of Ballast Water



Approximately 3-12 billion tons of ballast water are transported every year

Peraclean® Ocean

- Acts as Oxidiser
- Degradation products are readily biodegradable
- Is not persistant and does not accumulate: No toxic residues

Peraclean® Ocean

Kills:

- bacteria
- yeasts
- viruses
- molds
- spores
- algae
- protozoa

- Higher organisms in ballast water, e.g.
  - zooplankton
  - phythoplankton
  - larval stages
  - fish eggs

Peraclean® Ocean

Is active at:

high concentrations of sediment and / or organic matter

pH 5 - 9

-5°C to more than 40°C

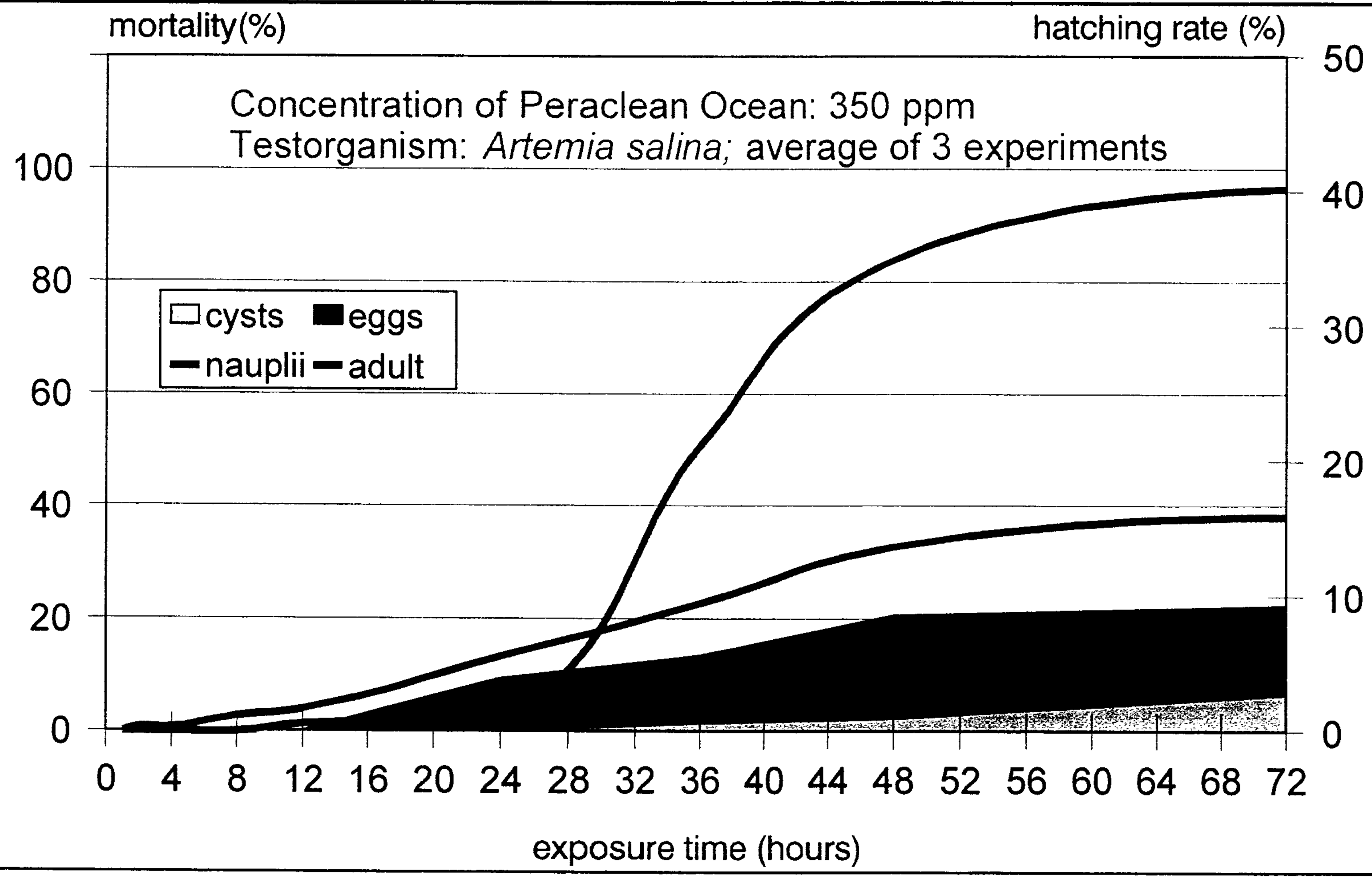
Peraclean® Ocean

- Short half-life after application to ballast water (hours to days), depending on water salinity, pH and temperature
- Degradation products are readily biodegradable
- Applicable to marine, brackish & freshwater

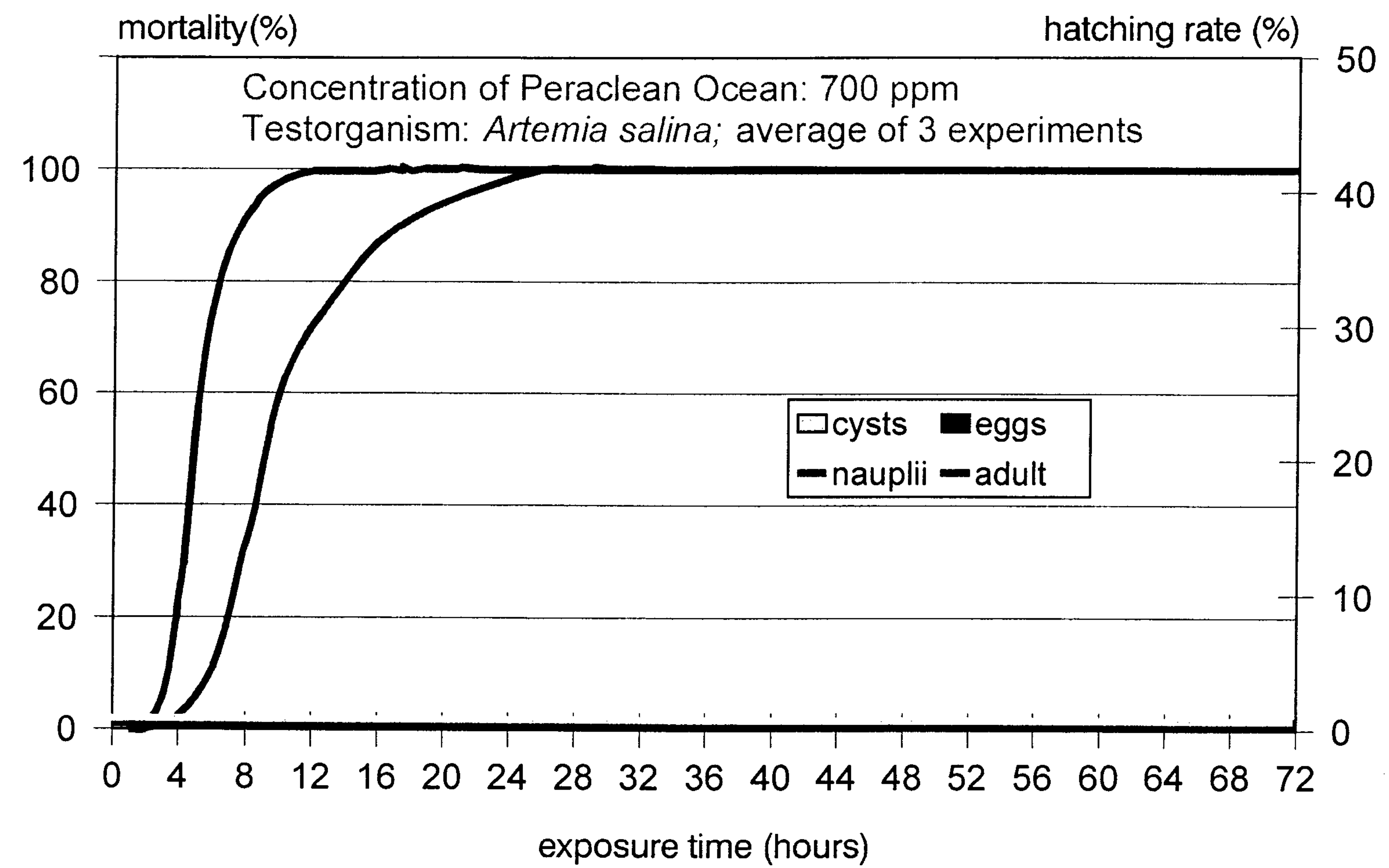
Characteristics of Peraclean® Ocean

- **Liquid**
- **Easy to apply (e.g. injection during ballast water intake)**
- **Can be delivered in: 220 kg-drums, 1.1t-IBCs,**
  20 tons-ISO-containers
- **Proprietary formulation based on peroxygen chemistry**
- **Long shelf-life of the pure formulation:**
  still >95% activity after one year storage at 20°C

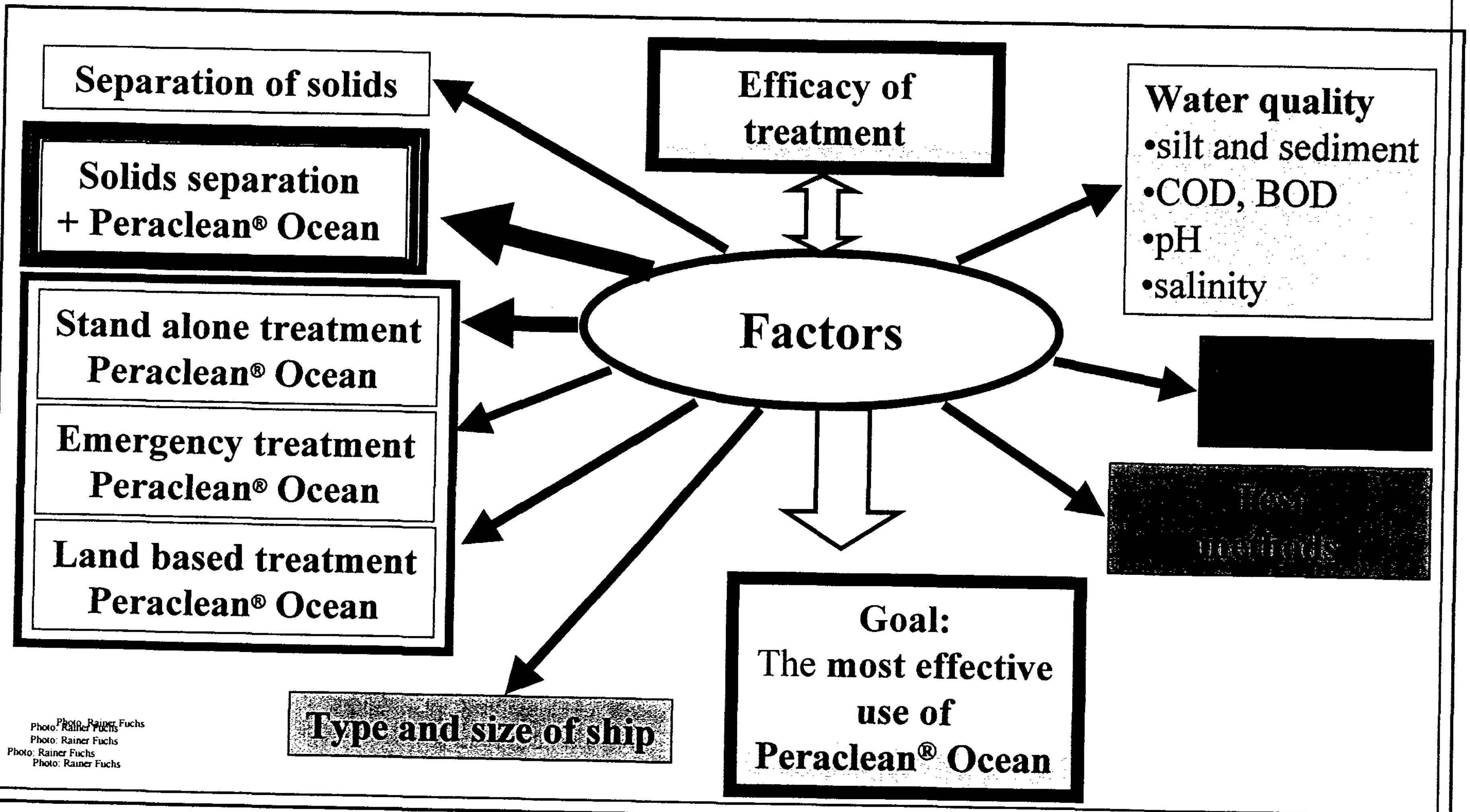
Early Laboratory Tests, Stand Alone Treatment: ATS-Test with 350 ppm Peraclean® Ocean



Early Laboratory Tests, Stand Alone Treatment: ATS-Test with 700 ppm Peraclean® Ocean



Practical Tests with Peraclean® Ocean

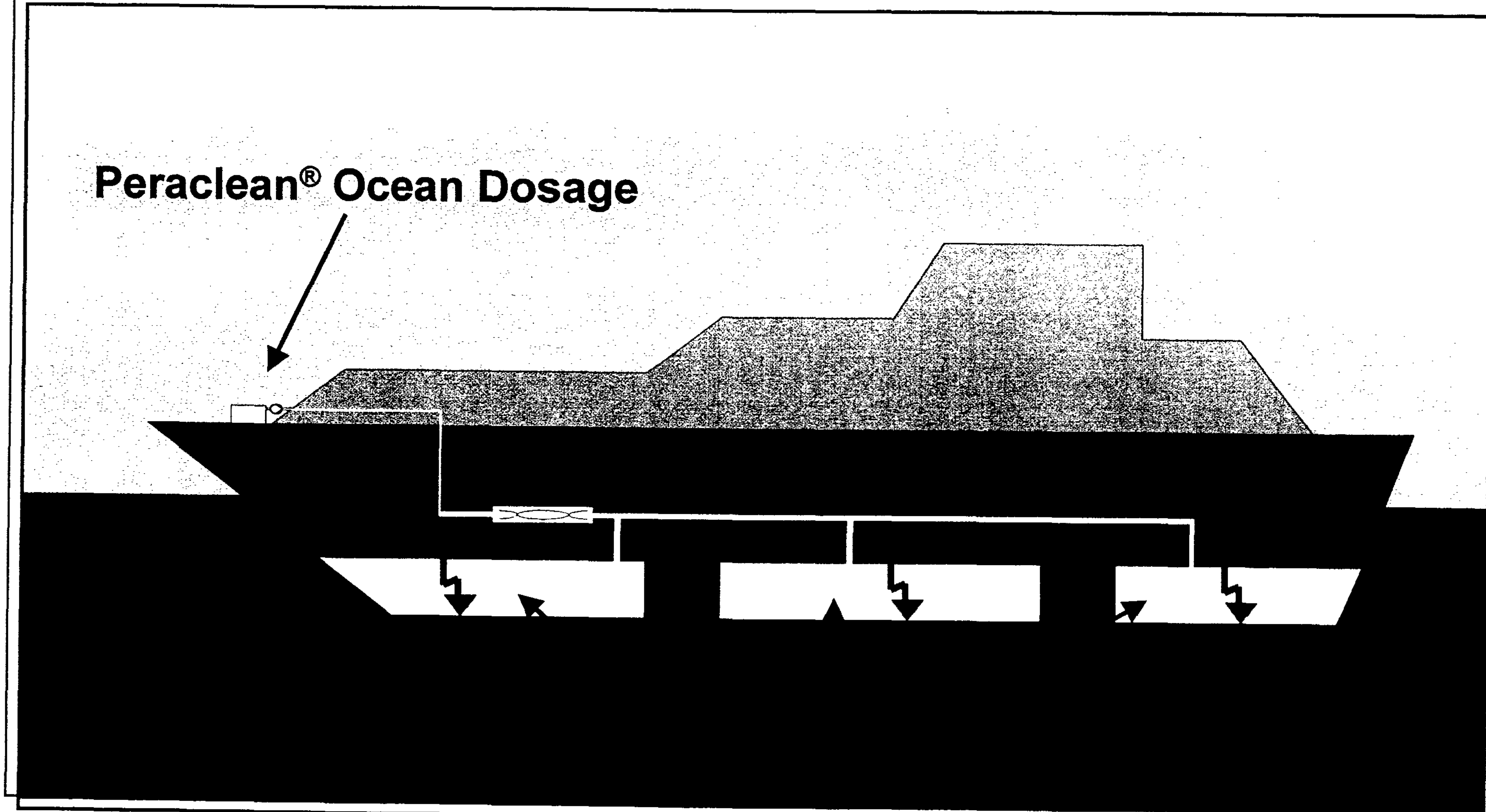


IMO: Separation + Biocidal Treatment: a Future?

"It now seems likely
that any new ballast water treatment system
will involve a combination of technologies,
for example
primary filtration or physical separation
followed
by a secondary biocidal treatment"

IMO NEWS, 2, 2001

Scheme of the Ballast Water Treatment



Field Trial with Peraclean® Ocean: USA

Organization of experimental setup: **Maritime Solutions Inc.**

June, July 2001:
dosage of 50-400 ppm
Peraclean® Ocean

→ necessary dosage for effective killing: 100-400 ppm Peraclean® Ocean (stand alone)

Summer 2003:
dosage
with separation

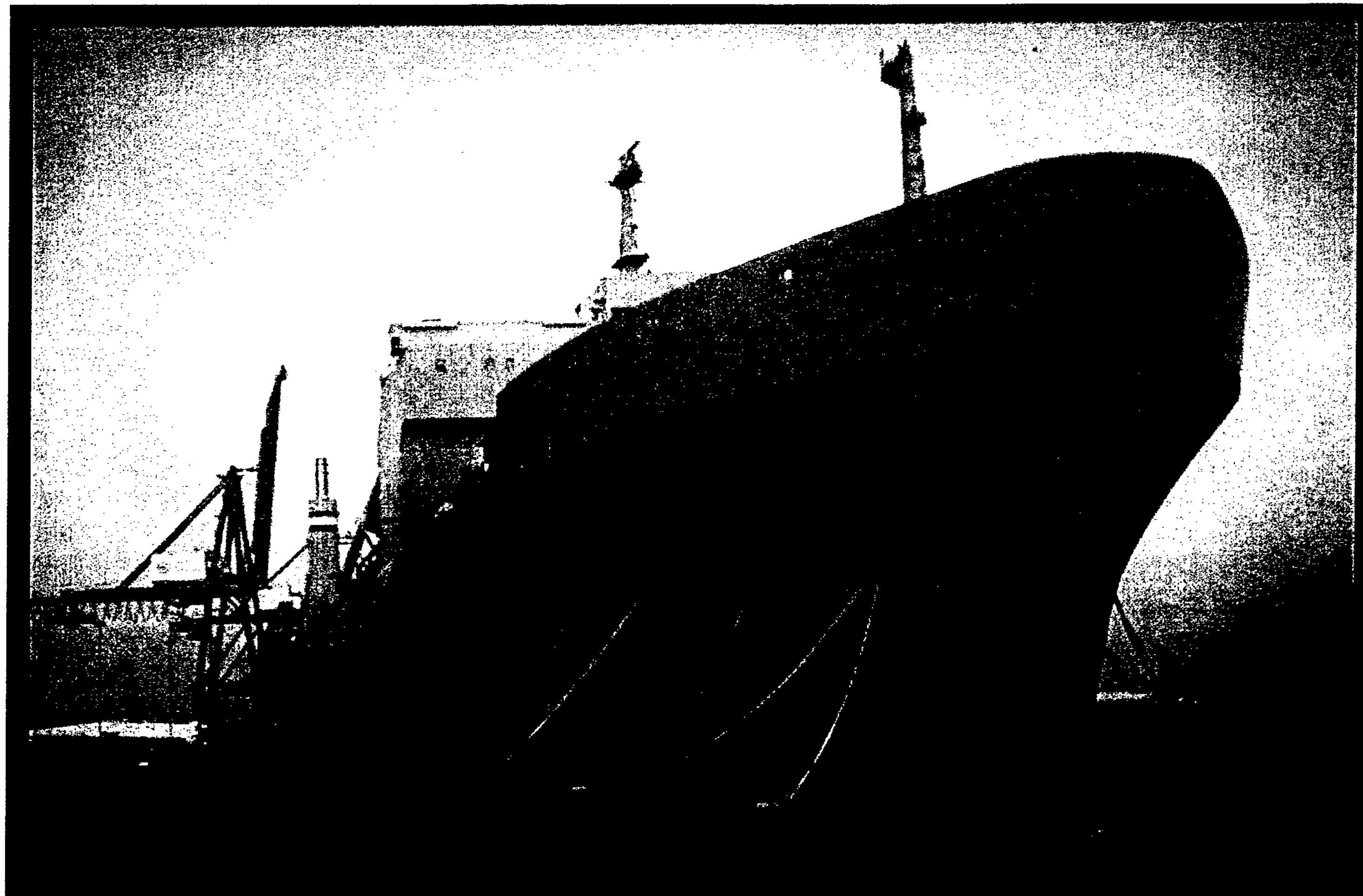
→ Lower dosage needed for effective killing?

Field Trial with Peraclean® Ocean: USA;

Species	Mortality [%] of Species at different Peraclean® Ocean dosage rates in CAPE MAY ballast tank			
	50 ppm	100 ppm	200 ppm	Mortality of different control groups [%]
Copepod Adults	100 (48 hours)			6-40
Copepod Nauplii	100			3-68
Polychaetes		100		0-3
Bivalves		100		15-26
Rotifiers		100		18-71
Nematodes		100		0
Ostracods			100 (48 hours)	0-11
Protozoans			100	70-95

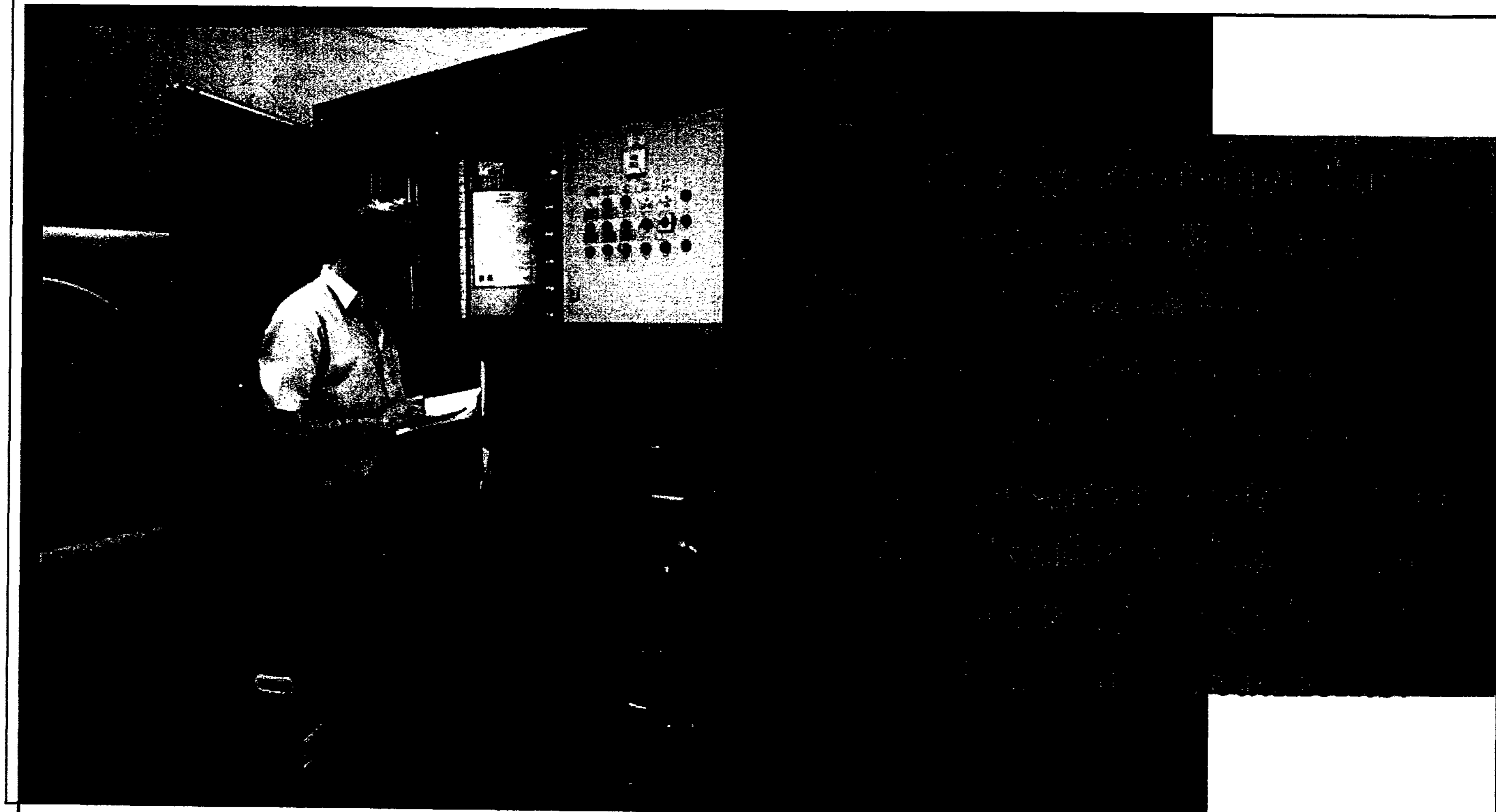
Exposure time: 24 hours; unless not otherwise noted

The Vessel „CAPE MAY“ in the Port of Baltimore

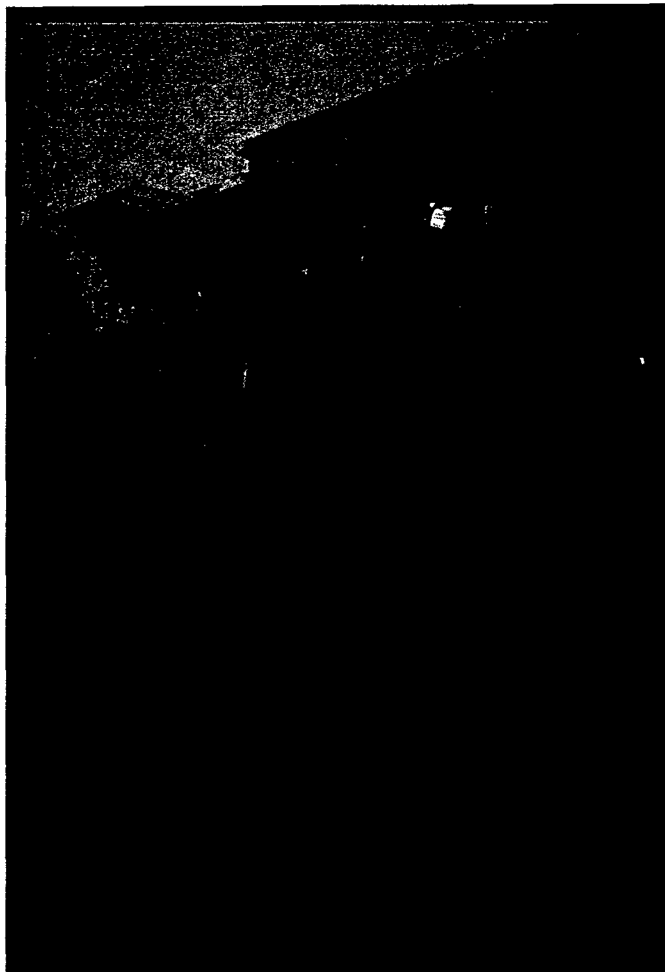


- 10.000 t Ballast-water
- 30.000 t dead weight (DWT)

Peraclean® Ocean Dosage onboard of „CAPE MAY“



Peraclean® Ocean dosage onboard „CAPE MAY“



Impressive:
Dosage of 2 t Peraclean® Ocean enables a complete treatment of the ship's ballast water (10.000 t).

Thin:
1 cm internal diameter of the dosage line is in this case enough for a proper treatment

Field trial with Peraclean® Ocean: Germany

Organization of experimental setup:

Hamann Wassertechnik, Hamburg

August - October 2001:
Dosage of 50 - 500 ppm Peraclean® Ocean

→ Efficacy of Peraclean® Ocean in brackish- and sea water

→ Effective killing achieved with less than 200 ppm Peraclean® Ocean

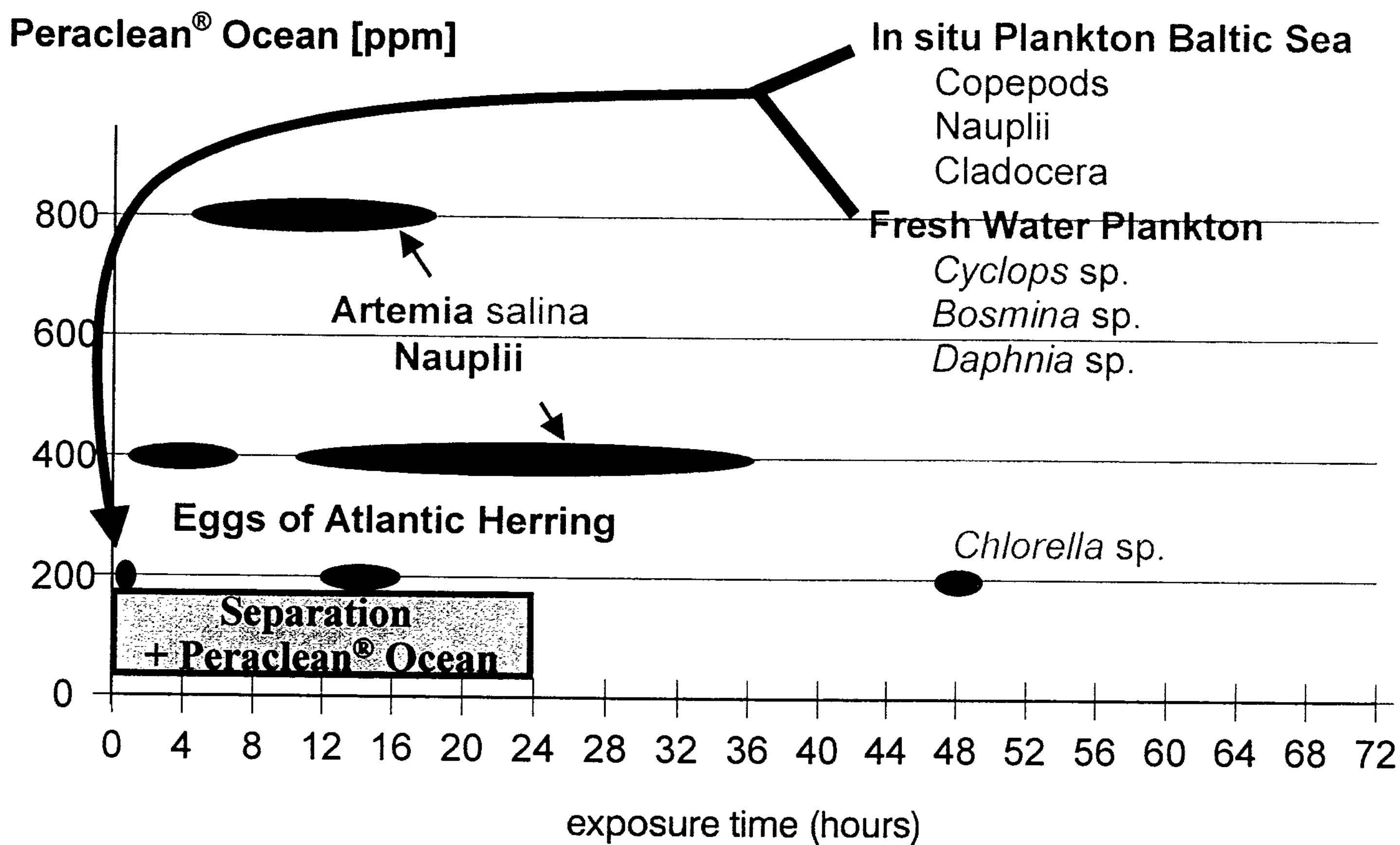
→ **Less Peraclean® Ocean necessary with separation of solids**

Field trial: Dosage of Peraclean® Ocean at Hamburg; Hamann Wassertechnik

←

Flow of treated brackish water: 135 m³/h

Two Possibilities: Peraclean® Ocean alone or Separation of Solids + Peraclean® Ocean

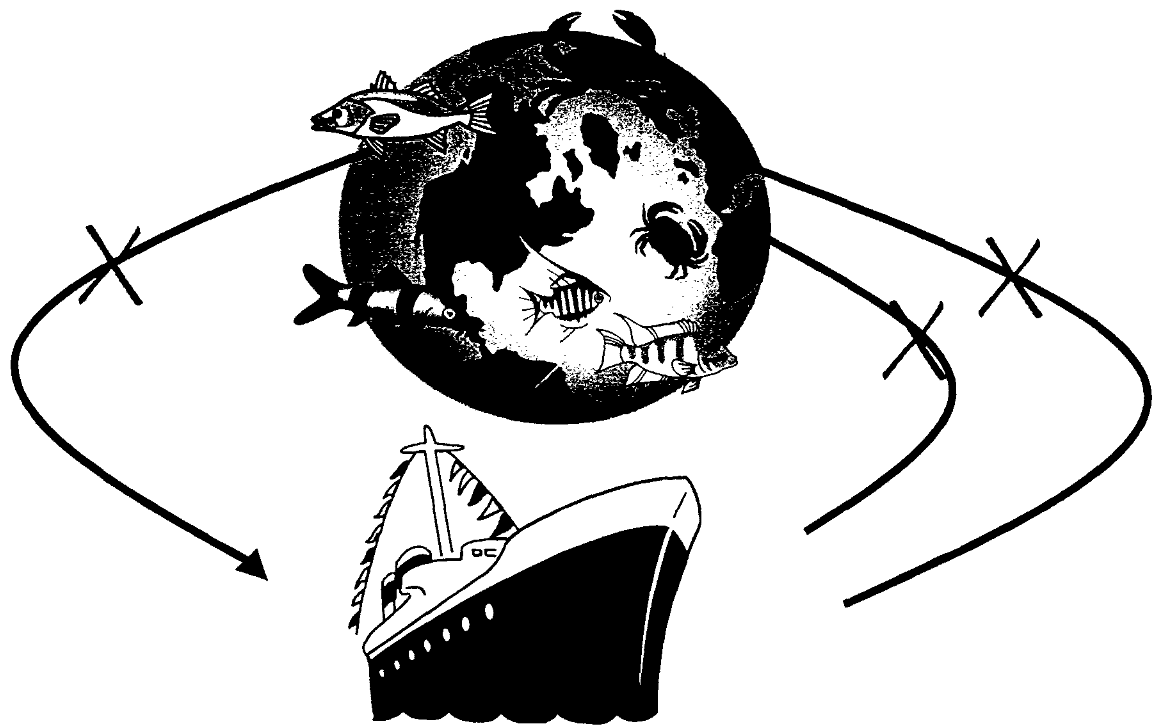


Acknowledgements

We gratefully thank
the following institutions and colleagues for their support:

- Ministry for Research and Technology of Germany (BMBF)
- Maritime Solutions Inc., USA
- Hamann Wassertechnik, Germany
- Dr. Stephan Gollasch, Germany
- Prof. Dr. H. Rosenthal (Institute for Marine Research), Germany
- Dr. Matthias Voigt, Germany

Peraclean® Ocean -



a viable alternative for ballast water treatment.

Contact Adress „Ballast Water Treatment“

degussa.

Bleaching & Water Chemicals

Dr. Rainer Fuchs

Senior Manager
Environment Chemistry
Peroxygen Chemicals

Degussa AG
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D-63457 Hanau-Wolfgang

Phone +49-6181-59-3892
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@degussa.com

OptiMarin AS

OptiMar Ballast System

Combining technologies

Bremerhaven

June 11th 2003

Author: Birgir Nilsen
OptiMarin AS

History

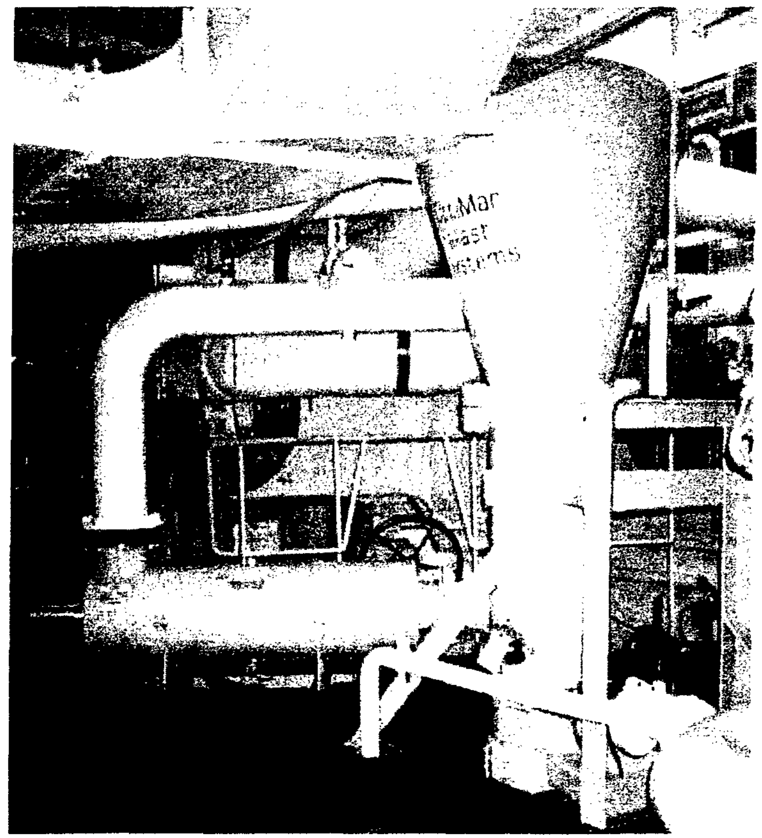
- The idea for the OptiMar Ballast Systems was first conceived, after an inquiry from the Norwegian Department of Shipping in 1995.
- The concept of OptiMar Ballast Systems was developed and presented to the Department of Shipping in May 1997.

Objective

The objective in developing the OptiMar Ballast system was to be able to offer an cost effective and practical solution for the treatment of ballast water on ships and also to be able to retrofit to existing seagoing vessels and to participate in new buildings.

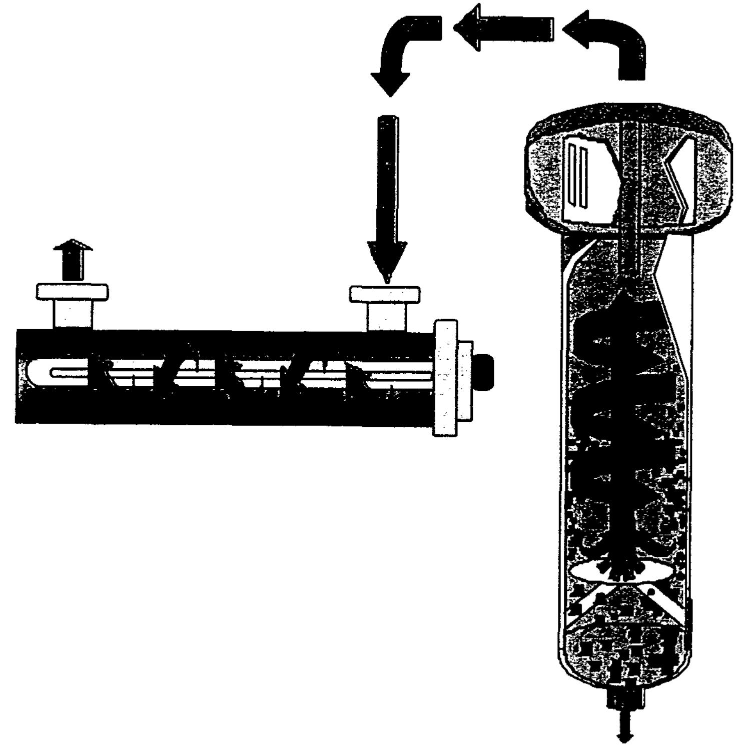
OptiMar Ballast System

- MicroKill Separator
- MicroKill UV



OptiMar Ballast System

- Ballast inn
  - MicroKill Separator and/or Filter removes particles
  - MicroKill UV kills or inactivates life forms
- Ballast out
  - MicroKill UV 2nd treatment kills remaining live organisms

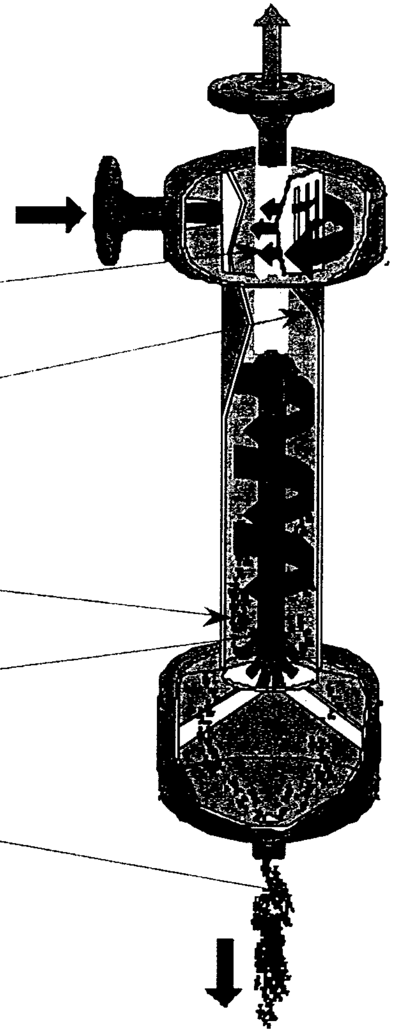


OptiMar Ballast Systems Capacities

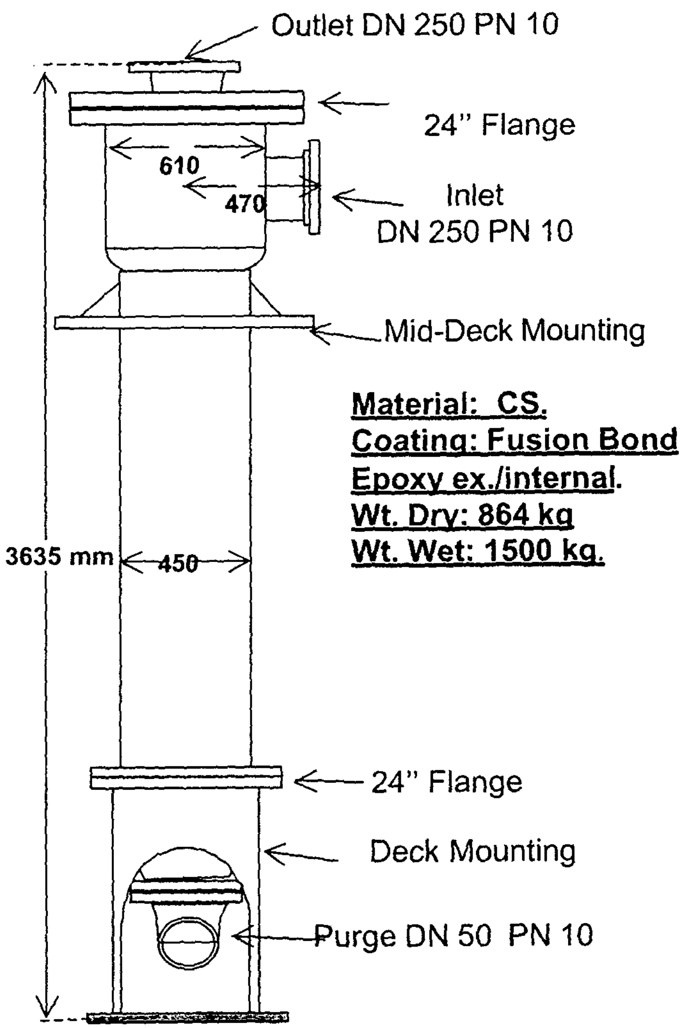
- MicroKill Separator
  - Capacity: 1 - 3000 m3/h
  - Materials: CS Scotch Coated
- MicroKill UV
  - Capacity: 10 - 3000 m3/h
  - UV Dose: 200 mWs/cm2 @ 250m3/h
  - Materials: CuNi
  - Power: 15 kW

MicroKill Separator

1. Liquid/solids enter tangentially and sets up a circular flow
2. Liquid/solids are drawn through tangial slots and accelated into the separation chamber
3. Centrifugal action spiral the particles to the perimeter of the separation chamber.
4. Solids gently drop along perimeter and into the calm collection chamber
5. Solids-free liquid is drawn towards the separator's vortex and up through the outlet
6. Solids are continuously or periodically bled, as necessary, from the collection chamber

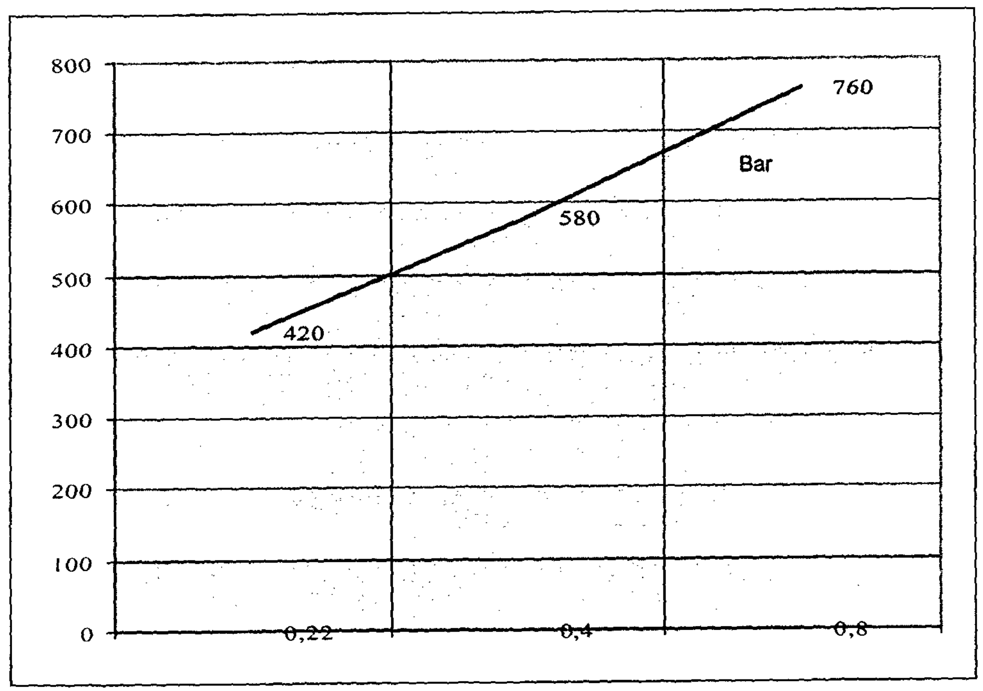


MicroKill Sep HRN Mod: 500

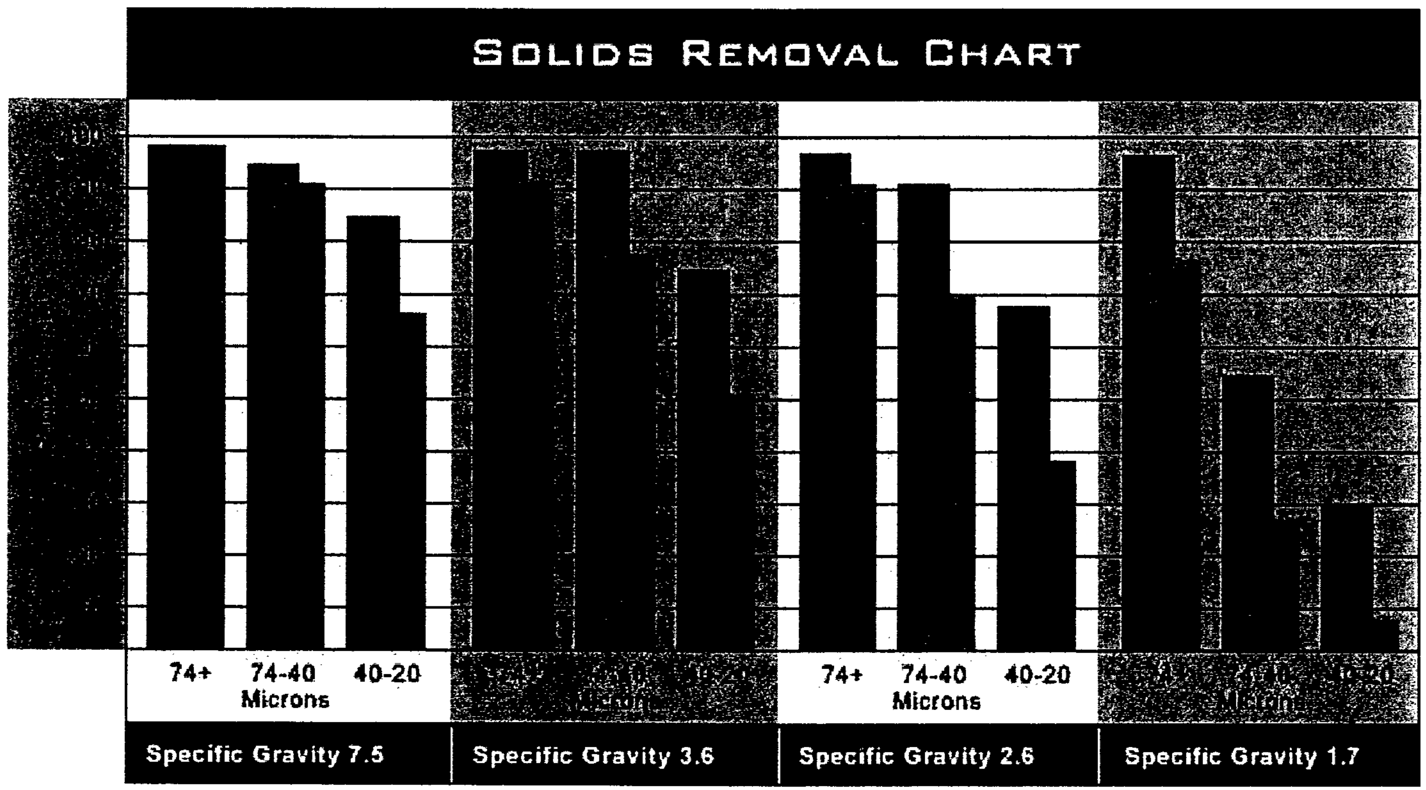


Material: CS.
Coating: Fusion Bond Epoxy ex./internal.
Wt. Dry: 864 kg
Wt. Wet: 1500 kg.

Flow range 420-775 m3/h

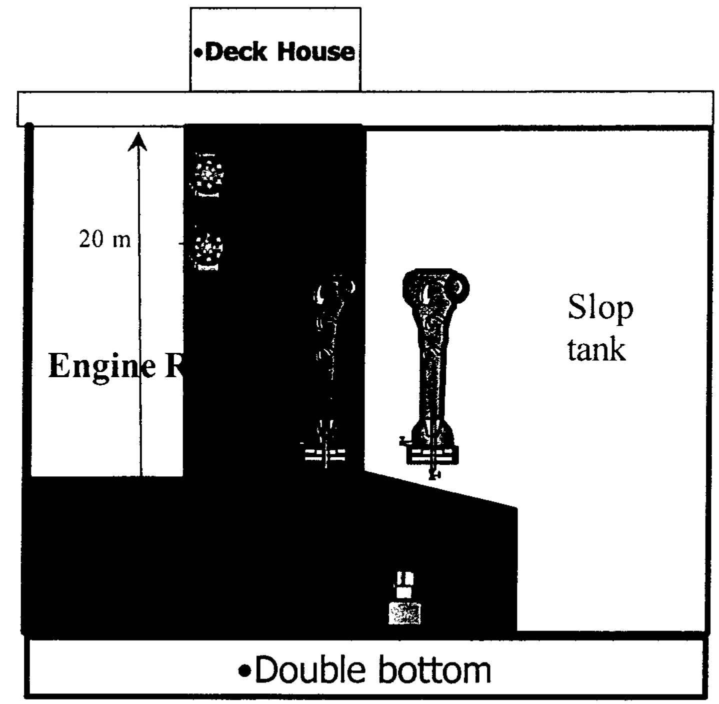


Separator Removal

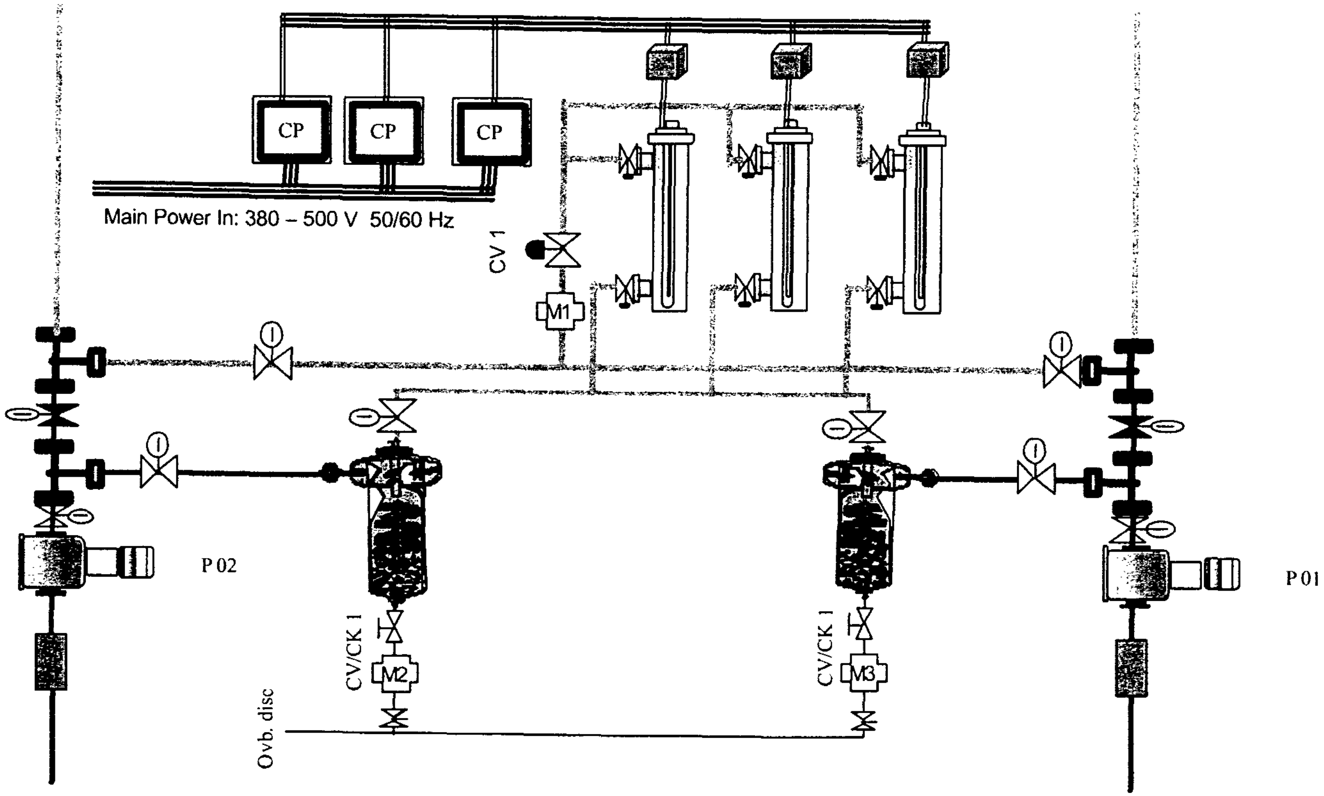


Installation

- Where to install
  - In pump room shaft
  - In pump room if space
  - In engine room
  - Void spaces
- How to install
  - In a by-pass line after ballast pumps



OptiMar Ballast System Flow Diagram

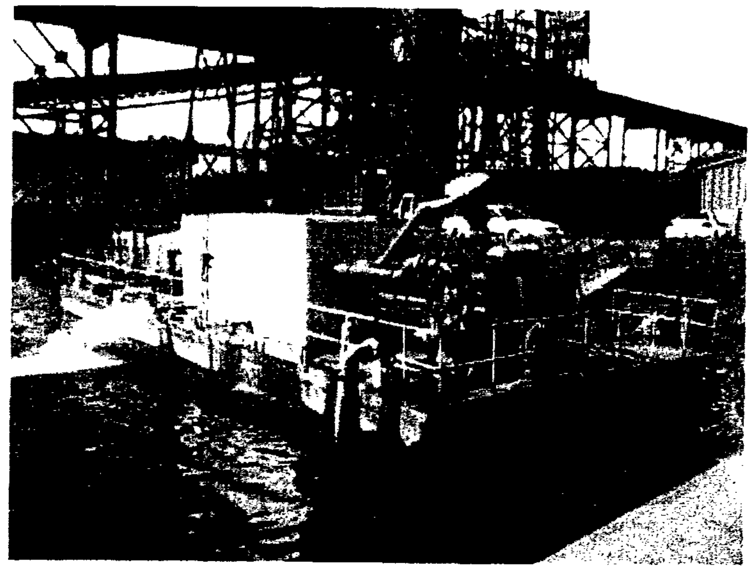


Advantages OptiMar System

- Reduce sediments in ballast tanks
- Simplicity, no moving parts
- Minimal impact on existing ballast system
- Modular installation
- Low cost of operation
- Reduce emissions compared with Ballast Water Exchange

Test projects

- 1998 and 1999 Institute of Marine Research, Norway
  - Anders Jelmert
- 1999 Vancouver, Canada
  - Terry Sutherland
- 2000 GLBDP, USA
  - Allegra Cangelosi
- 2000 Princess Cruises, USA
  - Allegra Cangelosi
- 2001 GLBDP, USA
  - Allegra Cangelosi
- 2002 California State
  - Sea Princess



Awards

OptiMarin received a certificate for countering marine pollution at the SeaTrade Award 2001

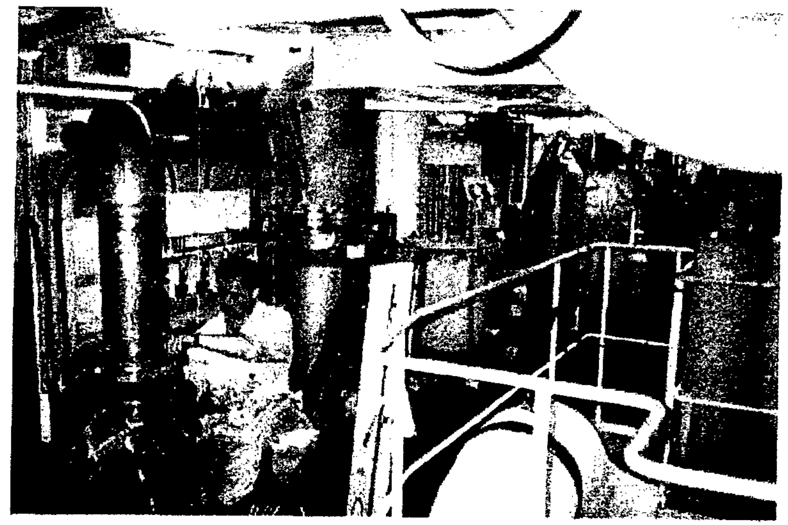
Seatrade
AWARDS
2001

Princess Installations

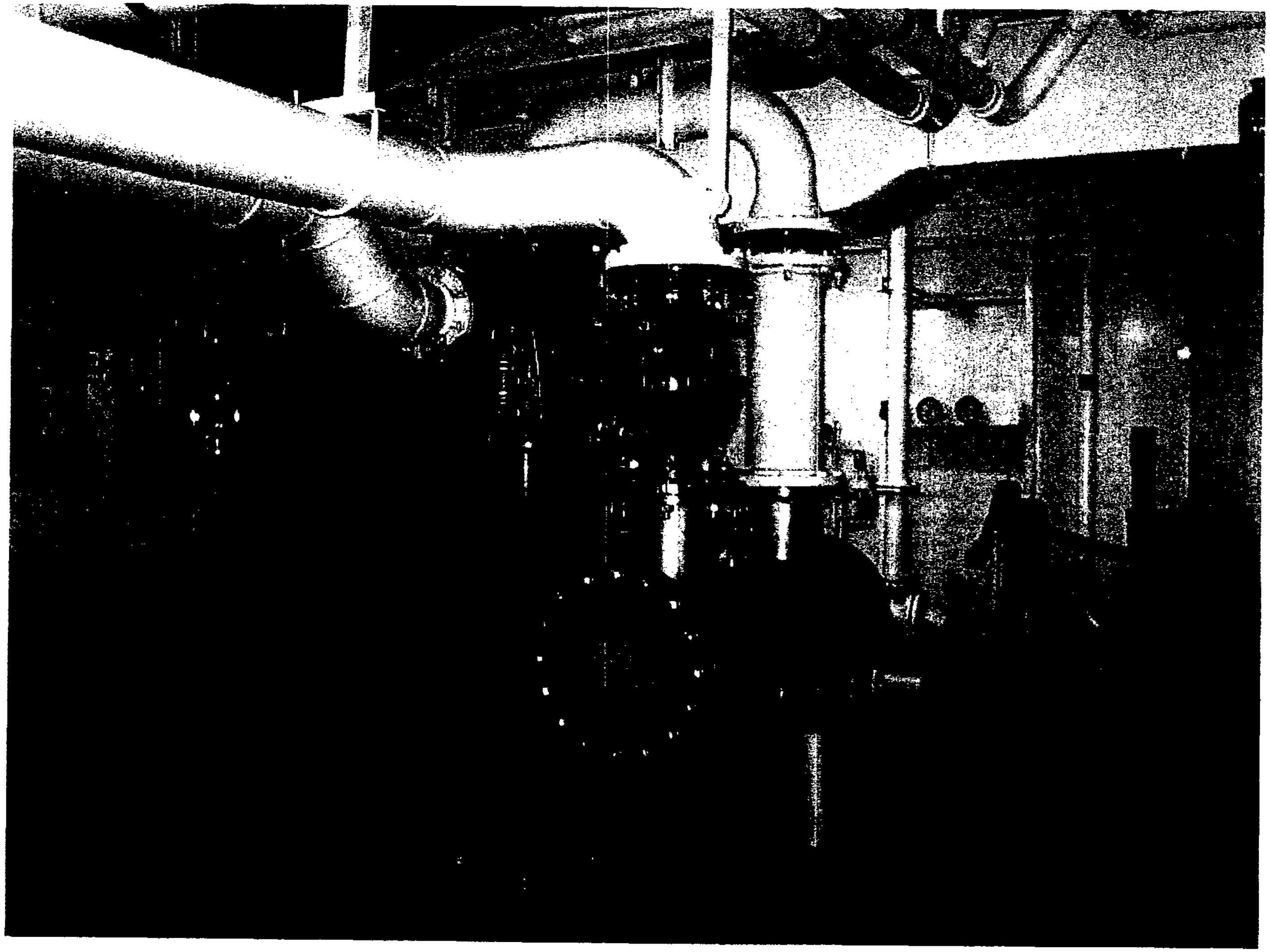
- **M/S Regal Princess**
  - Cruise/passenger vessel
  - Pump capacity: 200 m3/h
  - Testing by Allegra Cangelosi Northeast Midwest Institute
- **M/S Star Princess**
  - Cruise/passenger vessel
  - Pump capacity: 255 m3/h
- **M/S Sea Princess**
  - Cruise/passenger vessel
  - Pump capacity: 260 m3/h
  - Testing by Moss Landing Marine Laboratories under a contract with the California State Lands Commission September 2002. Results not yet available

M/S Regal Princess

- Installed under normal operating conditions
- 2 weeks, 150 hours
- Complete installation April 5, 2000
- Total installed cost $105,000
- Fully operational since installation

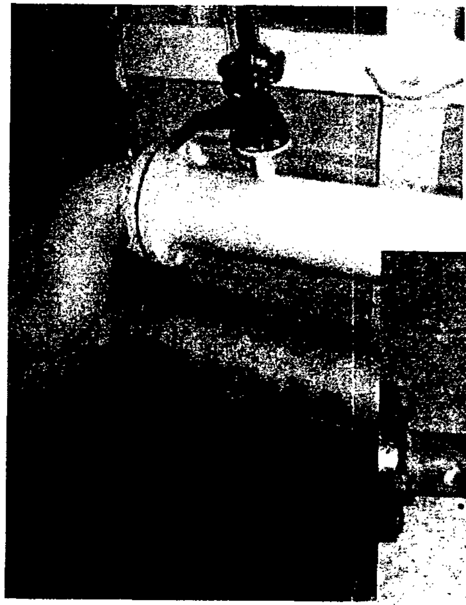


M/S Sea Princess

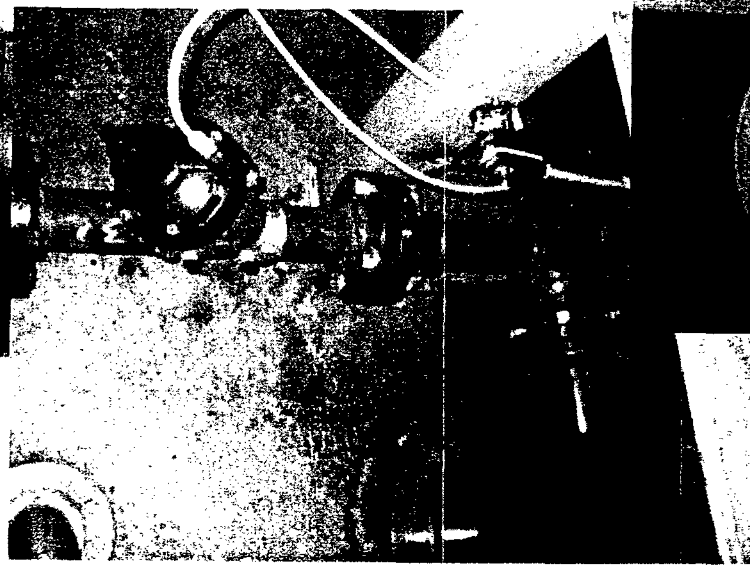


Details from installation

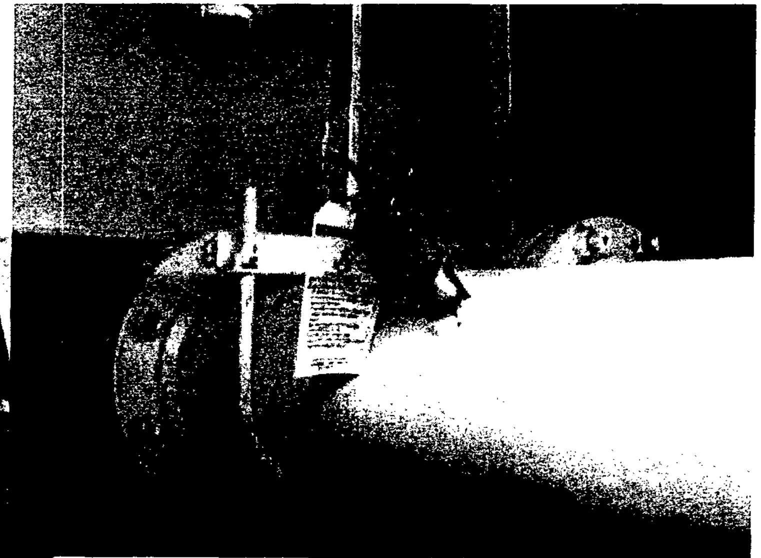
Sample Port



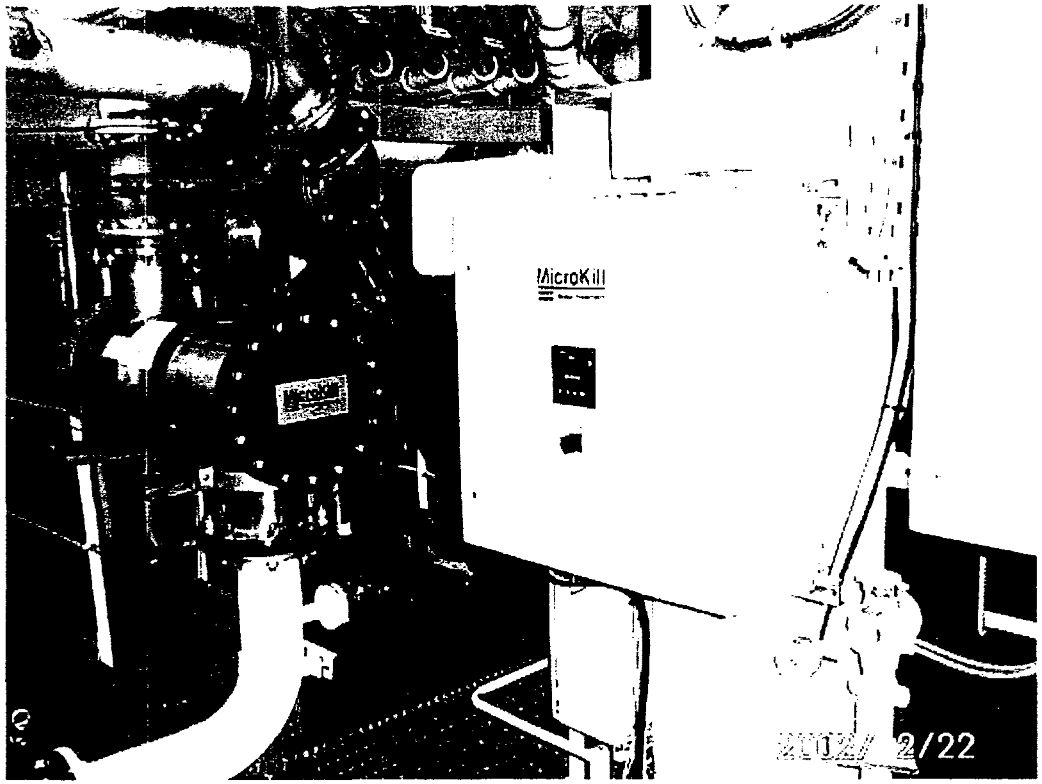
Drain valve



Flow Sensor



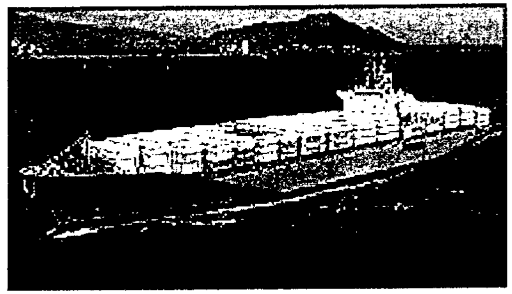
M/S Star Princess

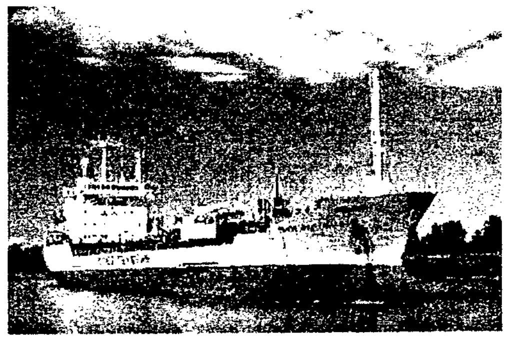


OptiMarin AS

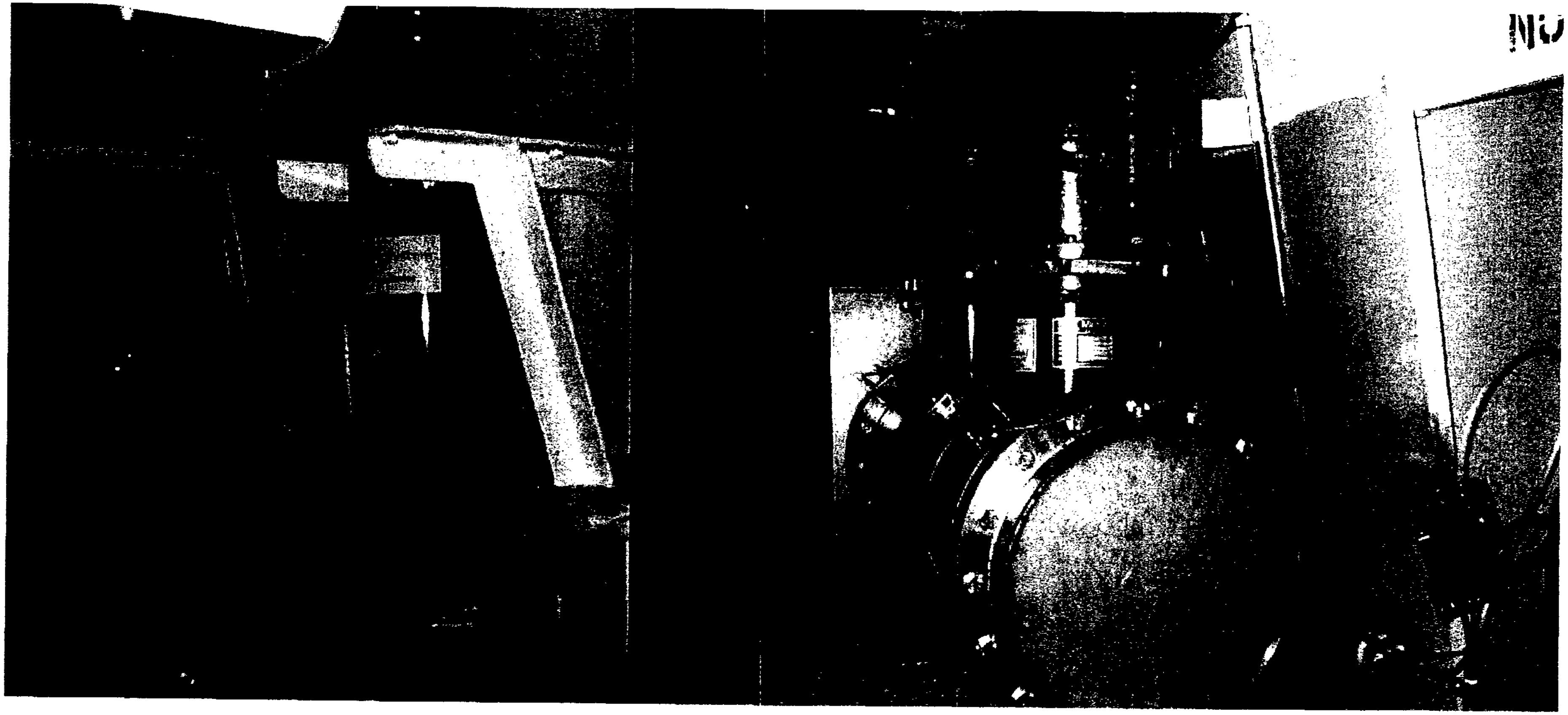
Other Installations

- Matson Navigation Company
  - MV R.J Pfeiffer
    - Container vessel
    - Ballast pump 2 x 350 m3/h
    - Testing by Moss Landing summer 2003
- Stolt-Nielsen Transportation
  - Stolt Aspiration
    - Product Tanker
    - Ballast Pump 2 x 250 m3/h
    - Explosion proof
    - Testing by Northeast Midwest Institute under a contract with the Great Lakes Environmental fund Summer 2003





Stolt Aspiration



New Builds

- Wagenborg Shipping B.V.
  - 2 Ro-Ro vessels
  - Long term charter
  - Paper transport for Kappa Kraftliner
  - Trade in the Baltic Area
  - Ballast system 1000 m3/h (2x500)
  - Comply with Clean Sea/Clean Air concept
  - Delivery from shipyard late 2003 and 2004

Challenges and considerations

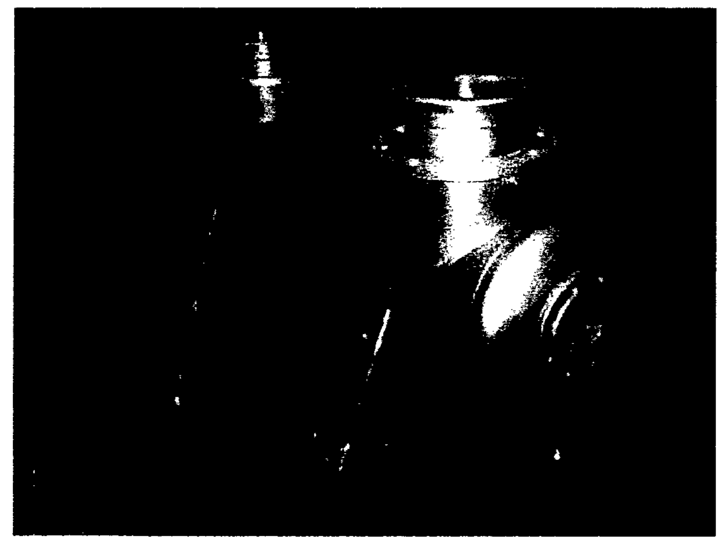
- Treatment level, what will be the regulation?
- Uniform test protocols for shipboard treatment
- Establish the dose required for treatment
  - IMO, Harbour Authorities, Water Analyses
- Establish the right UV transmission values
  - Harbour Authorities, water analyses
- Get independent data on treatment

OptiMarin R & D

- TREBAWA
  - Optimizing separation and UV
- MicroKill Separator
  - Increase separation minimizing the pressure drop to avoid increased ballasting time or problems topping up.
  - Project with University of Herefordshire and University of Amman for modelling of flow and Computational Fluid Dynamics within the MicroKill Sep.
  - New materials to avoid corrosion in separator.

OptiMarin R & D

- MicroKill UV
  - Using Medium pressure Multi UV lamp system
  - Power 15 kW UV-C per unit.
  - UV dose 200 mWs/cm2 @ 250 m3/h and 95% transmission, adding UV units for higher flows
  - Standardized CuNi reaction chamber
  - First installation 3 units 1000 m3/h new build
  - Reduced size and weight, control panel and transformer (320 kg to 80Kg)



UV Control and power supply

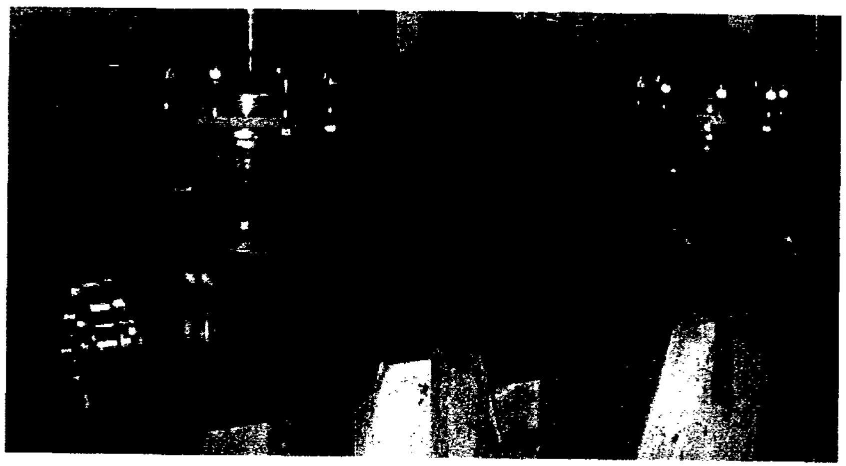
- Complies with the EMC-requirements with external filter
- Easy commissioning
- The ballast transformer can be carried by one man
- The Controller can be removed / replaced for service
- Installation in individual enclosures or all in one enclosure
  - All in one Size W800 x H1200 x D600mm
- Installation up to 30m from each other and the reactor
- I/O's for interfacing with PLC or Central Control System

MicroKill UV 15K

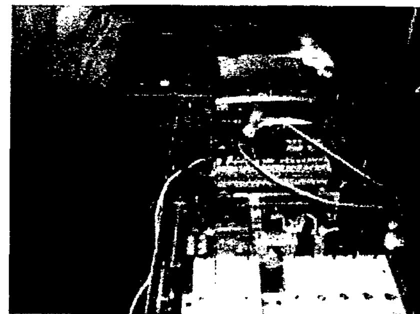
Components

Quartz glass installation

Reactor in CuNi

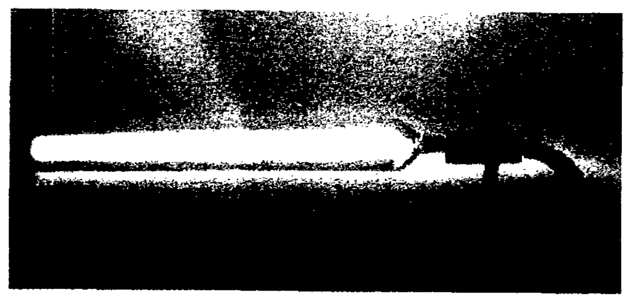


Control Unit



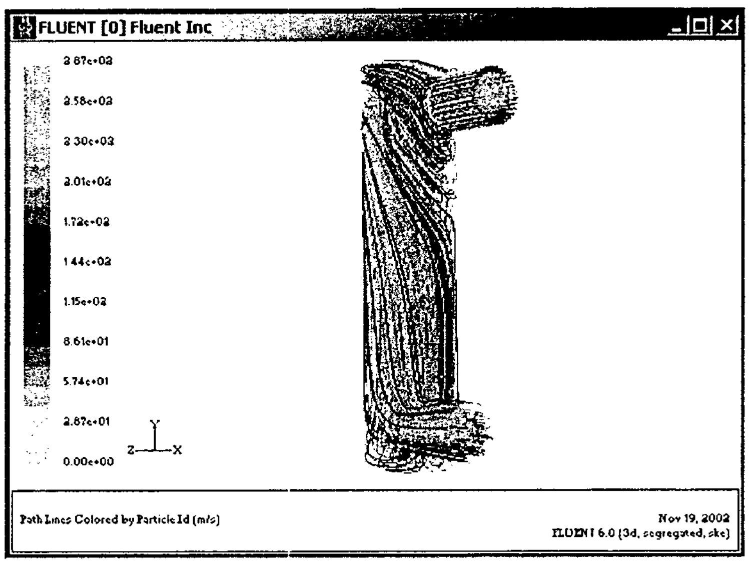
Transformer

UV Lamp

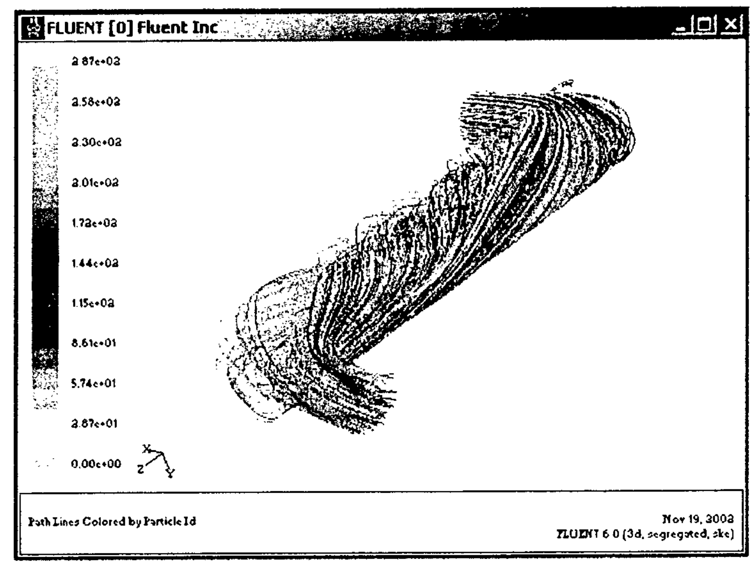


CFD Modelling

Vertical flow



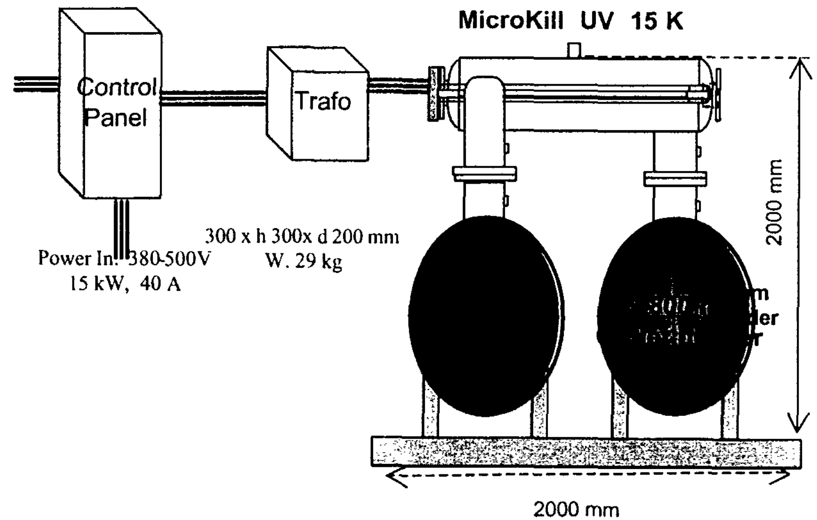
Rear horizontal

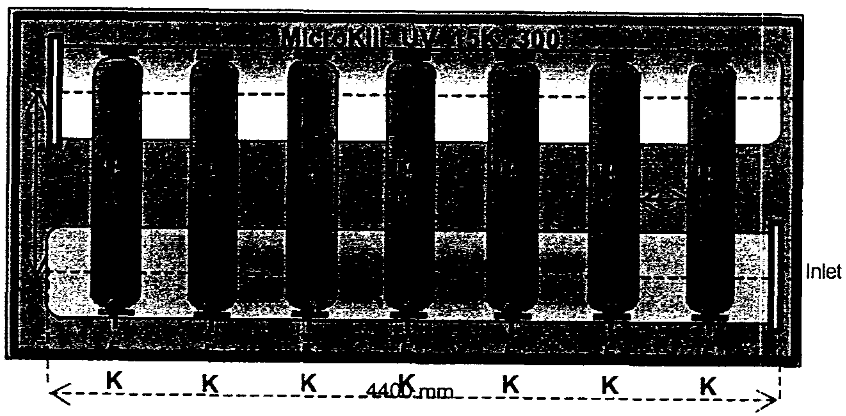


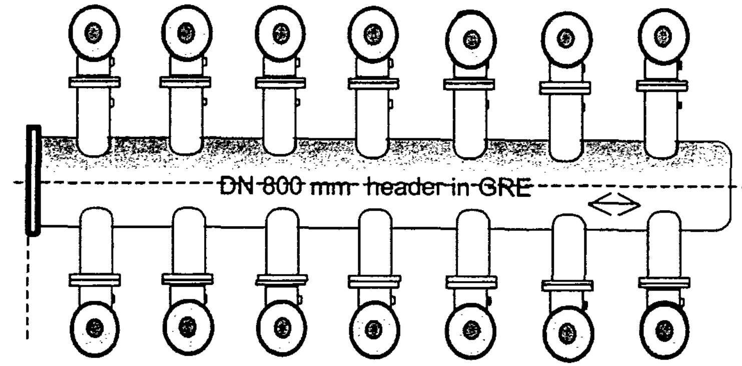
OptiMar BWT Land Systems

Example capacity:

- 12 units operational
- 2 units on stand by
- 3000 m3/h at UV dose of 150 to 200 mJ/ cm2
- UV transmission 90% T1.



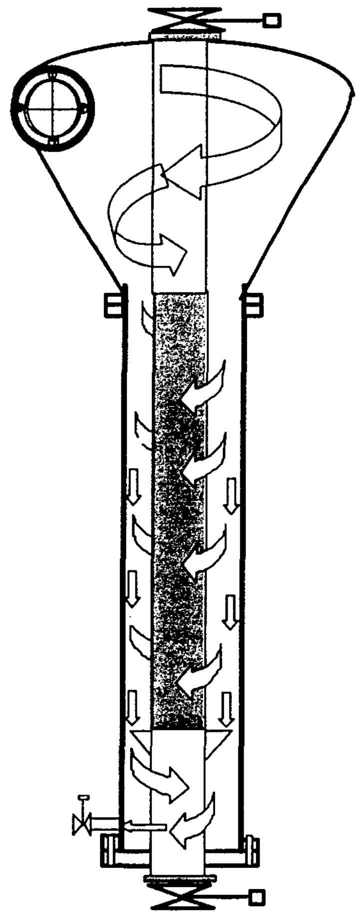




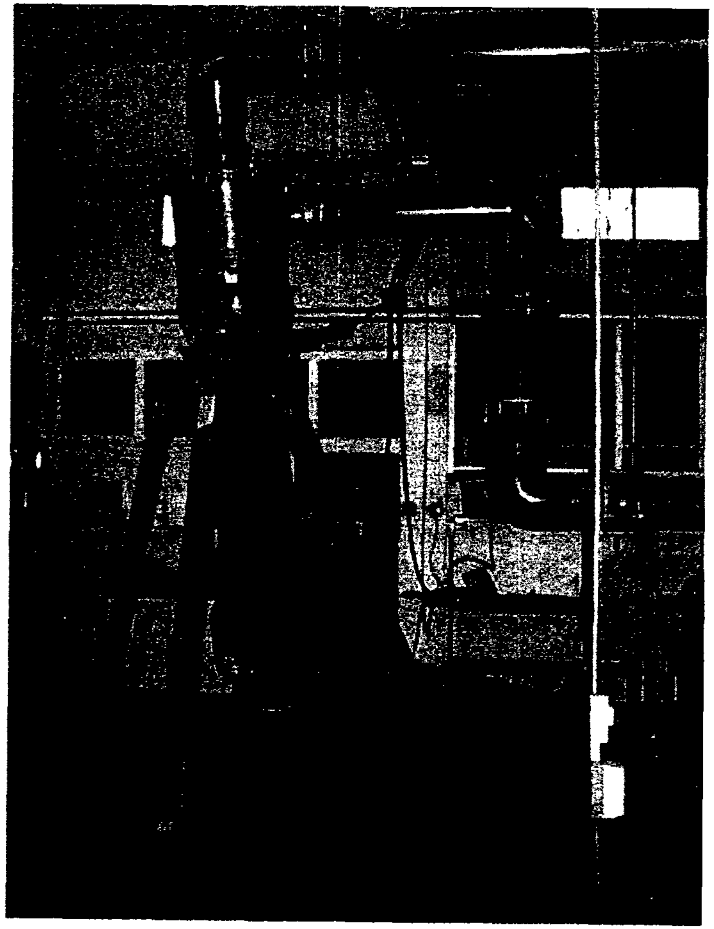
OptiMarin AS 30

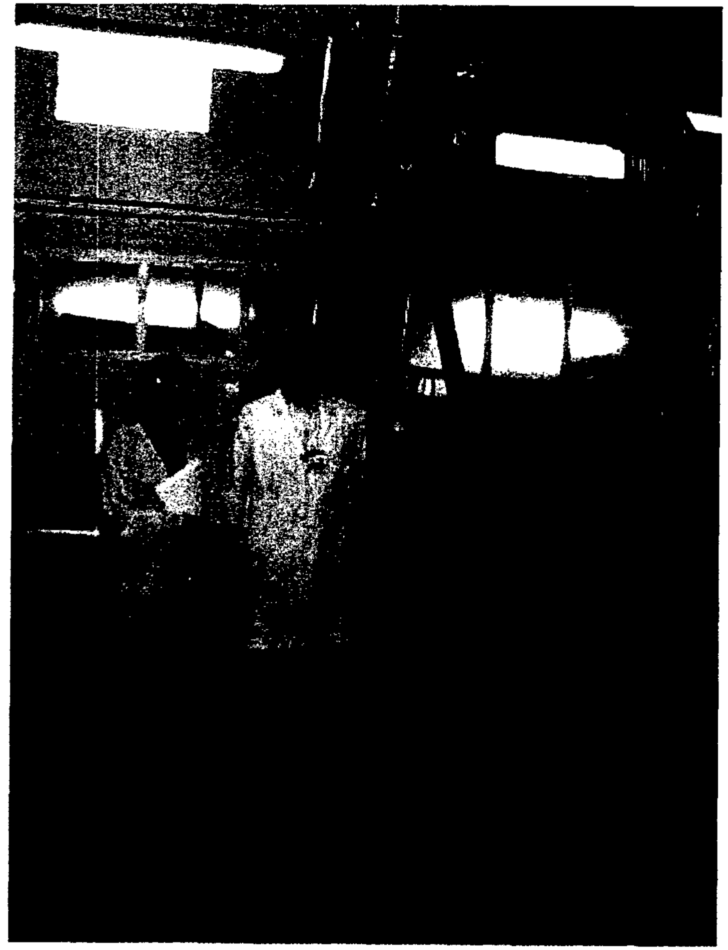
OptiMarin R & D

- MicroKill FilterSep
  - 50 micron filter element
  - Separates and filters solids in the same process
  - Reduced load on filter element
  - Automatic back flushing system



MicroKill FilterSep





R&D projects where OptiMar products have been used

- Institute of Marine Research Norway, 1998 and 99
  - Anders Jelmert
- Fisheries and Oceans Canada, 2000
  - Terry F. Sutherland
- Northeast, Midwest Institute
  - Allegra Cangelosi
    - Regal Princess
    - Great Lakes Ballast Technology Demonstration Project
    - Stolt Aspiration onboard testing planned July 2003
- California, onboard testing program
  - Sea Princess testing (September 2002)
  - R.J. Pfeiffer planned July 2003

The reports from these projects can be found on our web pages

www.ballastwater.com

or

www.optimarin.com

Title: **Electro-Ionization Treatment of Ballast Water**
Submitted for Eule & Partners, Ballast Water and Waste Water Treatment Aboard Ships and in Ports, June 11 – 13, 2003

Authors: Jon Stewart, VP Sales, C.E. (Bud) Leffler, CEO, Ann Salamone
Marine Environmental Partners, Inc. (MEP)
Address: 3874 Fiscal Court, Suite 200
West Palm Beach, Florida 33404
Phone: 561-842-9900 Fax: 561-842-9922
Email: jon@mepi.net Website: www.mepi.net

ABSTRACT

Ships must discharge water: ballast water, bilge water, and wastewater. Unfortunately, when ballast water is discharged, migrating biota are discharged with it. These biota can have devastating impacts on the new environments into which they are introduced. As a result, 14 countries now have regulations governing the discharge of ballast water.

MEP's research team began by evaluating the strengths and limitations of various treatment methods: heat treatment, chemical additives, ultraviolet radiation, and biological cleaning. The team then investigated numerous alternatives, and through a series of laboratory, pilot, and onboard experiments, developed the MariSan® *Ballast Water Treatment System.*

The MariSan® *BWT system filters ballast water as it is loaded onto ships, removing organisms larger than 50 microns. Traces of bromine produced through electro-chemistry from the ballast water and ionized gases produced from ambient air, then disinfect the ballast water to eliminate most biota prior to discharge.*

The compact system is not only efficient; it is able to detect operational problems and, when necessary, automatically changes its configuration to optimize decontamination.

After a year and a half of research, in January 2002, MEP installed a pilot recirculating system on the Carnival cruise ship Elation that was refined to a single-pass system as reported in this paper. Independent testing (both aboard ship and in the laboratory) has shown that MEP's electro-ionization process kills more than 95% of the marine biota and exceeds the existing and proposed standards for water purity.

A full-scale single-pass system was subsequently purchased by Carnival, with installation begun in January 2003.

INTRODUCTION

BALLAST WATER DISCHARGE REGULATIONS

Australia, the first country to impose control, has developed special ballast water quarantine measures. Ships entering Australian waters must comply with one of the following options: 1) provide a certificate from an overseas authority that the port of origin is free of toxic dinoflagellates; 2) provide evidence that they have re-ballasted at sea; 3) provide evidence that they have treated ballast water; 4) discharge ballast tank sediments in designated safe areas; 5) provide evidence that their management practice is to keep ballast tanks clear of sediment; or 6) give an undertaking not to release ballast water in Australian territorial waters.

The New Zealand Ministry of Fisheries has imposed mandatory measures since April 30, 1998, requiring mid-ocean exchange of ballast water loaded in another country and due for discharge in New Zealand.

Following the ballast water introduction of zebra mussels into the Canadian Great Lakes (Hebert, et al. 1989), the Canadian Coast Guard introduced voluntary measures to encourage ships to flush ballast tanks in the Atlantic before entering the St. Lawrence Seaway. In British Columbia, through the Vancouver Port Authority, mandatory ballast water exchange in mid-ocean, prior to entering Canadian waters, became effective January 1, 1998.

In the U.S., the Coast Guard requests that ships coming from foreign ports exchange ballast water in the open sea, following the passage of the Non-Indigenous Aquatic Nuisance Prevention Control Act of 1990. This was extended by the National Invasive Species Act of 1996, which set up the regime of voluntary ballast water exchange and required reports on ballast samples for most vessels entering U.S. waters from abroad. This voluntary ballast management reporting program is under conversion to a mandatory program.

Several states in the USA have become impatient and have begun establishing their own rules. The California legislature passed a bill requiring that no ship arriving from a foreign port will be able to discharge ballast water containing alien species in California waters. In the state of Washington, regulations specify that ships cannot discharge ballast in state waters unless it has been exchanged with seawater from the open ocean, or has been treated to kill marine organisms to a level equivalent to, or better than, open ocean exchange (99% bacteria and 95% cumulative organism removal or inactivation). Mandatory reporting of ballast water discharge also is in effect in the states of Virginia, Maryland, Oregon, and Washington.

In Qatar-Res Laffran, ships are not allowed to discharge ballast in port apart from segregated ballast. Ballast to be discharged in this port is subject to chemical analysis; reporting is mandatory.

The Orkney Islands, UK, allows discharge only to shore reception ballast water treatment facilities, which have a capacity to receive 40,000 barrels per hour.

France reserves the right to intercept ships caught in the act of polluting by the dumping of ballast water or wastewater up to 90 miles from its southern coast. Captains of tankers and other large vessels could be sentenced up to four years in prison, as well as fines of up to $600,000.

Argentina, Brazil, and Chile have mandatory regulations in place to protect their waters from carrying health risks, such as cholera.

REGULATION STANDARDIZATON

The International Maritime Organization's Marine Environmental Committee is the rulemaking body for the shipping industry for all United Nations member nations. A convention, based on UNCLOS Article 196, is in development to set discharge requirements which are targeted to be instituted in 2003.

Research and development efforts are underway around the world to find a ballast treatment solution. However, a major problem faced by researchers is the lack of an internationally approved standard.

To address this hurdle the Global Ballast Water Management Program (GloBallast) organized an International Ballast Water Treatments Standards Workshop (March 2001). The objective was to propose a biological effectiveness standard for the evaluation and approval of new ballast water treatment systems. One of MEP's research team members was invited to participate in this workshop. The participants unanimously agreed on five primary criteria for ballast water treatment (BWT) technologies.

1) Treatment must be safe to ship and crew
2) Treatment must be environmentally acceptable
3) Treatment must be practical (i.e. compatible with ship design and operations)
4) Treatment must be cost effective
5) Treatment must be biologically effective

The workshop participants proposed two main options as possible international BWT biological effectiveness standards. Option one requires 95% removal/kill/inactivation of representative species from at least five taxonomic groups (not yet defined). The group acknowledged that for pathogens, dinoflagellate cysts, and other organisms of concern, a higher removal criterion might be required. Option two is the removal/kill/inactivation of all organisms larger than 100 μm. Staged developments towards more stringent targets of 50μm and eventually 10 μm would follow.

Several conclusions were drawn:

1) Ballast water discharge is causing severe economic, ecological, and health concerns

2) There is a recognized need for effective ballast water treatment technology
3) Existing technological treatment options are not capable of dealing with the scale of the problem
4) A survival rate of no more than 5% will be required. Removing larger organisms by filtering might offset some of the ecological upsets (often due to organisms > 100 μm) but does not address the fisheries health concerns (often due to viruses, bacteria and protists all < 100 μm).

THE PROBLEM ADDRESSED BY REGULATIONS

Most large ships, whether they carry cargo, tank fluids, or people need ballast water to operate. A tank ship can carry more than 8 million gallons of water as ballast. Carlton, et al. (1995) estimated that the U.S. alone receives more than 79 million tons of ballast water from overseas each year.

This global movement of ballast water creates a long-distance dispersal mechanism of marine organisms, ranging from viruses to fish. The movement of non-indigenous species can create problems such as the elimination or suppression of native marine life, the contamination of commercial marine beds, and the spread of human diseases. Because ballast water is considered to be the single largest source of non-indigenous species transfer throughout the world (Carlton et al.1995), the introduction of exotic aquatic organisms via ship's ballast has been identified as one of the four greatest threats to the world's oceans. It has been estimated that an exotic marine species is introduced via ballast water to a new environment every nine weeks (Workshop 2001).

Local organisms, usually in planktonic life stages, are routinely transported with the moving ballast water. In addition to the thousands of phyto and zooplankton (per liter), a few young fish and adult invertebrates may be transported. When water is taken from harbors contaminated with sewage, human pathogens, such as bacteria and viruses, are transported in the ballast tanks as well. Often tidal conditions stir up the water column during pumping adding fine sediment (including the resting cysts of potentially toxic diatoms and dinoflagellates) to ballast intake. Commonly, estuaries are the sites of invasion. It has been estimated that there are approximately 400 non-indigenous species along the Pacific, Atlantic and Gulf coasts of the U.S. (Ruiz et al. 1997).

Ecological concerns: In 1988, the zebra mussel, *Dreissena polymorpha*, was released into the Great Lakes region in part from ballast water movement from Europe. Starting in Lake St. Claire, in just over 10 years, zebra mussels spread through the Hudson, Susquehanna, and Mississippi drainage basins. This invasion has cost billions of dollars. There are many recorded examples of how this species' proliferation has damaged intake pipes by preventing the proper transfer of heat and the eventual clogging of the pipes. Many have lost fisheries (Ruiz, et al. 1997). The zebra mussels are depleting the Great Lakes of plankton and out-competing the fish for planktonic prey.

When non-indigenous species are introduced, the balance of a natural ecosystem is disturbed. This happens because foreign species often have no natural predators. By the introduction of new competition, other species are gradually eliminated by predation pressures. As an example, Scavia, et al. (1988) developed a model that accurately predicted the disastrous outcomes of introducing the predatory cladoceran, *Bythotrephes cederstroemi,* via ballast water. The establishment of this exotic caused a decline in the number of zooplankton species in Lake Michigan, resulting in a change in water clarity and the abundance of plankton-feeding fishes.

Another example is the invasion of the Asian clam, *Potamocorbula amurensis,* into San Francisco Bay. This clam has become dominant, achieving densities above 10,000 per m^2. This means that it has replaced other benthic communities and has cleared plankton from overlying waters (Cloern 1996).

Sightings of Australian jellyfish were found in Melbourne, Florida and a venomous and carnivorous lionfish were found off of St. Augustine in Florida within the last year. Both of these could have a significant impact on the tourist industry of South Florida if they are allowed to reproduce and flourish.

Fisheries concerns: In many cases, accidental introductions adversely affect existing commercial and recreational fisheries, thereby causing negative economic impact to local coastal communities. The introduction of the ctenophore, *Mnemiopsis ledyi,* is associated with the loss of a $250 million fishery in the Azoc and Black Seas. Similarly, the European green crab, *Carcinus maena*, appears to have had a significant impact on the commercial bi-valve fishery of the northeastern U.S. In the shallow lagoons of San Francisco Bay, the mitten crab costs aquaculture operations and other industries $44 million per year (Cohen et al. 1995).

The Chesapeake Bay, USA is an example of an important shellfish area that is under threat from the spread of exotics. A recent analysis showed that the Bay receives 10 million tons of ballast water per year, mainly from Europe and the Mediterranean (Carlton et al. 1995). As an example, the rapa whelk, an Asian snail, is becoming established and is eating native clams and oysters.

Health concerns: Last summer, toxic blooms were affecting the harbors in southern California, resulting in dead fish and noxious odors along the coast. The increased frequency of toxic blooms (red tides) has received much attention since they threaten both public health and marine fisheries around the globe.

Toxic dinoflagellate blooms are not just recent phenomena. Reports of humans suffering the effects of paralytic shellfish intoxication (caused by the bioaccumulation of toxins in shellfish) date back to the 1700s (Hallegraeff and Christopher 1991). However, within the last two decades the frequency of large algae blooms has increased around the world. A toxic bloom started at Monte Carlo and has spread rampantly.

There are several explanations for this apparent 'epidemic': increased utilization of coastal waters for aquaculture, blooms fertilized by coastal populations, increased awareness, and finally transportation of dinoflagellates or their cysts in ships' ballast water (Smayda 1990). All of these are from time to time responsible for blooms; the latter (ballast water) is the one causing most concern. It alone is responsible for the recent outbreaks of toxic dinoflagellate blooms in Australian estuaries. Three toxic species *(Alexandrium catenella, A. minutum* and *G. catenuatum)* now occur in Australian waters well away from their nearest known distributions in Europe and Japan (Hallegraeff and Christopher 1991). In the same study, 40% of ballast water from 80 cargo vessels entering Australian ports contained viable dinoflagellate cysts. Six percent of the vessels contained cysts of the toxic species *A. catenella* and *A. tamarense* (up to an estimated 300-million cysts per ship).

Ship transfer plays a role in the movement of pathogenic bacteria and viruses. *Vibrio cholerae*, the bacterium responsible for the human epidemic cholera, was found in ballast water of ships arriving in the Chesapeake Bay in the USA from foreign ports (Ruiz et al. 2000). Since some of these bacteria were actively dividing, it shows that they were viable during discharge. Another microbial species, *Clostridium botulinum*, responsible for botulism, was found in ballast sediment in Australia. This was from sediment from a Norwegian vessel that docked in Queensland after visiting Singapore.

Multiple countries and agencies have determined that it is ecologically, medically, and economically imperative to stop the spread of exotics around the globe as 10 – 15% of these exotic species are thought to be nuisance species. Effective solutions to deal with the large diversity of nuisance biota - microbes to fish, plus resistant stages such as the cysts of dinoflagellates – are under development.

BALLAST WATER MANAGEMENT OPTIONS

Several different approaches can be adopted to treat ballast water to minimize the spread of exotic organisms, which are summarized below:

Retention of ballast on board. While the complete elimination of ballast discharge is not practical, good management practice can reduce the volumes of water being discharged.

Reduction of the number of organisms taken on board. Since most problem organisms originate in sediments or polluted harbors, whenever practical, the loading of ballast may be delayed until the ship is in open water. Ballasting should be avoided in shallow water, in stagnant areas, in areas close to sewage outfalls, and in areas adjacent to dredging operations. However, sometimes it is not practical for the crew to ballast in deeper waters as they must take on the ballast while discharging cargo.

Removing organisms prior to placing ballast water in tanks reduces the risk of transporting the organisms. Also, some cruise ship applications create an opportunity to clean grey water and retain this as ballast, thereby eliminating the problem of exotics. Treated grey water must meet local discharge standards.

Exchange of ballast at sea. This has been the most practical method for ballast water management. It is achieved either by the sequential (empty-refill) method or by the flow-through (overflow) method. These methods are reportedly 95% effective in eliminating aquatic organisms. But emptying and re-filling tanks at sea significantly reduces stability and imposes unacceptably high stresses on the hull. Moreover, many ships do not reach open ocean during their voyage. This is the situation on the west coast of the United States where ships traverse the coast, and also in Europe where shipping traffic is regional rather than international. Although ballast exchange has been the best treatment available, it has several serious safety limitations.

Shipboard ballast water treatment. Although many ballast water treatments are currently being investigated, until now none has been shown to be either practical or cost effective for general use by most ships. Several treatment options are available such as the oxidative action of halogens (e.g. chlorine), ozonation (O_3), oxygen depletion, biocides, floatation separation, filtration, acoustic methods, electrical pulses, ultraviolet radiation, and heat. Most of the systems tested have been unsuccessful either due to lack of ability to scale-up, inadequate safety, or the inability to remove greater than 95% of life forms. Most of the added chemical treatment processes have proven to be prohibitively expensive; the volume of chemicals required makes use and safe storage difficult; and the added chemicals may affect the marine environment upon de-ballasting. Some of these experimental technologies may prove to be more effective for fresh water sanitization and contamination clean-up.

On-shore ballast water treatment. This, in principle, has several advantages to shipboard treatment. However, many ships do not currently have the capability in their piping system to discharge water ashore. Also, space in harbors is at a premium, and few ports have the room to accommodate an on-shore facility with the capacity to hold waste fluids from several ships at one time. In-ground water pollution, sludge sedimentation, and difficult cleaning of on-shore facilities are recognized disadvantages for on-shore treatment.

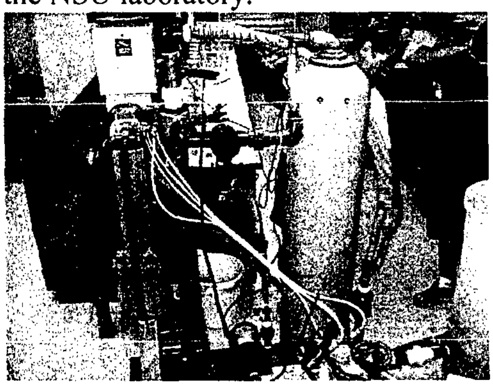
MEP OBJECTIVES REPORTED IN THIS PAPER

1) Refine onboard ship tested recirculating system to produce commercial single pass system for ballast water sanitization.
2) Construct an innovative core IONZ™ (defined below) gas generating system that incorporates multiple IONZ™ units rather than a single unit in order to deliver higher oxidant concentrations as needed based on ballast volume and content.
3) Develop other available technologies to complement the IONZ™ treatment system, such as MEP electrolysis system utilizing seawater chemistry in synergy with the IONZ™ gases, to improve kill/inactivation efficiency of the integrated treatment system.
4) Conduct tests to optimize performance of treatment system.
5) Develop new methods for rapidly verifying biological effectiveness of the treatment system.

6) Install a system capable of treating all of the ballast on a ship. Incorporate pre-filtration modules. After the components have been specified and optimized, test on-board ship, and assess performance. Modify the onboard system as required.
7) Build all shipboard equipment to Lloyd's classification standards. This includes electrical, mechanical, and pressurization standards.

BRIEF HISTORY OF DEVELOPMENT

Over the last three years, Marine Environmental Partners Inc. (MEP) (with C. E. Bud Leffler as the lead technical investigator) and the Oceanographic Center of Nova Southeastern University (NSU), (with Dr. Andrew Rogerson as the lead independent investigator in biological testing) have evaluated multiple processes for sanitizing ballast water. Electro-ionization technology was found to be the most promising. Electro-ionization is a treatment method used to disinfect freshwater effluents, which MEP modified and applied to treat marine and estuarine waters. This work led MEP to believe that by utilizing this technology and creating a mixed oxidant reaction, the technology had the potential to treat ballast water effectively via onboard treatment systems. The technology development began with an electro-ionization system built and operated in the NSU laboratory.



Original *In-situ* System tested in NSU laboratory at Ocean Research Center, Dania Beach, Florida

This *in-situ* electro-ionization system was used to test synergistic electrolysis and ionization processes to increase sanitization efficiency of ballast water.

The most effective treatment system found consists of:

1) Solids removal module
2) Electrolysis module
3) Ionization (IONZ$^{TM)}$ module
4) Static mixing module

BALLAST WATER TREATMENT SYSTEM REFINEMENT

SOLIDS REMOVAL MODULE

After testing alternative means of solids removal, filtration modules were selected and are deployed based on the quality of the seawater influent anticipated aboard a given ship as determined by its proposed routing.

Based on anticipated regulatory action and system efficiency, biota larger than 50 microns were removed during ballast intake in pilot test systems. Using a 50-micron filter at intake, seawater went from an average bacteria count of greater than 300,000 per mL to less than 1,000 per mL. In addition, virtually all adult life forms were removed.

MEP selected a self-cleaning 50-micron filtration module and tied its operation into a PLC (programmable logic controller). When taking on ballast, the discharge of the filtrate can be returned overboard, as only local species should be present during ballast intake. When de-ballasting begins the PLC initiates the filtration process utilizing the same filter on the ballast water held during transit. Since a ship is normally in port at this stage, the filtrate must be managed onboard. Several options exist for filtrate management including – mixing concentrated filtrate with other wastes for discharge at sea or disposal ashore, further treatment via BWT system, or other treatments such as heat.

ELECTROLYSIS AND IONIZATION MODULES

Once larger biota is removed by filtration, smaller biota is killed by reactive chemicals (sanitizing agents), which are generated by electrolysis of the seawater coupled with ionization of atmospheric air. Effective mixing of the sanitizing agents within seawater held in the reaction vessel is a key research area.

The sanitization system is designed to process 1000 gpm of ballast water, a treatment rate that can be increased by the addition of parallel electrolysis and ionization modules.

The electrolysis module generates reactive chlorine and bromine ions by electrolysis of the seawater. Concurrently, atmospheric air is ionized into various species of oxygen and nitrogen in the IONZ™ module. These ionized species include various singlet molecular oxygen species, ionized nitrogen, and peroxyl ions (e.g. O_2^-, O_2^{--}, N_2^+, e^-, H_2O_2, OH^-). The ionized air (gas) stream is fed into the electrolyzed seawater stream where the reaction occurs with the previously electrolyzed chlorine and bromine to produce ClO^- and ClO_3^-, as well as the originally produced reactive species, thereby enhancing biota termination.

As shown by reduction potential analysis, the MEP system utilizes a combination of hydrogen peroxide, oxygen species, and bromine species as disinfectants. This is consistent with the analytical data where bromo species (40–54 µg/l bromoform and 2-11µg/l dibromochloromethane) are the main trace contaminants left in the seawater

(Spectrum Laboratories). Both oxygen and hydrogen peroxide dissipate rapidly in the oceans to environmental levels. The net result of the treatment system is the disinfection of the ballast water using only trace amounts of bromoform and even smaller amounts of dibromochloromethane, with no persistent disinfectant species released to the environment. It must be recognized that even the bromoform is below drinking water standards.

Data on various treatment configurations employing electro-ionization technology was collected over the last two years. Generally, the results show the technology to be capable of killing (or inactivating) approximately 95% of indigenous (i.e. native), culturable bacteria in water from Port Everglades, Florida. On one occasion, up to 99% of bacteria were killed or inactivated. Trials conducted on indigenous protist (algae and protozoa) indicate a kill efficiency of around 90%. These promising results guided the evolution of the treatment system to its present configuration.

Prototypes used electro-ionization in either a recirculation system (recirculation through a single tank) or a one-pass system taking untreated water from the tank into a reservoir (while adding reactive species to the linking line). Recirculation was a successful process and was capable of consistently killing over 90% of the bacteria contained in 300 L of water (some 3×10^{11} bacteria) with just 2 minutes of treatment exposure.

Testing for halogen residues using a recirculating system indicate a maximum concentration of halogens (chlorine and bromine) of 0.5 ppm (0.35 ppm free and 0.15 ppm combined), which is well below the 1.5 ppm threshold established earlier.

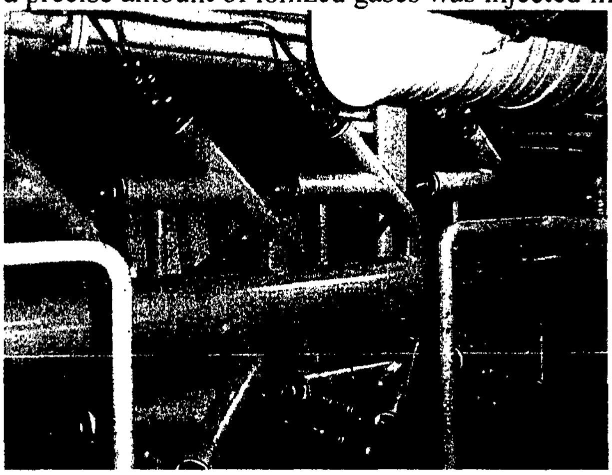
Notably, the use of chlorine in potable water is known to react with organic materials in water and form a variety of carcinogenic trihalomethanes (THMs) and other molecular species. Therefore, the U.S. Environmental Protection Agency (EPA) set an absolute limit of 100 ppb for THMs in any potable water system. As existing discharge standards do not address the presence of THMs, Spectrum Laboratories tested MEP's treated shipboard ballast water for THMs utilizing EPA drinking water standards and found it to be well within the EPA drinking standards [bromoform (80 – 100 ppb), dibromochloromethane (0.5-3.1 ppb), and dibromoethane (1-4 ppb)]. Furthermore, no detectable THMs were present at the point of discharge. MEP confirmed ballast water processed in its recirculating system remains within EPA's parameter even when fluid is circulated for several days.

Therefore, with encouraging tests showing high biota kill results at low halogen levels and no detectable THMs at discharge, a prototype recirculation system was installed initially on the Carnival ELATION.

RECIRCULATION SYSTEM

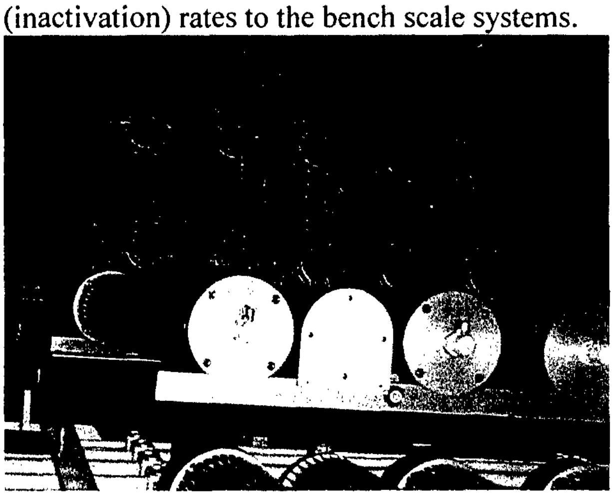
Carnival Cruise Lines asked MEP to work with them to prototype a MariSan® ballast water treatment system onboard one of their vessels, the Carnival ELATION. Prior to shipboard installation, MEP designed mock ballast water tanks to simulate the transmissive qualities of the ionized gases and electrolyzed seawater into the ballast water. In order to expose all of the ballast water in a tank to the treatment process, the reactants had to be distributed in a manner where virtually all fluids would come into contact with the sterilizing ionized gases and electrolyzed bromine/chlorine species.

Based on the laboratory tests, the shipboard pilot system was designed in such a manner that a slipstream was diverted from the main ballast to feed several electrolysis cells for generation of primary disinfectants. This slipstream and the airflow from the gas ion generators were then introduced via a mixing module, known on the ship as "the octopus", for combining the ionized air (gas) and halogen species, in tandem, with the ballast water to kill biota. The shipboard prototype system utilized air compressors so that a precise amount of ionized gases was injected into the system.



The "octopus" onboard the Carnival ELATION pilot project

Although MEP was not able to install a filtration module into the onboard pilot treatment process because of space constraints, the results were encouraging as the tests on this full scale recirculating system for sanitizing Carnival's ballast tank achieved similar biota kill (inactivation) rates to the bench scale systems.



Racks of Ionz™ generators (30) on Carnival's ELATION pilot project

Upon further onboard testing of bacteria re-growth, it was found that during active treatment little bacteria remained. However, within 24 hours after termination of treatment, surviving species quickly became established. Due to concerns of establishing large quantities of biota colonies (composed of treatment-resistant highly fit/durable strains) during idle treatment periods, treatment of ballast water during passage was deemed undesirable. Therefore, it was concluded that sanitization treatment should occur at de-ballasting to ensure the highest effective kill level.

SINGLE-PASS SYSTEM

On board the ELATION, a single-pass pilot system without a pre- or post-filter was preliminarily tested and found to provide a promising level of bacteria kill.

Based on findings from the ELATION onboard testing, MEP constructed a 1/20 scale-model (40gpm) single-pass system to be utilized at the Nova Oceanographic Research Center to simulate what was learned on the ship and to allow for testing of environmental, biological, and process variables. Testing for residual toxicity of the treated seawater and evaluation of potential modifications for the on-board systems will occur. MEP has been testing this particular system since January 2003 and test results continue to indicate the system can meet or exceed all anticipated standards.

A 50-micron filter element was installed on the model system and used to treat ballast water during intake. After filtering, the ballast water was treated as onboard Carnival's ship, except a single-pass process is utilized where the ballast is treated at de-ballast with electrolyzed seawater and ionized air in tandem. The first lab results indicated that the selected 50-micron filter was blinding and as a result removed organisms as small as 25 microns. Concerns about flow restriction resulting from this blinding led to the selection of a self-cleaning 50-micron filter. This filter cleans during full flow operation and does not require a back-flush cycle. Bacterial kills are consistently in the 95 – 99% range at halogen concentrations of 2ppm or less.

During May/June 2003 laboratory tests on ecological impact of discharged treated ballast water from the model system are being studied (Whole Effluent Toxicity – WET tests) at Toxikon Corporation. The acute exposure results to date on discharged ballast water indicate no-impact, no surrogate organism (mysid shrimp) death even at MariSan® treatment levels at twice that required for > 95% biota kill.

SUMMARY OF MARISAN® TESTING RESULTS

	1/20 scale single-pass model
Biological testing	
Bacteria kill	> 95%
Protists kill	> 90%
Effluent toxicology(WET testing) at twice full capacity	
- 96-hr acute	NOEC = 100% effluent
	LD_{50} > 100% effluent
Chemical analysis at full capacity	
- halogen residuals	0.5 ppm
	(0.35 ppm free, 0.15 ppm combined)
- THM residuals	
during treatment	80 – 100 ppb bromoform
	0.5 – 3.1 ppb dibromochloromethane
	1 – 4 ppb dibromoethane
at discharge	not detectable

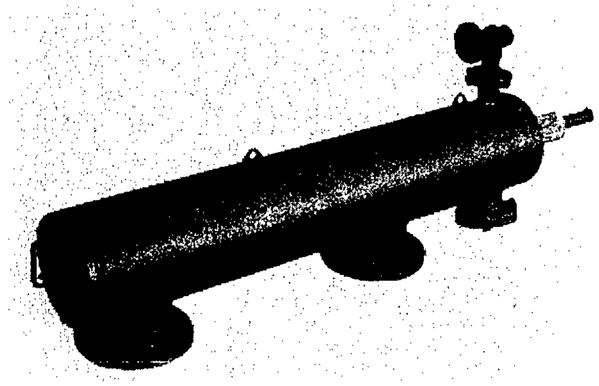
SINGLE PASS COMMERCIAL SYSTEM

Discussions with Carnival led to installation of a commercial system in January 2003.

MEP built the single-pass system as a 1000 gpm commercial unit. Each of the system modules meets class certification and is built to perform over the life of the ship. The system is designed with integrated power and control systems driven by a PLC module, which monitors and controls over 300 points. This system, to be tested over a five-year period, is designed to operate at a cost of $0.005 or ½ cent per metric ton based on $0.15/ kW hr energy charge as estimated by Carnival Cruise Lines. The system consists of four modules: a filtration module, an electrolysis module, an ionized gas module, and a static mixing module. MEP is currently developing a modular system to treat 6,500 gpm of ballast water by adding duplicate modules operating in parallel.

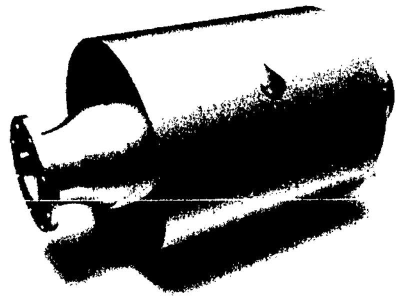
See Appendix 1 for engineering details.

The commercial filtration module is a self-cleaning filter that does not require a backwash but can be cleaned during operation. This module is made entirely of stainless steel. MEP modified the module to accept commands from a PLC so that the filtration module may initiate a cleaning operation after completing a de-ballasting operation. This allows management of the filtrate to meet applicable requirements.



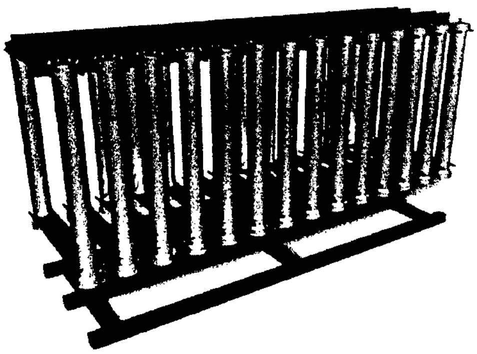
Self-cleaning filtration module

The commercial electrolysis reactor is used to electrically generate small amounts of chlorine/bromine from seawater to help in the destruction of biota. This sophisticated module contains 10 reactor cells with over 23 flanges and many machined surfaces beneath the cover. The module is manufactured to have built-in redundancy, and is monitored by the PLC for voltage, current, flow, temperature, leakage, etc.



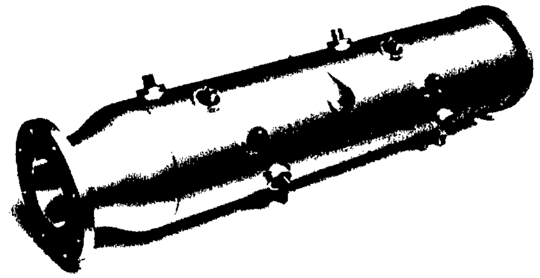
Electrolysis reactor module

IONZ™ gas is generated utilizing air as the raw product in the IONZ™ gas generators. These are rack mounted onboard the ELATION. They may be mounted to a bulkhead in other applications. The IONZ™ generator rack is monitored for flow from each cylinder as well as temperature, pressure etc.



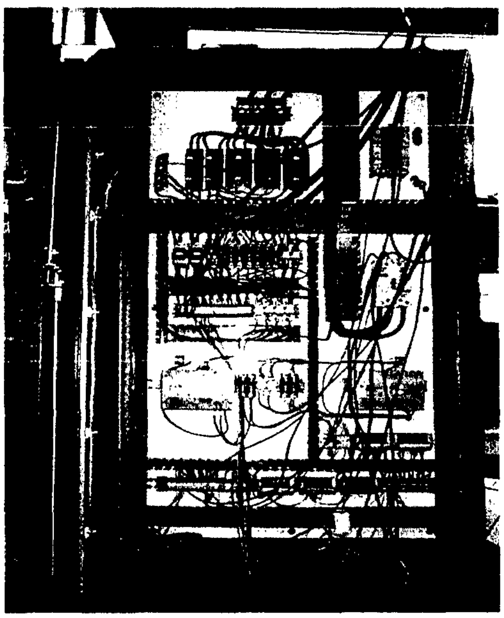
IONZ™ generator rack module

The last module is the Static Mixer™. This module replaces the "octopus" and provides thorough mixing of the IONZ™ gas and electrolyzed seawater with the ballast water flow for disinfection, while stabilizing the water chemistry in preparation for discharge.



Static Mixer™ module

The ballast water treatment system is controlled and monitored by an electronic control system. The controls are installed in four cabinets that start with a stabilized and conditioned power supply to the PLC, which monitors and drives the entire system. The PLC monitors the system and can self- repair by turning on additional back-up units if it senses a problem; and is designed to self-report and generate information for remote troubleshooting. The PLC is being developed to notify shore-based facilities that the system is operating correctly and that the ballast has been treated.



E-cell ™ power cabinet - one of four power and control cabinets

The testing of the system is designed to integrate the modules and determine the least amount of equipment/energy required to fully sanitize the biota. MEP uses periodic biological plate counts to validate system operation.

Formal testing of the Carnival ELATION's commercial single-pass system for the California Lands Commission is expected to begin in Summer 2003.

CONCLUSION

MEP's single-pass system, as tested in its 1/20 scale pilot system at NSU, sanitizes seawater to at least a 95% kill of biota. No detectable THMs are present at discharge and the concentrations of reactive halogens present at discharge are ecologically non-toxic. Ergonomic engineering benefits include no stored or added external chemicals, fully automated operation, and is practical for adaptation to a variety of ships (cruise and cargo).

APPENDIX 1: ENGINEERING

ENGINEERING AND VESSEL OPERATIONS DESCRIPTION

Ship Type: Passenger (Fantasy Class) – Carnival ELATION

Size: 260.78 Meters (855 Feet)

Beam: 103 Feet

Year Built: February 2, 1998

Cost: $300 Million

Built by: Kvaerner Masa-Yards
Helsinki, Finland

Crew: Italian

Gross Tons: 70,367

Crew size: 920

Passengers: 2,606

Route: Los Angeles (Port of San Pedro), Puerto Vallarta, Mazatlan, Cabo San Lucas & Back to Los Angeles (Port of San Pedro).

Home Port: Los Angeles (Port of San Pedro)

Flag State: Panama

Classification Society: Lloyd's

Nationalities of (Senior) Deck Officers: Italian

Crew Engineering (Senior) Officers: Italian

GENERAL DESCRIPTION - TREATMENT SYSTEM CONFIGURATION

There are four basic operating units with the MariSan® Ballast Water Treatment System (trademarked name for MEP commercial system). The first unit is the 50-micron pre-filter, the second unit produces bromine, chlorine and other reactive chemicals through electrolysis of seawater, next ionized air is formed via IONZ™ gas generators, and last is the Static Mixer™ which provides thorough mixing and stabilization of the water chemistry prior to discharge.

SHIPS OPERATION INTERFACE AND CREW IMPACT

The operation of the ballast treatment system is through the use of a PLC. The ballast treatment system functions, as does the current ballasting/de-ballasting system, with minimal crew interface.

The PLC is preprogrammed with necessary alarms and shutdown procedures per each ship's requirements. Manual override and by-pass operations are in place to allow the crew to operate the "normal" ballasting system in the event of a system failure.

PLC alarm and operation monitoring conditions:
No-flow ballast pump
High-pressure ballast pump
Ballast treatment system pump run-time counter
Main flow meter/gpm and totalize
Valve positions
No-flow pre-filter
High-pressure pre-filter
High-temperature pre-filter
Pre-filter by-pass
Pre-filter backwash
Electrolysis cell water flow
Electrolysis cell high temperature
Electrolysis cell current high/low
Electrolysis cell run-time counter
Electrolysis cell housing water detection
Electrolysis cell change required
Ionized gas cell pressure high
Ionized gas cell temperature high
Ionized gas cell pressure at mixing manifold high
Ionized gas cell low power output
Ionized gas cell change required
Gas mixing manifold flow
Gas mixing manifold pressure high
Existing ballast system valve positions
Existing ballast tanks level sensor

MAINTENANCE AND RELIABILITY

Each component is evaluated against that particular component manufacturer's claims for component service life expectancy. Each component's service life expectancy is checked against any failure and actual service life. Each component in the system is selected based on its use on shipboard applications, its service life and/or reliability claims from the manufacturers.

There are redundant logging procedures in place. Data to be logged are start date, start time, flow meter reading start, flow meter reading end, ORP reading (hourly), IONZ™ airflow, and all alarms during operation.

Manual engineering log books are kept along with the electronic data logs. The engineering logs are compared against electronic logs and both databases are then used for operation and maintenance performance evaluations. Every time the system is activated, information is automatically logged in the electronic data logging system within the control panel. For example, the system is capable of de-ballasting at a certain flow rate, so that rate can be multiplied by the amount of system operation time to verify how much ballast is processed through the system on a particular date/time.

MAINTENANCE AND TRAINING

Each component will have an operating and maintenance manual for operation and maintenance reference. The ship's engineering command is planned to have 16 hours of hands-on training of operation and 8 hours of hands-on training for maintenance of system. A video of the installed *Elation* system will be produced for future reference on operation and maintenance.

Pre-filter: The pre-filter of choice is in use for filtering power plant cooling and feed water from open bodies of water, including seawater.

During biological testing visits, the filtering unit is taken from service after the ballasting operation is completed for each voyage and inspected. These inspections are recorded with all the other data collected for system performance. Annual recommended maintenance is approximately one man-hour.

Crew:
Inspect cover seal
Inspect fine screen
Insect piston
Inspect dirt collector if installed
Inspect lower bearing
Inspect rinse controllers
Inspect O-rings
Inspect hydraulic motor
Inspect upper bearing
Replace components as required

Electrolysis cells: Due to the manufacturer's recommended product life of 12,000 hours it is not expected that the units will need to be replaced during the five years of the test plan; however, removal and replacement with a new unit annually is recommended. Two to three man-hours are needed to replace an electrolysis cell. Efficiency of the electrolysis unit is evaluated during shipboard biological testing visits.

Ionized gas cells: The main component of the ionized gas chamber (IONZ™) has an expected life of up to 7,500 hours. These units are taken off-line as required by either time or system alarm condition. Each unit requiring service is disconnected and replaced with a factory prepared unit. Actual unit efficiency is measured during shipboard visits for biological testing. When the PLC indicates an ionized gas cell failure has occurred the ship's crew changes the cell. Due to proprietary components the entire cell must be changed, a 15- minute operation.

Valves: Annual maintenance is estimated at less than 4 man-hours. All valves operated in the ballast line are type approved and match exactly the valves and specifications already in place for shipboard use. The exact matching of the valves helps the ship and crew with spare parts and repair. The crew does not require additional training on these components.

Ballast Pump: Annual maintenance is less than 8 man-hours. The recommended additional ballast pump for the ballast treatment system is a duplicate of the existing pump in operation on the ELATION as it is approved for shipboard installation and operation. Additional training is not required as the crew is familiar with the pump and carries required spare parts onboard the ship.

ENVIRONMENTAL, SAFETY, AND HUMAN HEALTH

Environmental Matters

Tests for residual toxic chemicals were performed for both the small-scale lab testing and the shipboard trials. As electrolytic separation of seawater is a component of treatment, the primary concern is for the production of residual THMs and residual bromine and chlorine compounds.

Baseline tests for THMs were performed by Spectrum Laboratories under method 8260 for drinking water. The EPA method 8260 test confirms that with additions of bromine in quantities of up to 5.0 ppm in seawater, no THM production above the 80 ppb has been measured. Test method 8260 was performed on seawater samples with bromine concentrations ranging from 0.25 to 5.5 ppm.

During both shipboard and laboratory pilot-scale testing of the MariSan® Ballast Water Treatment system treated seawater, the total bromine concentrations produced are typically around 0.25 ppm. Total bromine test was performed in accordance with EPA drinking water methods. Therefore, no post-conditioning of the treated water is required prior to discharge.

Whole Effluent Toxicity (WET) tests performed by Toxikon Corporation for acute exposure to discharged ballast water indicate no-impact, no surrogate organism (mysid shrimp) death even at MariSan® treatment levels at twice that required for > 95% biota kill.

Waste Stream Management - The primary waste stream is the rejection of most organisms above 50 microns in size during the pre-filtration stage of the ballasting mode. The marine life filtered out at this stage is re-deposited back to its native environment as the ship is taking on the ballast water. At de-ballasting, solids removed by re-filtering (50-micron) are held onboard and managed as required.

Human Health and Safety

The pre-filter poses no health hazard. Exposure to bromine in water is at drinking water levels and not considered a health hazard. The ORP meter in place is set to control the production of bromine. There is a redundant ORP meter to back up the primary meter. This redundancy in the bromine production monitoring reduces the chances for excess amounts of bromine to be produced, reducing the possibility for dangerous exposure.

The gases produced by the ionized gas generators do not come in contact with the atmosphere. The gases are contained in stainless steel housings and fed through tubing to the shear mix manifold. The ionized gas is combined with the electrolyzed water just prior to being delivered overboard.

The ionized gas generators are pressure tested to 90psi and cannot leak to the atmosphere. Each ionized gas cell generator has a pressure switch that senses when the pressure is altered beyond the predetermined set points; upon an alarm being reached, the PLC shuts down the system.

Safety Impacts of Treatment System

Ergonomics: No studies completed, however, no repetitive motion is required by crew operating the system. The system is automatic. Ambient temperature where equipment is installed is not significantly impacted. Posture of operator is not affected while operating the equipment.

Escape arrangements: Placement of the ballast treatment system in the starboard side MSD room poses no escape hazards or problems. No organically designed or approved escape routes or areas are altered or blocked with the ballast treatment system.

Pumping and damage control arrangements: All lines added to allow for the additional ballast pump and ancillary ballast treatment equipment are done in accordance with Lloyd's approval. The ship's current damage control plan is in place for ballasting and de-ballasting operations.

Added weight and moment: Weight and moment studies have not been performed. The entire system will weigh less than three tons when installed.

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MSI Ballast Water Treatment System

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Maritime Solutions, Inc.

SYNOPSIS

Ballast water management practices, voluntary for the most part now but expected to become mandatory in the near future, are largely based upon the seriously troubled practice of ballast water exchange with open ocean water. This approach puts many ships, their cargoes and, most importantly, the lives of their crews at risk due to the possible resulting loss of transverse stability and/or the consequences of longitudinal hull-girder failure. In the interest of providing a viable shipboard alternative to ballast water exchange, Maritime Solutions has lead the development of a two-stage system resulting in what is expected to be proven to be a safe, effective, practical, and cost effective solution. The MSI System is based upon the separation capability of the MST Microfugal® Separator serving as the first stage and the UV technology of Aquionics, Inc. or, alternatively, the chemical biocide technology of Degussa AG or Ozone Technology AB providing second stage treatment.

INTRODUCTION

Current IMO prescribed ballast water management practices, voluntary for the most part now but expected to become mandatory in the near future, are largely based upon the seriously troubled practice of ballast exchange with open ocean water. Ballast water exchange at sea puts many ships, their cargoes and, most importantly, the lives of their crews at risk due to the possible changes in transverse stability and/or longitudinal hull-girder loading. Beyond this, ballast water exchange has, with little exception, been variously determined to achieve a level of < 65 % to 90 % effectiveness in the exchange of the original ballast water; the actual result being dependent on ship type (tanker, bulk carrier, containership, etc.), the specific design of a particular vessel, and its trade route or voyage pattern. In fact, the level of effectiveness of ballast water exchange is 0 % when it is not practiced (i.e., whenever the Master determines that 'conditions' do not allow it to be performed). At the same time, only a fraction of the sediment contained in the original ballast water is eliminated, leaving a refuge and an active breeding ground for many marine organisms. It is, as a result, abundantly clear that higher-level technology needs to be employed to assure shipboard safety, to reduce sediment loading in ballast water, and to provide for a higher level of effectiveness in the mitigation of biological invasions.

BACKGROUND

In the interest of offering a viable shipboard alternative to ballast water exchange, Maritime Solutions, Inc. has lead the development of a two-stage system as recommended by The Shipping Study (Carlton et al. 1995), wherein it was clearly predicted that a multi-stage system would be necessary to effectively mitigate against sediment and organism introduction by ballast waters. The approach taken by Maritime Solutions also conforms with the conclusions reported by the National Research Council (1996) in that it couples state-of-the-art separator technology with advanced UV or, alternatively, chemical biocide or ozone technology resulting in what is expected to be a safe, effective, practical, and cost effective solution to the ballast water problem.

The resulting patented 'Maritime Solutions Ballast Water Treatment System' (MSI System), is based upon the separation technology of Maritime Solutions Technology, Inc. (MST), serving as the first stage and the UV technology of Aquionics, Inc. or, alternatively, the chemical biocide technology of Degussa AG or Ozone Technology AB providing second stage treatment. The two-stage MSI System offers the promise of superior organism elimination, increased silt and sediment reduction, and flow rates to meet shipboard requirements; all within a compact, crew friendly and energy efficient installation. Maritime Solutions is currently involved in a rigorous program of system engineering and independent shipboard system testing.

The MSI System will utilize the proprietary MST model MSX 1500 Microfugal® Separator to separate the components of the influent ballast water in the primary treatment stage. As a primary treatment, the MST model MSX 1500 Separator is intended to remove silt and sediments and certain large organisms from the influent ballast water and then immediately return these materials back to the source waters in a small fraction of the water stream. The remaining 'clean' water stream is then to be treated by UV or, alternatively, by chemical biocide in a secondary system stage. The primary treatment stage will be assessed as to its value in removing sediments from ballast-bound water, as well as its effect on the efficacy of the secondary treatments. Following treatment, the 'cleaned' and disinfected ballast water will be transferred via the vessel's ballast pump to the ballast tanks.

Maritime Solutions is working with leaders in the fields of UV testing and biocide toxicity testing who will participate in this project. New high intensity UV systems have been developed which promise to increase treatment effectiveness against a broader spectrum of organisms and, at the same time, decrease necessary exposure time, which is critical in the high flow-rate systems needed for shipboard ballast water treatment systems. The use of two new chemical biocides will also be tested; both proprietary compounds having short (hours) half-lives. Short half-life is essential because it reduces the required period of shipboard holding and the potential environmental problem of introducing these chemical compounds into the environment when the treated ballast water is finally discharged. Thus, Maritime Solutions is coupling its MST Microfugal® Separator technology with both recommended approaches to secondary treatment in order to determine and verify the increased level of overall treatment effectiveness that results from the removal of larger organisms as well as the removal of silt and sediment particulates that would otherwise shield organisms from UV treatment or that would interfere with chemical biocide or ozone treatment necessitating an increase in chemical dosage.

By removing particles more dense than water (e.g., silt and detrital material) from the influent water, the first stage MST Microfugal® Separator will make ultraviolet treatment in the second stage more effective because of the reduction in 'shadow' produced by these particles. Similarly, particulate removal will assist when chemical biocides are used as the secondary means of treatment. Adsorption of compounds into silts and humic materials (detritus) occurs in many applications (Khan and Dupont 1987; Morillo et al. 1992; Piccolo et al. 1998; Undabeytia et al. 2000). Adsorption percentages of some herbicides can be as high as 42% on clay alone and much higher on organo-clay complexes (binding coefficients as high as 1500 $k(M^{-1})$, Undabeytia et al. 2000). Thus, clays, silts, and detritus have a high potential to force an increased application of chemical biocides in order to achieve effective treatment of ballast water. In addition, the high-binding capacity of these sediments for biocides suggests that in cases of sediment build-up in ballast tanks, a sediment refuge may be established. Adsorption by overlying sediments may produce a biocide barrier to organisms including bacteria and viruses, cysts of dinoflagellates, the resting stages of crustaceans, and burrowing invertebrates.

MST MICRFUGAL® SEPARATOR

The proprietary MST model MSX 1500 Microfugal® Separator is a continuous flow machine that is designed to generate high centrifugal forces capable of separating particles and organisms of different specific gravities including those of small micron size from the liquid stream at extremely high flow rates per unit size of separator. As the liquid stream passes through the MST Microfugal® Separator particle separation is accomplished by a fixed stator and a rotating impeller of proprietary design that are contained within a Sterling Fluid Systems (USA), Inc. fabricated housing that is coupled to a static separation chamber. In liquid/solid mixture separation, the separator's centrifugal forces cause the denser particle components to gravitate to the outside of the liquid stream. The liquid stream is divided into separate fractions as a function of relative density as it passes through the separation chamber. The various liquid and solid fractions are ultimately separated at the discharge end of the chamber where they pass through separate collection ports with the 'clean' water passing on to secondary treatment.

IN-LINE UV TREATMENT SYSTEM

The Aquionics In-Line UV treatment system has been selected for incorporation in the MSI System because of its superior design, quality of construction and proven ability to provide proper disinfection, even to poor quality liquid streams. In order to properly disinfect, UV germicidal energy must pass through all of the fluid that requires treatment. If even 1% of the liquid stream goes untreated there will be a dramatic reduction in overall effectiveness. A standard design UV chamber will not be effective in treating water with poor UV transmission because of the hydrodynamic complexities affecting the application of uniform UV treatment. The Aquionics In-Line chamber, with its unique design, was developed to address just this problem.

The Aquionics In-Line chamber system contains multiple lamps (specific number determined by treatment and flow rate requirements) installed perpendicular to the liquid flow. The lamps are situated in such an arrangement that all of the liquid (in this case influent ballast water) is forced to pass within close tolerances to the surface of the high intensity, medium pressure UV arc tube lamps thereby eliminating untreated 'dead legs' of water. In addition, the Aquionics In-Line UV systems are self-cleaning and monitoring and can treat flows ranging from 50-13,000 gpm (i.e., 11- 2,955 $m^3 \cdot h^{-1}$). Minimal annual maintenance is required.

CHEMICAL BIOCIDE TREATMENT

PERACLEAN® OCEAN is a special biocide formulation based on peroxy acetic acid for ballast water treatment. It has excellent biocidal, virucidal and fungicidal properties at very low concentrations as well as good effectiveness on phytoplankton, zooplankton and other species found in the ballast water of ships. PERACLEAN® OCEAN is effective over a wide range of pH and temperatures. It is also readily biodegradable according to OECD test guidelines. Residual PERACLEAN® OCEAN in ballast water decomposes to water, acetic acid (e.g., vinegar) and oxygen. The half-life is in the range from 10 minutes to 24hrs depending on pH, salinity and temperature.

PERACLEAN® OCEAN is commercially available in 220 l drums, 1 m^3 IBCs or in bulk containers. PERACLEAN® OCEAN itself has a shelf life of > 1 year (< 10% loss in activity). Analytical methods to determine PERACLEAN® OCEAN in ballast water have been developed. Test strips for quick semi-quantitative analysis of residual PERACLEAN® OCEAN in ballast water are also available.

OZONE

Ozone is a very powerful oxidation agent. It is easily soluble in water and its ability to eliminate microorganisms that form pollutants is very good. Ozone can be produced photochemically with UV light or electrical discharges (corona discharges) in an oxygen-filled atmosphere. Ozone Technology, a leading producer of high quality ozone, uses the advantage of its patented technique to generate corona discharge to the maximum. Air or oxygen is channeled between two electrodes and then subjected to electronic discharges. The oxygen atoms are then partly atomized and from ozone when free oxygen molecules react with the oxygen molecules present.

CONCLUSIONS

After independent testing and reporting on performance has been completed, Maritime Solutions believes that the MSI System will be recognized as:

1. Completely scaleable and capable, as a result, to produce ballast water flow rates equal to the loading rates required by virtually all merchant and naval vessels.

2. Able to provide an economic benefit to ship owners/operators due to its removal of silt and sediment from the ballast water intake stream, obviating the need for periodic and expensive tank clean-out and insuring, all the while, the maximum cargo carrying capacity of the vessel.

3. Having a 'secondary' treatment stage, UV, chemical biocide or ozone subject to throughput capacity requirement, which is extremely effective and safe for both the crew and the environment. Ballast water 'residence' time associated with effective 'secondary' treatment is significantly reduced due to the system's removal of entrained silt and sediments and does not, as a result, hinder the ballasting process and the vessel's time schedule.

4. A compact size and energy efficiency of the complete two-stage system that allows for easy, cost effective, retrofit or installation and operation aboard both existing vessels and new building tonnage.

5. Environmental benefits accruing from the ship's ability to utilize the system at the time of every ballasting, with no subsequent impact or slowdown on other vessel activities or operations.

6. Having no crew, vessel, or cargo related safety (stability and trim, longitudinal hull strength, etc.) issues as are associated with the current practice of ballast water exchange.

7. Being virtually automatic, requiring minimal crew training and operating instructions. Owing to its design simplicity and quality of construction, the system requires only limited maintenance.

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MARITIME SOLUTIONS, INC.

MSI Ballast Water Treatment System

MSI TREATMENT SYSTEM
The Problem – Aquatic Nuisance Species

"The introduction of harmful aquatic organisms and pathogens to new environments, including via ships' ballast water, has been identified as one of the four greatest threats to the world's oceans."

Mr. William O'Neil, Secretary-General
International Maritime Organization
United Nations

MSI TREATMENT SYSTEM
The Problem – Aquatic Nuisance Species

"Introduced species are a growing and imminent threat to living marine resources in the United States. Hundreds of species arrive in U.S. waters from overseas each day, playing a game of ecological roulette with ecosystem and economic stability."

"Introduced Species in U.S. Coastal Waters"
Prepared for the Pew Oceans Commission, 2001
James T. Carlton, Ph.D.
Williams College and Mystic Seaport

MSI TREATMENT SYSTEM

Ballast Water – Facts and Figures

- 47,228 vessels in the world fleet use sea water for ballast, excluding tugs, fishing vessels, etc.
- 10-12 billion tons of ballast water are carried and discharged around the world each year
- Many thousands of different species of marine organisms may be carried in ballast water
- Severe impacts include the European Zebra Mussel, the North Pacific Seastar and Toxic dinoflagelattes, among many, many others

MSI TREATMENT SYSTEM

Ballast Water Management – Regulations

- World – At present some 14 countries have ballast water management regulations
- IMO – An international standard is expected and a convention signed in 2003
- U.S.A. – The Great Lakes and the Hudson River north of GW Bridge are regulated
- U.S. States – More than a dozen states have management regulations

MSI TREATMENT SYSTEM
Ballast Water Exchange (BWE)

The current shipboard practice:

- **BWE puts many ships, their crews, cargoes and the environment at risk due to changes in longitudinal hull-girder loading and/or transverse stability**

- **BWE achieves, variously, < 65 – 90 percent level of effectiveness in exchanging original ballast water, and minimal effectiveness in reducing retained silt and sediment**

MSI TREATMENT SYSTEM
Ballast Water Treatment (BWT)

To be accepted as an alternative to BWE:

- ◈ It must be safe
- ◈ It must be environmentally acceptable
- ◈ It must be effective
- ◈ It must be practical
- ◈ It must be cost-effective

Global Ballast Water Management Programme
International Maritime Organization
United Nations

MSI TREATMENT SYSTEM
Shipboard System Design Attributes

- Safe for the ship, crew and environment
- Effective treatment for all ballast water
- Crew friendly operation & maintenance
- Scaleable to all shipboard requirements
- Remove silt and sediment from water
- Energy efficient
- Cost-effective
- Compact

MSI TREATMENT SYSTEM
Two-Stage System Configuration

- **Stage One – mechanical system designed to remove silt, sediment and large marine organisms from the influent ballast water**
- **Stage Two – ultra violet (UV), chemical biocide or ozone technology for treatment of small organisms remaining in the 'clean' ballast water**

MSI TREATMENT SYSTEM

Shipboard System – U.S. Patents

- MSI Ballast Water Treatment System
- MST Microfugal® Separator

MSI TREATMENT SYSTEM
Treatment System Participants

- Aquionics, Inc.
- Degussa.
- Maritime Solutions Technology, Inc.
- Ozone Technology AB
- Sterling Fluid Systems (USA), Inc.
- Unitor AS
- Unnamed others

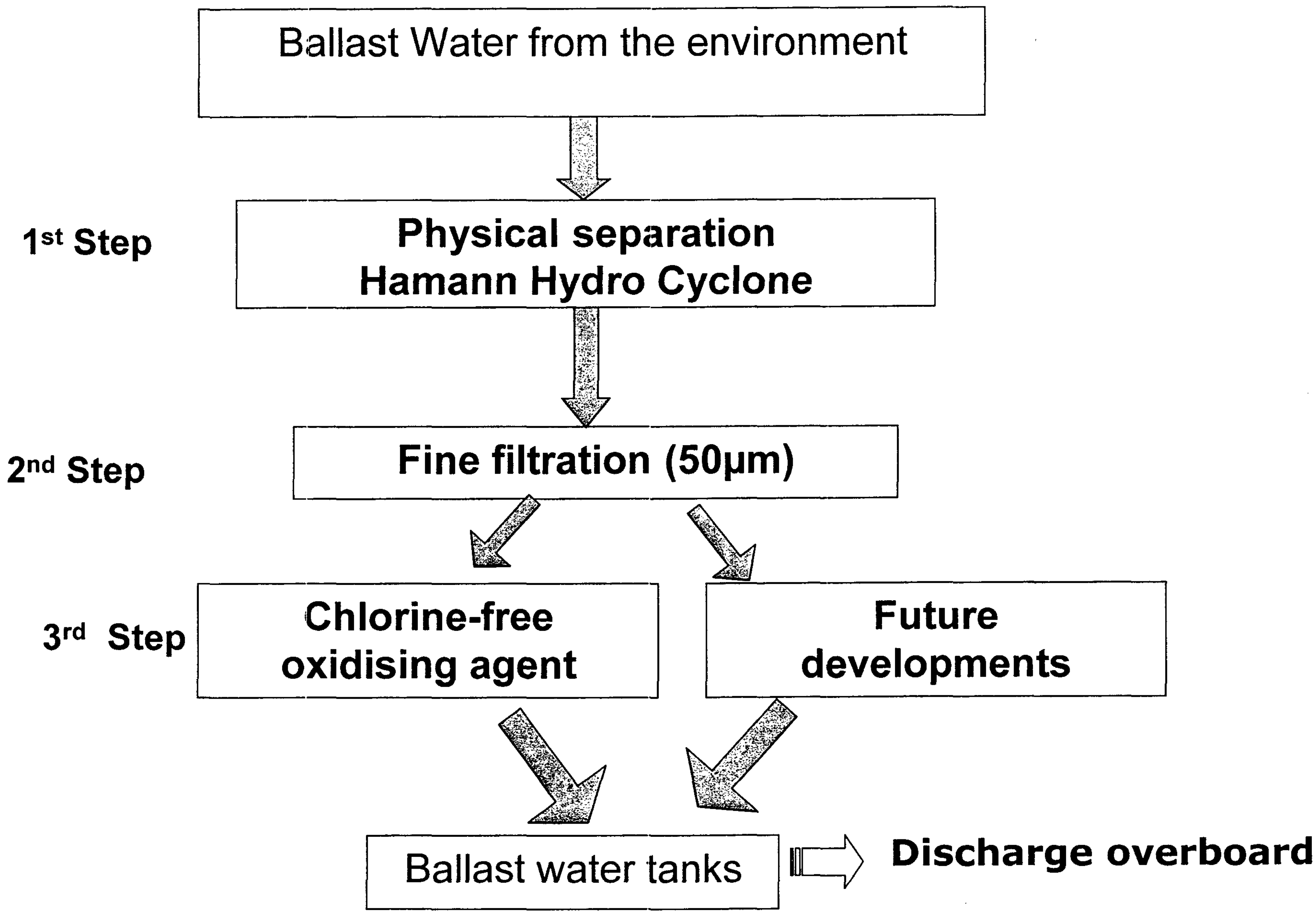
MSI TREATMENT SYSTEM
Challenges – Technical

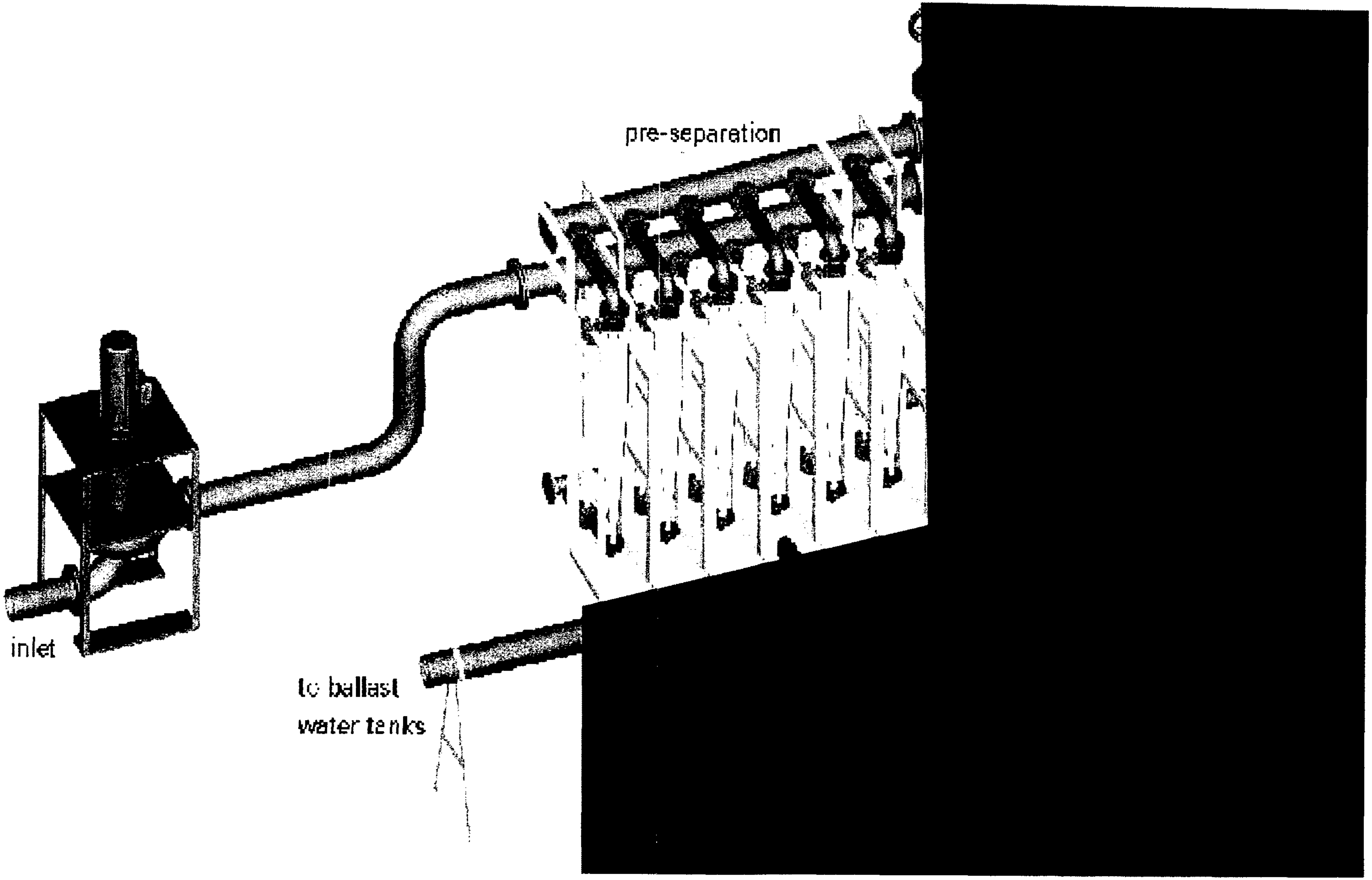
- Integrate Microfugal® Separator into the MSI System
- Complete shipboard testing program
- Develop complete range of high flow rate MSI Systems

BWT Hamann Wassertechnik and the ATS - Testing Ballast Water Treatment Options with Surrogate Organisms

Holger Hamann
Hamann Wassertechnik GmbH
Seevetal, Germany

The Hamann modular Ballast Water Treatment System





Hamann Modular Ballast Water Treatment System

The Hamann modular Ballast Water Treatment System

Description and Technical Requirements

Physical separation
Hamann Hydrocyclone

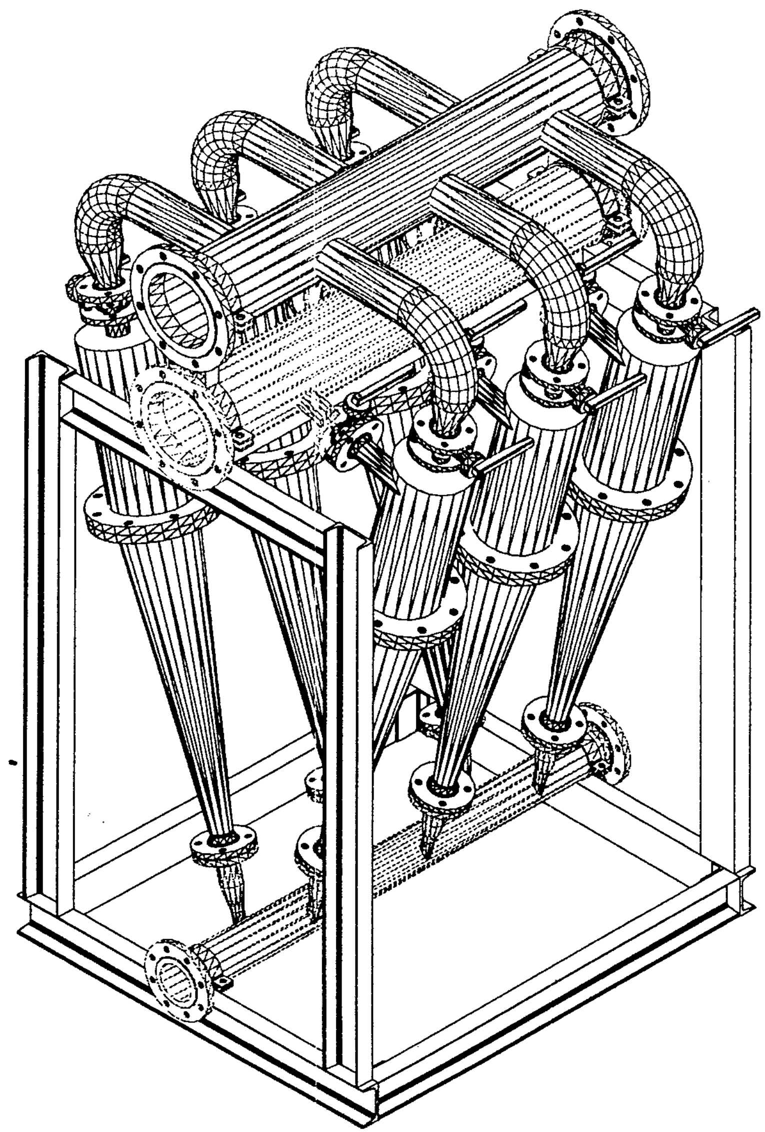
Specially designed for ballast water applications.

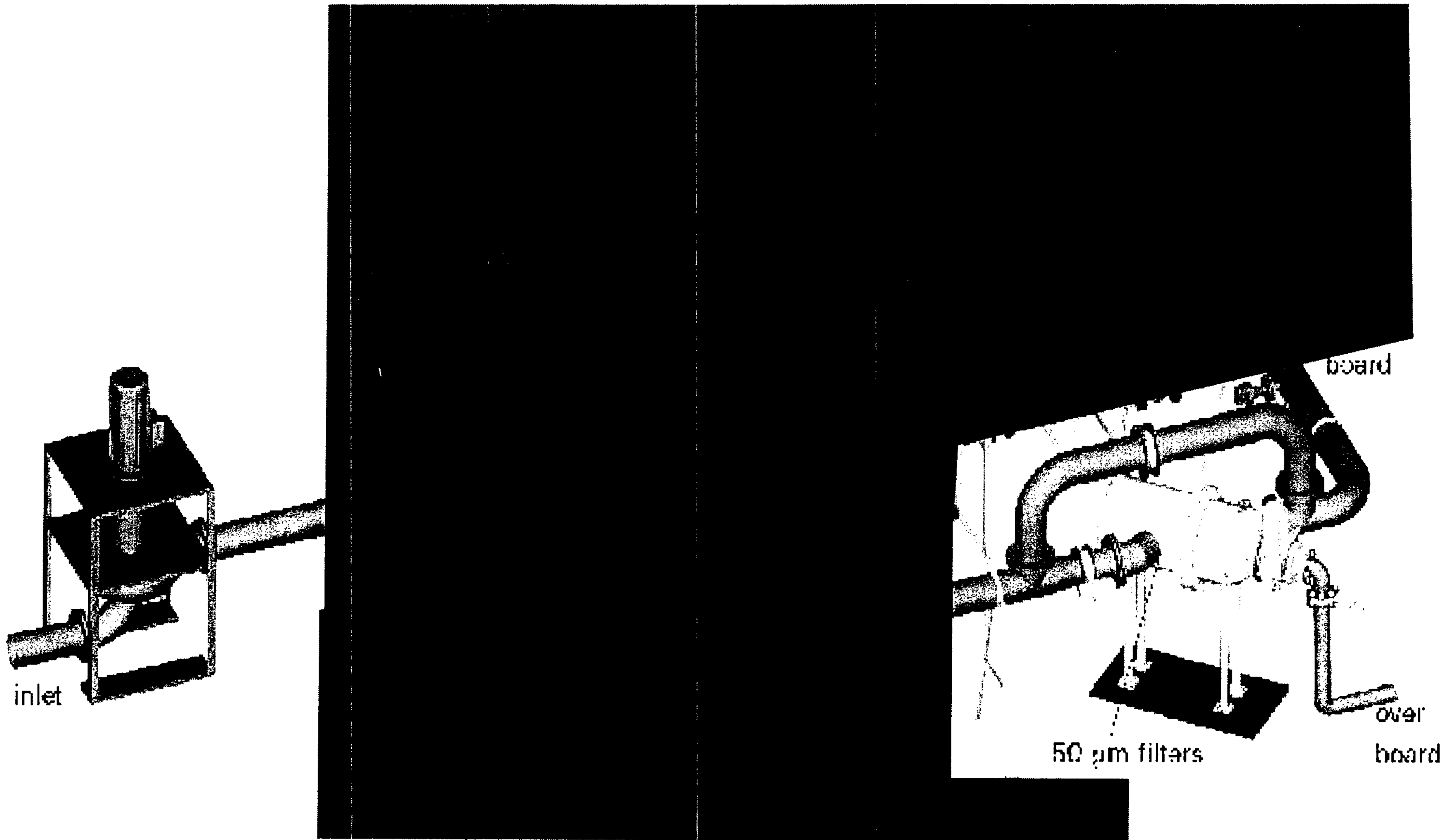
Significantly reduces the **sediment load** of the ballast water and **removes significant numbers** of **organisms**.

Small size of individual hydro cyclone allows installation on a single deck.

The number of hydro cyclones needed (35 m^3 to 45m^3/h each) depends on the flow rate of the ballast water pump.

Hamann Hydrocyclone six-pack



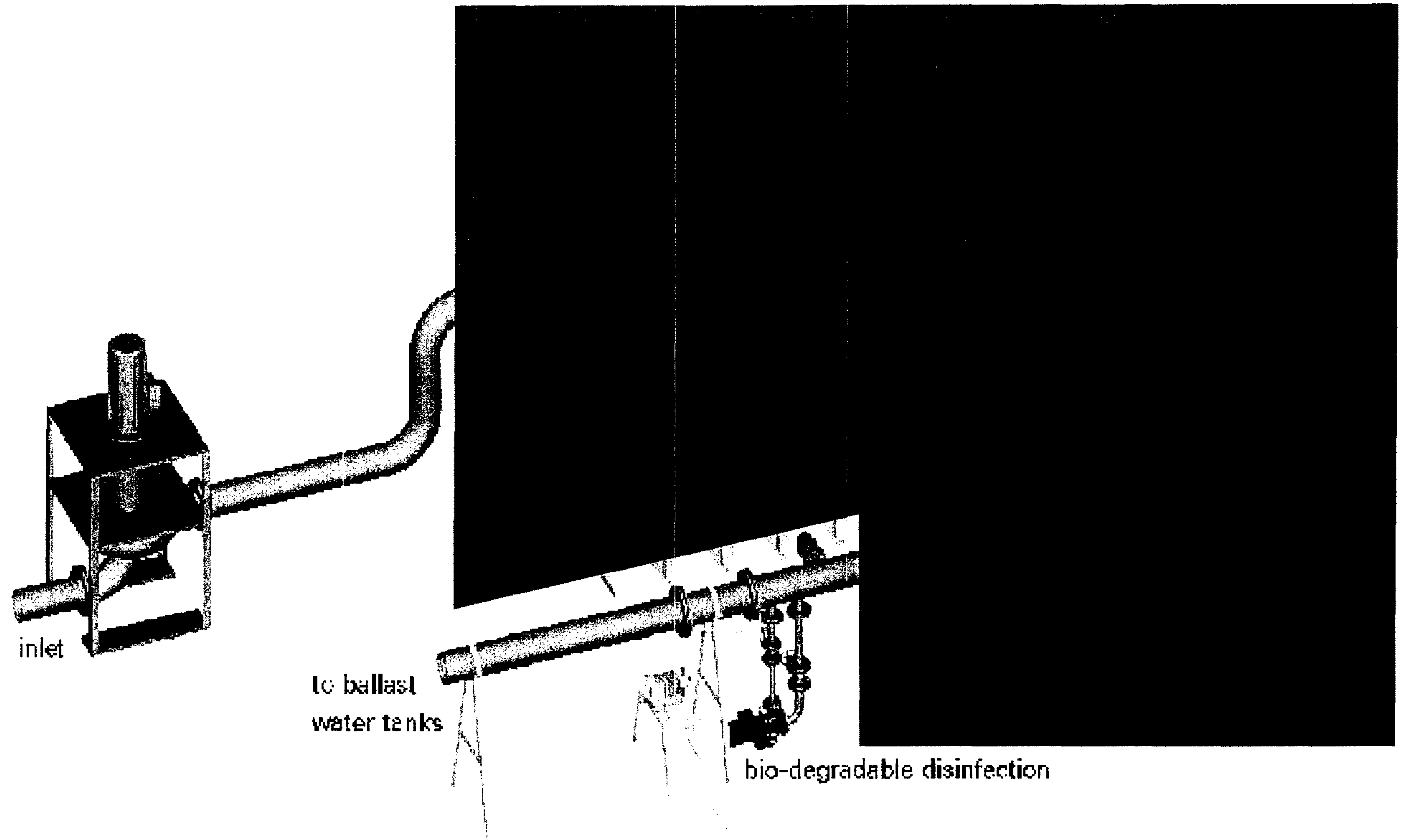


Hamann Modular Ballast Water Treatment System

Fine filter (50µm)

The optional fine filtration (50µm) has two functions:

1. It **removes** nearly all **organisms with a body length > 100µm**, which is one of the possible efficacy criteria for ballast water treatment.
2. It **increases** the **stress** imposed on the organisms present in the ballast water, resulting in **physical damage** of the organisms as well as an **increased sensitivities** towards the **chemical disinfection**.



Hamann Modular Ballast Water Treatment System

Disinfection
Oxidising agent

After the physical step, the ballast water is dosed with Peraclean®Ocean, a chlorine free oxidant that is fully bio-degradable. This will inactivate and / or kill those organisms that passed the physical separation.

Only 150 ppm of Peraclean®Ocean are needed, which is equivalent to 15 l per 100 m^3 of ballast water.

The Hamann modular Ballast Water Treatment System

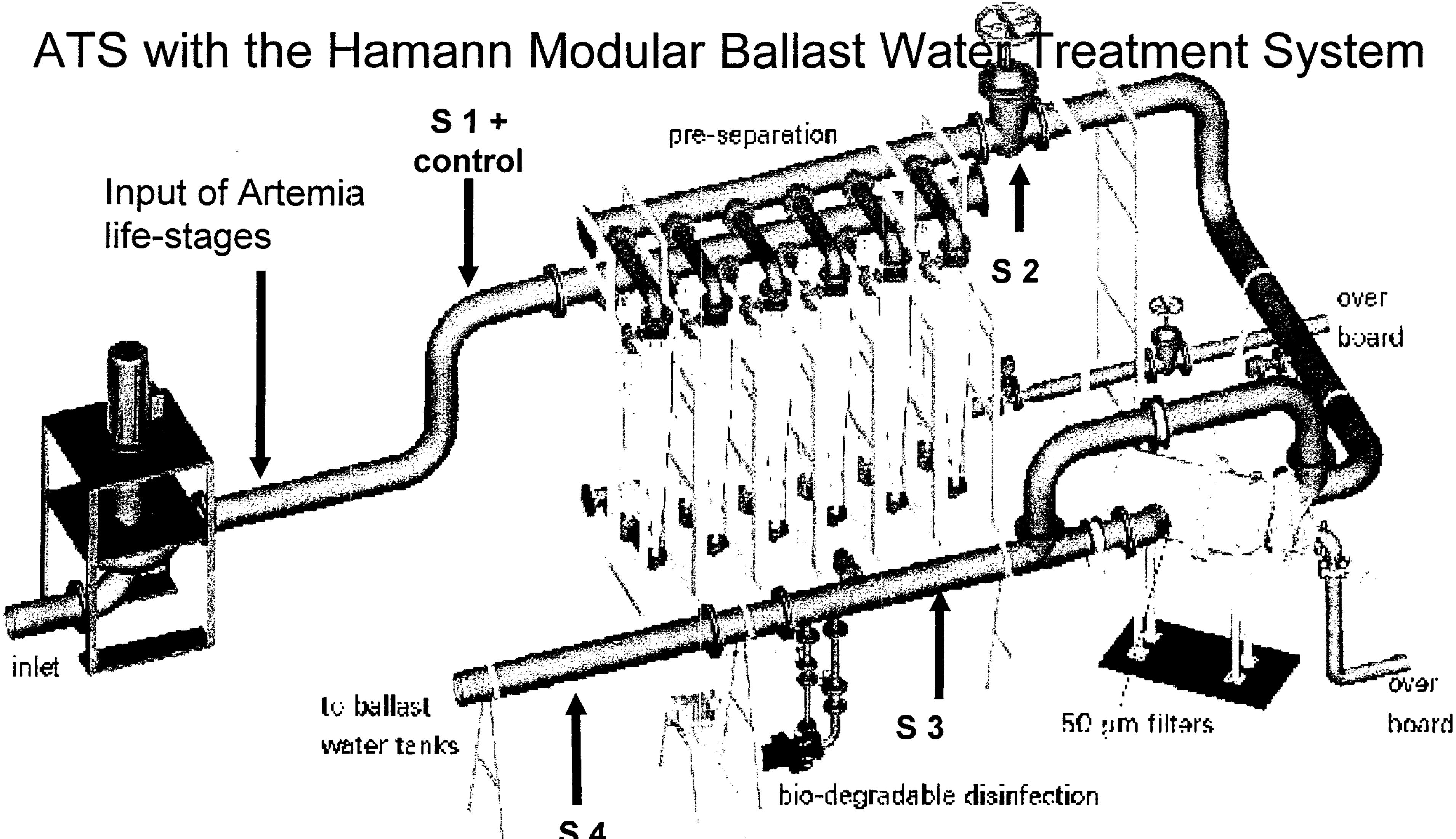
Test procedures

The Artemia Testing System (ATS) was used in the tests at full scale flow rates of 130 m^3/h to 200 m^3/h

The ATS can be applied as a surrogate for a wide range of organisms

The robust *Artemia* can be regarded as a worst case scenario for the assessment of the biological efficacy.

ATS with the Hamann Modular Ballast Water Treatment System



200 l of sample were collected at each sampling point (S1 to S4)

Duration of sampling = some 2 to 3 minutes

The Hamann modular BWT

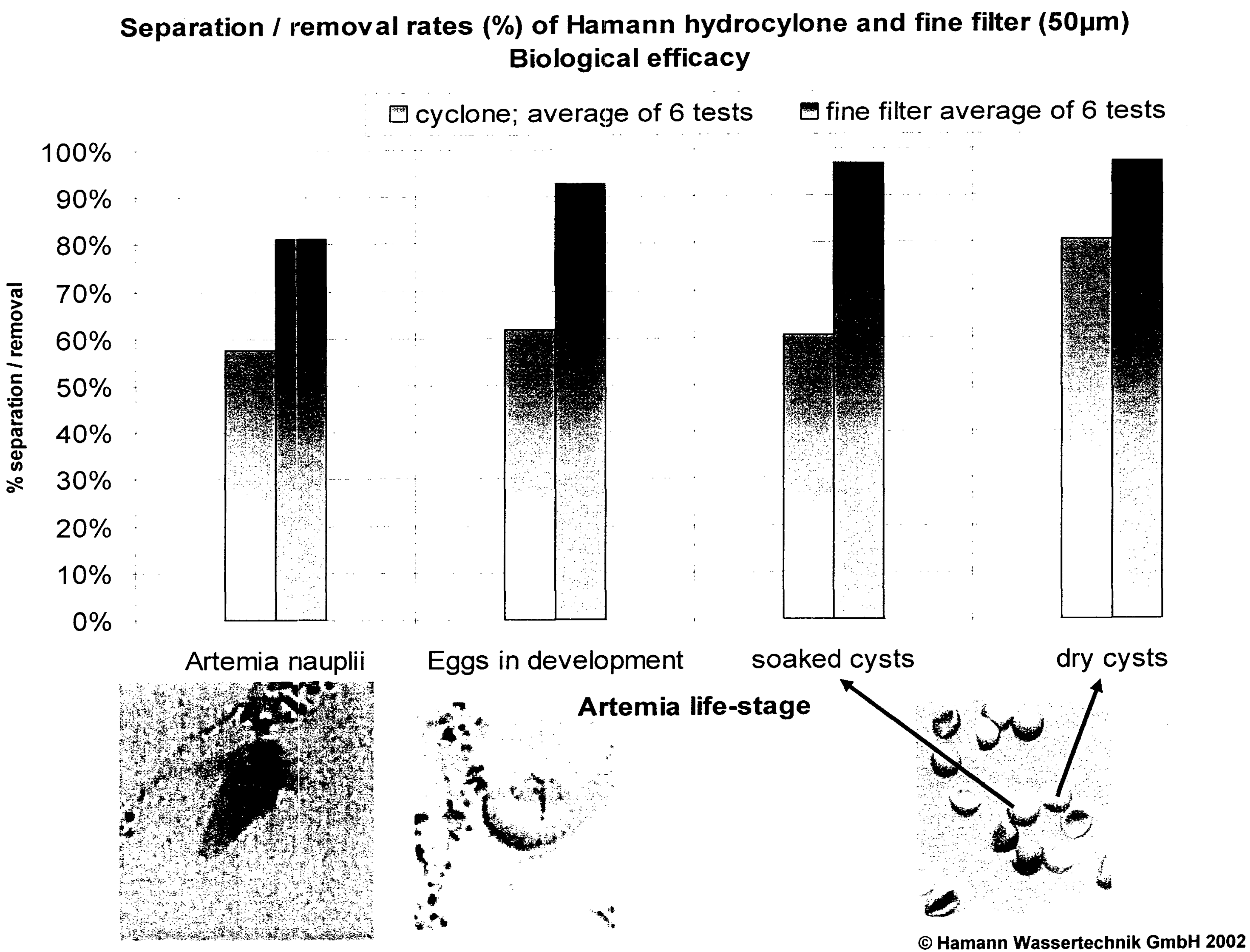
Test Results

The Hamann modular BWT – Test Results

- ✓ The treatment plant performed during the test cycles without mechanical problems, giving good continuous flow conditions at each of the testing sites.
- ✓ The biological efficacy was evaluated for each treatment step separately. The different qualities of the water at the testing sites had no influence on the biological efficacy.

The Hamann modular BWT – Test Results

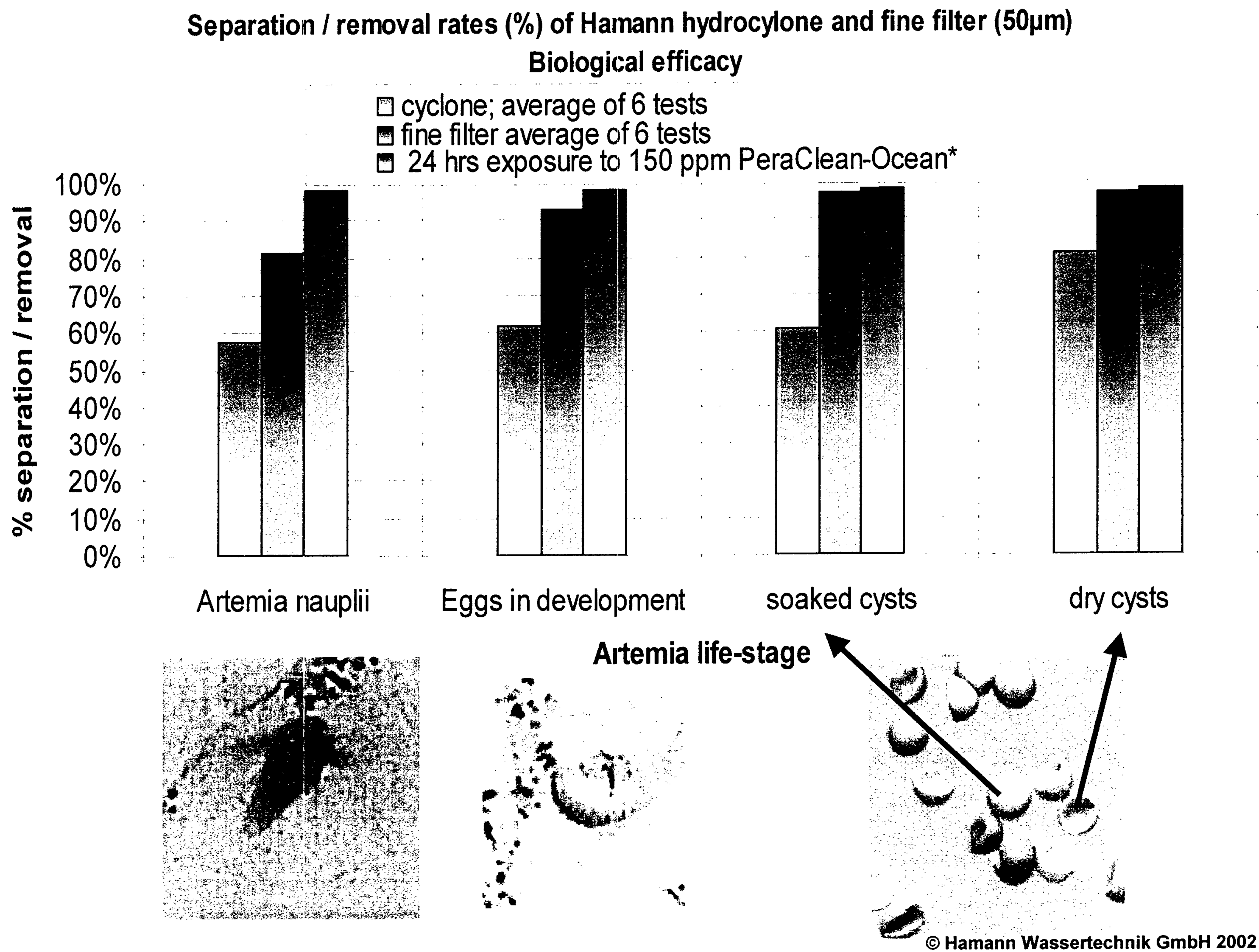
- ✓ According to the different sizes and physical properties of the test organisms, great differences occurred in the separation rates of the Hamann hydrocyclones and the 50µm filter.



Separation / removal rates (%) of Hamann hydrocylone and fine filter (50µm)
Biological efficacy
cyclone; average of 6 tests
fine filter average of 6 tests
% separation / removal
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Artemia nauplii
Eggs in development
soaked cysts
dry cysts
Artemia life-stage
© Hamann Wassertechnik GmbH 2002

The Hamann modular BWT – Test Results

After 24 hours of exposure time to 150 ppm of Peraclean® Ocean, no living organisms were detected in any of the samples.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20%
10%
0%
Artemia nauplii
Eggs in development
soaked cysts
dry cysts
Artemia life-stage
© Hamann Wassertechnik GmbH 2002

Conclusion

General aspects: The Hamann modular BWT addresses all of the following criteria:

- compliance with short term regulations that are currently discussed by IMO and options for upgrading to future requirements
- the type of ship and the individual ballast water management plan
- Space requirements (footprint of set-up)
- Risks involved: safety & handling, environmental risks (aquatic toxicity)

Current treatment modules

-Physical separation in two steps:
-Hamann Hydrocyclone
+ 50 µm fine filtration

Test results: removal of 97% and better of all organisms of > 100 µm in smallest dimension. 80 % and better of all organisms of < 100 µm in smallest dimension

Flow rate	Foot print cyclones row	Foot print cyclones V6-modules	Foot print filter 50µm
200 m^3/h	1.4 m^2	1.8 m^2	2.0 m^2
500 m^3/h	3.4 m^2	4.0 m^2	5.2 m^2
750 m^3/h	4.8 m^2	6.0 m^2	7.8 m^2
1000 m^3/h	6.2 m^2	8.0 m^2	10 m^2

Current treatment modules

-<u>Disinfection:</u>
-Chlorine free oxidising agent (Peraclean®Ocean)
- Dosage only 150 ppm

Test results: killing / inactivation of ALL organisms during the tests. No living organisms were detected after 24 hrs of exposure.

Only 15 l of Peraclean®Ocean are needed per each $100m^3$ of ballast water.

The Bremen Ballast Water Project

Presented

by

GAUSS, Institute for Environmental Protection and Safety in Shipping

www.gauss.org

GAUSS, Institute for Environmental Protection and Safety in Shipping

- GAUSS was founded in 1994
- Number of Employees: Presently 12

- Scope of Business:
  - Research and Development
  - Training
  - Transfer & Consulting

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Example of Projects

- **Research and Development**
  - Treatment of Black- and Grey Water
  - Treatment of Ballast Water
  - Environmental Impact of HSC
- **Training Courses**
  - Environmental Officer
  - ISPS
  - Cargo Securing
  - Advanced Oil- and Chemical Tanker
- **Transfer and Consulting**
  - Environmental Sound Shipping
  - Bonus Model to foster Quality Shipping
  - Implementation of Agenda 21 in Ports
  - Risk Analysis for Offshore Wind Farms

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The Bremen Ballast Water Project

Development and Construction of an Efficient and Marketable Ballast Water Treatment Plant

Funded by the

Senator of Building & Environment
Federal state of Bremen / Germany
(1. Phase)

BIS Bremerhavener Gesellschaft für
Investitionsförderung und Stadtentwicklung mbH
Bremerhaven / Germany
(2. Phase)

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Timeframe: September 2001 – August 2005 (?)

Project Partner:

- Motorenwerke Bremerhaven
- BW-Consult GbR.
- GAUSS gem. GmbH
- Alfred Wegener Institute
- Additional Industry Partner

Stiftung Alfred-Wegener-Institut
für Polar- und Meeresforschung
in der Helmholtz-Gemeinschaft

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Project Structure

1. Phase:

   Framework and Feasibility

   Completed

2. Phase:

   Research and Experiments on shore

   Prepared - Start July 2003

3. Phase:

   Prototyping and Service on board

   Planned for October 2004

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Investigations of 1. Phase

- Status of Ballast Water Legislation Worldwide
- General Biological Conditions of Ballast Water
- Impact of Introduced Species
- Technical Approaches and Options
- Possible System Components / Supplier
- Particular Constructive Requirements
- Market Situation and Feasibility
- Test Parameter and Standards

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Results of 1. Phase

- No Single Technique will achieve requirements
  - Combination of Techniques
- No Efficiency Standard
  - Several Proposals
    (IMO / GloBallast, MEPC-Submissions, ETV, IWACO...)
- No Treatment System Verification Standard
  - Methodology of Testing
  - Sampling
  - Biological Test Method
  - Several Proposals
    (MEPC-Submission, German Proposal, ETV...)

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Specifications

It is Essential to define:

- Plant Parameter
- Biological Test Method
- Physical- and Chemical Parameter of the Water

Results after Tests → Effectiveness Standard And Verification Standard

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Technical Options

- Approx. 30 Contacts to different Companies
- Consultation with 17 Companies
- Start with 10 – 12 Companies
- Comparison with existing Systems

Test -- Scheme

			1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	20
			Pre-Treatmentsystems / Filtration					[redacted]		Combination Pretreatment with Single-Stage Secondary Treatment							Combination Pretreatment with Two-Stage Secondary Treatment						
	Treatment Components	Test Series	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	20
	Pre-Treatment	**Place**																					
1	Hydrozyklon	Shore	X					[redacted]		X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	Separator	Supplier		X																			
3	Filter-System Type A	Shore			X			[redacted]															
4	Filter-System Type B	Shore				X			[redacted]	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Filter-System Type C	Shore					X																
	Secondary-Treatment																						
6	UV-System	Shore								X							X	X	X	X	X	X	X
	Electrochemical-Treatment																						
7	El.-Ch.-Treatm. System Type A	Lab									X						X						
8	El.-Ch.-Treatm. System Type B	Lab										X						X					
9	El.-Ch.-Treatm. System Type C	Lab											X						X				
	Miscellaneous-Treatment																						
10	Dosage of Chemicals	Lab												X						X			
11	Pressure Treatment	Shore													X						X		
13	Ultrasonic Treatment	Shore / Supplier														X						X	
12	Heat Treatment	Lab																					X
	Comparison with Complete Treatment Systems																						
14	Manufacturer A	Shore																					
15	Manufacturer B	Shore																					
16	Manufacturer C	Shore																					
17	Manufacturer D	Shore																					

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Biological Test Methods

Proposals of Biological Test Methods

- Artemia Testing System
- MARTOB Standard Sea Water (MARTOB Soup)
- ETV
- IMO / MEPC Submissions
- Natural Water / Sediments Samples

Evaluation Biological Test Methods

- **Disadvantages**

- Only one single organism → Restricted Informative
- Proposed organisms too large (Artemia, Benthic Larvae ...) → Removal by Filtration
- Proposed organisms can be toxic (Toxic algal bloom of Dinoflagellates) → Inapplicable

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Natural Water / Sediments Samples

- **Problematic**
  - Resting Stages / Cyst

- **Difficult to grow as Test Organism in large numbers**

Consequence → **Using of Natural Water / Sediment Samples for Tests**

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Evaluation of "Natural Water"- Method

- **Analysis difficult**
  - Samples pre- and after treatment
  - Grow out
  - Only specialised scientists
- **No Standard Method**
- **Control of standardised Methods**

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Standardisation in Germany

DIN ISO

- Initiated by GAUSS Standardisation Working Group
  "Behandlung von Ballastwasser"
  ("Treatment of Ballast Water")
  within German Standardisation Organisation DIN
  Normstelle für Schiffs- und Meeres Technik - NSMT

- Objectives
  - Definition of Standards to be met
  - Approval Standards of Ballast Water Systems
  - Verification of Ballast Water Discharge Quality

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Members of Standardisation Group

- Suppliers
- Shipyards
- Shipping Companies
- Classification Societies
- Authorities
- Institutes / Scientists / Universities
- Navy

- About 18 Members

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Ballast water treatment on-board of ships
Market potential and R&D requirements

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Texel, The Netherlands

Summary

In this paper, we provide an overview of the future needs for ballast water treatment systems on board of the worlds' shipping fleet. In our view, such systems should consist of a two-stage setup, involving a primary particle exclusion step followed by a secondary step, that kills the remaining living organisms. An important prerequisite of the treatment is, that the receiving ecosystem should not be damaged by discharged ballast water. Therefore the use of (toxic) chemicals for this purpose seems a risky way to go.

The minimum size of the organisms that should be separated from the seawater during the primary treatment should be in the order of 10 µm. A larger diameter of the particle will result in an incomplete removal of silt and clay particles and will not prevent the formation of a significant sediment layer acting as a seabottom providing shelter for living organisms in the ballast tanks. A secondary treatment step should kill the remaining organisms after primary treatment. These mainly involve part of the algal species responsible for harmful algal blooms, bacteria and viruses.

The performance of ballast water treatment equipment should in the future be monitored in an automated way. Flow-cytometry provides the best possibility to achieve this goal, sine it can be fully automated, and discriminate between living and dead cells.

A future global market potential has been estimated based on a relevant world fleet for ballast water management requirements of some 33,000 vessels (larger than 1,000 tonnes dwt) and a modal general cargo vessel of 12,000 tonnes dwt with a ballasting capacity in the range of 600 – 1,000 m3/h. This resulted in an annual market potential ranging from USD 225 million until USD 350 million for the period between adoption and ratification of the international convention. After ratification of the international convention this annual market potential will increase to a range from USD 700 million until USD 1,100 million.

Introduction

Ballast water has been subject to development of (inter)national legislation and to performing various studies for many years already.

One of the preliminary results is the "draft international convention for the control and management of ships' ballast water and sediments", which is expected to be adopted in 2004 by IMO.

Recent studies performed by Royal Haskoning looked into the possibilities and constraints of ballast water treatment on-board of ships and the global market potential for this equipment. The most relevant studies are "Application of ballast water treatment techniques on Dutch vessels (2001)", "Global market analysis of ballast water treatment technology (2001)" and "Ballast water treatment; full scale tests, strategies and techniques (2002, in co-operation with Royal Netherlands Institute for Sea Research - NIOZ)". This is intended to lead to full-scale tests of treatment equipment on-board of ships, which is currently in development by NIOZ and Royal Haskoning.

Ballast water: the problem

The use of (sea) water as ballast for the stability and trim of the vessel and to submerge the propeller is a necessity on one hand, but poses a risk of the movement of non-indigenous marine organisms between ecosystems on the other hand. This is considered today to be one of the most important threats to the stability of local ecosystems, and thereby biodiversity.

The size of organisms and sediment particles is a key factor and a classification basis in ballast water management, because it determines the effectiveness of ballast water treatment for their removal and because it is related to the techniques that should be applied to analyse for them. The natural range of organisms is very variable, and as an example the size classes of pelagic organisms are given in figure 1, indicating a wide range of size classes from < 1 µm until > 1000 µm.

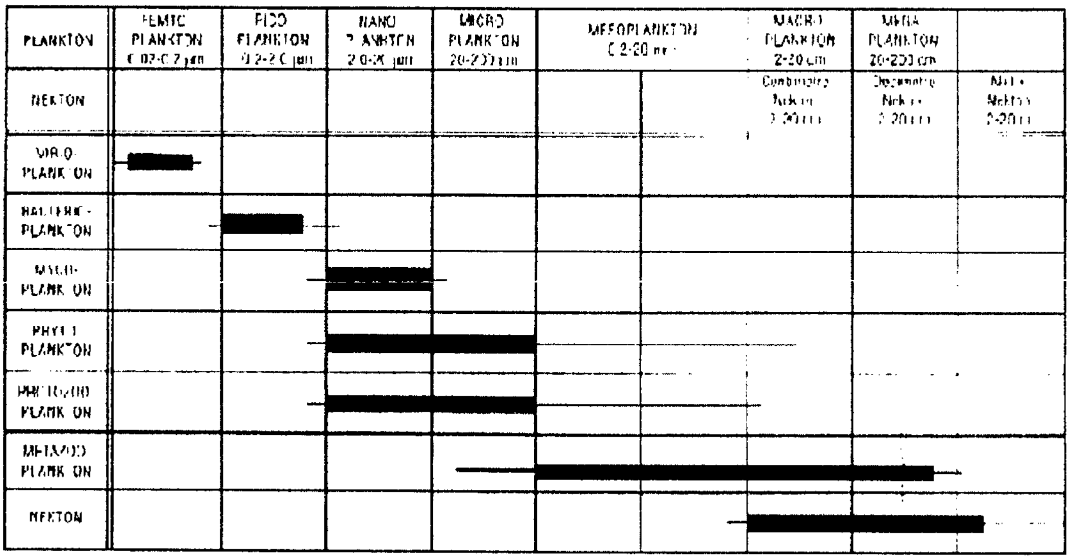


Figure 1:2 A grade scale for the size classification of pelagic organisms.

Fig. 1: Size classes of Pelagic organisms.

Besides marine organisms ballast water also contains sediment (sand and clay). Sediment in itself is not a problem in the sense as described above, although it reduces the maximum cargo weight to be loaded. But a stable sediment layer in a ballast tank provides a 'sea-bottom' and thereby a stable hide-out place for organisms when the ballast tank are emptied. Many organisms experience this a low-tide situation, and as a reaction they hide in the sediment, only to emerge again at the next flood, i.e. when the ballast tanks are filled again.
The size range of sediment plays an important role; clay particles are generally smaller than 2 µm and sand particles are generally larger than 50 µm. Depending on the location of intake of the ballast water, sediment can be easy or very difficult to remove. E.g. in certain NW European ports sediment mainly in the range of 10 – 50 µm (i.e. the silt fraction) is not an exception.

IMO requirements for ballast water management

The current draft international convention for the control and management of ships' ballast water and sediments (MEPC 49) gives, amongst others, guidelines for ballast water treatment. This includes a definition for acceptable ballast water, standards for ballast water management and the review of standards.
Acceptable ballast water should minimise the risk of harm to the environment, human health, property and resources. Ballast water should meet the following performance standard: zooplankton greater than 10 µm in size shall be less than 25 viable individuals per litre and phytoplankton greater than 10 µm in size shall be less than 200 viable cells per litre. It is also proposed to review the standards before the effective date in order to determine the availability of appropriate technologies.
The ballast water management systems should be safe in terms of the ship and its crew, environmentally acceptable (i.e. not causing more or greater environmental impacts than it solves), practicable (i.e. compatible with ships' design and operations), cost effective (i.e. economical) and biological effective in terms of removing, or otherwise rendering inactive harmful aquatic organisms and pathogens in ballast water.

Ballast water treatment options and restrictions

In theory ballast water can be treated on-board of the ship or in a land-based facility. This paper will focus on on-board treatment only.

The treatment of ballast water can be performed during the intake or discharge of ballast water, and during the voyage. Each option has its own advantages and disadvantages and the choice in favour of an option is

also dependent on the type/size of the marine organisms and sediment and the treatment equipment to be used.
Treatment during intake of the ballast water has of course the advantage to prevent organisms and sediment to enter the ballast tanks in the first place, but the required equipment will be relatively large. It has also been proven, since a hundred percent prevention and/or killing is not possible, that some organisms even at a low initial concentration are able to increase in numbers during the voyage, while others will die. This indicates that treatment during intake alone will not be sufficient.
Treatment during discharge has the advantage that organisms are prevented to enter the threatened marine environment, but this option also requires relatively large equipment. Another negative aspect of this option is that the removed and/or killed organisms and sediment will either built up in the ballast tanks or have to be given off as waste in the respective ports.
Treatment during the voyage requires fairly small equipment, because of the time available for treatment. On the other hand there is no guarantee that all ballast water (including organisms and sediment) will be treated during circulation over the ballast tanks. mainly because organisms and sediment has a tendency to settle during the voyage. Also the removed and/or killed organisms and sediment will either built up in the ballast tanks or will produce additional waste.
This all indicates that treatment at one moment is not enough. Because the required equipment for treatment during intake and discharge are of similar capacity, this seems to be the most likely combination.

The ship itself also gives a set of restrictions to the treatment equipment because of its design characteristics and operating circumstances, which might prevent well-proven land-based equipment to be installed on-board a ship without modifications.
The restrictions due to the ships' design are related mainly to the available space and specific ballast water piping configuration on-board the ship. The main operating constraints relate to the changing atmospheric conditions during the voyages, the highly corrosive atmosphere at sea and the limited availability of crewmembers to operate the treatment equipment.

Ballast water treatment equipment

The treatment of ballast water can be both the removal of marine organisms and sediment and the killing of the marine organisms.
Based on the characteristics/sizes of the organisms and sediment and the possibilities of the treatment equipment, it is not likely that one type of equipment will cure the problem sufficiently. This will result in the necessity of a combination of techniques to cure the problem to the maximum extend possible; this will be explained below. The effectiveness of each technique will not be discussed.

Techniques to remove the organisms and sediment from seawater include filtration, separation, (hydro) cyclonation and centrifugation. These techniques are all based on physical properties, like particle size and specific weight.. The smaller the particles and the smaller the specific gravity differences, the more difficult it becomes to remove the particles from the water. Very small particles (< appr. 10 µm) will be very difficult to remove. Based on the given size distribution of both organisms and sediment, it is not unlikely that this will be the case. Also some organisms consist mainly of water and consequently have almost the same specific gravity as water, which will decrease the efficency of especially hydrocyclonation and centrifugation

Since the application of the above mentioned primary techniques cannot be expected to result in ballast water of the required quality, secondary techniques that kill the organisms are necessary. Examples that have been applied in ballast water treatment are UV-irradiation, heat treatment, chemical treatment, ultrasonic treatment, and biological treatment. For all these techniques, the actual contacting or reaching of the organisms to be killed is crucial. Without primary -treatment, this will be merely impossible because of the presence of high concentrations of suspended sediment and the possibilities of the organisms to "hide", from the mortal secondary treatment.

The above justifies the statement that a combination of of primary and secondary treatment techniques will be required. In the first place the sediment and larger organisms should be removed as much as possible, to allow for a high efficiency of the secondary treatment meant to kill the remaining organisms. These will mainly be of a size below 10 um, and involve (the cysts of) algae contribution to harmful algal blooms, bacteria, and virusses.
Promising combinations of techniques include filtration and hydrocyclones as the primary treatment, followed by UV-irradiation as secondary treatment. Other combinations are also considered, but the investigations are currently in a much earlier phase.

A well-designed ballast water treatment system will contain more than just the equipment to remove and kill the organisms and sediment. Although the system will be type-approved and as such will not require prove of effectiveness by analysis of samples every journey, a sampling system will be required for random checks in harbours or for monitoring the equipment by the crew during the journey. Because of the type approval of the system, it requires an independent, automated control and register device that will prove the proper use of the system.

For the measurement techniques, a purpose-oriented adaptation of flow-cytometry is promising for the realisation of an automated measurement of ranges of particle sizes and forms present in ballast water before and directly after treatment, and during ballast water discharge at the end of a journey. For this purpose, automated equipment should be developed, which allows monitoring of the performance of the installed ballast water treatment system and which can also be used by the responsible authorities. The more elaborate, research-oriented forms can also discriminate between life and dead particles.

Ballast water treatment equipment: market potential

A study (Royal Haskoning, 2001) was performed to estimate the market potential for ballast water treatment equipment. This study used a three-step approach:
?? Step 1: defining the relevant part of the world fleet
?? Step 2: determine the "qualified available market"
?? Step 3: predict the future market behaviour
This study made use of the data of the world fleet, but based its qualitative analysis on information from Dutch ship owners.

Step 1: defining the relevant part of the world fleet
In 2001 some 91,000 vessels were registered with Lloyds. Part of the registered vessel types does not use seawater as ballast, or return always to the same port. Examples of such vessels are tugs, lighthouse vessels, fishing vessels etc. After excluding these vessels a number of appr. 47,000 vessels remains. Besides the type of vessel, also the area of operation will determine whether a vessel will need to comply to ballast water regulations. As a measure to determine whether a vessel makes long voyages (i.e. international or intercontinental trade) the vessel size was used. Most of the world fleet is actually quite small (see figure 2). In the study it was concluded that all vessels under 1000 tonnes dead-weight probably have regional modes of operation. Excluding also these category of vessels yields an estimate of about 33,000 vessels that will in some way face regulations on ballast water management.

Step 2: determine the "qualified available market"
It was assumed that after the adoption of the international convention (expected in 2004) the main driving force for installing treatment equipment, during the first 5 years, would be unilateral legislation based on this convention. Ship owners with sufficient awareness and financial means were selected to be the short-term market (the first 5 years); this was based on the 52 high-income countries. The ship owner can either consider retrofitting or phasing out the vessel .
The age-distribution of the world fleet is important to determine the expected amount of new buildings in the future, and the number of vessels on which retrofit will be likely. Based on expert opinions, an age of 10 years (dependent on trades, vessel types, ship owner) was deemed the maximum age on which a vessel may still be considered for retrofitting ballast water treatment equipment.

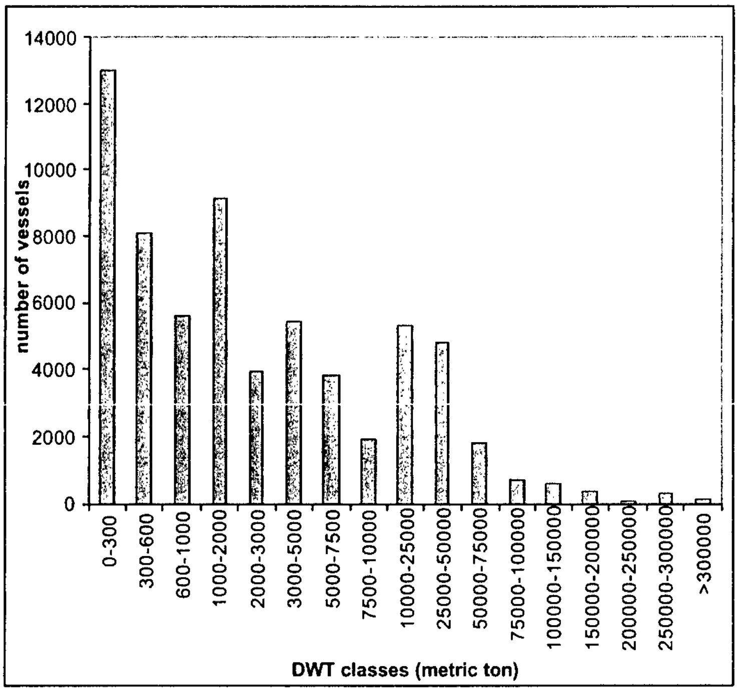


Figure 2: distribution of dead-weight in the world fleet

These analyses resulted in an estimate of appr. 675 vessels to be retrofitted and appr. 450 to be newly built as replacement for old ships per annum for the short-term market.

<u>Step 3: predict the future market behaviour</u>
After ratification of the convention (expected in 2009?), much more ship owners will be obliged to either retrofit existing vessels or phase out and replace the vessel. The analysis resulted in an estimate of appr. 2,400 vessels to be retrofitted and appr. 1,050 to be newly built per annum for the mid-term market (after 5 years until all existing vessels have been retrofitted). In the long-term the market will mainly consist of new-builts only.

<u>Potential market prediction</u>
Based on the analysis of the Lloyds' register, the modal vessel is probably a general cargo vessel of 12,000 tonnes dead-weight. According to a survey for the Royal Netherlands Association of Shipowners (KVNR), this coincides with approximately 4000 tonnes ballast capacity, and a ballasting capacity of 600-1,000 m3/h.

Data from suppliers of treatment equipment, provided cost estimates of USD 200,000 (lower estimate of 600 m3/h) until USD 310,000 (higher estimate of 1,000 m3/h) per vessel for the modal vessel.
For the short-term period (2004 – 2009) the annual turnover is estimated to be in the range of USD 225 million until 350 million. After ratification of the convention the potential annual turnover will increase and is estimated to be in the range of USD 700 million until 1,100 million. The long-term annual turnover is estimated to be in the range of USD 200 million until 325 million.

These estimates of course are subject to a number of uncertainties and constraints. Firstly the actual adoption and ratification of the convention is still uncertain and this will be the main determining factor. Secondly the appropriate treatment technologies are under development and so far it is not clear which technologies can and will be used in the future. A last, but not least, aspect is the market penetration of the equipment suppliers, which will require a thorough marketing strategy.

Ballast water treatment full scale on-board testing

Before on-board test on commercial ships can be performed, land-based and controlled sea borne (pilot) tests in a research environment (preferably a research vessel) are required to prevent major setbacks .
The test program, which is being developed by the NIOZ and Royal Haskoning in co-operation with e.g. shipowners and equipment suppliers, includes three main parts, which are (1) a land-based pilot test close to

NIOZ, (2) a controlled pilot test on the NIOZ research vessel and (3) a full-scale test on-board of a commercial vessel.

This test program will investigate different treatment options and develop at the same time protocols for sampling and analysis. The sampling technique will also require modifications to the currently available sampling systems, which will be part of the project.

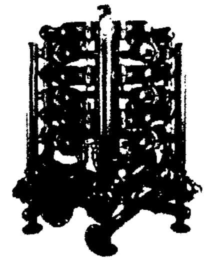
It is also envisaged as being important to cover all seasons of the year, because of the variations in presence and absence of the relevant organisms over the year.

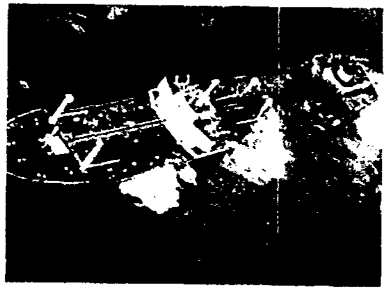
BALLAST WATER TREATMENT

ON-BOARD OF SHIPS

MARKET POTENTIAL

R&D REQUIREMENTS





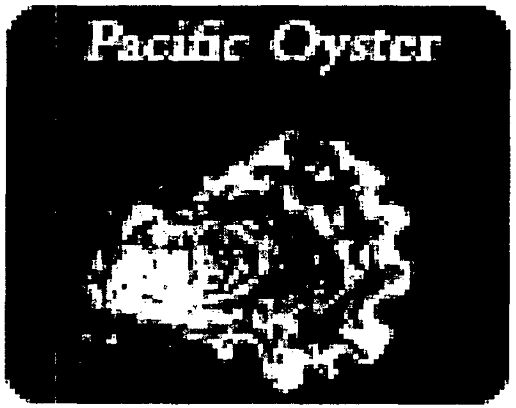
Royal Haskoning: Han van Niekerk and Leo Brouwer

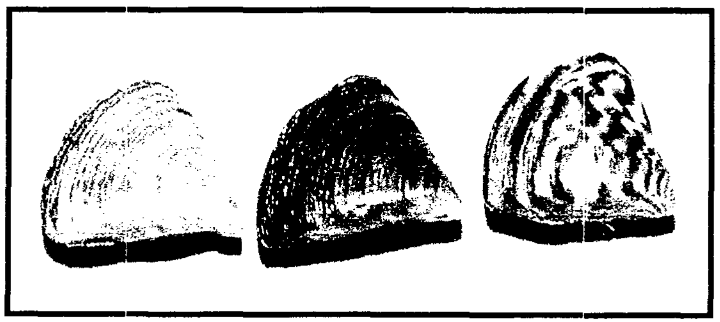
NIOZ: Jan Boon, Marcel Veldhuis and Cato ten Hallers-Tjabbes

1

Ballast water - the problem

"Being in the wrong place"





2

What is really the problem?

Who is the enemy?

"organisms"

What is hiding the enemy?

"sediment"

What are we dealing with?

" a Trojan Horse"

NIOZ

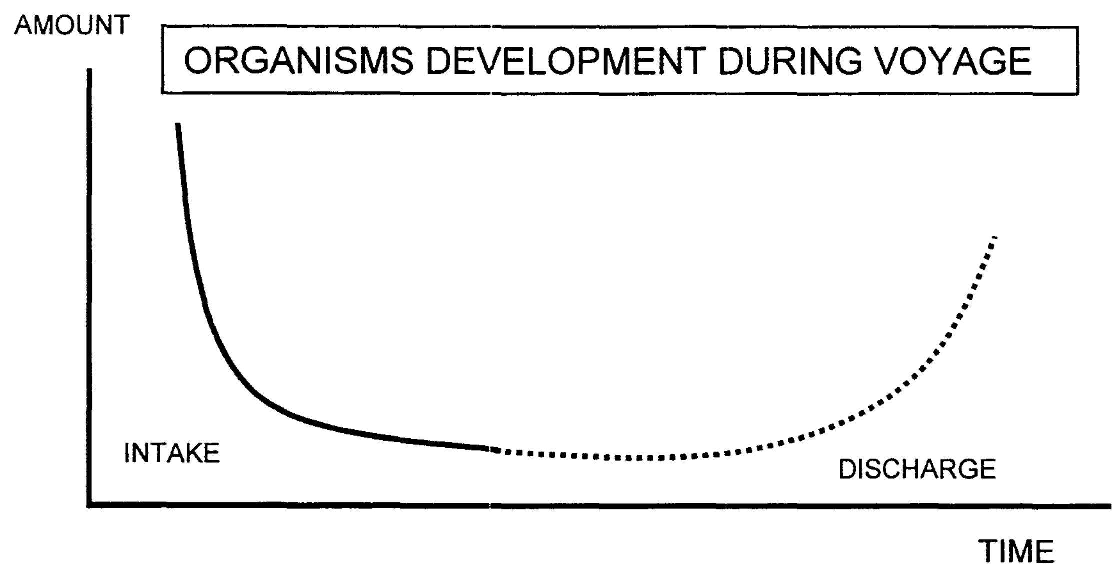
3

IMO standards (proposed for MEPC49)

- Zooplankton > 10 µm: less than 25 viable individuals per litre
- Phytoplankton > 10 µm: less than 200 viable cells per litre
- In addition to this:
  - safe
  - environmental acceptable
  - practicable
  - cost effective
  - biological effective

When to treat ballast water?

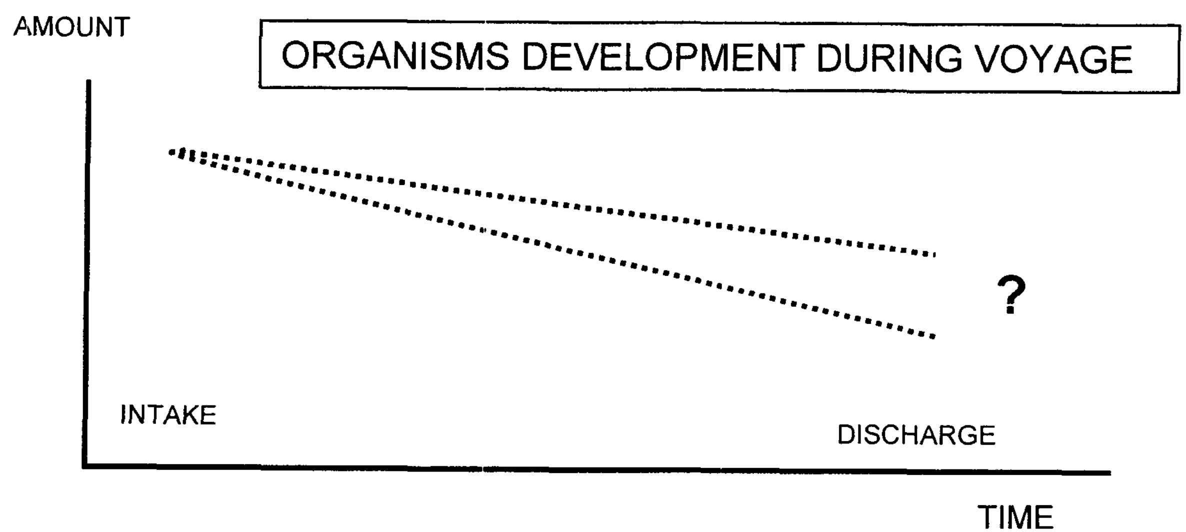
- During intake?
  - Prevent organisms and sediment to enter ship
  - Large equipment
  - Risk of increase during the voyage



5

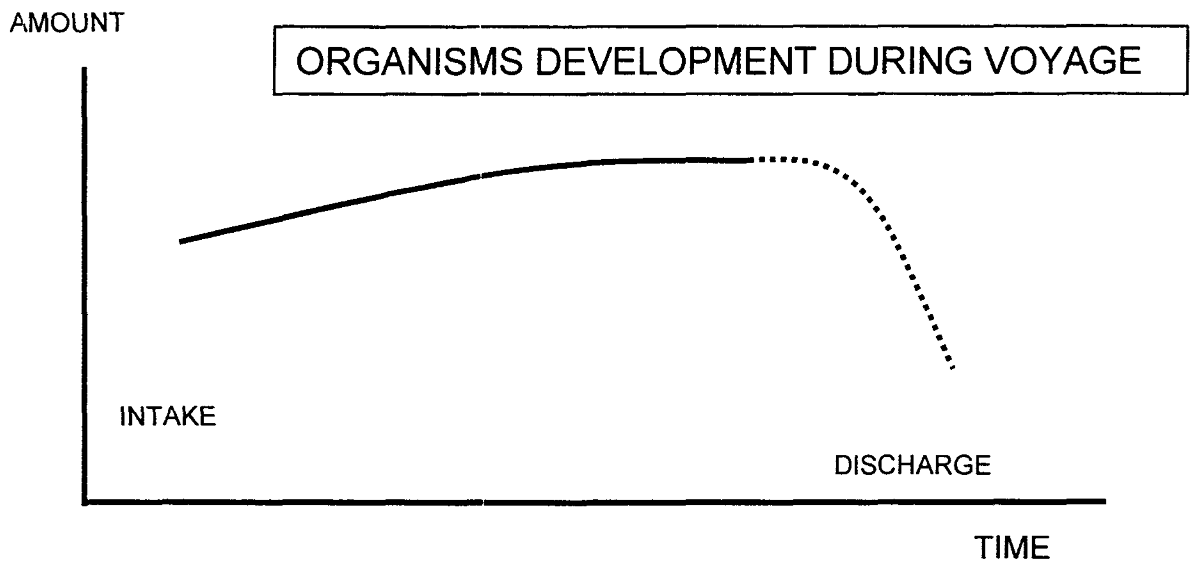
When to treat ballast water?

- During the voyage?
  - Organisms and sediment will enter the ship
  - Small equipment
  - Risk of not reaching all of the organisms
  - The sediment is an excellent breeding ground
  - Production of additional waste



When to treat ballast water?

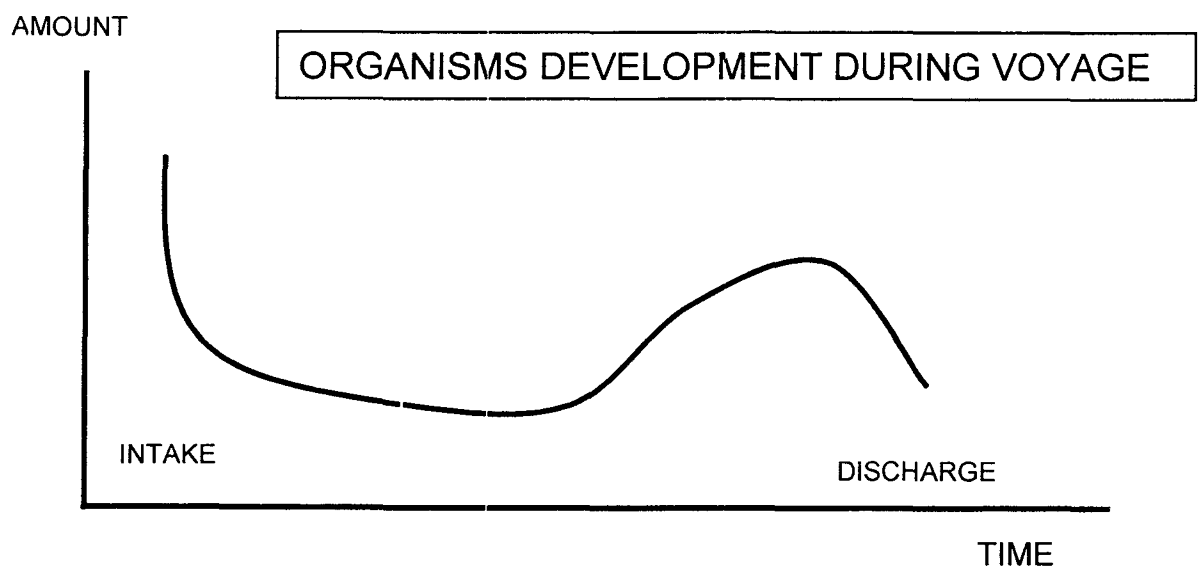
- During discharge?
  - Organisms are prevented to enter the threatened environment
  - Large equipment
  - Ballast tanks become a breeding ground
  - Additional waste



7

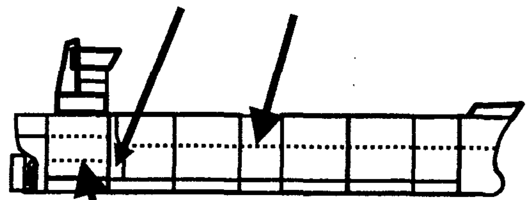
When to treat ballast water?

- During intake and discharge!!
  - Prevent organisms and sediment to enter ship
  - Large equipment
  - The increase during the voyage is undone during the discharge treatment

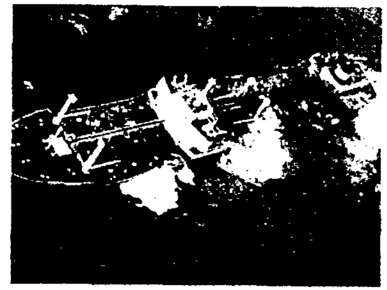


The ships' restrictions

- Available space



- Changing atmospheric conditions



- Corrosive environment

- availability of crewmembers

9

BWT equipment requirements

- Remove sediment & organisms:
  - relatively large organisms
  - 10 µm seems to be the lower target:
    - IMO standard
    - dominating sediment range NEW ports
  - Concentration will vary a lot
- Kill the remaining organisms:
  - different organisms require different treatment
  - preventing: “the remedy is worse than the disease”
- Flexibility:
  - size distribution
  - concentration
  - types of organisms

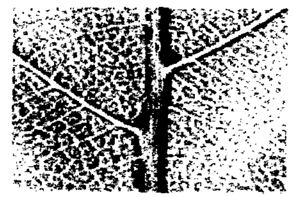
NIOZ

Removal and killing - theses

(1) If we are able to remove the sediment, then …

- the majority of the problem will be removed
- killing the remaining organisms will be childs' play.

==> Problem will be solved



(2) If we are **not** able to remove the sediment, then …

- killing of the remaining organisms will be obstructed
- killing will become very difficult at very high costs

==> Problem will **not** be solved

NIOZ

BWT equipment - relevant world fleet

- In 2001: 91,000 vessels (worldfleet)

→ Exclude:
  - ships that does not use ballast water
  - ships that return to the same port

- Remaining: 47,000 vessels

→ Exclude:
  - all vessel smaller than 1,000 tonnes DWT

- Remaining: 33,000 vessels relevant to ballast water management

NIOZ

BWT equipment - qualified available market

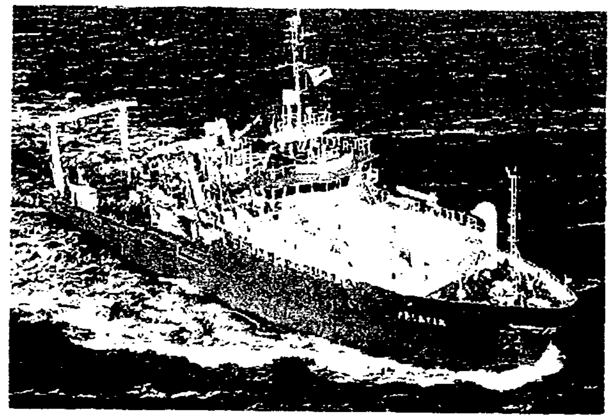
- Adoption IMO convention in 2004:
  - unilateral legislation based on convention
  - shipowners: awareness and financial means (52 high-income countries)
- Ratification IMO convention in 2009:
  - convention will be global legislation
  - more shipowners are obliged to comply
- Retrofitting: age < 10 years
- The modal ship for this investigation:
  - general cargo ship of 12,000 tonnes DWT
  - ballast water: 4,000 tonnes; 600-1,200 m3/hr
- Ballast water treatment equipment: k$ 200-310

BWT equipment - market potential

Period (million $/yr)	2004-2009	2009-+	Long term
Retrofitting	135 – 210	480 – 760	
New-built	90 -- 140	220 – 340	200 – 325
Total	225 - 350	700 – 1,100	200 - 325

Full scale test in The Netherlands

- Land-based tests
- Pilot tests on a research vessels (NIOZ - Palagia)
- Full scale tests on commercial ships
- The tests will include:
  - removal of sediment
  - killing organisms
  - making use of available equipment
  - all seasons
  - sampling system
  - measurement techniques



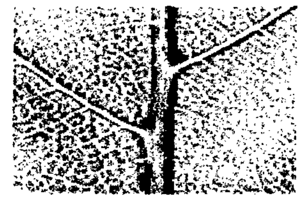
NIOZ

Summary

- "The Trojan horse"

  - Treatment during intake and discharge

- Removing the sediment is crucial



  - There is a huge future market

MORE -- BETTER -- SOONER

16

Presented at the International Conference and Exhibition on
Ballast Water and Waste Water Treatment Aboard Ships and in Ports
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Discussion of the Concept of a Marine Testing Board for Certification of Ballast Water Treatment Technologies

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Abstract

The International Maritime Organization's (IMO) proposed regulation of discharged ballast water has brought several issues to the forefront. An immediate concern is the need for an international organization and system to evaluate and certify the performance of the plethora of unknown and new ballast water treatment ("control") technologies. Exhibits at recent conferences have demonstrated high levels of inventiveness and diversity in new technologies that may create a multitude of problems for shipowners making purchasing decisions from lists of needed technologies that range and vary significantly in costs and effectiveness and lack third party-neutral validation or certification. Worse, standardized performance data is not available due to a lack of an international testing infrastructure and development of standardized long-term testing and assessments protocols to certify that a technology meets IMO international regulations.

This paper outlines and updates the concept for the development of an independent, international **Marine Testing Board (MTB)** as first proposed by Champ (2002a, b), funded by shipowners, regulators, and interested parties with the endorsement of national and international regulatory bodies and environmental organizations for: (1) the development of standardized international performance protocols, (2) full-scale field-testing (aboard a ship), and (3) "*Certification of Ballast Water Treatment Technologies*". Shipowners have an interest in supporting the development of international performance standards and the certification of ballast water treatment technologies to provide them with diverse and competitive products in the marketplace.

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INTRODUCTION

Varying national and international environmental regulations can present formidable barriers for market entry for new technologies. Both IMO and the shipping industry have identified the need for a third party, independent, and independent funded neutral organization with the special expertise to:

- Develop international performance standards and testing protocols for certification of ballast water treatment technologies, and
- To manage performance testing and the certification of ballast water treatment technologies.

The shipping industry must ensure that multiple efforts are underway to create a significant number of diverse ballast water treatment technologies to create a high degree of competitiveness (and competition in the marketplace) or the industry will pay dearly for unproven technologies as was pointed out in Champ (1999; 2000a) for development of antifouling marine paints. Leveling the playing field and maximizing the entry into the marketplace is key to developing competitive new technologies. Establishing an effective MTB will assist in removing barriers to market entry and stimulating competition.

The purpose of this paper is to:

- Discuss the need and the concept for the proposed MTB.
- Delineate the organization, structure, and function of the MTB.

The promotion of new ballast water treatment technologies is a genuine public policy concern because they are factored into the price that the public pays for vessel-shipped common goods, food, energy, etc. One only needs to lightly read Claudi and Mackie's (1994) book on the introduction, monitoring and control of the Zebra Mussel in North America to fully appreciate the scope of this problem.

For a national regulatory policy to support the creation of high technology products, the policy must include the promotion of continued research and development to push these technologies towards additional refinements that enhance their environmental attributes and improve competitiveness and competition in the global marketplace.

Some may ask, "Why not let market forces alone drive the development of these technologies?" Though this is a laudable goal, uneven environmental regulation (regulated versus non-regulated nations) in global markets defeats the driving forces in the marketplace for better products (supply and demand) by altering the decision-models. The shipping industry has been supportive of IMO, because it would rather be regulated by one international regulation that all in the industry are subject to rather than facing varying national regulations.

International Legal Regime for Ballast Water Treatment

All of the approaches recommended under the current IMO guidelines for ballast water treatment are subject to limitations. Reballasting at sea [as a ballast water treatment technology] is currently the best-available risk minimization measure to control the transport and introduction of ballast water transported invasive species, but is subject to serious ship-safety limits. Even when ships at sea can fully implement reballasting at sea, this technique however is less than 100% effective in removing organisms from ballast water (MEPC 48/2)

In recognition of these limitations of the present IMO voluntary guidelines, and the current lack of a totally effective ballast water treatment solution and the serious threats still posed by the introduction of invasive marine species, IMO member countries have agreed to develop a mandatory international legal regime in the future to regulate and treat ballast water.

The IMO's MEPC and its Ballast Water Working Group are well advanced with planning and preparation of a legal regime and it is their hope that it will be adopted by IMO in 2003 and subsequently be ratified as an International Treaty/Convention by the necessary number of member Nations (Contracting Parties to IMO) as soon as possible (Gollasch, personal communication). For the Treaty to *Enter Into Force*, the ratification formula can require signatures by 15 IMO Member countries and 50 percent of World Shipping Tonnage.

Interim international guidelines have been adopted as the IMO Assembly Resolution A.868 (20) recommending three options of ballast water exchange for the treatment of ballast water. These guidelines and the three reballasting options are discussed in more detail later in this paper. The IMO has not generally promoted regionally different systems, emphasizing that a universal global approach is preferred. However, IMO realizes that some local restrictions may be appropriate to manage or control a particular organism of concern. And, IMO is aware that using different management options and treatment techniques could result in unwanted regional restrictive practices, restraints of trade and competitive advantages. Nevertheless, some concerned countries have already implemented voluntary and mandatory guidelines requiring ballast water exchange.

Since 1973, the Marine Environment Protection Committee (MEPC) of IMO has been interested in preventing the introduction of unwanted aquatic species by discharge of ballast water, with the adoption of adopted Resolution 18 by the International Conference on Marine Pollution drawing attention to the global transport of aquatic organisms and pathogens in ships' ballast tanks. In the late 1980s, the MEPC formed a working group, which concluded that voluntary guidelines were the appropriate first step in addressing this problem. MEPC adopted guidelines by resolution in 1991 and in 1993 these were adopted by the IMO Assembly under Resolution A.774 (18) entitled "International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ships Ballast Water and Sediment Discharges". These Guidelines were then replaced in 1997, by the IMO Assembly Resolution A.868 (20) "Guidelines for the Control and Management of Ship's Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens". These Guidelines include a recommendation that an exchange of ballast water be carried out in open water as far as possible from the shore (IMO Assembly Resolution A.868 (20)). This is commonly referred to as a mid/ocean exchange of ballast water, it is currently the only readily available approach that can be used in order to minimize the risk of transfer of unwanted organisms on existing vessels. However, shipowners feel that the mid/ocean exchange of ballast water can pose a structural risk to certain ships.

Management and ballast water treatment measures recommended by the guidelines also included:

- Minimizing the uptake of organisms during ballasting, by avoiding areas in ports where populations of harmful organisms are known to occur, in shallow water and in darkness, when bottom-dwelling organisms may rise in the water column;
- Cleaning ballast tanks and removing muds and sediments that accumulate in these tanks on a regular basis, which may harbor harmful organisms;
- Avoiding unnecessary discharge of ballast; and
- Undertaking ballast water management procedures, including:
    1. Exchanging ballast water at sea, replacing it with 'clean' open ocean water. Any marine species taken on at the source port are less likely to survive in the open ocean, where environmental conditions are different from coastal and port waters; and
    2. Non-release or minimal release of ballast water.

The justification for the exchange in mid/ocean areas is that deep ocean waters are generally expected to contain fewer organisms, and in addition, species occurring in open ocean waters are generally not likely to survive in coastal zones and vice versa. If ballast water exchange is not possible, requirements developed within regional agreements may be applicable.

The Guidelines also note that no form of ballast exchange should be undertaken unless it is included in the ship's Ballast Water Management Plan and approved by the ship's Classification Society via the ship's "Trim and Stability" booklet. It is always the responsibility of the ship's Master to ensure that any operation carried out at sea is done so in a safe manner.

In addition to the exchange of ballast water at sea the guidelines include reference to simple ballast water management practices that would reduce the risk of introducing surface water invasive species to ballast water, i.e., taking on ballast water in low light and/or darkness (IMO Assemble Resolution A.868(20)). Such as:

- Ballast water uptake should be avoided in the presence of harmful algal blooms and known unwanted contaminants (e.g., Cholera disease outbreaks);
- Precautionary procedures when taking on ballast water in shallow areas, propeller may stir up sediments and bottom living organisms;
- Discharging ballast water and sediments to onshore facilities (if available); and
- Avoiding ballast water uptakes at night as many zooplankton organisms migrate towards the water surface in darkness (IMO Assembly Resolution A.868 (20)).

Altering the ballast condition while under way may jeopardize vessel safety. Also it should be noted, that the design of most ballast systems does not permit the removal of all ballast and associated biota from the tanks. Thus, while changing ballast may be an acceptable and effective control method under certain circumstances, it is neither universally applicable nor totally effective, and alternative ballast water treatment strategies are needed (NRC, 1996).

The MEPC Ballast Water Working Group is currently working towards a set of legally binding regulations for ballast water management to prevent the transfer of harmful aquatic organisms in the estimated 10 billion tonnes of ballast water (with invasive species) that are transferred globally each year. MEPC plans to hold a diplomatic conference during 2004 to adopt the new measures. The proposed instrument is a new international convention "for the control and management of ships' ballast water and sediments."

"The proposed new instrument is being developed on the basis of a two-tier approach.

- Tier 1 includes requirements that would apply to all ships, including mandatory requirements for a Ballast Water and Sediments Management Plan, a Ballast Water Record Book and a requirement that new ships shall carry out ballast water and sediment management procedures to a given standard or range of standards. Existing ships would be required to carry out ballast water management procedures after a phase-in period, but these procedures may differ from those to be applied to new ships.
- Tier 2 includes special requirements, which may apply in certain areas and would include procedures and criteria for the designation of such areas in which additional controls may be applied to the discharge and/or uptake of ballast water. The text for Tier 2 remains to be developed."

The deliberations at IMO regarding what to do about treatment of ballast water have been extensive. A search of the IMO web site will find 118 documents written by delegates of member nations and parties to IMO conventions related to ballast water from MEPC 42 on. Extensive discussions and debates have been held on ballast water treatment strategies and regulatory requirements. The summary report of MEPC 47 [held in London, 4-8 March 2002] is published as (IMO/MEPC/48/2) and is an excellent and very thoughtful document. Annex 2 of this document (Standards for Approval Tests of Ballast Water Treatment Systems) discusses the need and problems associated with drafting guidelines for ballast water management standards referred to in the Draft Regulations:

- Full-scale Tests
- Species for Testing
- Acceptable Limits
- Utilization of Current Knowledge

The Working Group at MEPC 47 developed fourteen ballast water treatment standards for further consideration at MEPC 48:

- Five possible "percentage standards": expressing a percentage of organism that should be removed or inactivated;
- Five possible "size standards": expressing effectiveness of removal of organism based on size;
- Two possible "zero" standards: permitting no discharge of specified organism with ballast water; and
- Two possible combinations of the above standards (IMO/MEPC 48/2).

As a future work program, the Working Group agreed that it needed to:

> "Carry our a detailed comparative assessment of each of the proposed standards, taking into account the various technologies that might be used to achieve these standards and all other relevant factors and considerations with particular attention to practicality, biological effectiveness (including pathogens), cost-benefit and the time frames within the standards could practically be implemented; and prepare a report with recommendations that will enable the Committee to decide on the standards that should be included in the test of the Convention" (IMO/MEPC 48/2).

The texts to these standards are included in Document E-2 (Annex 3 of MEPC 48/2). This report also includes a new consolidated test of the Draft International Convention for the Control and Management of Ships' Ballast Water and Sediments, as Annex 3 to MEPC 48/2.

Ballast Water Exchange Management Options

The following is a brief summary and description of present ballast water exchange management options to reduce the risk of introduction of species (not necessarily in order of preference or effectiveness) identified by MEPC. The list does not claim to be fully comprehensive. Nor does it include a discussion of new technologies which could include: mechanical and physical; chemical; biological; and any combination of these processes.

Ballast water exchange was originally developed as a method to be used by vessels on trans-oceanic journeys. The strategy is that the water that was loaded in one port would then be exchanged for open oceanic water with a salinity of 35 parts-per-thousand (ppt) which would contain fewer organisms and that these high salinity organisms are unlikely to survive in lower salinity coastal waters in ports and harbors. This exchange process was also recommended for when a vessel was traveling between two fresh water ports as the increase in salinity (35 ppt from the open ocean) would kill most freshwater organisms remaining in the tanks and the oceanic species taken on board in mid ocean would not survive in when discharged in freshwater of the next port.

The MEPC Working Group on Ballast Water Management has confirmed that ballast exchange on the high seas is the only widely used technique currently available to prevent the spread of unwanted aquatic organisms in ballast water and its use should continue to be accepted. The concept of mid/ocean ballast water exchange as Recommended by IMO has three options:

Option 1 - Empty/refill (Reballasting)

In the empty-refill (deballasting & reballasting) option, the ballast tanks are entirely emptied of port water and then refilled with open oceanic water. Stripping pumps or eductors should be used wherever possible to minimize the amount of original ballasted water remaining in the tanks. Sea trials undertaken in such a manner have found that at least 95% of the original water can be replaced (Table 1) (Rigby, 1994; Rigby & Taylor, 2001; Miller, 1998; Wonham et al., 1996). However there is concern that the exchange of 95% of the volume of the ballast water may not be equivalent to the exchange of 95% of the organisms in ballast tanks as these are not necessarily equally distributed in the ballast water, but may accumulate at the bottom and tank walls (GloBallast Programme, 2001). On many ships this method may result in unacceptable bending moments or shear stresses to the physical structure (Rigby & Hallegraeff, 1994; Karaminas, 2000), but potentially could be 100% effective at removing all the original ballast water on some vessels and exposing the remaining organisms to full seawater. In practice, many woodchip carriers that claimed to have undergone reballasting still had sediments present in the tanks that included toxic dinoflagellate cysts (Hallegraeff & Bolch, 1991, 1992; Taylor et al., In Press).

Option 2 Continuous Flow/through of Ballast Water (Ballast Continuous Exchange)

A continuous flow through system allows continuous sea/to/sea circulation of ballast water while the ship is underway and the ballast tanks remain filled. In this option, seawater is pumped continuously into the ballast tanks while the tank is simultaneously overflowed from the top of the tank. The recommendation for the flow-through method is that at least three times the tank volume should be pumped through the tank (on some vessels this has been shown to correspond to a replacement of approximately 95% of the original water). In addition, some pipe work modifications may be necessary on some ships to enable this option to be utilized safely and effectively (Taylor & Rigby, 2001).

In contrast to deballasting in high seas during bad weather using the empty/refill technique, the continuous flow through system does not impose excessive bending moments or shearing forces and minimizes stability and structural problems. However, Rigby & Hallegraeff (1993, 1994) demonstrated that by emptying certain ballast tanks on the bulk carrier *Iron Whyalla*, the still water bending moment may be much higher than the maximum allowable value. Option 1 is not yet proven less effective than option 2, but these results in combination with the high number of organisms in the remaining water bodies in the ballast tank after emptying (option 1, above), made the flow through option more favorable of the two options. However, future research is needed to validate the effectiveness of this option and to confirm the above results, which based on a limited number of sea trials.

Option 3 Dilution Method

The dilution method is a further modification of the continuous flow through option in which additional piping is installed on a vessel to allow continuous ballasting from the top of the ballast tanks via one pipe system and at the same time continuous deballasting by a second pipe system at the bottom of the tank (IMO MEPC 38/13/2 1996; Villac et al. 2000). A real advantage of the dilution method is that it enables a continuous flow through of ballast water in partly filled tanks that is not possible with option 2. Mathematical modeling of the effectiveness of this method has demonstrated a comparable effectiveness to the ballast tank flushing for three times the ballast tank volume (Armstrong et al. 1999).

The Global Ballast Water Management Programme (GloBallast)

The Global Ballast Water Management Programme (GloBallast) was developed in response to the threats proposed by the introduction of invasive marine species by the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. Agenda 21 at this Conference called on IMO and other international bodies to take action to stop the transfer of harmful aquatic organisms in ships' ballast water. This led to the development of a three year, US $10.2 million initiative under the International Waters portfolio of the Global Environment Facility (GEF). The GloBallast Programme utilizes funding from GEF, deployed through the United Nation's Development Programme (UNDP), to allow the International Maritime Organization (IMO) to assist developing countries to tackle the transfer of harmful aquatic organisms in ships' ballast water.

The shipping industry has also been very active in helping to address the introduction of invasive marine species from ballast water transfers and participates in the MEPC Ballast Water Working Group. The International Chamber of Shipping (ICS) and the International Association of Independent Tanker Owners (INTERTANKO) have developed and published a Model Ballast Water Management Plan which can be purchased from ICS through ics@marisec.org. This plan presents practical guidance for the implementation on board ships of the IMO voluntary guidelines.

Other Ballast Water Treatment Technologies

New future ballast water treatment technologies under development include:

- Mechanical processes/methods - filtration and separation;
- Physical processes/methods - sterilization by ozone, ultra-violet light, pulsating strobe lights, electric currents, acoustics, heat treatment, mixing, etc.;
- Chemical processes/methods – biocides (toxic chemicals) and oxidizing chemicals, and related chlorine compounds), nitrogen, oxygen depletion, pH, flocculation, etc.;
- Biological process; and
- Any combinations of the above.

Most of these ballast water treatment "technologies" are new and are in some stage of research and development. None of these technologies have been tested and/or certified as to meeting any set of international guidelines. Major barriers still exist in scaling up these technologies to deal effectively with the huge volumes of ballast water carried by large ships (e.g. there is about 60,000 tonnes of ballast water on a 200,000 DWT bulk carrier), and the large flow rates required for ballasting (up to 3,000 M^3/hr).

Ballast Water Treatment technologies must not interfere unduly with the operation of the ship and must consider ship design limitations. Any control measure that is developed must meet a number of on board ship operating criteria, including:

- It must be safe,
- It must be economical,
- It must be environmentally acceptable,

- It must be reasonable
- It must be cost-effective,
- It must work,
- It can not be toxic to non-target organisms when discharged in port,
- It must be practical and consistent with ship operations and level of training of existing crew, and
- It must be certifiable by a neutral – independent international third party.

One of the problems currently faced by the global R&D community is that apart from the general criteria above, there are currently no internationally agreed and approved performance standards or an evaluation system or testing body to certify new ballast water treatment technologies that meet international standards. In addition, many groups are working in isolation from each other, and there are no formal mechanisms in place to ensure effective lines of communication between the R&D community, governments and ship designers, builders and owners. These are vital if the R&D effort is to succeed (GloBallast Programme, http://www.imo.org).

The IMO GloBallast Programme has undertaken two initiatives to reduce these barriers:

- The development of a Directory of Ballast Water Treatment R&D (who is doing what) on their web-site, and
- The Development of Global Ballast Water R&D Symposium, which was held at IMO, 26-27 March 2001.

One of the objectives of this Symposium was an international workshop for the development of performance standards and an evaluation system for the formal acceptance of new treatment techniques. General requirements have been discussed at MEPC (MEPC 48/2) and are presented in Annex 2 (MEPC 48/2). They are currently under consideration and refinement as part of the International Convention to be adopted in 2003.

These standards need to be developed into international test protocols by a certification organization, such as the proposed Marine Testing Board. However, a question that comes to mind is why would the international classification or testing organizations, such as ASTM, UL, IASC, ABS, and DNV to name a few, not be better qualified to undertake such an activity instead of creating a new organization. The simple answer might be that the MTB needs to be more biological than engineering. These organizations have extensive experience in areas of engineering and performance evaluation and testing or in naval architect roles and not biological testing or culturing. For over 40 years, shipowners could have used some type of certification for the effectiveness of biocides in marine antifouling paints and these organizations were not interested in biological testing (Champ, 1999; 2000b).

In addition, part of the problem with the ballast water treatment testing service is that it will not be an economic growth sector (perhaps over 10 year period, it might test 20-30 technologies), and it will be an academic R&D (culture and testing) type business, in which a large number of specialty taxonomic, culture and toxicity testing experts are needed. It may also be a controversial area, because it will conduct difficult measurements such as survival, growth, and reproduction of organisms that range from algae to mollusks, to fish and will not be like taking a physical measurement such as a stress force, similar to the difficulties in toxicity or bio-assay testing (White and Champ, 1983).

The GloBallast Programme has direct links on its Website to:

- The Ballast Water Treatment R&D Directory (Database – has 43 pages of global R&D Projects) [http://globallast.imo.org/searchprojects/index.htm];
- The Ballast Water Treatment R&D Directory (Document) [http://globallast.imo.org/R&DDirectory7thEd.doc];
- The Abstracts from the Ballast Water Treatment R&D Symposium, held at IMO, 26-27 March 2001 [http://globlast.imo.org/Abstracts.htm]; and
- The Report from the Ballast Water Treatment Standards Workshop, held at IMO, 28-30 March 2001 [http://globlast.imo.org/workshopreport.htm].

United States Coast Guard

The USCG has on its Ballast Water Management Website [http://www.uscg.mil/hq-m/mso/mso4/ans.htm] extensive materials about Aquatic Nuisance Species (ANS) – Invasive Species, and will make available information to US citizens, papers from the discussions at IMO and MEPC.

On its Web Page the Reporting Forms and Further Information and the Voluntary Guidelines for discharge of ballast water in US waters are presented. It is mandatory that ships with ballast water tanks that enter into the waters of the US after operation beyond the US EEZ for a vessel to exchange ballast water beyond the US EEZ in an area more than 200 nautical miles from shore and in waters more than 2,000 meters in depth. Vessels are required to fax their ballast water reporting forms 24 hours in advance of entering most US and or Canadian ports and harbors.

In addition, three other US Websites provide information on some aspect of invasive species:

- The Aquatic Invasions Research Directory (AIRD) – General Focus [http://invasivions.si.edu/ard.htm]
- The US National Ballast Water Information Clearing House – US Focus Only [http://invasions.si.edu/ballast.htm]
- US National Marine and Estuarine Invasions Database – US Focus Only [http://invasions.si.edu.nis.htm].

THE MARINE TESTING BOARD (MTB)

The Marine Testing Board (MTB) has been proposed in this paper as a third party and neutral scientific organization to facilitate the development of international testing protocols to meet IMO standards and regulations and for the testing and certification of new technologies.

The MTB can best be described by the following:

- It is a scientific, and technical corporation to facilitate biological testing;
- It conducts only full scale testing and only after technologies have demonstrated success in the laboratory;
- It tests only technologies recommended for testing by a MTB International Scientific and Engineering Advisory Board following a formal application process and review;
- It supports the national and international regulatory review process by providing the highest quality of independent scientific and engineering data and information on performance for each tested technology;
- It supports the shipping industry and the ballast water treatment industry in getting new products into the marketplace by providing regulators and shipowners with results from independent third party-neutral and standardized international test data and information.
- It would not have any ownership in any of the companies or products tested or provide any support for the development of a technology.
- 'It would only manage the full-scale field-testing of a technology and would pay for the testing from its general funds that have accrued from government funding and shipowners fees and never receive funds or support for testing from companies with technologies tested or to be tested, or even be perceived to have or create a conflict of interest,
- It is not a consulting or advertising organization or an organization to help companies refine or develop new technologies, information provided by the MTB from full-scale field testing is only a "Notice of Technology Certification" (Approval) and not to provide test data and/or information of comparable ranking of tested technologies or support for subsequent refinement of a tested technology;
- It provides considerable time and cost savings in accelerating the time required for review and regulatory approval and acceptance of new technologies into the marketplace.
- It is not a regulatory body nor does it make regulatory decisions or provide regulatory advice;
- It is not a governmental or non-governmental organization;
- It is comparable to the Underwriters Laboratory organization that is responsible for developing international standardized protocols for testing existing and new products in the marketplace;

The creation of a Marine Testing Board (MTB) would combine the needs of regulatory processes and free market forces to work synergistically to get new technologies in the marketplace in the shortest time period. It would act as a neutral, independent third party using international testing protocols developed in concert with all interested parties.

The MTB's functions would be to:

- Identify the policy and regulatory requirements of different nations and interested parties and develop standardized international testing and performance evaluation protocols through consensus of expert working groups;
- Establish and fund testing at international test and evaluation centers to provide data and information on performance; Conducts **only full scale on-board testing** and only after technologies have demonstrated success in full-scale land-based tests. The tests are to be carried out on a **vessel that is owned by the MTB**; and
- Provides a fast track for the development and evaluation of certifiable technologies.

The MTB's organization, structure, and function would:

- Include all stakeholders and interested parties and be managed as a neutral third party independent organization;
- Develop international standardized protocols for testing and evaluation of ballast water treatment technologies to be reviewed and approved by a formal peer review process;
- Hold international peer review conferences and working group meetings (of international experts) to review and select available technologies for testing and certification;
- Holds training and intercalibration exercises for testing with potential international testing laboratories and directly oversee the testing and evaluation of the most promising ballast water treatment/control measures (technologies). These would be bid out by RFP (Request For Proposals) to ship research and development groups, as well as industry and academic research and development and testing laboratories across the world to conduct standardized assessments; and
- Publish the MTB's "Notice of Technology Certification" and product description data and information for certified technologies on the Internet available to anyone, anytime, anywhere.

The above concept has been proposed not to compete with or substitute for the regulatory processes that governments conduct in reviewing and permitting new technologies. *Its purpose is to complement their processes by providing the highest level of independent and internationally standardized scientific data and information to support policy and decision-making in the shortest period of time.*

Table 1. Critical Structural and Functional Distinctions of the Marine Testing Board.

Component	The Marine Testing Board
Representation	A scientific and engineering testing organization
Governing Body	Independent board of directors representing stakeholders and interested parties
Member Qualification	Expert and technical discipline experience in selected areas (science, engineering, ship operations, economics, etc.)
Length of Appointment	Two year term appointments of members to the board of directors
Openness	Open and transparent
Approach	Facilitates standardized scientific and engineering international tests and testing Provides single, consistent, and comprehensive data sets for decision-making
Function	Performance and Technical Assessments Proactive: tests and performance
Funding	Matching with shipowners contributing $ 1/day/ship in global commerce
Sources of Information	Data from neutral, third-party, and independent testing sources contracted independently for standardized performance testing and protocols
Exchange of Information	Open, independent, available anytime, anywhere on the Internet MTB Website presents actual testing results and in-depth descriptions of new ballast water treatment technologies
Priority Information and Non Disclosure Agreements	None – Patents Pending on all Technologies Tested

Unbiased Evaluation (Marine Testing Board) is needed because:

- Ballast water treatment technologies are new;
- They have had very short trial test periods, and are basically untried, etc.;
- There is no shipping body, United Nations organization or agency, US Coast Guard or comparable international agency that wants the job of validating or certifying the performance of these new technologies in the marketplace;
- Shipowners and registries have little experience with ballast water treatment technologies. No one does;
- There are no comparative criteria, standards or testing protocols; and
- Most of the new ballast water treatment/control technologies are being developed by small academic groups of small companies and not shipping companies or large well funded business ventures, most of the new technologies are very expensive, and therefore represent a large risk for shipowners making multiple-year (~ 25yr.) investments without certification or guarantees.

"Win-Win" Aspects of the MTB

The concept of a Marine Testing Board (MTB) is proposed because there are no existing standardized international performance testing protocols and/or an existing marketplace (prior to future regulation) for ballast water treatment technologies.

In the review of this manuscript, it was brought to my attention that there are two independent groups attempting to develop policy guidelines for standards. One is the effort underway at IMO in the Global Ballast Water Program.

The other is at the US ETV (Environmental Technology Verification) Program and they have organized meetings to begin to develop standards. The US EPA and the US Coast Guard together have developed a Ballast Water ETV Project that is still in its early stages. There's some information about the project on the ETV website, at "http://www.epa.gov/etv/moa_coastguard.htm". The EPA ETV Program (see www.epa.gov/etv) is a government-run (but not regulatory) program for a wide range of environmental technologies in the EPA Office of Research & Development that has been established to verify performance and will initially support some testing, but plans to have the company that developed the technology pay for the testing. The ETV program will not provide "Certification" of technologies. Both EPA and NSF International will sign certificates of "Performance Verification". In addition, the EPA Program is not an international program and will not conduct or oversee (manage) the testing.

There are very few established or big companies among the ballast water treatment technology providers. Most are small companies (inventors) and engineering works, or research labs and they need some type of certification to help sell their new product in the marketplace.

Therefore contribution of the MTB are its ability to: (1) Provide the shipping industry with a benefit and service to meet future ballast water technology needs; (2) Help the small industries get their technology certified because they do not have the funding for testing; (3) Support individual small companies in securing investment and venture capital to bridge the technology gap to enter into the marketplace (see Fig. 1); and (4) Assure, most significantly, that the testing has been conducted by an independent and neutral third party.

Such an effort would save each individual shipping companies from:

- Paying individually to evaluate the market;
- Paying individually for testing costs;
- Paying for the costs of failure from purchasing untested and uncertified technologies;
- Paying any regulatory fines; and
- Paying for replacement systems costs and shipyard fees, which would be very expensive to the shipping industry.

One may suggest why the large shipowners should support the MTB when both the large and small shipowners would benefit from the certification of ballast water treatment technologies. A simple reply is that they have the:

- Largest portion (perhaps greater than 90%) of the problem;
- Largest ballast water volume needing treatment;
- Greatest frequency of trans oceans shipments;
- Most frequent ballast water discharges;
- Greatest range and distribution of shipping; and
- Most to gain from cost benefits of certified technologies.

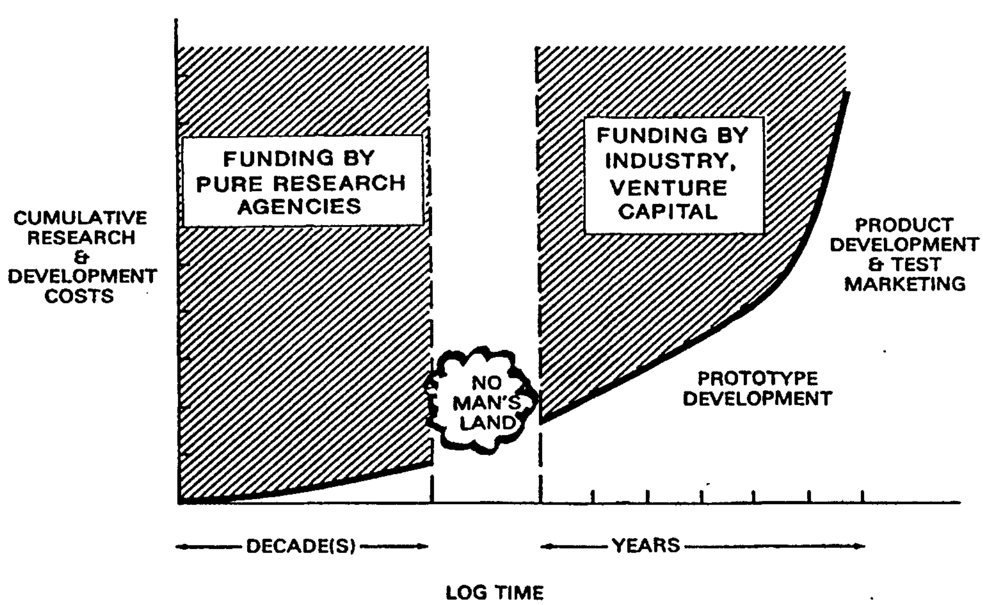

Figure 1. The "Gap" in funding in technology development between funding by research agencies and product development by industry and venture capital.

MTB Costs - Less than One Cup of Coffee per Day.

Certification testing today can run from US $ 500,000 to over 1 million. To raise the necessary funding, shipowners need only to contribute a small fee (perhaps as low as US $ 1 per day for each ship (and ship day) in global commerce (calculated as an annual average number of days at sea). This "average" would have to be standardized for different classes of ships.

This is less than the cost of one cup of coffee per day. Given that there are approximately 30,000 large ships in global commence and 365 days in a year, this would provide about $10 million per year for testing and certification. Within 12 months, shipowners would save millions of dollars. The estimated pay back to the shipowner would be with the purchase of the first certified system.

SUMMARY AND CONCLUSIONS

The proposed Marine Testing Board (MTB) is a process to expedite the implementation of international standards and regulations, and the subsequent testing, certification, and regulatory approval of new ballast water treatment ("control") technologies. This would expedite their acceptance in the global marketplace and reduce risks of shipowners following international regulation. The cost to test and evaluate and certify new ballast water treatment technologies for the global marketplace has been estimated to be less than US $ 1 per day per ship.

It is time for the shipping industry, national regulatory bodies, and IMO to endorse the concept of a neutral-third party **Marine Testing Board** to solve common industry environmental technology problems and for the shipping industry to support a proactive cost-saving solution for sustainable shipping and protecting the environment from unwanted invasions of aquatic species with their potential negative impacts.

Acknowledgements

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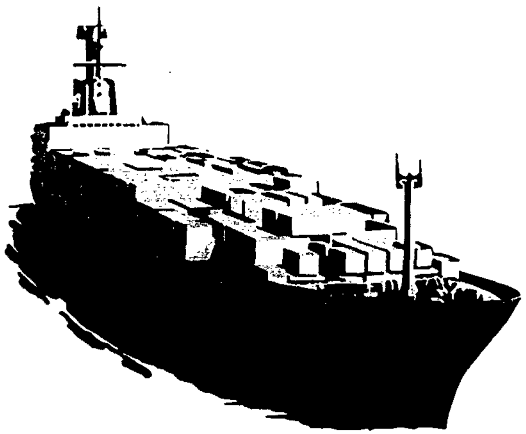
Discussion of the Concept of a Marine Testing Board for Certification of Ballast Water Treatment Technologies



Michael Champ
ATRP Corporation &
Matthias Voigt
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Presented at the International Conference and Exhibition on *Ballast Water and Waste Water Treatment Aboard Ships and in Ports* ; June 11-13, 2003, Bremerhaven, Germany

The IMO Proposed Regulation of Discharged Ballast Water:

- **An Immediate Concern Is the Need for an International Organization and System to Evaluate and *Certify the Performance* of the Plethora of Unknown and New Ballast Water Treatment ("Control") Technologies.**

Exhibits Have Demonstrated:

- High Levels of Inventiveness and Diversity in New Technologies
- That May Create a Multitude of Problems for Shipowners Making Purchasing Decisions
- From Lists of Needed Technologies That Range and Vary Significantly in Costs and Effectiveness and
- Lack Third Party-neutral Validation or Certification.

Worse:

- **Standardized Performance Data Is Not Available;**
- **Due to a Lack of an International Testing Infrastructure; and**
- **Development of Standardized Long-term Testing and Assessments Protocols to Certify That a Technology Meets IMO International Regulations.**

This has Led to the Concept for the Development of an Independent, International Marine Testing Board (MTB):

- **Funded by Shipowners, Regulators, and Interested Parties With the Endorsement of National and International Regulatory Bodies and Environmental Organizations**

- **For: (1) the Development of Standardized International Performance Protocols, (2) Full-scale Field-testing, and (3) "*Certification of Ballast Water Treatment Technologies*".**

Why?

- The Promotion of New Ballast Water Treatment Technologies Is a Genuine Public Policy Concern Because They Are Factored Into the Price That the Public Pays for Vessel-shipped Common Goods, Food, Energy, Etc.

But on the Other Hand:

"Why" Not Let Market Forces Alone Drive the Development of These Technologies?

Uneven Environmental Regulation in Global Markets Defeats the Driving Forces in the Marketplace for Better Products (Supply and Demand) by Altering the Decision-models.

National / Regional Ballast Water Regulations I

Argentina - Buenos Aires

in-tank treatment by adding chlorine

Australia

Ballast water exchange; flow through method with 3 x tank volume or in-tank treatment agreed with AQIS

Canada

Ballast water exchange as far from land as practicable, in ocean depth greater than 2000 metres.

Canada, Vancouver

Ballast water exchange in mid ocean prior to entering Canadian waters

Chile

Ballast water exchange in deep water. Entries in logbooks, showing geographical co-ordinates, amount replaced and what percentage of total ballast capacity it represents

National Ballast Water Regulations II

USA - National

1. Ballast water exchange at sea, outside US EEZ.
2. Ballast water exchange in designated sea area within US EEZ.
3. Environmentally sound alternative ballast water management methods that can include modifications to a ship.

California

Ballast water exchange at sea, outside the EEZ, from an area not less than 200 nautical miles from any shore, and in waters more than 2,000 meters deep, before entering waters of the state.

Great Lakes and Hudson River above George Washington bridge

1. Complete ballast water exchange at sea, outside US EEZ, in a depth of more than 2000 metres.
2. Retain ballast water on board ship.
3. Complete ballast water exchange in alternative designated areas approved in advance by the USCG Captain of the Port (COTP).
4. Alternative ballast water management practices approved in advance by the USCG.

National Ballast Water Regulations III

New Zealand

1. Ballast water exchange in deep water.
2. Use of fresh water in ballast tanks (<2.5ppt NaCl).
3. Use of approved on-shore treatment facility (none approved yet).
4. Use of approved in-tank treatment (none approved yet).
5. Discharge into an approved low risk zone (none approved yet).

Great Britain - Orkney Islands

Discharge to shore reception facilities

Israel

Ships bound for Eilat must exchange outside of the Red Sea, when practicable. Ships bound for Mediterranean ports must exchange in the Atlantic Ocean when practicable.

The Shipping Industry Has Been Supportive of IMO, Because It Would Rather Be Regulated by One International Regulation That All in the Industry Are Subject to Rather Than Facing Varying National / Regional Regulations.

- The IMO's MEPC is Preparing a Legal Regime to be Adopted by IMO in 2004; and Subsequently
- Be Ratified As an International Convention by the Necessary Number of Member Nations

(15 Countries and 50 Percent of World Shipping Tonnage)

The New BW Convention is going to Include several Methods of Ballast Water Management.

- **Ballast Water Exchange**
- **New Technologies Which Could Include: Mechanical and Physical; Chemical; Biological; and**
- **Any Combination of These Processes.**

The Mid/ocean Exchange of Ballast Water is Currently the Only Readily Available Approach that Can be Used in Order to Minimize the Risk of Transfer of Unwanted Organisms on Existing Vessels.

However, Shipowners Feel That the Mid/ocean Exchange of Ballast Water Can Pose a Structural Risk to Certain Ships.

Other Ballast Water Treatment Technologies:

- **Mechanical Processes/methods - Filtration and Separation;**
- **Physical Processes/methods - Sterilization by Ozone, Ultra-violet Light, Pulsating Strobe Lights, Electric Currents, Acoustics, Heat Treatment, Mixing, Etc.;**

- **Chemical Processes/methods – Biocides (Toxic Chemicals) and Oxidizing Chemicals, and Related Chlorine Compounds, Nitrogen, Oxygen Depletion, Ph, Flocculation, Etc.;**
- **Biological Process; and**
- **Any Combinations of the Above.**

Annex 2 (Standards for Approval Tests of Ballast Water Treatment Systems) Discusses the Problems Associated With Ballast Water Management Standards Referred to in the Draft Regulations:

- Full-scale Tests
- Species for Testing
- Acceptable Limits
- Utilization of Current Knowledge

Ballast Water Treatment Technology Must:

- Be Safe,
- Be Economical,
- Be Environmentally Acceptable,
- Be Reasonable
- Be Cost-effective,
- Work,
- Not Be Toxic to Non-target Organisms When Discharged in Port,
- Be Practical and Consistent With Ship Operations and Level of Training of Existing Crew, and
- Be Certifiable by a Neutral – Independent International Third Party.

THE MARINE TESTING BOARD (MTB)

- **It Is a Scientific, and Technical Corporation to Facilitate Biological Testing;**
- **It Conducts Only Full Scale On-board Testing and Only After Technologies Have Demonstrated Success in Full Scale Land-based Tests. The Tests Are to Be Carried Out on a Vessel That Is Owned by the MTB;**
- **It Tests Only Technologies Recommended for Testing by a International Scientific & Engineering Advisory Board Following a Formal Application Process and Review;**

- The MTB Is Not a Governmental or Non-governmental Organization;
- The MTB Is Comparable to the Underwriters Laboratory Organization That Is Responsible for Developing International Standardized Protocols for Testing Existing and New Products in the Marketplace;

- **The MTB Supports the National and International Regulatory Review Process by Providing the Highest Quality of Independent Scientific and Engineering Data and Information on Performance for Each Tested Technology;**

- The MTB Supports the Shipping Industry and the Ballast Water Treatment Industry in Getting New Products Into the Marketplace by Providing Regulators and Shipowners With Results From Independent Third Party-neutral and Standardized International Test Data and Information.

The MTB Would Not Have Any Ownership in Any of the Companies or Products Tested or Provide Any Support for the Development of a Technology.

The MTB Would:

- Identify the Policy and Regulatory Requirements of Different Nations and Interested Parties and Develop Standardized International Testing and Performance Evaluation Protocols for on Board Testing Through Consensus of Expert Working Groups.
- Manage the Full-scale Onboard-testing of a Technology .

The MTB Would:

- Pay for the Testing From Its General Funds That Have Accrued From Government Funding and Shipowners Fees.
- Provide Information From Full-scale Field Testing Only for a "Notice of Technology Certification" (Approval).

The MTB Would NOT:

- **Receive Funds or Support for Testing From Companies With Technologies Tested.**
- **Consult or Advertise to Help Companies Refine or Develop New Technologies.**
- **Provide Test Data And/or Information of Comparable Ranking of Tested Technologies or Support for Subsequent Refinement of a Tested Technology.**

- **The Creation of a Marine Testing Board (MTB) Would Combine the Needs of Regulatory Processes and Free Market Forces to Work Synergistically to Get New Technologies in the Marketplace in the Shortest Time Period.**

Such an Effort Would Save Each Individual Shipping Companies From:

- Paying Individually to Evaluate the Market;
- Paying Individually for Testing Costs;
- Paying for the Costs of Failure From Purchasing Untested and Uncertified Technologies;
- Paying Any Regulatory Fines; And
- Paying for Replacement Systems Costs and Shipyard Fees, Which Would Be Very Expensive to the Shipping Industry.

Why Should the Large Shipowners Support MTB?

- Largest Portion (Perhaps Greater Than 90%) of the Problem;
- Largest Ballast Water Volume Needing Treatment;
- Greatest Frequency of Trans Oceans Shipments;
- Most Frequent Ballast Water Discharges;
- Greatest Range and Distribution of Shipping; and
- Most to Gain From Cost Benefits of Certified Technologies.

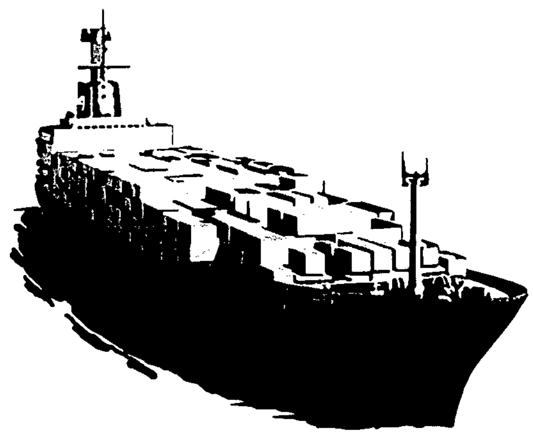
MTB Costs:

- Certification Testing Today Can Run From US $ 500,000 to Over 1 Million.
- To Rise the Necessary Funding, Shipowners Need Only to Contribute a Small Fee (Perhaps As Low As Us $ 1 Per Day for Each Ship (and Ship-day) in Global Commerce (Calculated As an Annual Average Number of Days at Sea). This "Average" Would Have to Be Standardized for Different Classes of Ships.

MTB Costs:

- This Is Less Than the Cost of One Cup of Coffee Per Day. Given That There Are Approximately 40,000 Large Ships in Global Commence and 250 Ship-days in a Year, This Would Provide About $10 Million Per Year for Testing and Certification.

Within 12 Months, Individual Shipowners Would Save Millions of Dollars. The Estimated Pay Back to the Individual Shipowner Would Be With the Purchase of the First Certified System.



For More Information on the MTB:

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Past and current ballast water research in North-Western Europe

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1 Introduction

Scientific knowledge is a key issue when considering biological invasions. Ballast water research is a relatively young field of research although it is in use since 1870s. The first mention of ships as introducing vector were published by Ostenfeld in 1908 after a phytoplankton bloom of an introduced species in the North Sea in 1903. It took about 70 years before the first ballast water sampling study was undertaken in Australia. Almost 100 studies, including e.g. desk studies on case histories of invaders, work on treatment options for ballast water, or risk assessment, in this comparably new field of research were completed or are ongoing in North-Western Europe. World-wide 93 ballast water sampling studies were undertaken (Fig. 1 & 2).

2 Ballast Water Studies in Europe

The first study on ships` ballast water in north-western Europe was carried out in Germany from 1992-1996. Shortly thereafter, until 1998, new shipping studies were initiated in Scotland, Belgium, Norway, England and Wales, Sweden, the Netherlands and in 1997 the EU funded Concerted Action "Introductions with Ship" was launched involving six European countries and the International Maritime Organization (IMO).

During European ballast water studies more than 560 vessels were sampled. Vessel types ranged from smaller cargo vessels of <1,000 deadweight tonnes (dwt) to very large crude carriers (VLCCs) of >300,000 dwt. The ballast water sampled originated from more than 200 different source regions world-wide. Key objectives of most studies included to document the variety of species and abundance of individuals transported in ballast water tanks of ships calling for European ports.

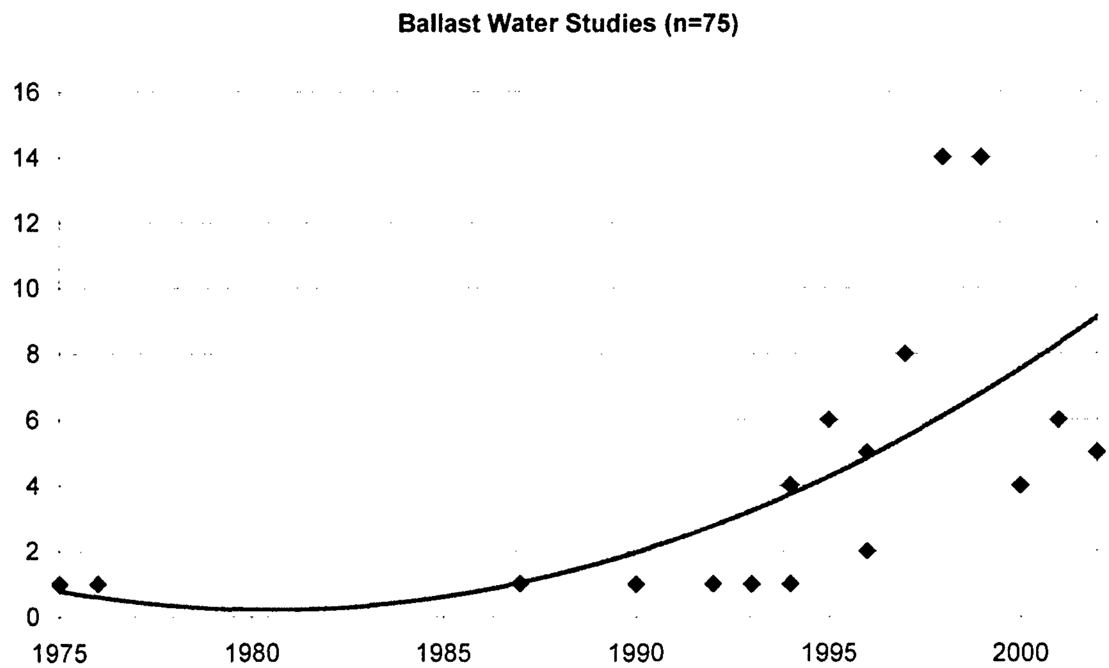


Fig. 1 World-wide ballast water studies over time, since 1975.

Most studies focussed ballast water sampling, but some included tank sediments. More than 1500 ballast water and tank sediment samples were collected. The total number of taxa collected during all studies was more than 1,000 including e.g. bacteria, fungi, protozoans, algae, invertebrates and fishes of different life stages.

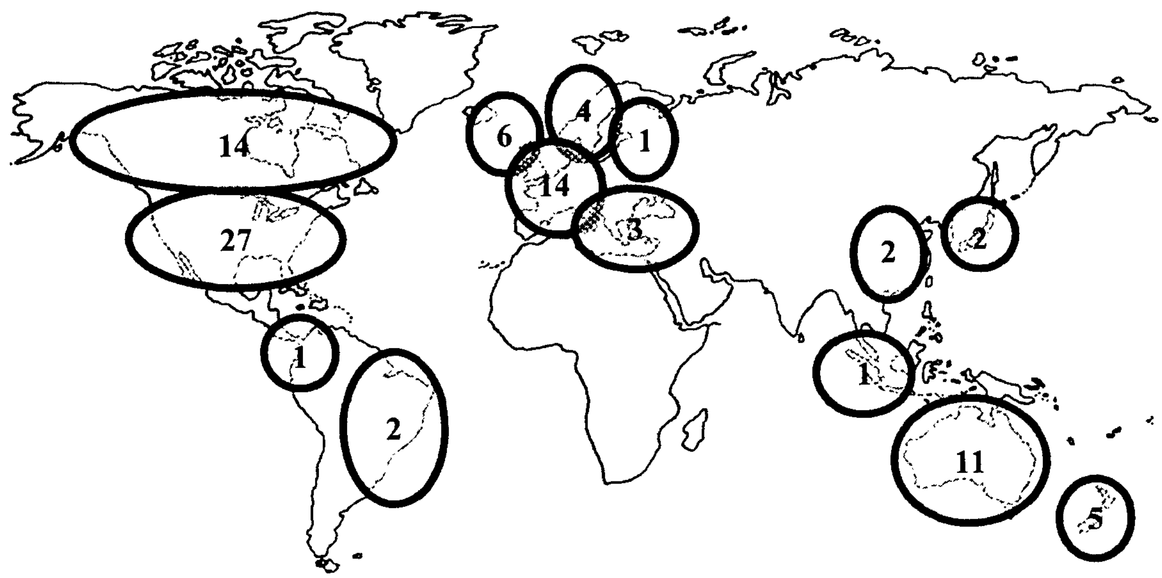


Fig. 2 Number of Ballast water studies world-wide.

Further information on the above mentioned projects may be found at existing European and world-wide networks:

- **European Research Network on Aquatic Invasive Species** (ERNAIS) The key objectives the ERNAIS network include to create a network facilitating cooperation and information exchange within invasion biologists European-wide, to develop an international database on aquatic alien species and to document the impact caused by invaders. Almost 60 scientists from more than 20 European countries join this initiative (http://www.zin.ru/projects/invasions/gaas/ernaismn.htm).
- **Non-Indigenous Estuarine and Marine Organisms** (NEMO) Working Group 30 of the Baltic Marine Biologists. The establishment of NEMO in the mid-1990s indicates the growing academic interest in bio-invasions. Key objectives include the collection and summarisation of information on non-indigenous aquatic plants and animals in the Baltic Sea. Data on non-native species are available as Baltic Sea Alien Species Database at http://www.ku.lt/nemo/mainnemo.htm.
- **Nordic Network on Introduced Species** focuses on the establishment of a Nordic network of people working as scientists or as administrators within the field of introduced species (http://www.sns.dk/natur/nnis/).
- **Study Group on Ballast Water and other Ship Vectors** (of ICES/IOC/IMO) (www.ices.dk) and
- **Working Group on Introductions and Transfers of Marine Organisms** (of ICES) (www.ices.dk).

- **Global Ballast Water management Programme (GloBallast)**
  The GloBallast Programme has a comprehensive homepage at http://globallast.imo.org with several reports and other relevant material to download.

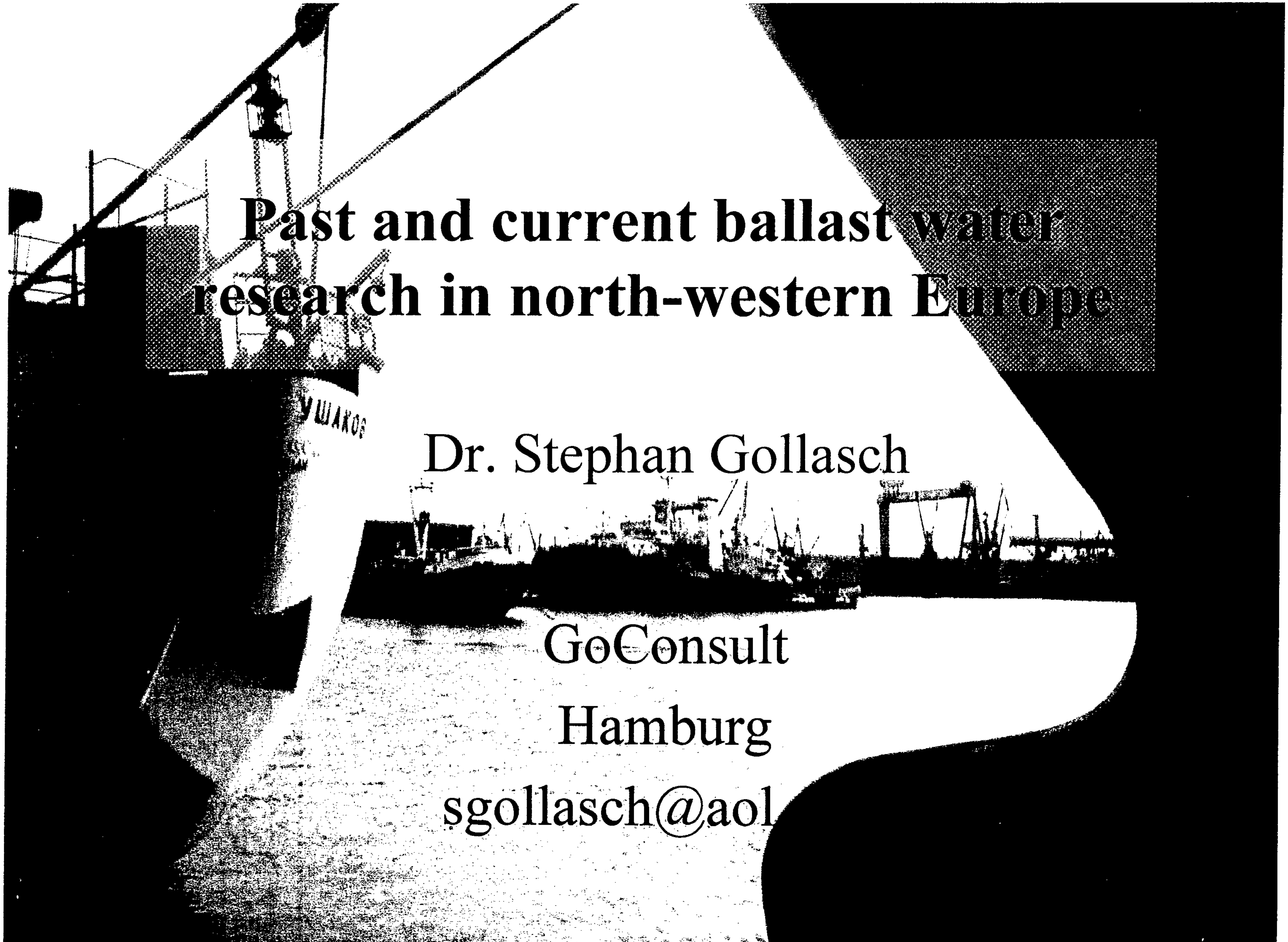
3 Research gaps

Although several studies on ballast water were undertaken, some research gaps remain. These include, e.g.

- Representativeness of sampling techniques,
- Comparison of sampling results of various studies,
- Are there habitat modifications within a tank (e.g. water stratification),
- How influencing is sampling on biota,
- Development of more representative sampling techniques (ballast water sampling standard), and
- Long-term survival of organisms in ballast tanks.

4 Summary and Conclusions

Ballast water is a new field of research which was started in the early 1970s. End-point sampling in ports and studies en-route have frequently been undertaken. Almost all life forms are found in ballast water tanks. Shipping is THE major vector in unintentional species movements, with ballast water and hull fouling as key vectors likely being of equal importance.


Past and current ballast water research in north-western Europe
Dr. Stephan Gollasch
GoConsult
Hamburg
sgollasch@aol

How I got started?

- In summer 1968, as kid, I "stepped" on a horseshoe crab during the family summer vacation on the island of Sylt in the Wadden Sea. Since today, I am angry with my mum as she said - come on Stephan, we are on our way to lunch. You can collect another one later today - what I never managed to do.
- Forgot about this, but it came to mind again when I spotted a pink flamingo in the Wadden Sea as a student during a bird excursion in 1987.
- Since, I am focussing on bioinvasions and related subjects.

What is in front of you

- Documentation of ballast water research in Europe
- Major findings
- Research gaps
- Conclusions

Invaders in Europe

- Very well documented in recently published book edited by E. Leppäkoski (Finland), S. Gollasch and S. Olenin (Lithuania)
- Kluwer Acad. Publishers
- 583 pp.

INVASIVE AQUATIC SPECIES OF EUROPE. DISTRIBUTION, IMPACTS AND MANAGEMENT

Erkki Leppäkoski, Stephan Gollasch and Sergej Olenin (eds.)

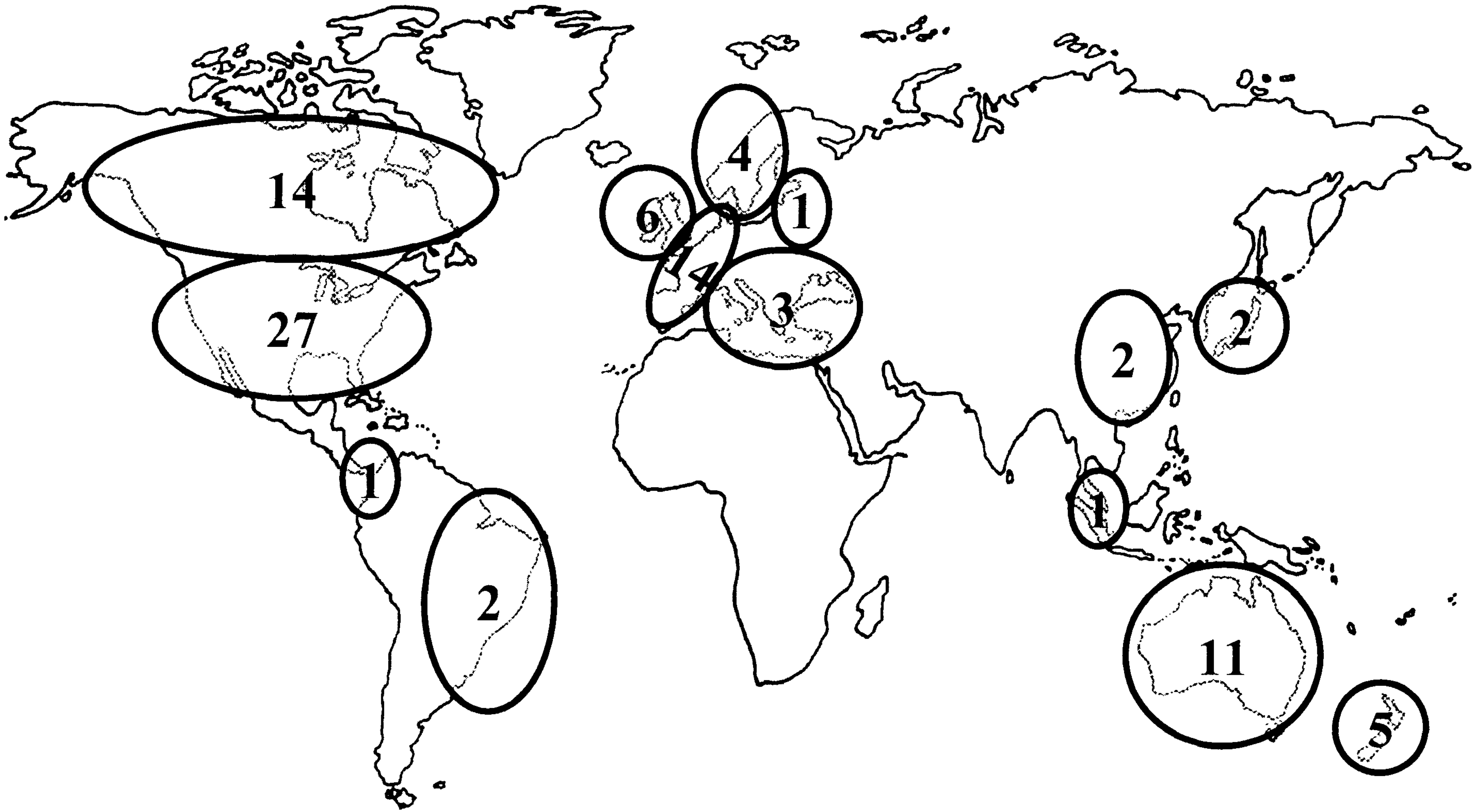
- Further information at: http://www.ku.lt/nemo/EuroAquaInvaders.htm

Coastal invaders in Europe

Ballast Water Research

- Ballast water research is a relatively young field of research although it is in use since 1870s
- The first mention of ships as introducing vector were published by Ostenfeld in 1908 after a phytoplankton bloom of an introduced species in the North Sea in 1903
- It took abot 70 years before the first ballast water sampling study was undertaken in Canada

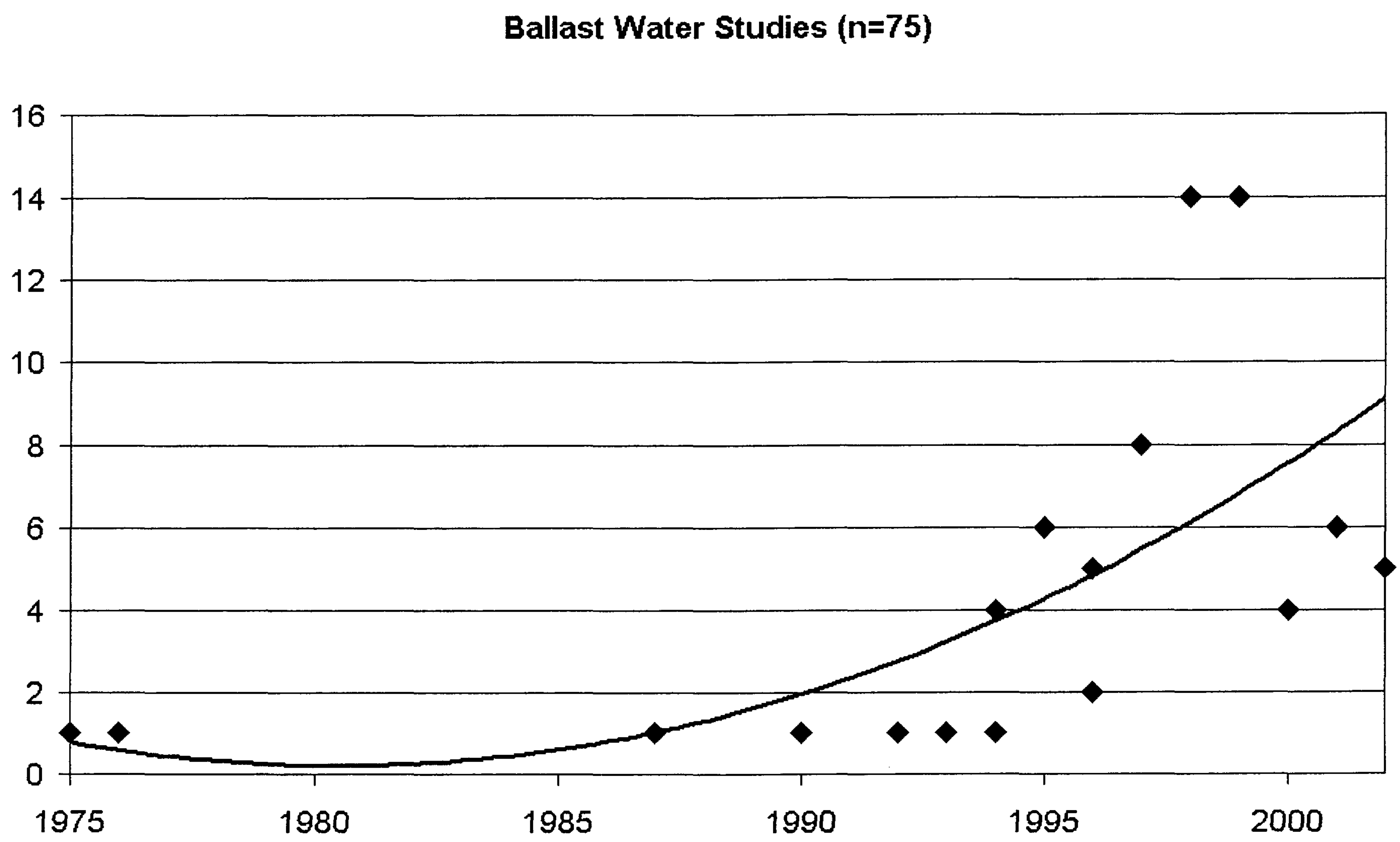
Ballast Water Studies



Ballast Water Research in Europe

- The first ballast water study in Europe was carried out in Germany 1992-1996
- 25 studies were undertaken by 11 countries so far (world-wide 93)
- Most studies focussed on the number and variety of organisms transported in ships ballast tanks

Timeline


Ballast Water Studies (n=75)
16
14
12
10
8
6
4
2
0
1975
1980
1985
1990
1995
2000

Focus of studies

- Total number: 93 studies world-wide
- Ballast water
  - Zooplankton: 52 studies
  - Phytoplanton: 52 studies
- Tank sediment: 28 studies
- Microbial analysis: 7 studies
- Testing of ballast water management: 11 studies

Sampling techniques

- Various sampling techniques have been used (e.g. nets, pumps, whole water samplers, buckets)

Major results on biota

- More than 1,000 different taxa have been found ranging from unicellular algae to fish of 15 cm body length
- Most common taxa found are dinoflagellates, diatoms and invertebrates
- Mean number of individuals during sampling:
  - phytoplankton: 299,200 ind./L
  - zooplankton: 4.6 ind./L

Major results on ballast treatment

- Efficient treatment systems will probably consist of several units
- Promising techniques tested onboard ships:
  - hydrocyclones
  - filtration
  - heat
  - UV
  - chemical treatment
- Ballast water exchange is of limited efficiency in regional seas, such as the North Sea

Research gaps

- Representativeness of sampling techniques
- Comparison of sampling results of various studes
- Are there habitat modifications within a tank (e.g. water stratification)
- How influencing is sampling on biota
- Development of more representative sampling techniques (ballast water sampling standard)
- Long-term survival of organisms in ballast tanks

Assuming that 12 Billion tonnes of ballast water are released annually (33 million tonnes per day) - during this 30 min talk:

- 685.000 tonnes of ballast water were released
- including
  - 3.1 Billion zooplankton organisms
  - 205.000 Billion phytoplankton organisms
  - and even more bacteriae, viruses and pathogens

Conclusions

- Ballast water is a new field of research which was started in the early 1970s
- End-point sampling in ports and studies en-route have frequently been undertaken
- Almost all life forms are found in ballast water tanks
- Shipping is THE major vector in unintentional species movements, with ballast water and hull fouling as key vectors of equal importance

Proposed land-based type approval tests for ballast water treatment systems

M. Voigt[1], S. Gollasch[2], A. Kornmüller[3], H. Röpell[4] , O. Kerschek[5], & C. Balke[5]

1- dr. voigt-consulting, Germany
2 – GoConsult, Germany
3 – Berkefeld, Germany
4 – Hamann Wassertechnik, Germany
5 – Gauss, Germany

Presented at the International Conference and Exhibition on *Ballast Water and Waste Water Treatment Aboard Ships and in Ports* ; June 11-13, 2003, Bremerhaven, Germany

This paper proposes a concept for the technical verification and the biological efficiency of ballast water treatment systems in land-based type approval tests.

The information presented is based upon discussions by experts participating in German R&D projects to develop ballast water treatment systems.

<u>Protocols are proposed for</u>

- **the preparation of tests,**
- **the test system design requirements,**
- **the sampling procedures,**
- **the selection of test organisms,**
- **and for analytical methodologies and data analysis.**

Some of the methodologies included in this concept (particularly for sampling biota) are in line with commonly agreed standard test intercalibration requirements such as proposed by ICES and GESAMP working groups.

Land-based tests require the production of a prototype ballast water treatment system.

This system should be identical in its design and dimension to systems intended for onboard installation.

Technical requirements

Any ballast water treatment equipment or processes has to comply with relevant safety regulations (e.g. SOLAS, ISO, EN and port state requirements)

In-line treatment options and in-tank treatment options require different test set-ups.

Technical requirements continued..

Prior to the beginning of the tests, the ballast water treatment system has to be run continuously for a minimum of 10 treatment cycles .

The treatment system should be

- cleaned well between all tests,
- left undisturbed during the individual test,
- operated when collecting samples

The ballast water treatment system has to proof its ability to perform under a wide range of scenarios, some presenting extreme conditions commonly found in freshwater, coastal, estuarine and marine habitats (not rare events).

Representative sets of biological conditions and non-biological water quality parameters are needed to evaluate the performance of the ballast water treatment systems.

Physical Test Water Conditions

Tests are to be carried out in marine (salinity > 30 ppt) and fresh water (salinity < 5 ppt) conditions

The following amount of dissolved and suspended water components should be used as these densities are frequently found over a wide geographic area:

- DOC 8-12 mg/l
- POM 8-12 mg/l
- MM 16-22 mg/l
- TSS 24-34 mg/l

Biological Test Water Conditions

Numbers of surrogate species should be sufficiently high to enable proper statistical analysis of data.

- Zooplankton > [25] ind. / l
- Phytoplankton > [100] cells / ml
- Macroalgae > [10] fragments of 1 cm^2 / l

Microbes excluded at this stage. If required the following density is suggested:

- Microbes > [10^5] / 100 ml

Suggested test organisms to be used from representative taxonomic groups – <u>1. Vertebrates</u>

The temperature optimum in (brackets),
the temperature tolerated <u>underlined</u>
and the suggested water temperature for test in bold.

Taxon	**Marine water > 30ppt salinity**	**Temperature**	**Fresh water < 5ppt salinity**	**Temperature**
Zooplankton				
Vertebrates	*Clupea harengus* (herring), larvae 7-29 mm	(10-15 °C) <u>4-20 °C</u> **10-15 °C**	*Cyprinus carpio*, larvae (Common carp) 5-10 mm	(18-20 °C) <u>10-30 °C</u> **15-20 °C**

Suggested test organisms to be used from representative taxonomic groups – 2. Invertebrates

Taxon	Marine water > 30ppt	Temperature	Fresh water < 5ppt	Temperature
Invertebrates				
Hard shell	***Artemia salina*, adult 7-12 mm**	(22-28 °C) 10-55 °C **15-20 °C**	***Daphnia magna*, adult 3-5 mm**	(12-20 °C) <5- >22°C **10-15 °C**
	***Artemia salina*, egg 100-150 µm**	15-28 °C **15-20 °C**	***(Neomysis integer)*, adult**	(14-18 °C) **15-20 °C**
	***Acartia clausi*, adult**	10-20 °C **15-20 °C**	***Gammarus tigrinus*, adult**	(15-18 °C) 0-26 °C **15-20 °C**
	***Corophium volutator*, adult 8 mm**	(10-25 °C) **15-20 °C**	***Cyclops* sp., adult**	(15-18 °C) 4-27 °C **10-15 °C**

Suggested test organisms to be used from representative taxonomic groups – 2. Invertebrates cont.

Invertebrates	Marine water > 30ppt	Temperature	Fresh water < 5ppt	Temperature
continued				
Soft shell	***Crassostrea gigas,*** **larvae* 50 µm**	(15-20 °C) 4-31 °C **15-20 °C**	***Dreissena polymorpha*****, larvae***	(15-20 °C) **15-20 °C**
	Artemia salina**, pre-nauplia (developing eggs)**	(15-25 °C) **15-20 °C**		
Soft bodied	***Artemia salina*****, early nauplius larvae >250 µm**	(15-25 °C) **15-20 °C**	***Tubifex tubifex*****, adult 40 mm**	(18-20 °C) **15-20 °C**
Resting stage	***Artemia*** **100 µm**	5-70 °C **10-25 °C**	***Daphnia magna***	not applicable

Suggested test organisms to be used from representative taxonomic groups – 3. Phytoplankton

Taxon	Marine water > 30ppt	Temperature	Fresh water < 5ppt	Temperature
Phytoplankton solitary	**dinoflagellate cysts, diatom spores**	not applicable	**dinoflagellate cysts, diatom spores**	not applicable
	Oxyrrhis marina **20 µm**	5-25 °C **10-20 °C**	***Peridinium umbonatum*** **25-35 µm**	(14-17 °C) 8-25 °C **10-15 °C**
	Scripsiella trochoidea **25 µm**	5-25 °C **10-20 °C**	***Surirella robusta*** **(75-250µm) x (40-60µm)**	(14-17 °C) 9-25 °C **10-15 °C**
Macroalgae	***Caulerpa taxifolia*** **up to 65 cm**	(20-30 °C) 5-32 °C **15-25 °C**	***Elodea canadensis*** **up to 3 m in length**	(<5-22 °C) 5-15 °C **10-15 °C**

Suggested test organisms to be used from representative taxonomic groups

Microbes excluded at this stage. If required the following candidate species are suggested:

Taxon	Marine water > 30ppt salinity	Temperature	Fresh water < 5ppt salinity	Temperature
Microbes	*Aeromonas* sp.	(36.5-37.5) 14.4-38 °C **25-35 °C**	*Pseudomonas* sp.	(35-37 °C) 4-41 °C **25-35 °C**
	Vibrio fischeri	(30-37 °C) <22- >37 °C **25-30 °C**		

1. In-line Treatment of Ballast Water

The minimum flow rate for in-line tests is 100 m^3/h

Three cycles with different flow rates should be run. One cycle includes the following three conditions:

•4h rated capacity according to specs,

•4h rated capacity according to specs + 10%,

•4h rated capacity according specs - 40%

The samples (volume min. 200 l each) should be taken every 60 minutes during each test cycle at the specified conditions.

Samples should be analysed for biota and water quality parameters (e.g. °C, salinity, DOC, TSS)

In-Tank Treatment of Ballast Water

- Tests are carried out in tanks that represent the typical / average design of ballast water tanks.

- This includes both, the size (ballast water capacity of the tank) and the structural design elements of the tank (support frames, in-tank manholes, structural layers etc.).

- The recommended minimum tank capacity for in-tank tests is 300 m^3.

Three cycles with different ballasting scenarios

Each scenario should represent tank and ship specific ballast water treatment cycles:

- 1 cycle with 100% filling – retention time 24 hrs
- 1 cycle with 50% filling – retention time 24 hrs
- 1 cycle with 100% filling – retention time 12 hrs

Each cycle to be repeated 3 times.

The samples (volume min. 200 l each) for biological analysis should be taken after 1 hour and 3 hours of continuous operation, and and the end of the retention time.

Water quality samples should be taken in regular intervals over the entire retention time.

Quarantine

In case non-native species are selected as surrogate organisms proper quarantine measures need to be applied to avoid accidental releases of these species and associated organisms

Detailed test protocols are going to be available in the near future.

• The Maritime Environment •

" Ballast Water and Waste Water Treatment Aboard Ships and in Ports"

Session 3

Black and Gray Water, Oily Water, Sewage and Sludges

Session Chairman*: Jochen Deerberg,*
DEERBERG-SYSTEMS, GE

SECOND ENVIRONMENTAL WORKSHOP
FOR
THE EXECUTIVES OF
THE CRUISE INDUSTRY

22. - 24.09.2002

HOTEL ATLANTIC
HAMBURG, GERMANY

INTRODUCTION & SUMMARY OF THE LWT WORKING GROUP RESULTS

Initiator – Organizer   Jochen Deerberg

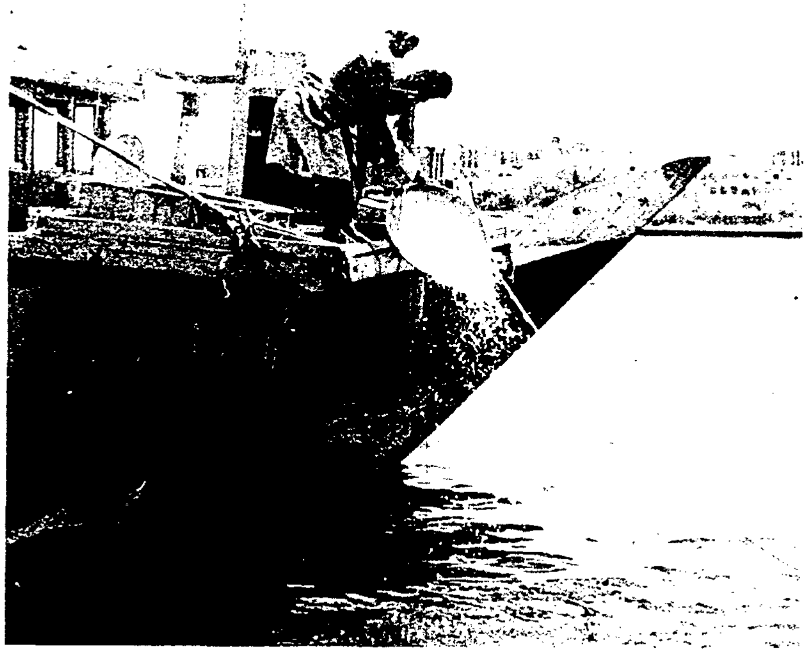
Closing the Gap between Solid and Liquid Waste Management

Introduction & Summary of the
Liquid Waste Treatment Working Group Results

Bremerhaven, 11-13 June, 2003

The Deerberg Complete Green Ship Philosophy 21
Solid, Wet & Liquid Waste Treatment Solutions

WASTE MANAGEMENT DEVELOPMENT – 1970



„OUT OF SIGHT-

OUT OF MIND“

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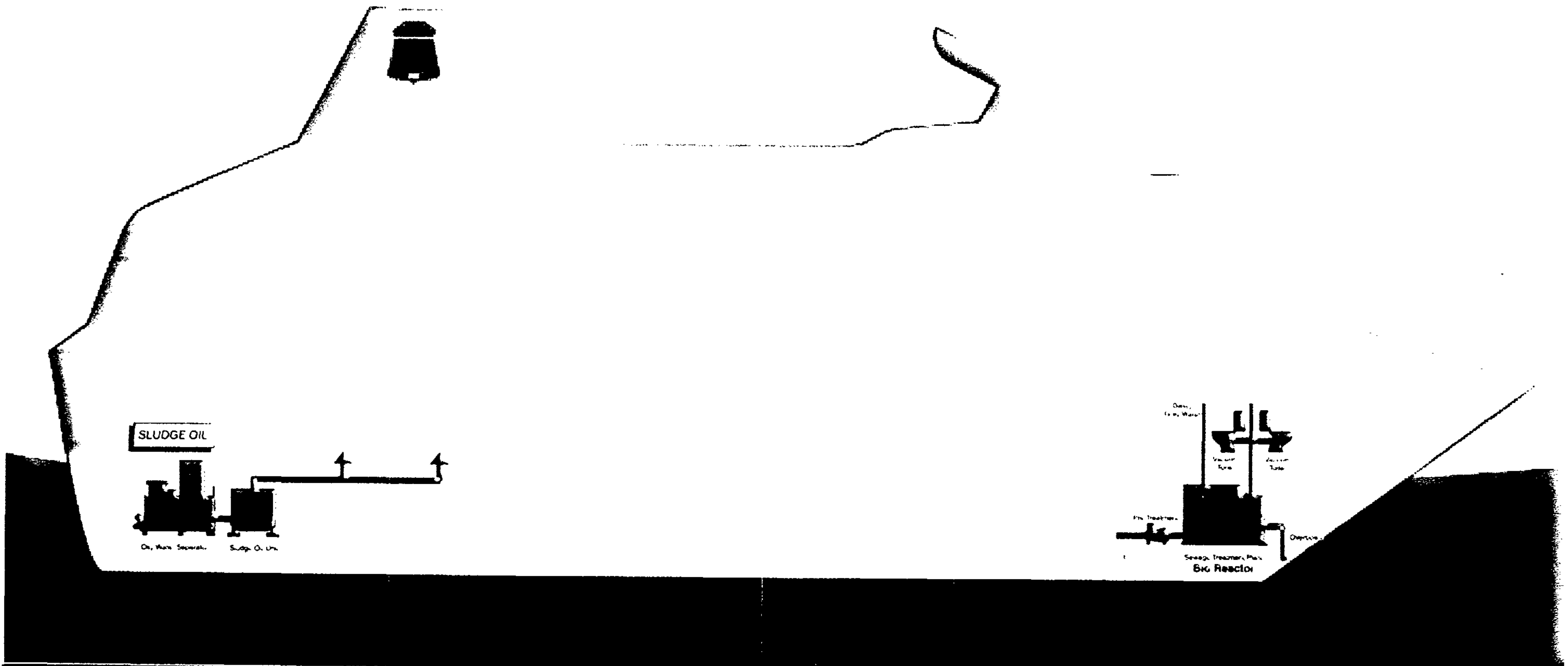
Solid, Wet & Liquid Waste Treatment Solutions

DEERBERG SYSTEMS

WASTE MANAGEMENT DEVELOPMENT - 1979



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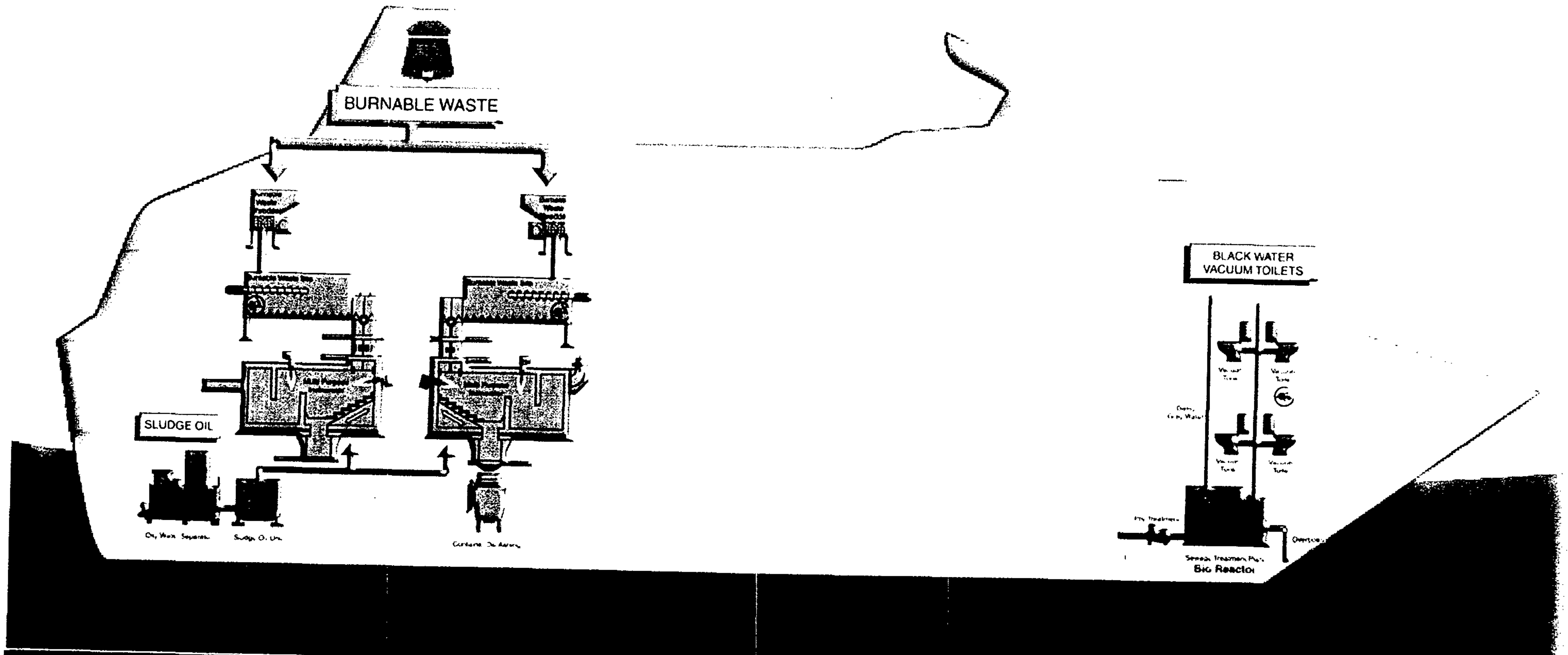
WASTE MANAGEMENT DEVELOPMENT - 1984



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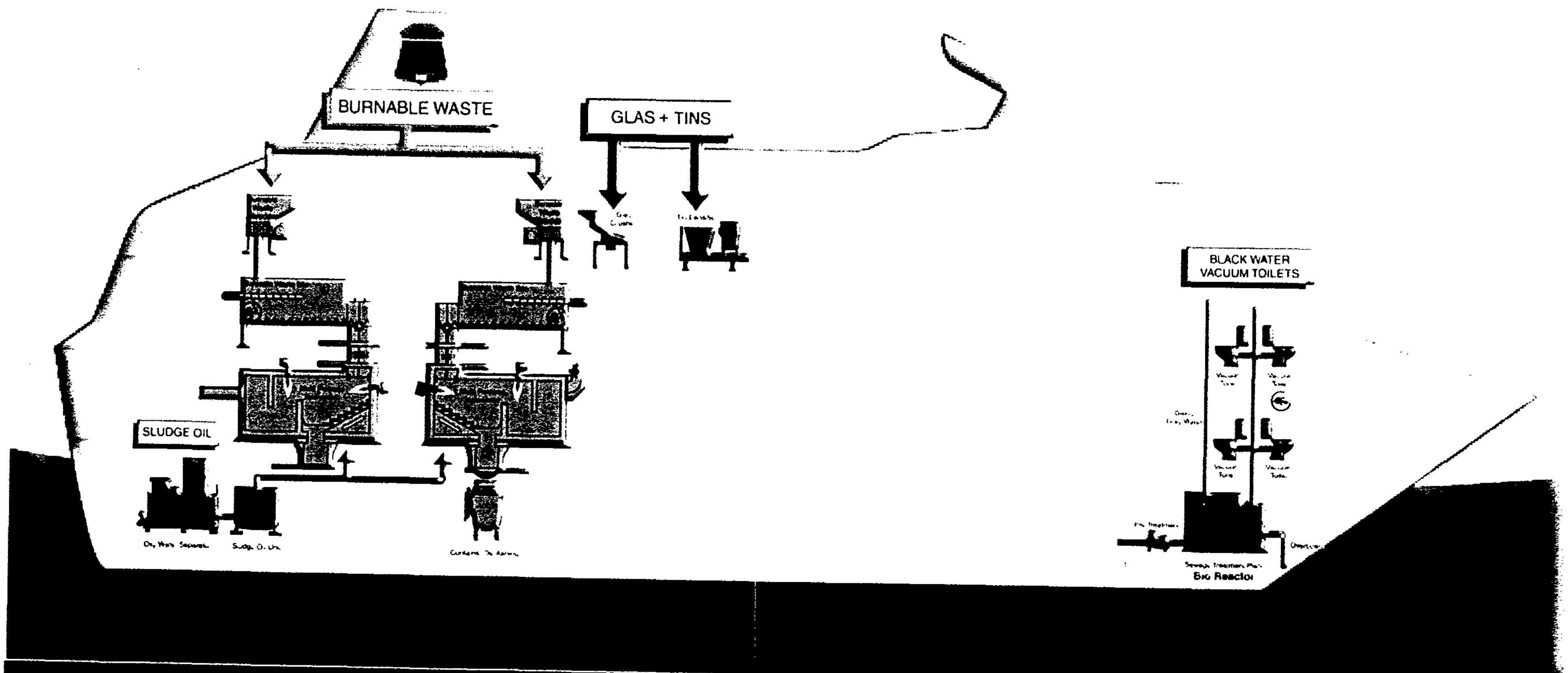
DEERBERG SYSTEMS

WASTE MANAGEMENT DEVELOPMENT - 1984



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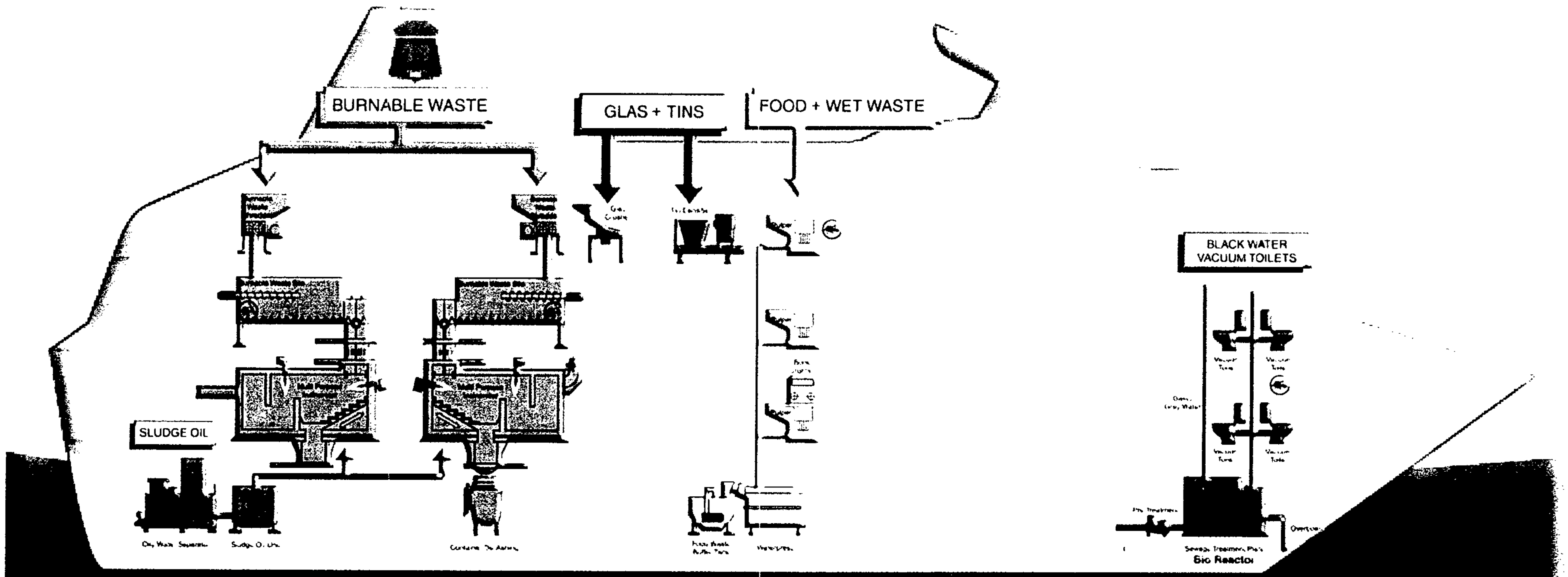
WASTE MANAGEMENT DEVELOPMENT - 1986



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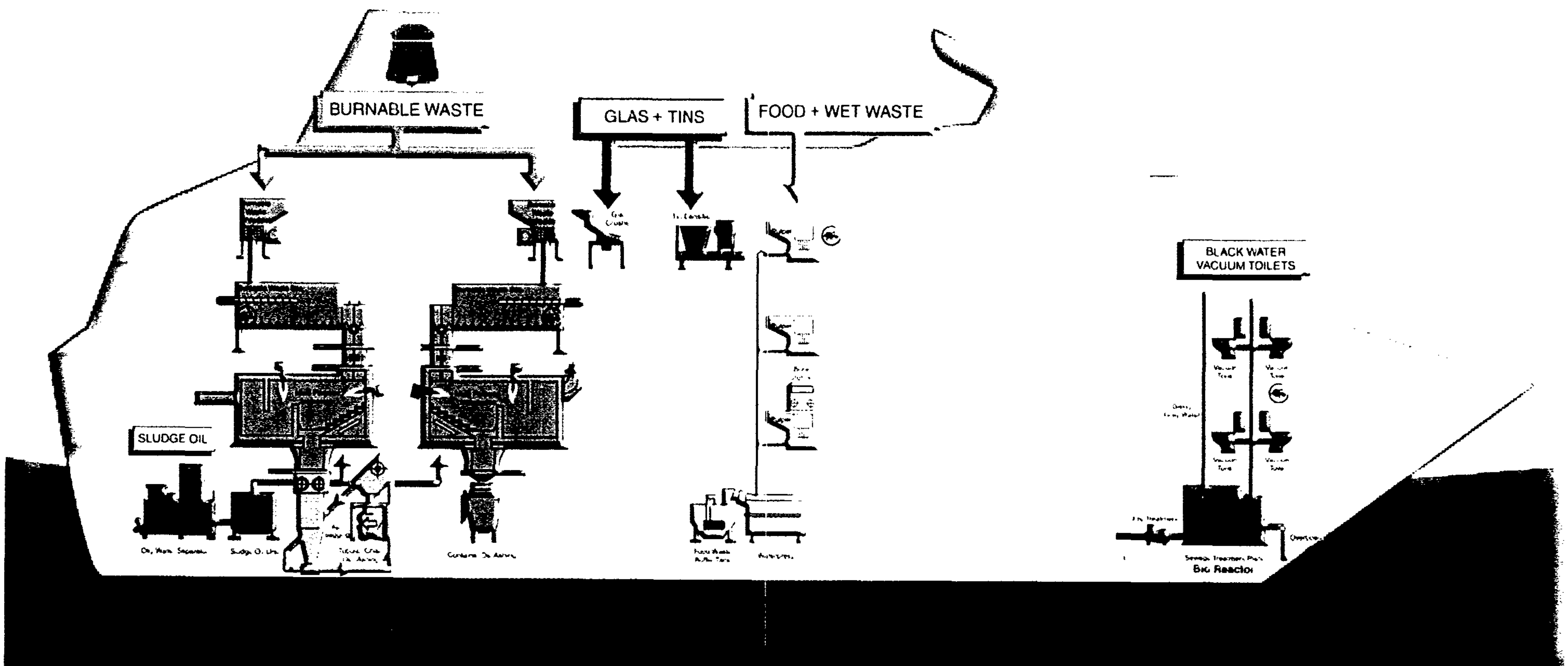
WASTE MANAGEMENT DEVELOPMENT - 1994



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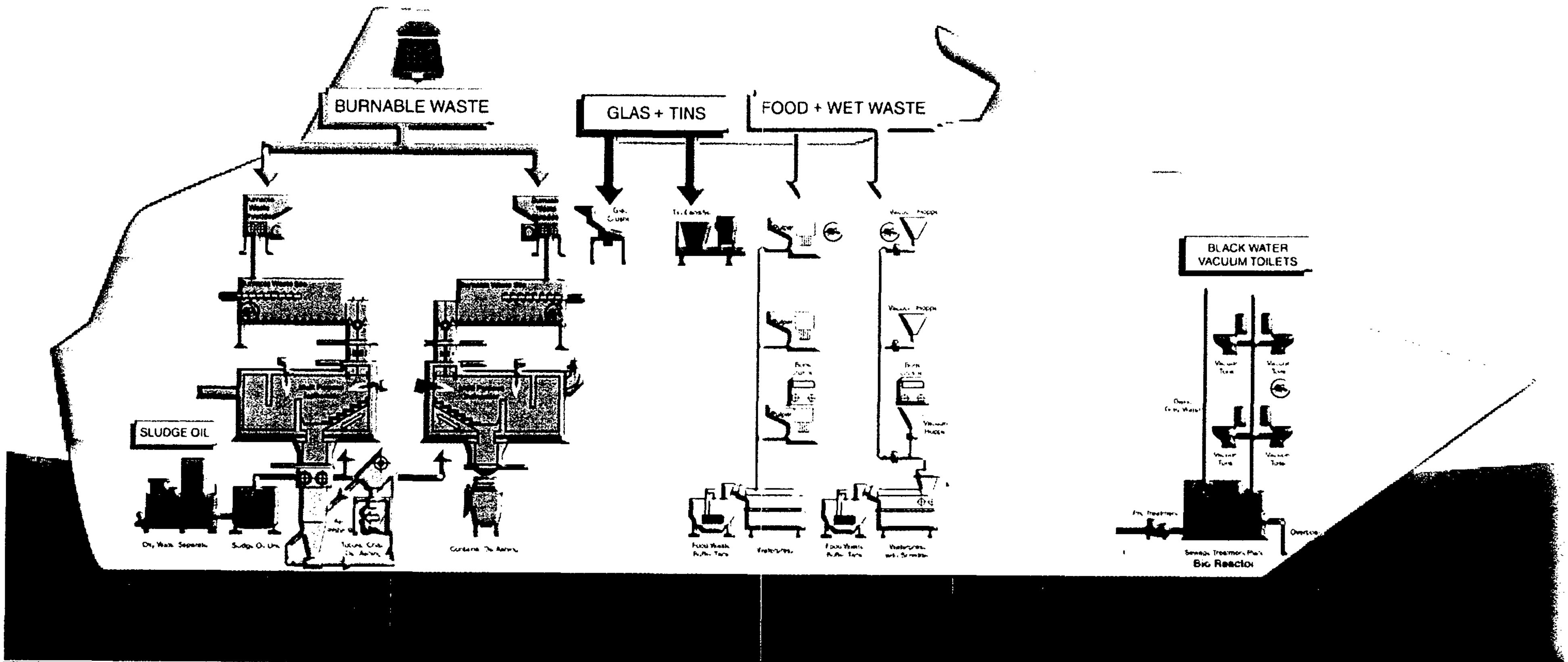
WASTE MANAGEMENT DEVELOPMENT - 2000



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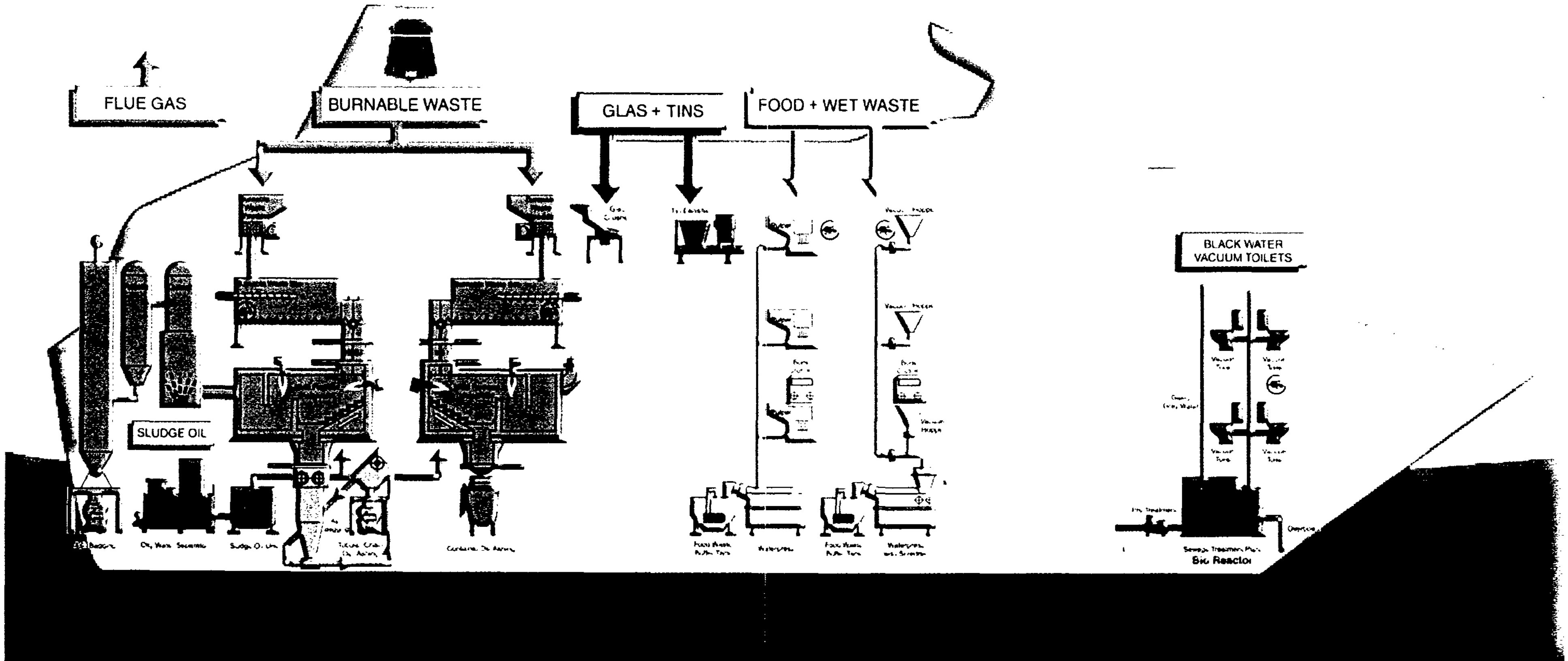
WASTE MANAGEMENT DEVELOPMENT – 2000



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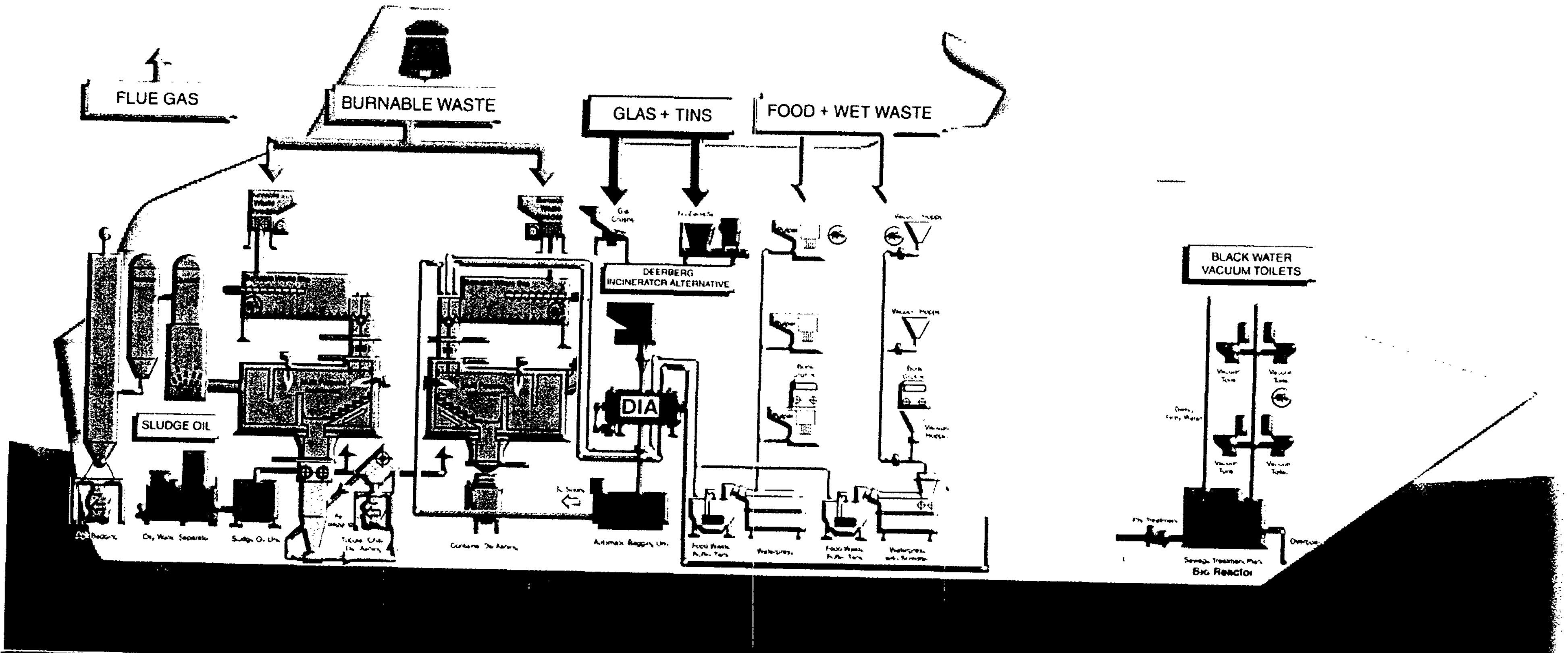
WASTE MANAGEMENT DEVELOPMENT - 2000



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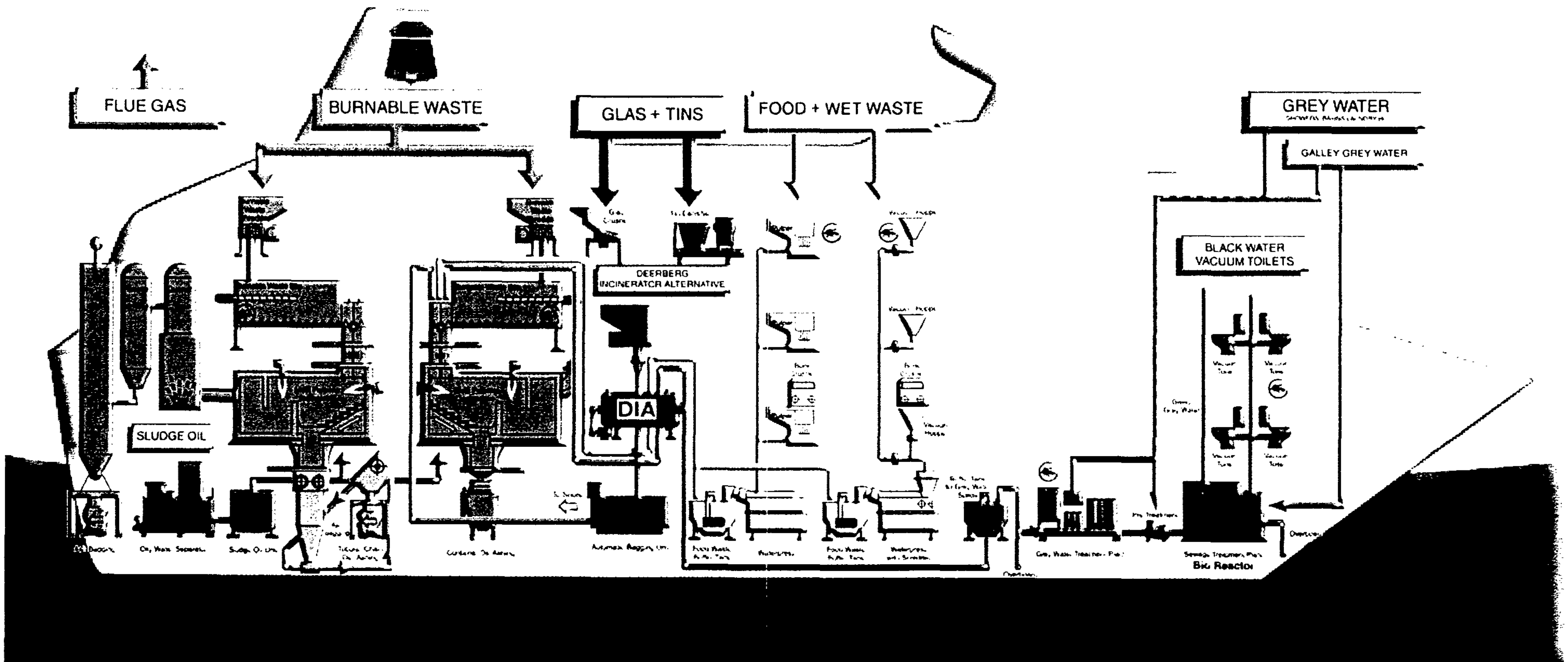
WASTE MANAGEMENT DEVELOPMENT - 2000



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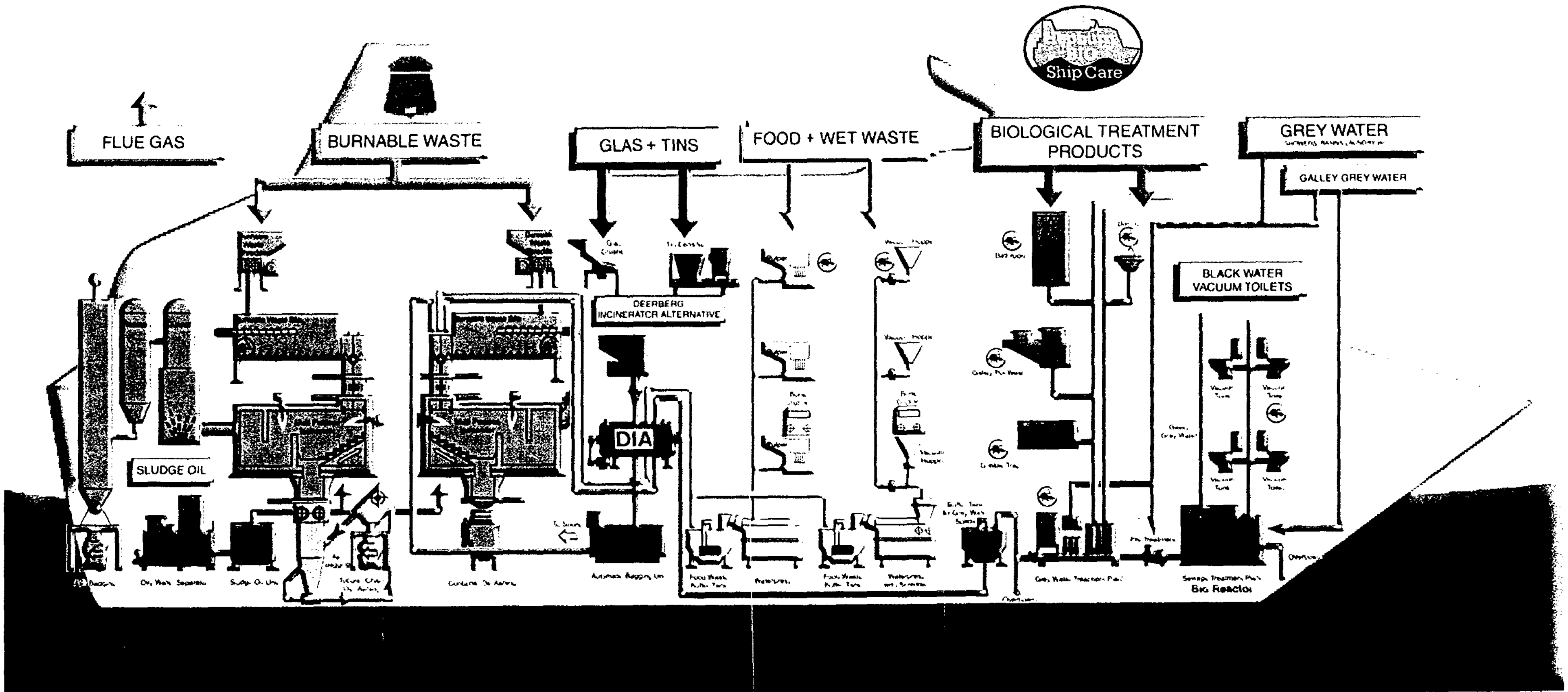
WASTE MANAGEMENT DEVELOPMENT - 2000



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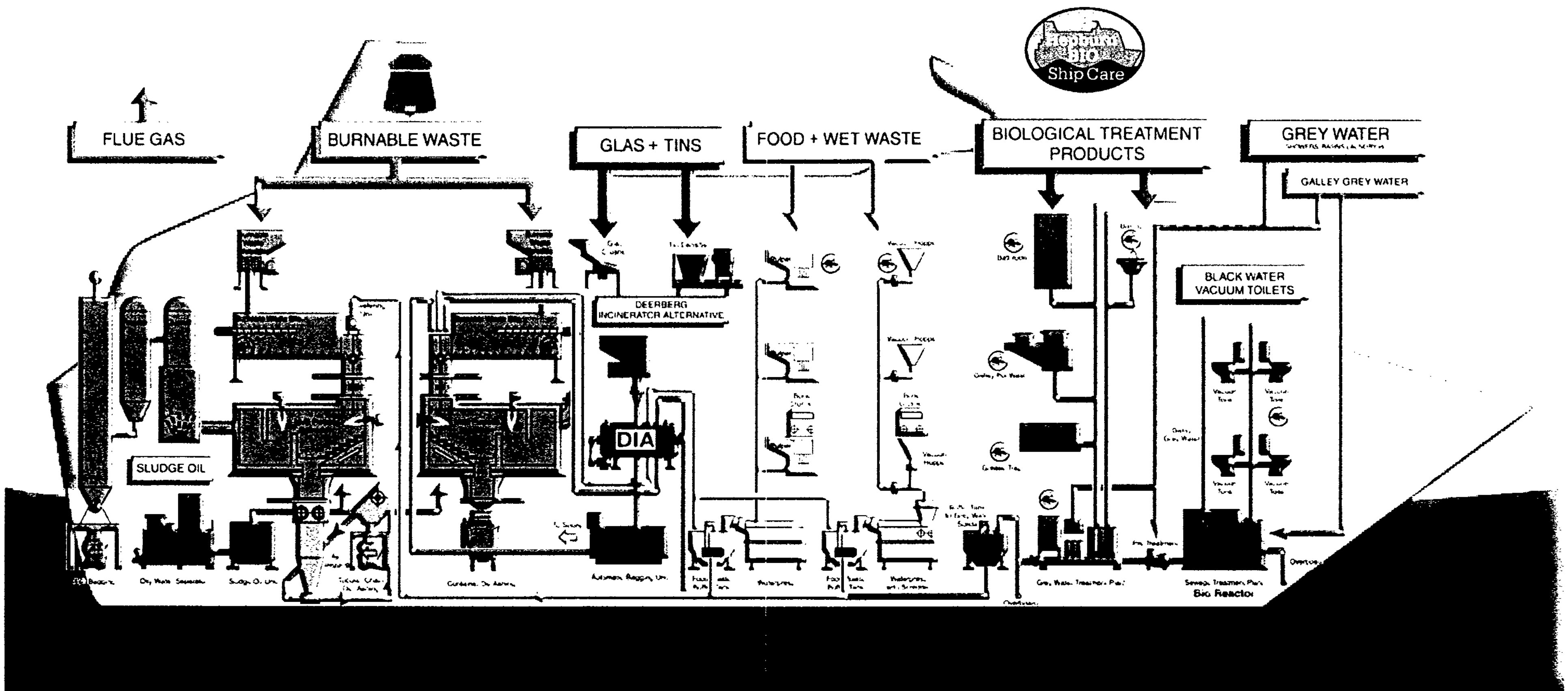
WASTE MANAGEMENT DEVELOPMENT - 2000



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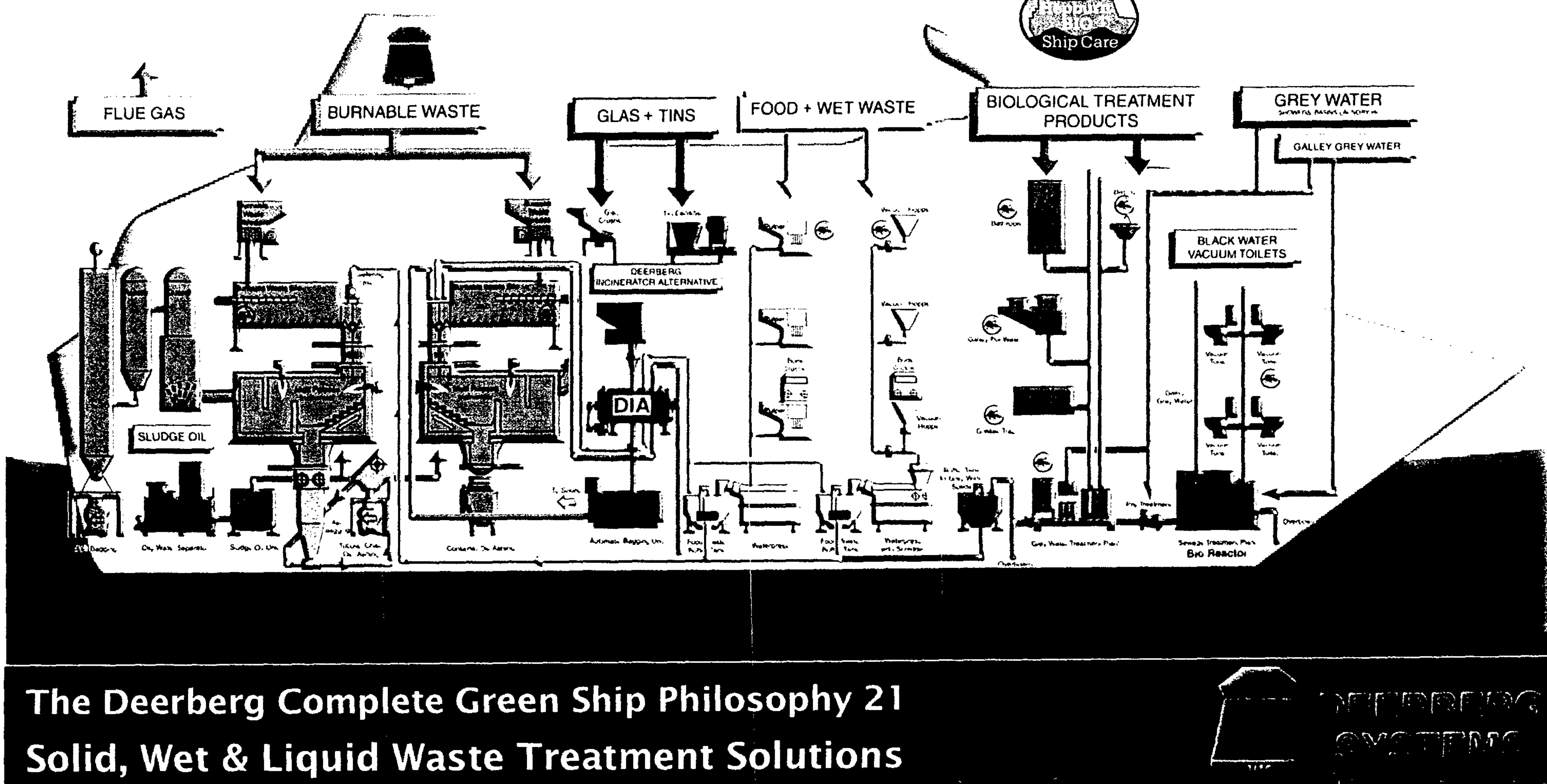
THE DEERBERG COMPLETE GREEN SHIP PHILOSOPHY 21

Presented to the Cruise Industry Executives during SMM 2000 on board Mississippi Queen



Erin Brockovich fights again

Sues Oil Giants over Cancer Cases in Schools

Los Angeles – Erin Brockovich, durch den gleichnamigen Hollywoodfilm bekannt gewordene US-Umweltaktivistin, hat am Montag Klage gegen eine Reihe großer Ölkonzerne eingereicht, die sie für die Krebserkrankung von Schülern einer renommierten Highschool in Beverly Hills verantwortlich macht. Im Namen von 21 an Krebs erkrankten ehemaligen Schülern, von denen drei inzwischen gestorben sind, warfen Brockovich und ihr Anwaltskollege Ed Masry den Ölgiganten vor, mehrere Ölquellen auf dem Schulgelände betrieben, ohne für ausreichenden Schutz gegen die giftigen Dämpfe gesorgt zu haben. Die Beklagten hätten in

Julia Roberts in dem Kinofilm „Erin Brockovich" FOTO: CINETEXT

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Solid, Wet & Liquid Waste Treatment Solutions

Int. RULES & REGULATIONS

IMO

NON-SORTING Operation

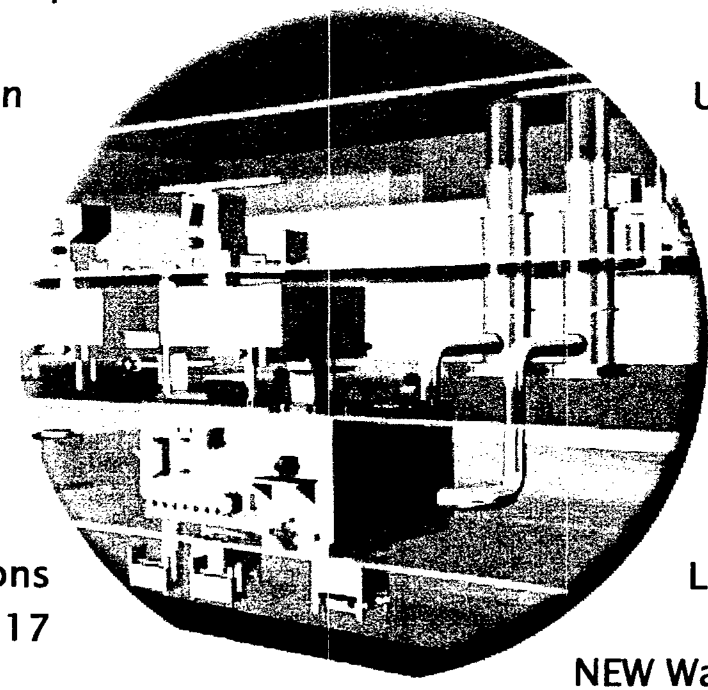
Sorting Operation

NO Bacteria Import Or Export

ZERO Discharge

Owners Own Requirements

Future Rules for Emissions
e.g. BlmschV.17



EPA

USDA

DERM

USCG

USPH

LOCAL RULES

Onshore Receiver Requirements
Onshore landing only
with prior sterilization

NEW Waste Water Rules e.g.
- Alaska (Murkowski Legislation)
- Hawaii
- Miami

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Solid, Wet & Liquid Waste Treatment Solutions

THE DEERBERG COMPLETE GREEN SHIP PHILOSOPHY 21

Liquid Waste Accumulation

Example of a Cruise Ship with 4000 Persons on board

Galley/Pulper Water
65-90 ltr/d/p
Average
85 ltr/d/p

Sanitary Waste Water
140-200 ltr/d/p
Average
175 ltr/d/p

Laundry WasteWater
30-75 ltr/d/p
Average
40 ltr/d/p

Black Water
25 ltr/d/p
Average
25 ltr/d/p

1.300 tons/day

To Incineration System
3,5 t LWT Residuals

After LWT Treatment
1.296,5 t out to sea

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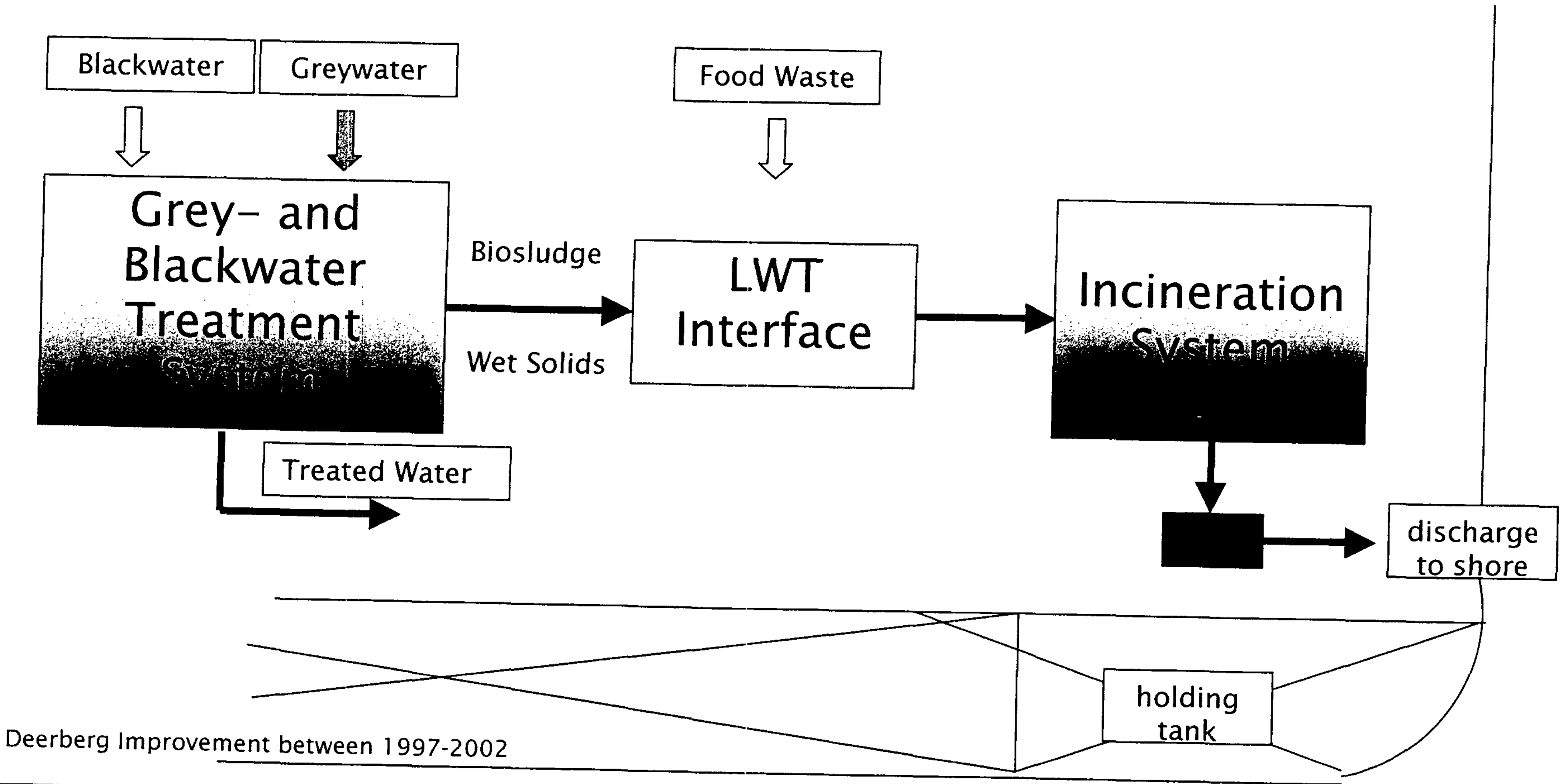
LIQUID WASTE SYSTEM
Principal Arrangement



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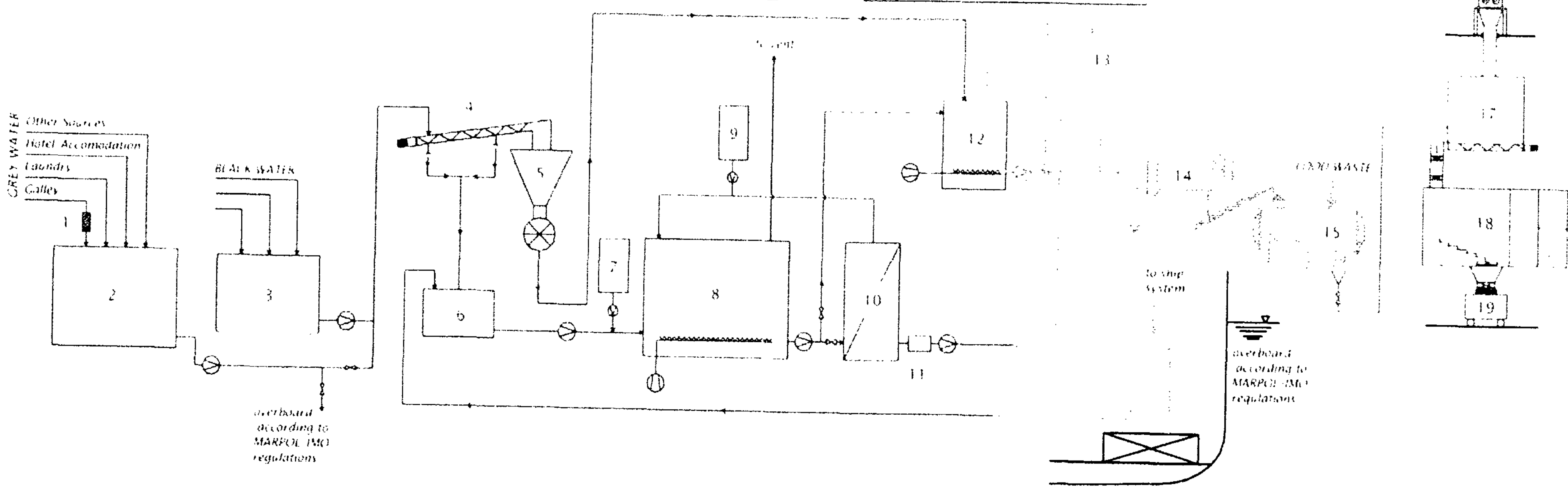
LIQUID WASTE SYSTEM
LWT Interface

Deerberg Liquid Waste Interface

(maximum solution, showing all options)

Key to Colours
Blue = Liquid Waste Treatment
Green = Deerberg Liquid Waste interface
Red = Solid Waste Treatment

1	Grease Separator
2	Grey Water Holding Tank
3	Black Water Holding Tank
4	Pre treatment Removal of Solids
5	Pre treatment Holding Tank for Solids
6	Grey and Black Water Transfer Tank
7	pH Adjustment
8	Bioreactor
9	Defoamer
10	Membrane System
11	UV Device
12	Biosludge Collecting Tank
13	Flocculent Unit
14	Decanter
15	Dryer, Sterilizer
16	Shredder for Solid Waste
17	Silo for Solid Waste, Dry Grey and Black Water and Dry Food Waste
18	Incinerator
19	Ash Container



Deerberg Improvement between 1997-2002

The Deerberg Complete Green Ship Philosophy 21
Solid, Wet & Liquid Waste Treatment Solutions

DEERBERG PHILOSOPHY

Long Experience in Liquid Waste Treatment

In 1979, as a consultant for Deutsche Gerätebau (then owned by the late Prof. Joachim Zahn, at that time President of Mercedes-Benz), Jochen Deerberg successfully introduced "Bio Compact" to the market, a biological sewage treatment plant. More than 500 of these and similar plants were sold during the following years, and Deerberg acquired valuable knowledge of the technical requirements of such plants — especially with respect to capacity, peak loads, foaming, smelling, necessary sizes (for the biophysical process), retention period and other important performance data.

Jochen Deerberg
Owner & CEO
Deerberg-Systems

LIQUID WASTE TREATMENT Working Group

As a primary result of the Second Environmental Workshop (Hamburg, September 2002), it was decided to form a Working Group on Liquid Waste Treatment (LWT).

Today, we are proud to present the results of this Working Group

The Deerberg Complete Green Ship Philosophy 21
Solid, Wet & Liquid Waste Treatment Solutions

LWT WORKING GROUP RESULTS FROM THE SHIPOWNER'S VIEWPOINT

Bremerhaven, 11-13 June 2003

Renato Storari - Principal Marine Engineer, R&D
Carnival Corporate Shipbuilding

1

RESULTS

- Productive opportunity of meeting around the table not only with representatives from different cruise companies, shipyards and water treatment plant manufacturers but also with makers and suppliers of other interface systems.
- Specific discussions with shipyard representatives on collecting the different waste streams in view of possible changes due to the installation of a LWT plant.
- Reiteration to shipyards of the importance of adequate holding capacity.

2

- Compilation of a concise baseline specification as a reference platform for plant proposals. This incorporates aspects of design and levels of performance expected by the shipowner and facilitates an objective and critical comparison of technologies.
- Compilation of a checklist for makers to facilitate their providing specific and comprehensive product information essential to the shipowner.

3

GOALS

- To equip ships with affordable and 100% reliable LWT plant producing an effluent which at least meets Alaska 2000 regulations.
- To fully comply with policy of zero discharge to sea of untreated waters and waste water treatment residuals.
- Environmental protection in terms reduced pollution and potential recovery of resources (energy and water).
- To develop a method to continuously monitor effluent quality.

4

DESIGN REQUIREMENTS

- Plant designed on a flexible, modular basis.
- Capacity to evolve by substituting or integrating stages.
- Guaranteed performance in terms of effluent quality; hydraulic and pollutant loads; energy consumption; operating costs.
- Safety in terms of redundancy/back-up; easy operation; automatic monitoring systems with self-diagnosis; reliable instrumentation for measuring parameters.

5

"Results from the Shipyards Point of View"

Hermann-Josef Mammes,

Meyer Werft, GE

Process description:

The first step of the process will be the **collection and pretreatment** of the waste water streams:

In general there was an agreement to use a common treatment system for all different waste water streams. It was discussed to check a separate solution for the food waste reject water in case a pulper system is used, caused by the very high biological load.

If a vacuum food waste system is used all waste water streams can be treated together.

The experience from the past shows that it is absolutely necessary to arrange a proper pretreatment of the waste water in front of the treatment to remove the solid part from the waste water stream. The solution for this was presented by the supplier.

The next important item is to realize a good mixing of the different waste water streams. Caused by the different biological loads of the different streams, peak loads can occur if the streams enter unmixed into the treatment. The mixing can be achieved with a buffer/mixing tank or by mixing the waste water in front of the treatment unit. In my opinion a sufficiently sized buffer/mixing tank is the most effective solution which ensures an optimal mixing and safe working without difficult pump operations. If the mixing of the different waste water streams is not sufficient, the peak load will influence the effluent figures or the hydraulic load of the system which means that the system cannot fulfill the design requirements. A proper pretreatment and mixing is the first important step of the treatment.

The second step will be the **treatment process**.

The treatment starts with a bioreactor with oxidation or with a oxidationunit to remove the biological load from the waste water.

To separate the bio sludge from the waste water, the suppliers are using two different procedures:

- Separation by using membrane filtration.

- Mechanical separation by using a flocculent and UV lights for disinfection.

Both of the systems are partly proven in practice and it seems that they can fulfill the requested effluent figures.

Based on the different techniques, the reaction on misfunctions will be different:

- in a membrane separation system the hydraulic load will be decreased without an influence on the effluent figures

- in a mechanical separation system the effluent figures will be increased but the hydraulic load will be constant.

This difference must be considered in the design and operation of the systems.

The third and last step is **sludge treatment.**The sludge from the pretreatment and the bio sludge from the treatment system, will be treated by dewatering and drying before the final burning or landing ashore. The storage as a intermediate stage of the sludge must be investigated, in case the burning or landing ashore is not possible.

Summary of the process description:

The industry has developed several different technical solutions for the treatment of the gray and black water. At least two of these techniques seem to be able to fulfill the requested effluent figures of Alska and Miami. The space and tank requirements for these two solutions seem to be in line with the available space in the actual cruise vessel design, if the storage capacity for treated/untreated water is in an acceptable amount (24 hours). If the system must be increased, based on the unclear influent figures, I think this over dimesioning cannot be accommodated inside the actual cruise vessel design without increasing the ship's volume or restrictions in the deadweight capacity and tank volume.

From the point of view of the shipyard I would like to highlight the following items:

The first item I would like to highlight are the **design criteria:**

There was a long discussion about this matter during the several meetings, about which parameters and which amount of the influent will be the basis for the design of the treatment system. The intention of the shipowner is to keep this matter as open as possible to be free in operation and cover all possible operation cases. The figures mentioned in the outline specification are proposed by the shipowner with the remark that these figures can be different between the different owners or the different operation profiles. From the owner's point of view this seems understandable, but not from the technical view. For a technical process with fixed output figures, the input figures are the starting point for the dimensioning and the performance of the system. If these figures are not clear, the dimensioning of the system can only be based on estimations and will include safety margins, which will create additional space, weight, tank capacities and all of these items will create additional cost. If it is not possible to come to common design criteria it is at least necessary to fix these figures case by case in the ship's specification to have a clearly accepted starting point.

The next important item is the **performance guarantee** for the system.

The performance of the systems is depending on at least three main items:

1. Function of all components of the system and a working biological process.
2. Correct hydraulic load and influent condition in accordance to the design.
3. Operation, control and maintenance of the system.

Based on these assumptions you can imagine that for the performance of the systems all parties involved are responsible. If the system is correctly designed and all components are working, the operation of the system is a very important part for the performance. It must be clear that these advanced treatment systems need a lot more maintenance, control and operation than the old existing systems. Also the influent figures can be influenced by the ship's operation (using wrong cleaning detergents, disposal of non-bio-degradable material into waste water system).

To help control the systems, and to be sure to discharge only treated water with the correct effluent figures, it is necessary that the industry will develop on line measurements for the main parameter or sub parameter, which allow the permanent control of the influent and effluent figures. With these possibilities it will be possible to follow the process and to identify the reason for misfunctions.

The performance guarantee especially in the situation today, where the first systems of the advanced technology will be installed and without any experience from the past, can only be taken by all parties involved.

At the end I would like to summarize the **results of the working group.**

The working group has worked successfully to develop a common basis specification as a guidance for the advanced waste water treatment systems. This specification has still some items which can and will be discussed. The exchange of information and the open-minded discussion were very helpful in bringing this important environmental subject to this point where we are today. As I mentioned before there are still some items which must be clarified in the near future, but if the working group continues in this way I am very optimistic that we will find solutions that we can solve together this important environmental subject. It is very important to demonstrate in the near future a proper and stable function of the treatment systems, with effluent data in accordance with the today's requests. Only then we can gain back the confidence of the authorities and maybe can come back to global valid rules and regulations regarding the discharge of treated water.

LWT WORKING GROUP RESULTS

From the producers view point
Bremerhaven, 11 - 12 June 2003

Lex van Dijk, Triqua bv

Opportunity

- Heterogeneous group
  - Ship owners
  - Ship yards
  - System suppliers
    - LWT system suppliers
    - Solid waste treatment system suppliers
- Establishment of a general specification and check list for LWT systems

Results - technological

- Establishing feed amounts and quality and buffer capacity - to be established ship by ship
- Minimum discharge standard: Alaska
- Zero discharge: sludge treatment / pulper waste treatment
- Clear definition of redundancy/back-up etc.
- Expansion of the systems to future standards

Check list (1)

- Process description
- Scope of supply
- Weight
- Space requirements
- Total power consumption
- Recommended buffer tank capacity
- Exclusion of waste streams
- FOG ?
- Used materials

Check list (2)

- Amount of waste produced (pretreament, precipitates, etc)
- Waste removal system
- Dryness of waste before waste handling and disposal
- Operation in case of maintenance
- Recommended spare parts and delivery time
- Chemical products to be used (normal operation/cleaning)
- Yearly chemical costs (normal operation/cleaning)

Check list (3)

- Yearly costs of other consumables
- Required monitoring and operation hours
- Values for COD, total Coliform, D.O., N-total, P-total, FOG
- Optimising plant for:
  - **COD** **< 25 mg/l**
  - **total Coliform** **< 200 MPN/100 ml**
  - **D.O.** **< 2 - 5 mg/l**
  - **N-total** **< 20 mg/l**
  - **P-total** **< 1 mg/l**
  - **FOG** **< 1 mg/l**
  - **TSS** **< 10 mg/l**

Conclusion

Co-operation between ship owners, ship yards and different makers / suppliers is a worthwhile exercise for implementing new technologies on board of ships.

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

Dr.-Ing. Thomas A. Peters [1), Dr.-Ing. Ralph Günther [2)]

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1. WASTE WATER TREATMENT ONBOARD CRUISESHIPS

Driving forces for the development of solutions for the wastewater treatment on cruiseships are mainly ecological aspects such as increasing environmental pollution, stricter discharge regulations and avoidance of chemicals, as well as, economical aspects like rising costs for waste handling in ports, reduction of waste water holding tank capacity and reduction of fresh water demand by water recycling for technical purposes /1/.

The main requirements for onboard wastewater treatment plants for both newbuildings and refit are:

- small footprint and low weight
- insensitivity to ship motion
- high process reliability
- insensitivity to changing peak loads
- fail-safe operation
- minimised use of chemicals
- high quality of the obtained water for technical uses like toilet flushing, laundry, cleaning and ballast
- reliable process monitoring
- reliable discharge control
- possibility to integrate the plant in a total water management based on graduated quality requirements

If membrane technology is used:

- highly efficient cleaning of the membranes
- an easy change of the membrane elements and modules.

2. "ONE STREAM" AND "TWO STREAM" SOLUTIONS

It can definitively not be the solution to add chlorine in order to disinfect wastewater before passing it overboard like in the past, even in combination with a biological treatment. Alternatives that are offered nowadays include one stream solutions, treating grey and black water together using membrane bioreactors (Figure 1), the combination of high cell density fermentation with ultrafiltration in compact modular plants /2/.

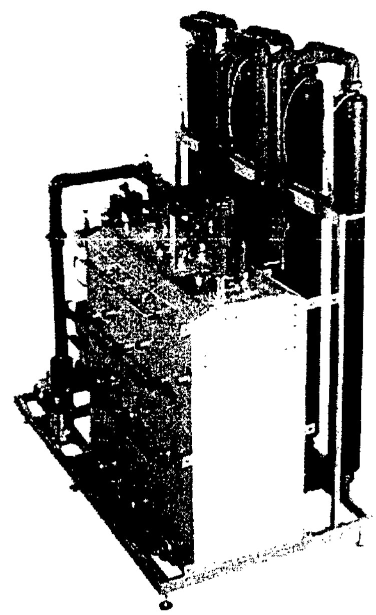

Figure 1: ROCHEM's Membrane bioreactor Bio-Filt®

Another option is a two stream solution, using low pressure reverse osmosis (Figure 2) for the purification of grey water, and a membrane bioreactor for the treatment of black water, RO concentrate and galley water /3/.

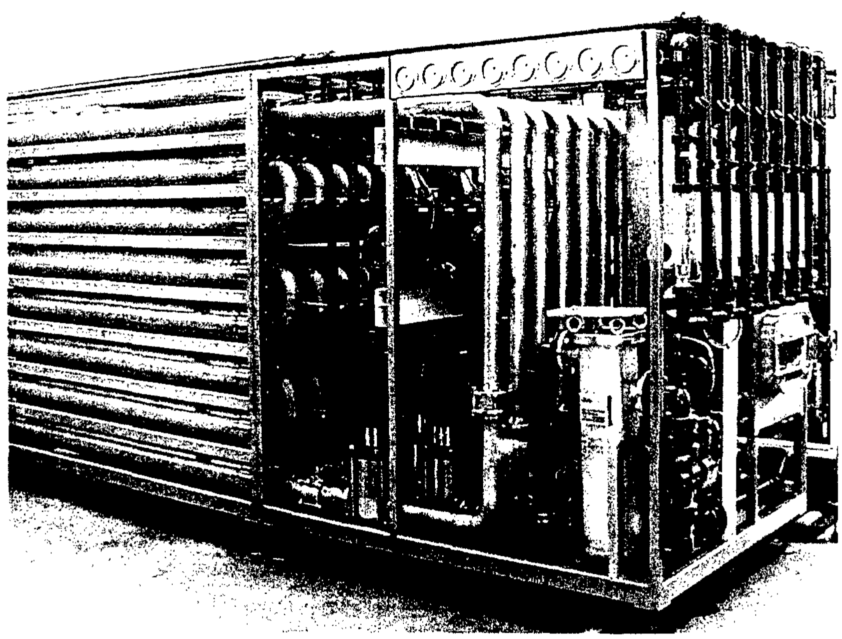

Figure 2: Low pressure reverse osmosis

The development of this "two stream" solution has been influenced by few findings and experiences that have been gained in the application of membrane technology for the treatment of industrial waste water. In many cases it was found that only a small partial stream contains most of the contamination. This has been addressed with the "90 to 10 formula", meaning that 90 % of the contamination is to be found in 10 % of the wastewater. From this was derived the postulate "do not mix !", because normally it is easier and more efficient to treat different kinds of contamination or different level of concentration with different technologies. This 90 to 10 formula does not apply strictly to the situation on board a 4,500 passenger cruise vessel as shown in Figure 3 /1/, but the average values should serve as example for this approach.

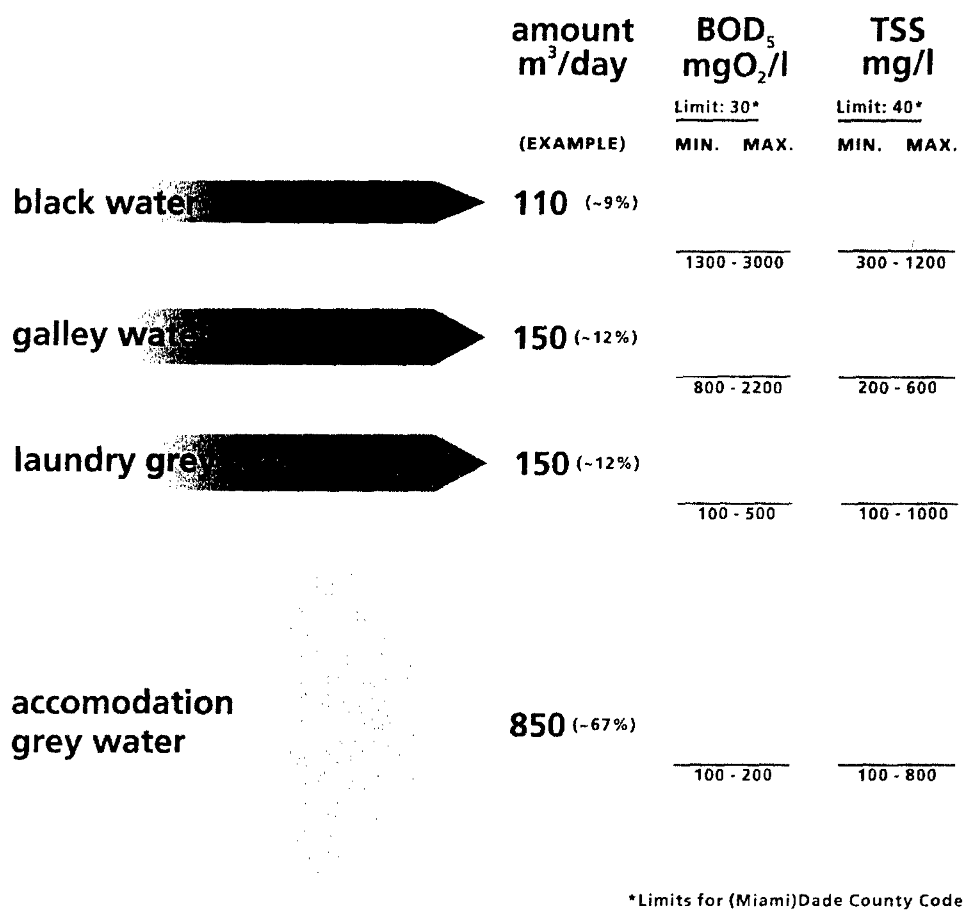

Figure 3: Wastewater evaluation on board a 4,500 pax cruise vessel

Another aspect is the fact that biological treatment is the most economical way to eliminate components in the water that produce the biochemical oxygen demand, taken as BOD_5 in mg O_2/L (biochemical oxygen demand in 5 days).

Beside the technological aspect of the philosophy, not to mix grey water and black water, has been considered also the psychological point of view. It is much more accepted to reuse water that has never been in contact with black water. Even if a high degree of purification is achieved and the water is used only for technical purposes like toilet flushing or cleaning, this detail is in discussion also in other areas of water reuse.

3. MEMBRANE TECHNOLOGY

There are several plants of this technology in operation, based on ultrafiltration and low pressure reverse osmosis (Figure 4) and it can be concluded that after the pioneering time and introduction phase for these technologies the plants are working reliable /4/.

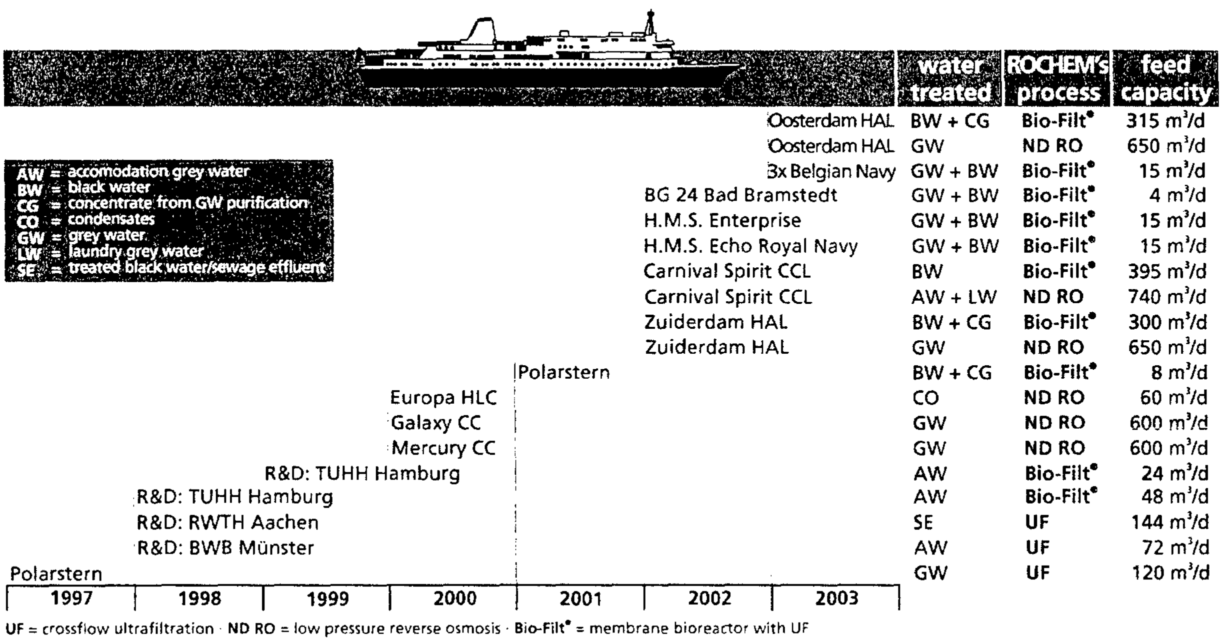

Figure 4: ROCHEM´s ship references for wastewater treatment

The operational results show, that the limit values like imposed by the Miami Dade County Code or other legislation (Figure 5) can be achieved with this technology.

PARAMETER	MARPOL 73/78 IMO Resolution MEPC.2 (VI)	USCG 33 CFR 159 Type II MSD	Alaska Titel XIV
Fecal Coliform [cfu/100mL]	250	200	20
Total Suspendid Solids (TSS) [mg/L]	100 (shipboard test)	150	30
Biochemical Oxygen Demand (BOD_5) [mg O_2/L]	50	n.a.	30
Free Chlorine [mg/L]	n.a.	n.a.	10
pH [-]	n.a.	n.a.	6-9

Figure 5: Performance criteria met or exceeded

One example for small plants is the German research vessel "Polarstern", where a ultrafiltration plant for the treatment of grey water is in operation since 1997. The membrane bioreactor Bio-Filt (Figure 6), treating the black water and the concentrate of this ultrafiltration plant, has been installed in 2001 /5/. Table 1 shows some data of this plant.

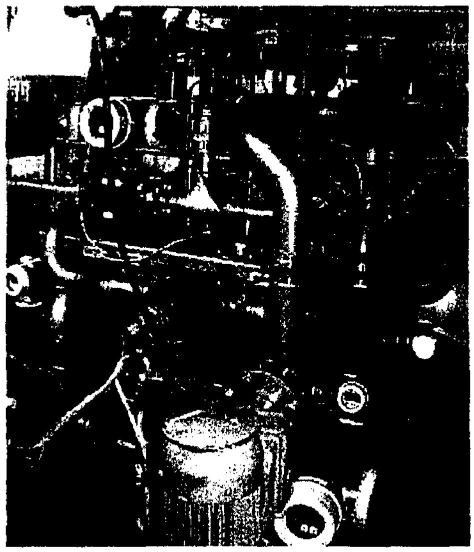

Figure 6: Membrane bioreactor Bio-Filt® on "Polarstern"

Table 1: technical details of the Bio-Filt "Polarstern

membrane area	14,42 m^2
membrane	PAN
MWCO	200 kDalton
feed volume black water	1,5 m^3/d
feed volume grey water concentrate	4,5 m^3/d
feed volume, up to	3 - 5 m^3/h
UF cycle flow	55 - 65 m^3/h
module inlet pressure	200 - 400 kPa (2 - 4 bar)
plant volume (L x W x H)	2.0 x 1.5 x 1.7 m

Example for the feed capacity of wastewater treatment plants in operation on cruiseships are the low pressure reverse osmosis for the treatment of grey water on GALAXY with 600 m^3 per day (Figure 2), in operation since 2000, or the Bio-Filt system on CARNIVAL SPIRIT with 395 m^3 per day, commissioned in 2002 (see Figure 4).

Main component of the ultrafiltration and the low pressure reverse osmosis plants is the FM (Flat Membrane) module (Figure 7) developed from ROCHEM specifically for the separation of bacteria, viruses and particles in the sub-micron range from water with high fouling potential.

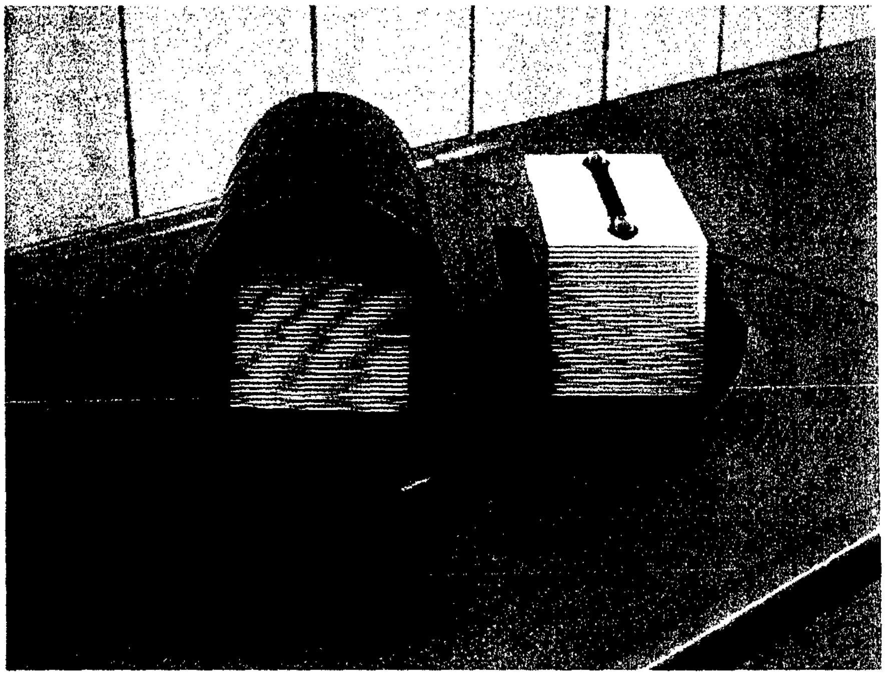

Figure 7: ROCHEM FM (Flat Membrane) module

The combination of open channel construction and narrow gap technology realised in this module allows for exceptional cleanability and high availability, as well as, high fluxes with low energy demand. In addition, the wide spectrum of commercially available flat sheet membranes means that optimal selection of a membrane for each individual application is possible.

4. FUTURE

The results obtained in the past have shown that there are different aspects that have to be investigated case by case in order to find the right solution for each cruise vessel. This includes questions related with:

- operating costs
- life-cycle-service
- redundancy and standards
- shut-down and emergency behaviour
- limiting factors for the processes as function of long time operation
- effects of mixing different kinds of wastewater
- sustainable solutions for the treatment of the residues in combination with an environmental impact analysis
- simplicity of operation
- proper training of the staff.

Furthermore technology evaluation criteria like

- "volumetric plant density factor",

➢ "plant volume to plant weight ratio" or
➢ "plant weight to plant feed ratio"

(Figure 8) /1/ should be used in order to support the decision of operators and yards selecting the best available solution for each project.

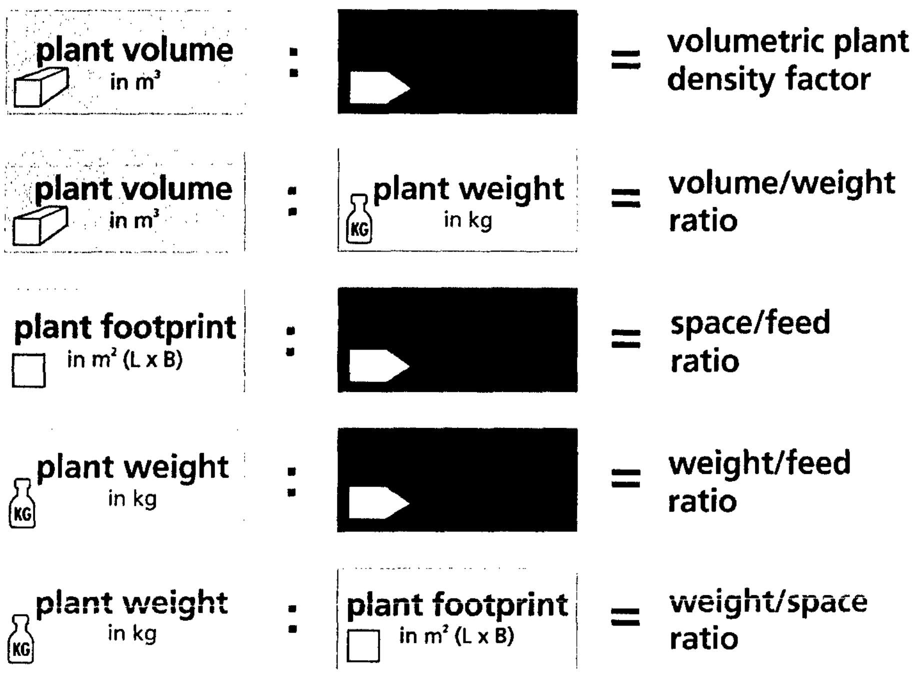

Figure 8: Technology evaluation criteria

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/4/ Report of the SECOND ENVIRONMENTAL WORKSHOP FOR THE EXECUTIVES OF THE CRUISE INDUSTRY, organised by SEATRADE/P&O PRINCESS/MEYER WERFT/DEERBERG SYSTEMS, Hotel ATLANTIC, Hamburg, 22-24 September 2002
/5/ Günther, R., Guttau, S., Wagner, E.: Decentralised wastewater treatment using ultrafiltration and membrane bioreactor on board FS "Polarstern". Preprints, 9th aachen membrane colloquium, 18-20 March 2003

FM Module Technique and Bio-Filt Membrane Bioreactor

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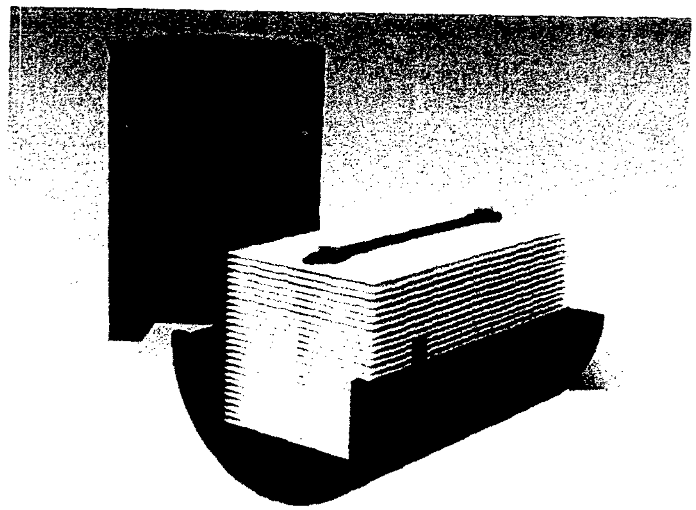

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Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- CONTENTS

- WASTE WATER TREATMENT ONBOARD CRUISESHIPS
- "ONE STREAM" AND "TWO STREAM" SOLUTIONS
- MEMBRANE TECHNOLOGY
- SUMMARY / FUTURE

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ DRIVING FORCES

WASTE WATER TREATMENT ONBOARD CRUISESHIPS

main driving forces for the development of solutions for wastewater treatment on cruiseships:

ecological aspects

- ▶ increasing environmental pollution
- ▶ stricter discharge regulations
- ▶ avoidance of chemicals

economical aspects

- ▶ rising costs for waste handling in ports
- ▶ reduction of waste water holding tank capacity
- ▶ reduction of fresh water demand by water recycling for technical purposes

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ MAIN REQUIREMENTS

main requirements for onboard wastewater treatment plants

(newbuildings and refit)

- ▶ small footprint and low weight
- ▶ insensitivity to ship motion
- ▶ high process reliability
- ▶ insensitivity to changing peak loads
- ▶ fail-safe operation
- ▶ minimised use of chemicals
- ▶ high quality of the obtained water for technical uses like toilet flushing, laundry, cleaning and ballast

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Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ MAIN REQUIREMENTS

- reliable process monitoring
- reliable discharge control
- possibility to integrate the plant in a **total water management** based on **graduated quality requirements**

if membrane technology is used:

- highly efficient cleaning of the membranes
- an easy change of the membrane elements and modules.

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **"ONE STREAM" AND "TWO STREAM" SOLUTIONS**

to add chlorine is definitively not a solution
in order to disinfect wastewater
before passing it overboard like in the past

alternatives offered nowadays

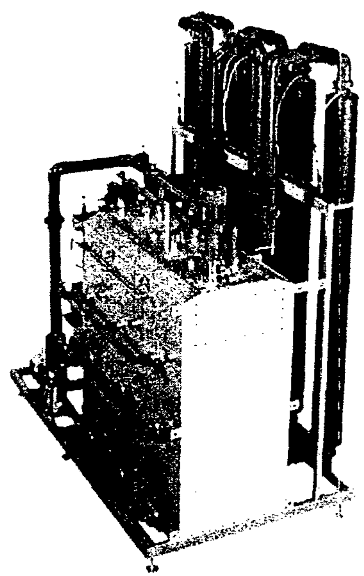
- **one stream solution:** membrane bioreactor for grey water and black water

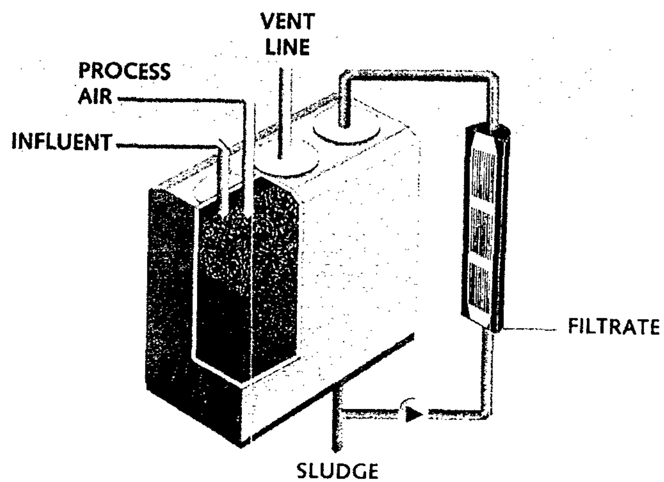
- **two stream solution:** low pressure reverse osmosis for the purification of grey water
  +
  membrane bioreactor for the treatment of black water, RO concentrate and galley water

Black and Grey Water Treatment Using
FM Module Technique and Bio-Filt Membrane Bioreactor

- **ONE STREAM SOLUTION**

treating grey and black water together
using **membrane bioreactors**
= combination of high cell density fermentation with ultrafiltration
in compact modular plants





Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **TWO STREAM SOLUTION**

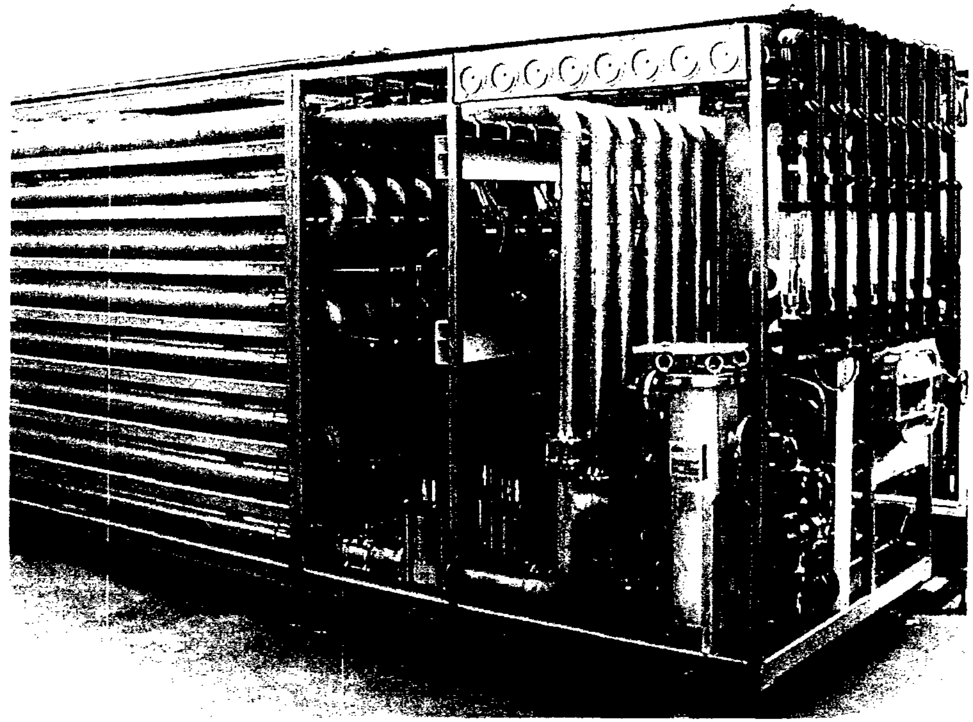
low pressure **reverse osmosis**

for the purification of grey water

+

membrane **bioreactor**

for the treatment of black water,
LP-RO concentrate and
galley water



Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ TWO STREAM SOLUTION

influenced by few findings and experiences
gained in the **application of membrane technology**
for the treatment of industrial waste water.

in **many cases**: a small partial stream
contains most of the contamination

addressed with the "**90 to 10 formula**":
90 % of the contamination is to be found in 10 % of the wastewater

basis for the postulate "**do not mix !**"

it is **easier and more efficient** to treat different kinds
of contamination or different level of concentration
with **different technologies**

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Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ WASTEWATER EVALUTION 4,500 PAX

situation on board a 4,500 passenger cruise vessel

	amount m^3/day (EXAMPLE)	BOD_5 mgO_2/l Limit: 30* MIN. - MAX.	TSS mg/l Limit: 40* MIN. - MAX.
black water	110 (~9%)	1300 - 3000	300 - 1200
galley water	150 (~12%)	800 - 2200	200 - 600
laundry grey	150 (~12%)	100 - 500	100 - 1000
accomodation grey water	850 (~67%)	100 - 200	100 - 800

*Limits for (Miami)Dade County Code

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ BIOLOGICAL TREATMENT – WATER REUSE

other aspects :

the **biological treatment** is the **most economical way**
to eliminate components in the water
that produce the biochemical oxygen demand,
taken as BOD_5 in mg O_2/L (biochemical oxygen demand in 5 days).

philosophy, not to mix grey water and black water,
considers the psychological point of view:

It is much more **accepted to reuse water**
that has **never been in contact with black water**.

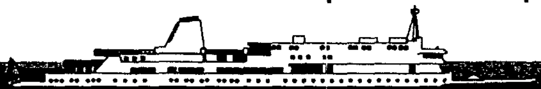
Even if a high degree of purification is achieved
and the water is used only for technical purposes
this detail is **in discussion also in other areas of water reuse**

Black and Grey Water Treatment Using
FM Module Technique and Bio-Filt Membrane Bioreactor

▪ MEMBRANE TECHNOLOGY

ROCHEM´s ship references for wastewater treatment

after the pioneering time and introduction phase the plants are working reliable



Year	Ship / project	water treated	ROCHEM's process	feed capacity
2003	Oosterdam HAL	BW + CG	Bio-Filt®	315 m³/d
2003	Oosterdam HAL	GW	ND RO	650 m³/d
2003	3x Belgian Navy	GW + BW	Bio-Filt®	15 m³/d
2002	BG 24 Bad Bramstedt	GW + BW	Bio-Filt®	4 m³/d
2002	H.M.S. Enterprise	GW + BW	Bio-Filt®	15 m³/d
2002	H.M.S. Echo Royal Navy	GW + BW	Bio-Filt®	15 m³/d
2002	Carnival Spirit CCL	BW	Bio-Filt®	395 m³/d
2002	Carnival Spirit CCL	AW + LW	ND RO	740 m³/d
2002	Zuiderdam HAL	BW + CG	Bio-Filt®	300 m³/d
2002	Zuiderdam HAL	GW	ND RO	650 m³/d
2001	Polarstern	BW + CG	Bio-Filt®	8 m³/d
2000	Europa HLC	CO	ND RO	60 m³/d
2000	Galaxy CC	GW	ND RO	600 m³/d
2000	Mercury CC	GW	ND RO	600 m³/d
1999	R&D: TUHH Hamburg	AW	Bio-Filt®	24 m³/d
1998	R&D: TUHH Hamburg	AW	Bio-Filt®	48 m³/d
1998	R&D: RWTH Aachen	SE	UF	144 m³/d
1998	R&D: BWB Münster	AW	UF	72 m³/d
1997	Polarstern	GW	UF	120 m³/d

AW = accomodation grey water
BW = black water
CG = concentrate from GW purification
CO = condensates
GW = grey water
LW = laundry grey water
SE = treated black water/sewage effluent

UF = crossflow ultrafiltration · **ND RO** = low pressure reverse osmosis · **Bio-Filt®** = membrane bioreactor with UF

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Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ LIMIT VALUES

performance criteria met or exceeded
operational results show, that the limit values can be achieved

PARAMETER	MARPOL 73/78 IMO Resolution MEPC.2 (VI)	USCG 33 CFR 159 Type II MSD	Alaska Titel XIV
Fecal Coliform [cfu/100mL]	250	200	20
Total Suspendid Solids (TSS) [mg/L]	100 (shipboard test)	150	30
Biochemical Oxygen Demand (BOD_5) [mg O_2/L]	50	n.a.	30
Free Chlorine [mg/L]	n.a.	n.a.	10
pH [-]	n.a.	n.a.	6-9

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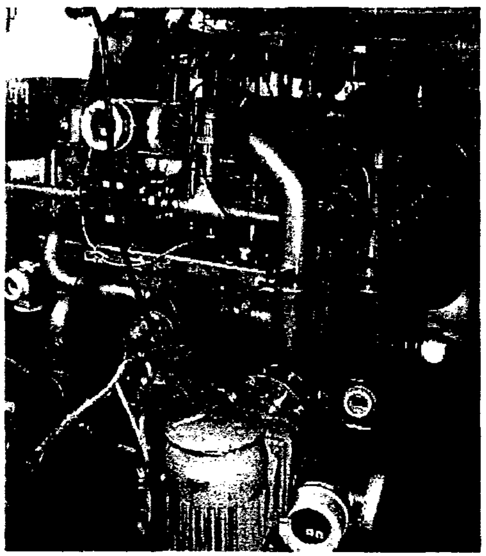
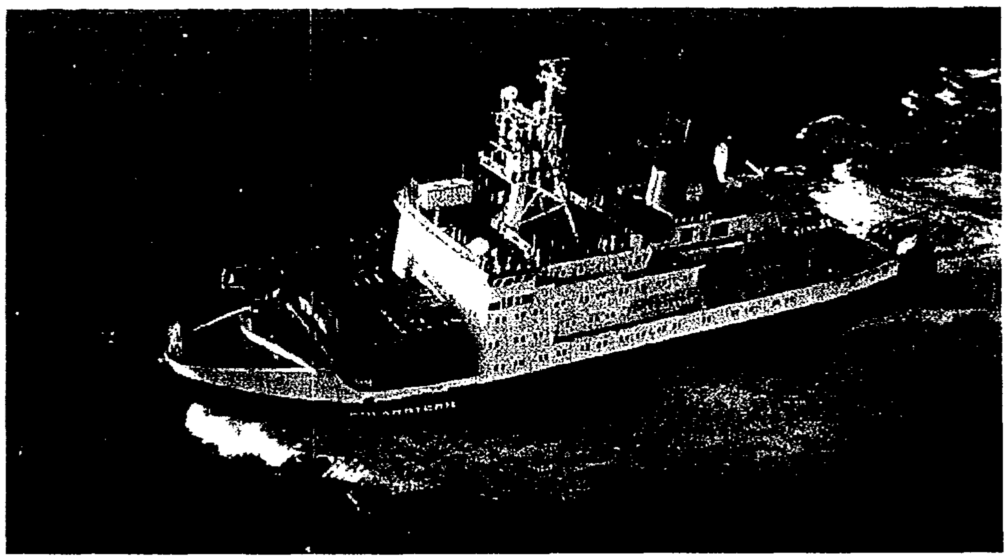
Black and Grey Water Treatment Using
FM Module Technique and Bio-Filt Membrane Bioreactor

▪ FS POLARSTERN

example for small plants: German research vessel "Polarstern"

- ultrafiltration plant for the treatment of **grey water** is in operation **since 1997**
- membrane bioreactor Bio-Filt , treating the **black water** and the concentrate of this ultrafiltration plant, has been installed in **2001**





Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- Bio-Filt® "POLARSTERN"

Table 1: technical details of the Bio-Filt "Polarstern

Bio-Filt® „Polarstern"	
membrane area	14,42 m^2
membrane	PAN
MWCO	200 kDalton
feed volume black water	1,5 m^3/d
f. volume GW concentrate	4,5 m^3/d
feed volume, up to	3 - 5 m^3/h
UF cycle flow	55 - 65 m^3/h
module inlet pressure	2 - 4 bar
plant volume (L x B x H)	2 x 1,5 x 1,7 m

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **FEED CAPACITY**

feed capacity of wastewater treatment plants in operation on cruiseships:

- ▶ low pressure reverse osmosis for the treatment of grey water on **GALAXY** **600 m³ per day**, in operation since 2000
- ▶ Bio-Filt® system on **CARNIVAL SPIRIT** **395 m³ per day**, commissioned in 2002

Dr.-Ing. Peters Consulting

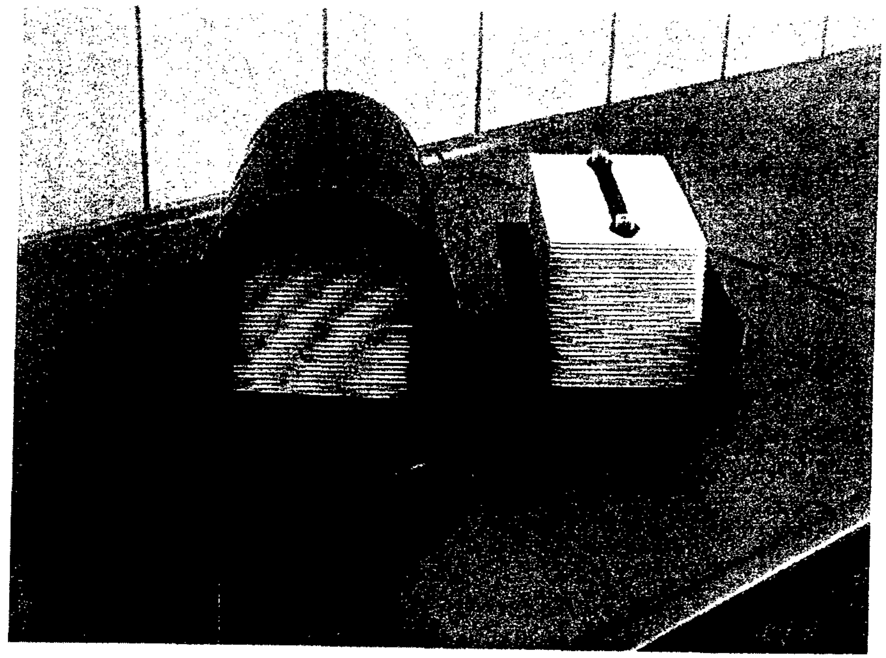
ROCHEM

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **FM MODULE**

Main component of the ultrafiltration **and** the low pressure reverse osmosis plants is the **FM (Flat Membrane) module**

developed from ROCHEM specifically for the separation of bacteria, viruses and particles in the sub-micron range from water with high fouling potential.



Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ FM MODULE

combination of **open channel construction**

and **narrow gap technology**

allows for:

- ▶ **exceptional cleanability**
- ▶ **high availability**
- ▶ **high fluxes with low energy demand**
- ▶ **selection of a membrane for each individual application**
  from the wide spectrum of commercially available flat sheet membranes

Dr.-Ing. Peters Consulting

ROCHEM

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **FUTURE**

results obtained in the past years have shown:

there are different aspects
that have to be investigated
case by case in order to find
the **right solution** for
each cruise vessel.

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ PROCESS EVALUATION ASPECTS

- operating costs
- life-cycle-service
- redundancy and standards
- shut-down and emergency behaviour
- limiting factors for the processes as function of long time operation
- effects of mixing different kinds of wastewater
- sustainable solutions
  for the treatment of the residues
  in combination with an environmental impact analysis

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **PROCESS EVALUATION ASPECTS**

▶ simplicity of operation
▶ proper training of the staff.

Furthermore **technology evaluation criteria** like

▶ "volumetric plant density factor"
▶ "plant volume to plant weight ratio"
▶ "plant weight to plant feed ratio"

should be used in order to
support the decision of operators
and yards selecting the
best available solution for each project

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

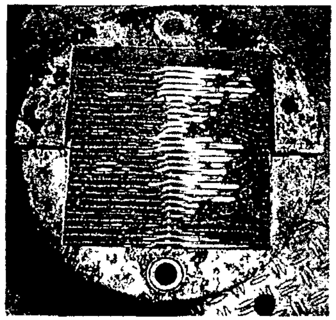
- **PROCESS EVALUATION CRITERIA**

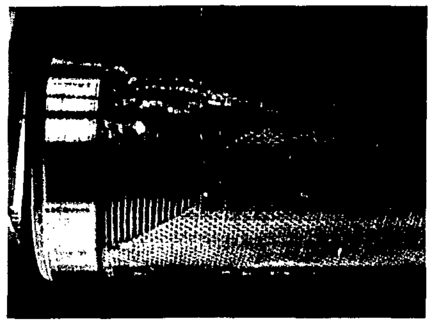
plant volume in m^3	:		=	volumetric plant density factor
plant volume in m^3	:	plant weight in kg	=	volume/weight ratio
plant footprint in m^2 (L x B)	:		=	space/feed ratio
plant weight in kg	:		=	weight/feed ratio
plant weight in kg	:	plant footprint in m^2 (L x B)	=	weight/space ratio

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

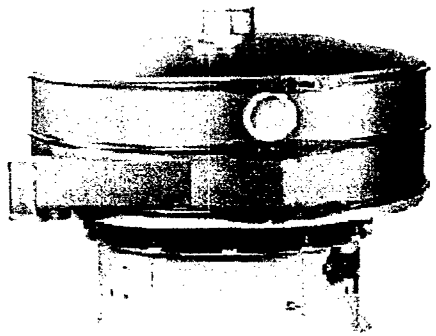
- **PROBLEMS AND SOLUTIONS 1**

Problem 1: fibre, hair, etc.





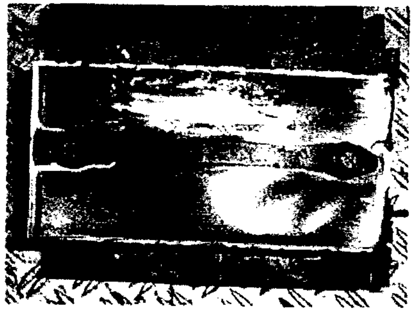
- **Solution 1:** optimized prefiltration

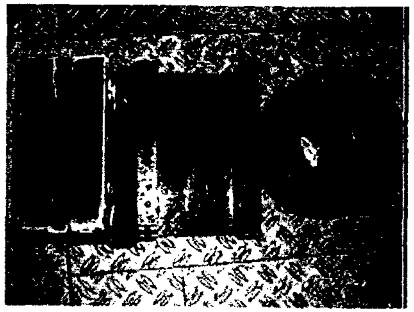


Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

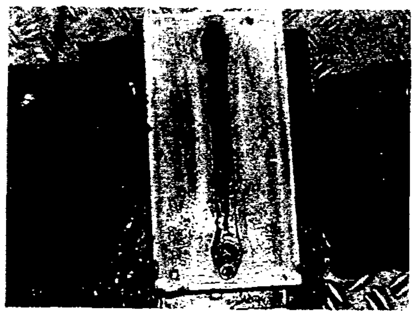
- **PROBLEMS AND SOLUTIONS 2**

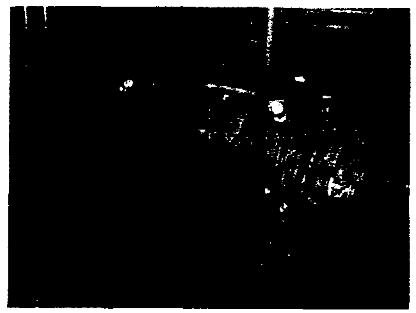
Problem 2: Fouling





- **Solution 2:** adapted cleaning procedere





Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

▪ SUMMARY

ROCHEM´s successful solution for grey water purification and black water treatment in the naval industry based on findings like

- adaptation of pretreatment and membrane cleaning to the wastewater quality decisive for the success of membrane technology

- compact design and fully automatic operation of the ROCHEM system guiding for newbuildings and refit

Black and Grey Water Treatment Using FM Module Technique and Bio-Filt Membrane Bioreactor

- **SUMMARY**

Example "FS Polarstern"

- **reliable operation** of the system under extreme conditions **proved** since more than 2 years
- success only due to a **close cooperation** of universities, owner, operator and plant manufacturer
- grey and black water treatment constituent for the **BLUE ANGEL** for FS Polarstern

Laundry Wash Water Recycling for the Marine Industry

Kim Karch, VP Sales and Marketing
AquaRecycle
866-272-9253 toll free
770-973-0283 fax
kim.karch@aquarecycle.com

Introduction:

AquaRecycle's EMI™ Laundry Water Recycle System is the only 100% closed loop, completely automated laundry water recycle system on the market today. This break-through technology has revolutionized the laundry industry by applying a simple process used successfully in water treatment plants, to the laundry environment.

AquaRecycle™ has developed an industry-specific recycle system for marine vessels to recycle all the laundry wastewater. This design takes into account several issues prevalent on ships: limited space and accessibility, complete automation and system monitoring, code appropriate piping, minimal labor requirement, and excellent ROI potential.

The EMI™ Laundry Wash Water Recycle System uses natural ground media's and ultra violet light technology to filtrate out unwanted contaminants while continuously disinfecting the wastewater. The end result is a recycle process that returns 100% of the wastewater back as recycled water with no chemicals added and a 95% reduction in wastewater discharge.

Advantages:

Advantages of recycling laundry wastewater are all encompassing and include water and energy savings, chemical reductions, complete automation, and the opportunity to make a positive impact on the environment and our natural resources.

The AquaRecycle™ System captures 100% of the laundry wastewater for reuse. The only water that is lost in the process is that which remains in the laundry and evaporates in the drying process. This reduces water usage by 85%. The only water to be discharged is the water used to backwash the ground media filters, or about 5% of the total water use. In addition to water savings, there can also be significant energy savings since our recycled water can be returned for reuse already heated at temperatures up to 49° C. The laundry can also receive shorter drying cycles since the final rinse water is much warmer, reducing the time required to heat the laundry before entering the dryer.

The Recycle Process:

EMI's state-of-the-art technology filtrates and disinfects lint, minute solids, organics, chemicals, odor, and bacteria from your wastewater, returning clean, disinfected water for reuse. The EMI™ patent pending process of recycling laundry wastewater is unique in that our system recycles 100% of the wastewater discharge and returns all 100% back to the laundry operation clean and germ-free.

The laundry wash water recycle system uses a unique blend of filtration processes to clean and disinfect the wastewater. The System consists of an initial wastewater collection tank, a final holding tank, injection of activated oxygen, pressure vessels containing various types of ground media, UV-disinfection, and a "smart" control panel which includes a PLC computer and digital flow meters that monitor, run and tract the system's performance automatically.

Our patent pending process begins with the removal of suspended solids down to 5 microns. We then filter the process water through our proprietary blend of media to remove soaps, organics, free oil and grease.

A final step cleans and sanitizes the water with an ultra-violet light process. This removes 99.9% of any bacteria in the water and brings the water back clean and fresh smelling. The water is then sent to a final holding tank, waiting for use as demanded by the washing machines. Our recycled water is returned for reuse as clean and disinfected with a temperature averaging as high as 48°C. The only water lost in the recycle process is that which remains in the linens, or approximately 10% of the total water.

Limited Space and Accessibility:

Each component is sized and designed to fit independently in the laundry or other location near the site. Equipment is lightweight and easy to maneuver and is sized to fit through any standard doorway of 36" or less. Piping of the pressure vessel valves have been modified to limit the number of pipes leaving one section and traveling to another. Utilizing existing holding tanks for laundry wastewater and incoming water dramatically reduces the footprint of the system.

System Operation and Maintenance:

All of AquaRecycle's EMI™ Systems are fully automated and completely self-contained to provide easy and maintenance free operations. Custom designed features for ships include additional monitoring devices with visual and audible alarms signaling potential problems with the System. This remote monitoring display can be installed anywhere on the ship so personnel have immediate indication of a System error or irregularity in the system's operation. In addition, the system is designed to automatically revert back to ship-produced water, if the system malfunctions for any reason.

We have also provided backup equipment including pumps, ozone and UV bulbs to insure that all components needed to resolve equipment problems are available when or if needed. Backup components have been designed to be replaced quickly and easily.

Annual Maintenance is also easy. The various blends of carbon used in our recycle process adsorbs contaminants in the process water and effectively, over time, will neutralize. Our systems are designed so that the media will last at least one year before replenishment is necessary. Change-outs are easy to perform on board the ship and can be done by the crew or, if desired AquaRecycle™ can provide these services for an additional fee.

Environment:

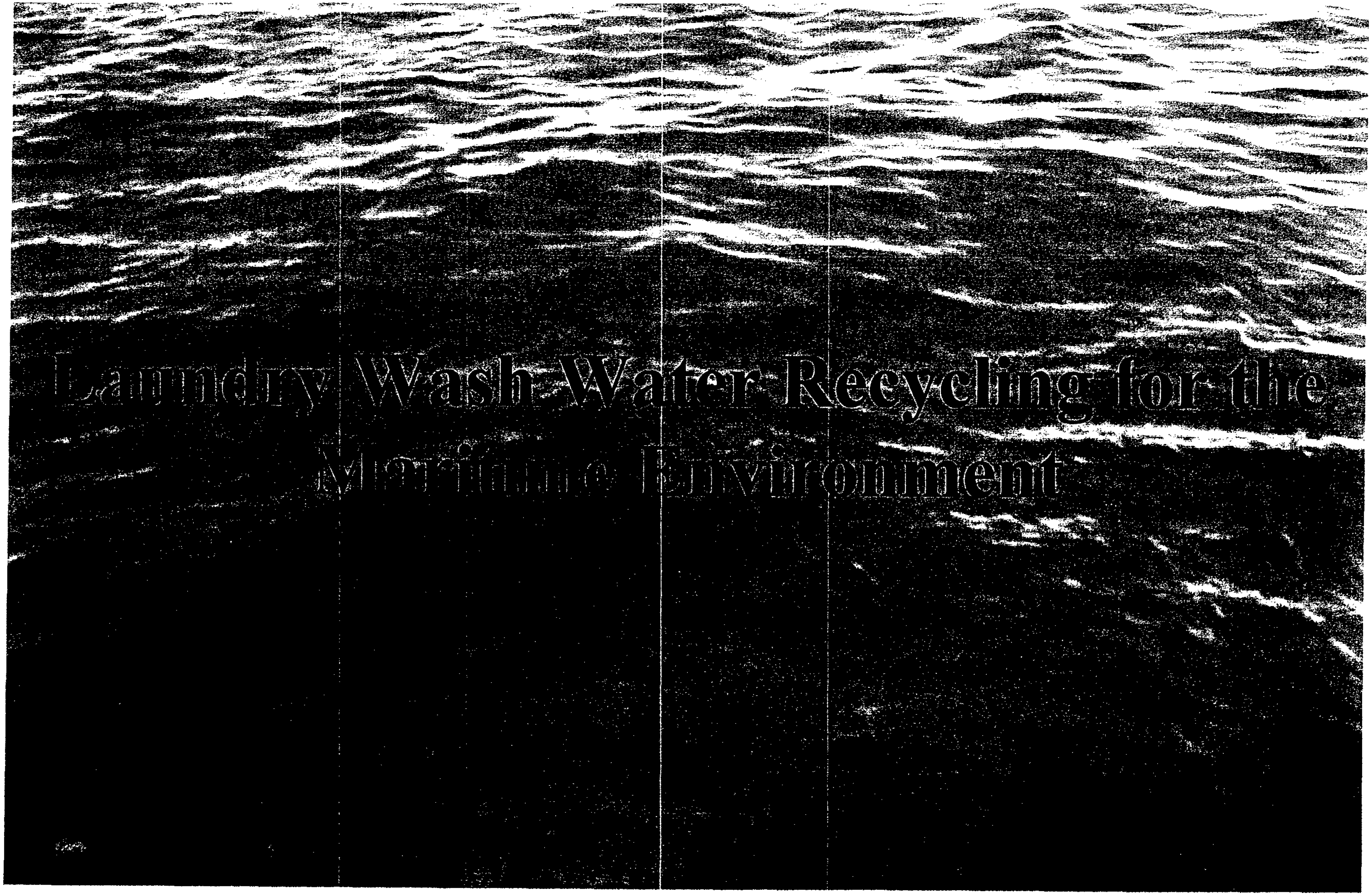
Water is rapidly becoming a scarce resource worldwide, and we all need to do our part to conserve and protect this precious resource. Recycling laundry water makes economical sense and is a simple solution for saving an enormous amount of fresh water. Chronic water shortages affect 40% of the Earth's population, and with demand for water doubling every 21 years, water supplies will not be able to keep up with demand.

As National Geographic Society's Gilbert M. Grosvenor stated in 1998, "Civilization as we know it will either survive or fail depending on our ability to solve the problem of water within ten years."

While recycling of laundry wash water may only be a small piece of the overall solution, it will not only conserve large amounts of water, but will also help preserve the integrity of our oceans by eliminating this discharge stream.

Recognitions / Installations:

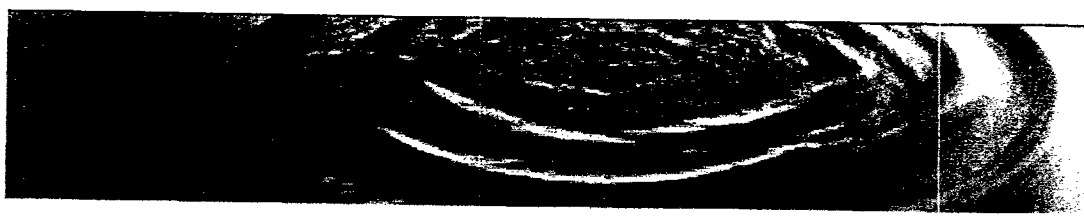
- Ritz-Carlton Hotels
- Marriott International
- Hilton Hotels
- Wellstar Health Systems (Centralized Hospital Laundry)
- California Prison System
- Sunsail Yacht Services
- Governor's Award for Pollution Prevention – Georgia
- Georgia Pollution Control Association – Certificate of Achievement
- Georgia Conservancy
- Featured Story - CNN Science and Technology



AQUARECYCLE™

Our Goal

How **Recycling** eliminates laundry wastewater discharge while providing tremendous operational savings.



AQUARECYCLE™

Overview

- How laundry wash water is recycled
- Components and Layout
- Operating Cost Reductions / Savings
- Daily Operation, Care and Maintenance
- Environmental Impact
- Recognitions/Installations
- Alternative Systems

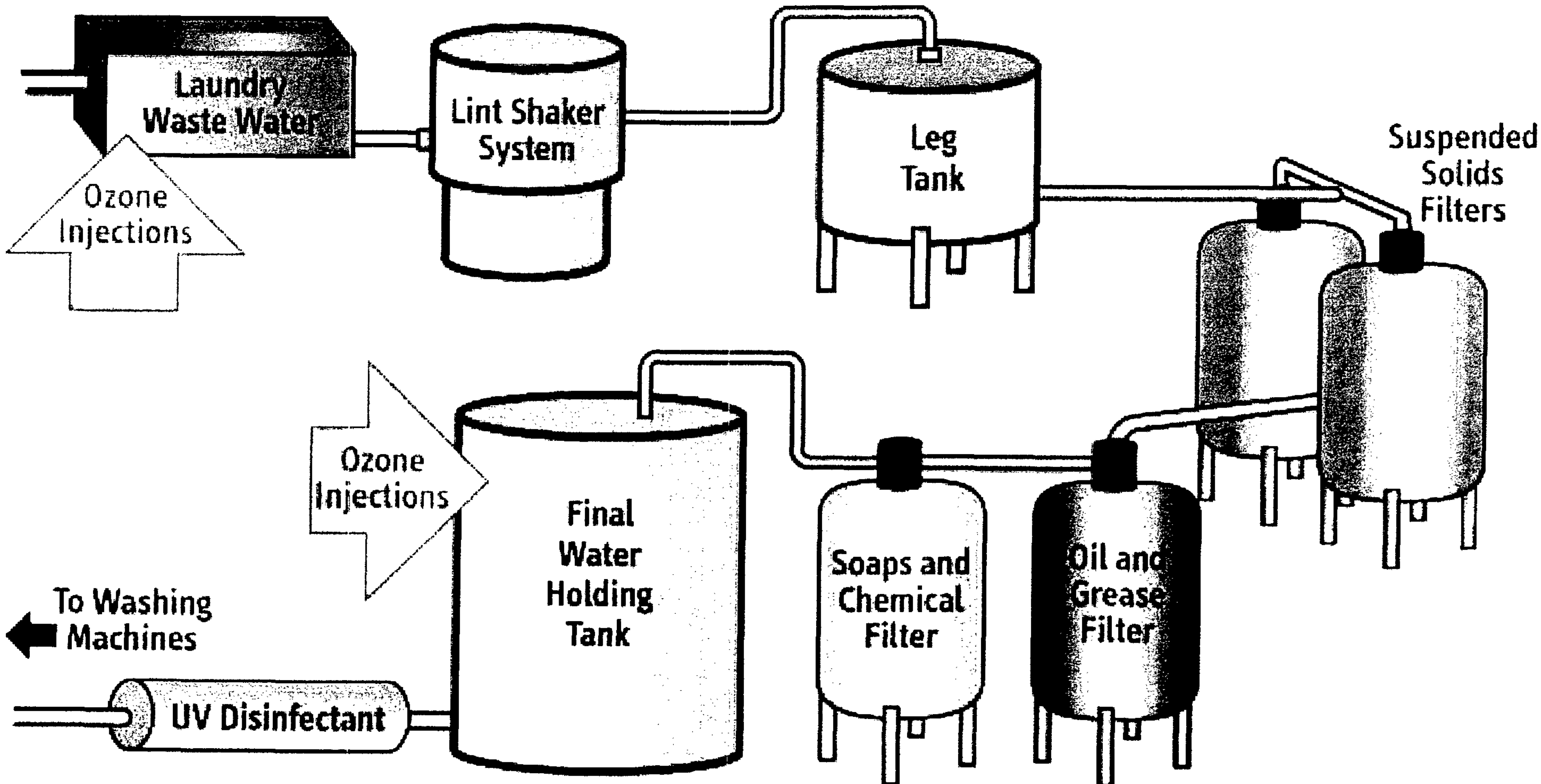
AQUARECYCLE™

Overview of Recycle Process

- What is in Laundry Wastewater?
  - Lint, Hair, Paper, Sand and Dirt, Etc
  - Oil and Grease from Foodstuff
  - Free Oils (body and hair oils)
  - Organics (food, human waste)
  - Chemicals (bleach, detergent, alkaline, acid)
  - Bacteria and Viruses
- How do we clean it?
  - Suspended Solids Removal
  - Soaps and Chemical Adsorption
  - Oil and Grease Adsorption
  - Disinfection, Odor Removal

AQUARECYCLE™

System flow chart

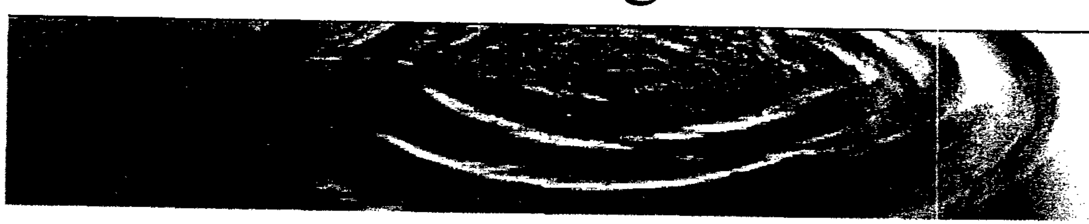


Patent Pending

AQUARECYCLE™

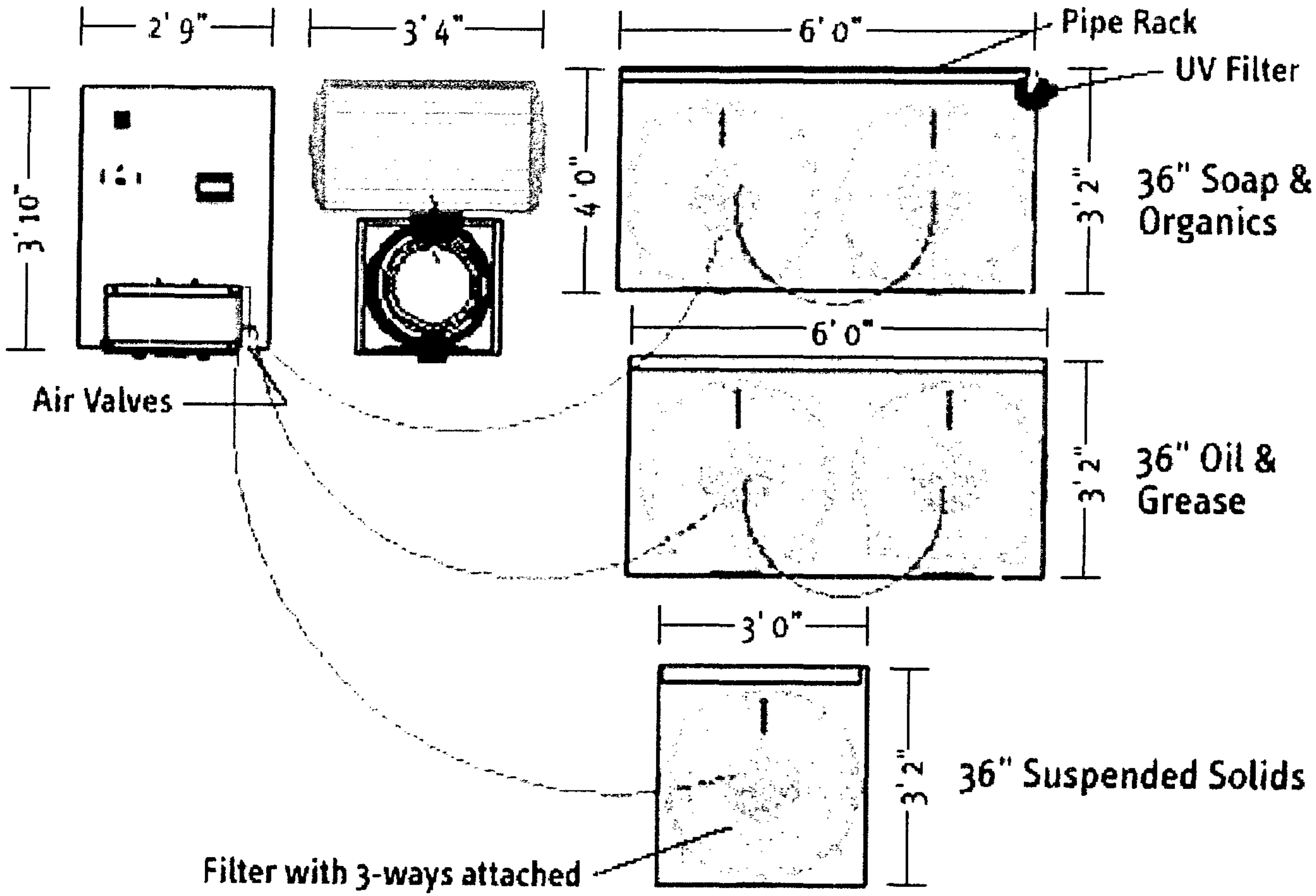
EMI™ Recycle System

- Lint Shaker / Bag Filter
- Multi Media Pressure Filter
- Organics / Chemicals Pressure Vessels
- Ultraviolet Disinfection
- Ozone
- Automated Control Panel
- Holding Tanks
- Pumps and Valves
- Patent Pending



AQUARECYCLE™

50 gpm layout

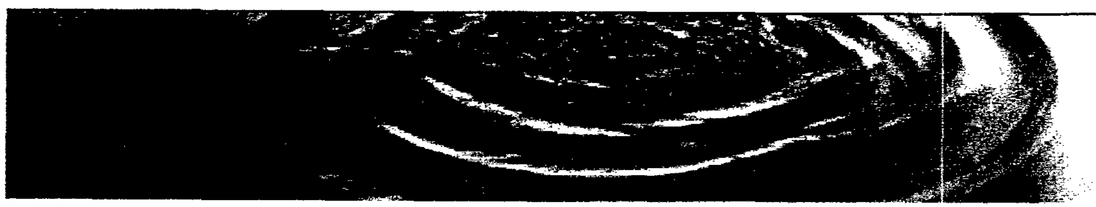


Patent Pending

AQUARECYCLE™

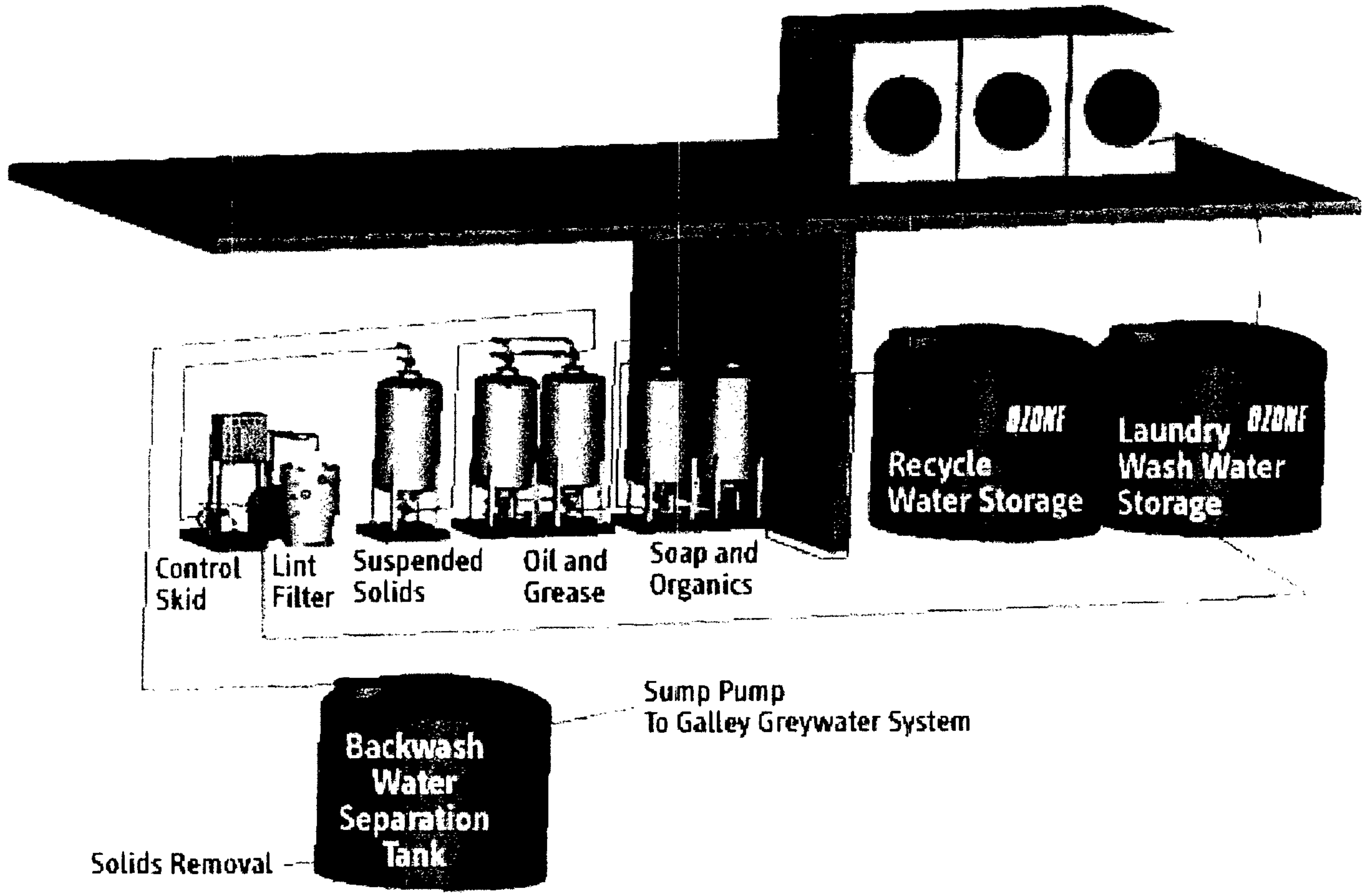
System Layout

- Utilize Existing Ship Equipment
- Limited Space and Access
- Install by Components - no contiguous space required
- Specially Designed Small Tanks
- Easy Maintenance, Spare Parts



AQUARECYCLE™

Recycle Process



Patent Pending

AQUARECYCLE™

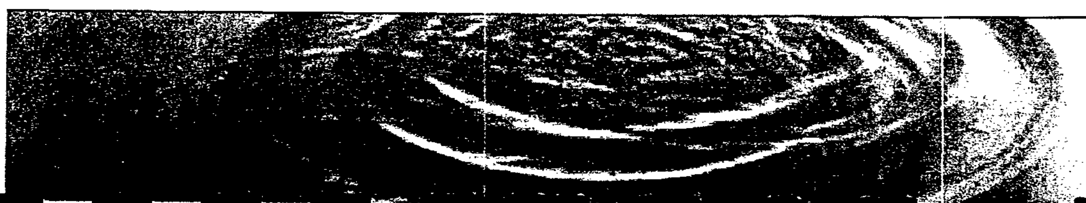
Sizing a Recycle System

- Number of passengers and pounds of linen per cabin
- Load Capacity of Laundry Washers
- Actual Water usage, if available
- Pounds of linen processed, if available
- Water Weights - conversions

AQUARECYCLE™

System Operation and Maintenance

- Automation
- Computerized Monitoring
- Quality Testing Equipment
- Totalizers and Savings Reporting
- Back-up Supplies
- Annual Media Replenishment



AQUARECYCLE™

Advantages

- Proven System
- Tremendous Cost Savings
- 85% Water / Discharge Savings
- Energy Savings
- 25% Chemical Reduction
- Shorter Drying Cycles – Longer Lasting Laundry
- Eliminate Laundry Waste Stream from overall Ship Waste Streams
- Assists in Managing Other Ship Waste Streams

AQUARECYCLE™

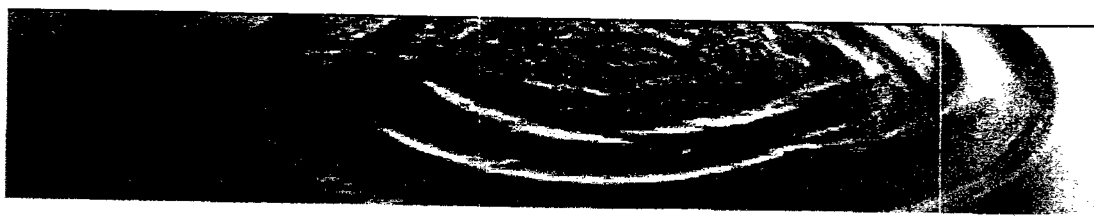
Environmental Impact

- Supports Sustainable Environmental Development
- Eliminate EPA Concerns – No Laundry Wastewater Discharged to Sea
- Reduces Energy Consumption and Air Emissions
- Positive Environmental Image

AQUARECYCLE™

Recognitions / Installations

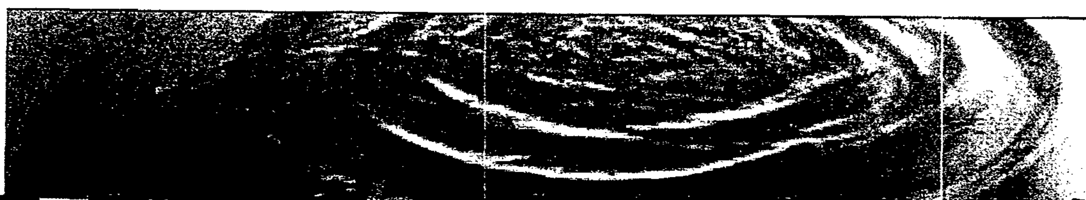
- Ritz-Carlton Hotels
- Marriott International
- Hilton Hotels
- Wellstar Health Systems (Centralized Hospital Laundry)
- California Prison System
- Sunsail Yacht Services
- Governor's Award for Pollution Prevention (GA)
- Georgia Pollution Control Association
- Featured Story - CNN Science and Technology



AQUARECYCLE™

Alternate Technologies

- Reverse Osmosis
- Membrane/Ceramic Systems
- Micro/Nano Filtration Systems
- Ozone Systems
- Water Reuse Systems
- Heat Exchangers
- Rinse Reuse Systems



AQUARECYCLE™

Ballast Water and Waste Water Treatment Aboard Ships and in Ports
11th-13th June 2003
Bremerhaven, Germany

Installation, start up and running of Scanship Waste Water Treatment Plant's onboard MS Norwegian Sun, -Sky and –Wind, Approved for continuous discharge in Alaska year 2003.

Henrik Badin
Vice President

Asgeir Wien
R&D Manager

- presentation of the retrofit projects
- operation results from the compliance period
- **ECS™** and **SSC™**
  effluent control system and ship to shore control

The Vessels

Ship Owner: Norwegian Cruise Line Limited

MS Norwegian Wind:	2.800
MS Norwegian Sky:	3.200
MS Norwegian Sun:	3.200

Hydraulic loads:

700-900 M3/day of Black & Grey Water

Norwegian SUN, SKY and WIND

In September 2002, Scanship signed the contracts with the owner:

"a turn key installation, with start up in March 2003, compliance test and USCG approval for the Alaska 2003 operations"

PRELIMINARY TARGETS

- engineering, planning and production of equipment to be done within 10 weeks.
- transports from Norway to US Ports within 6-9 weeks, sending a total of 12 (40feet) Containers:

  4 to San Juan, Puerto Rico (the Sky)
  4 to Miami (the Sun)
  4 to Honolulu, Hawaii (the Wind)

- removal of all existing MSD's and preparations within 3 weeks.

TARGETS CONTINUED

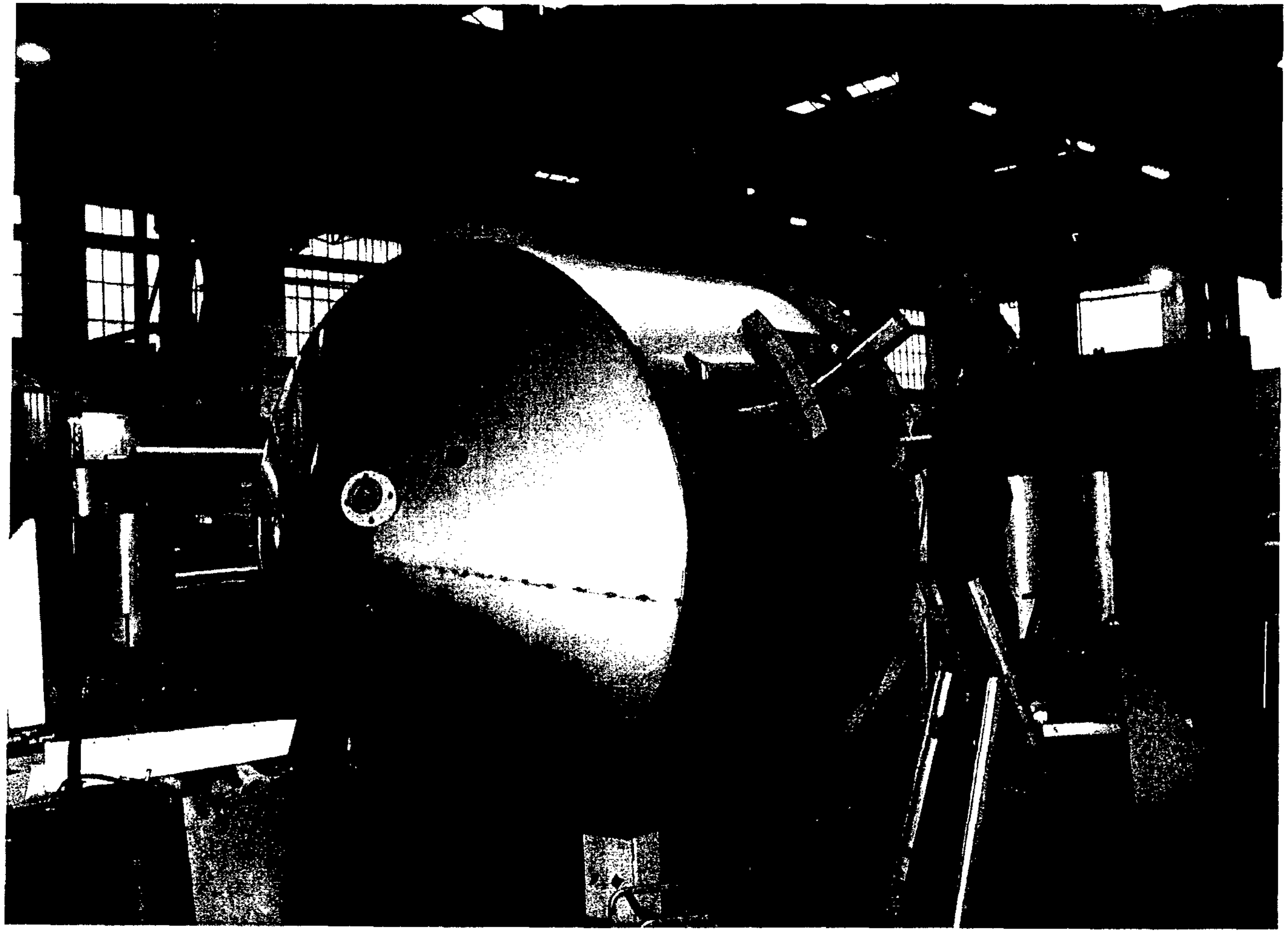
- unloading of containers in ports after luggage handling, bunkering and provision supplies, <u>without delaying the vessels</u>.
- Installation to be done under normal cruise itinerary <u>without effecting the cruise and the passengers</u>.
- transports inside the vessels without any cutting of hull, bulkheads etc. Existing access must be used.
- the start up of plants early March (24 weeks after the contract signed) entering the compliance period in April and May 2003.

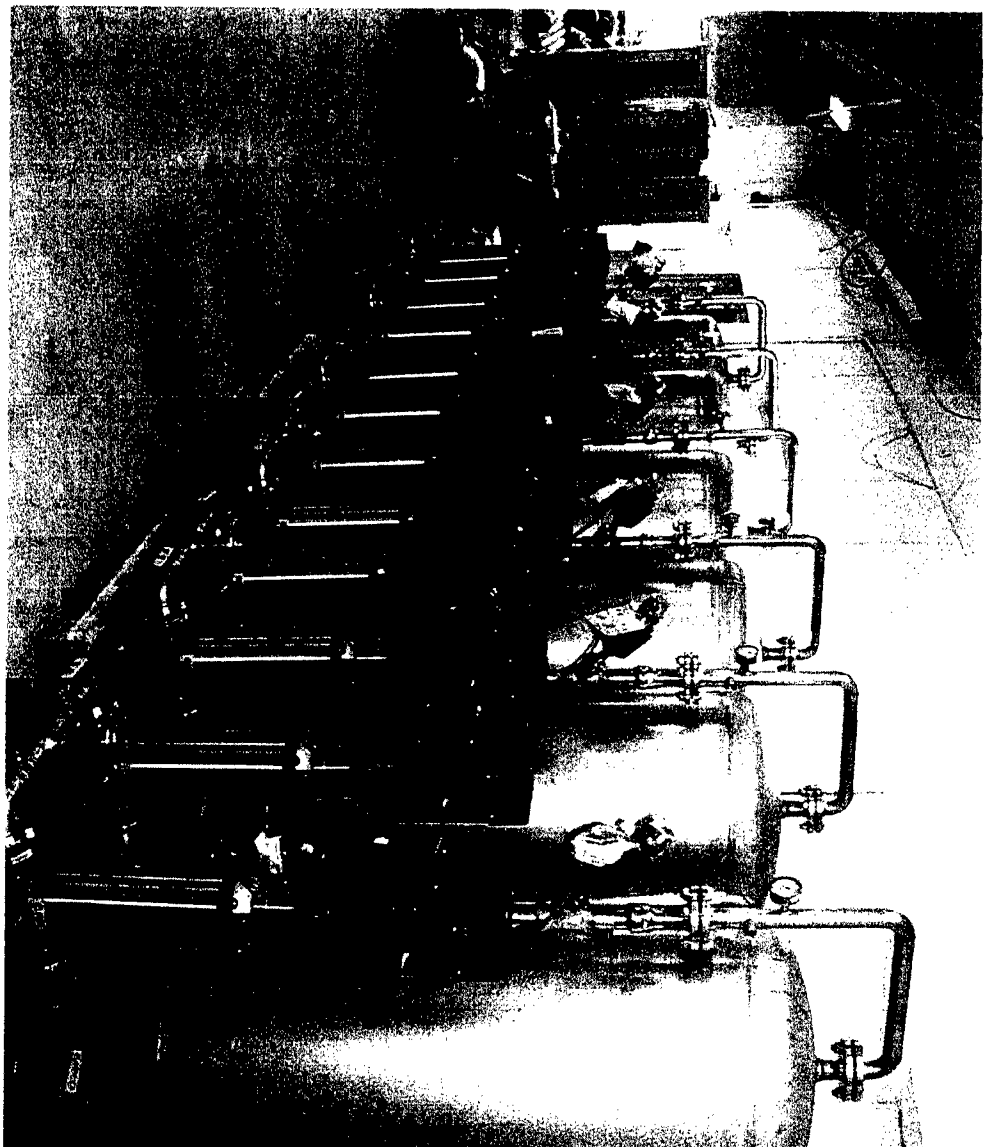
Installation of a total waste water plant using the available space removing the existing black water plants (MSD) onboard !

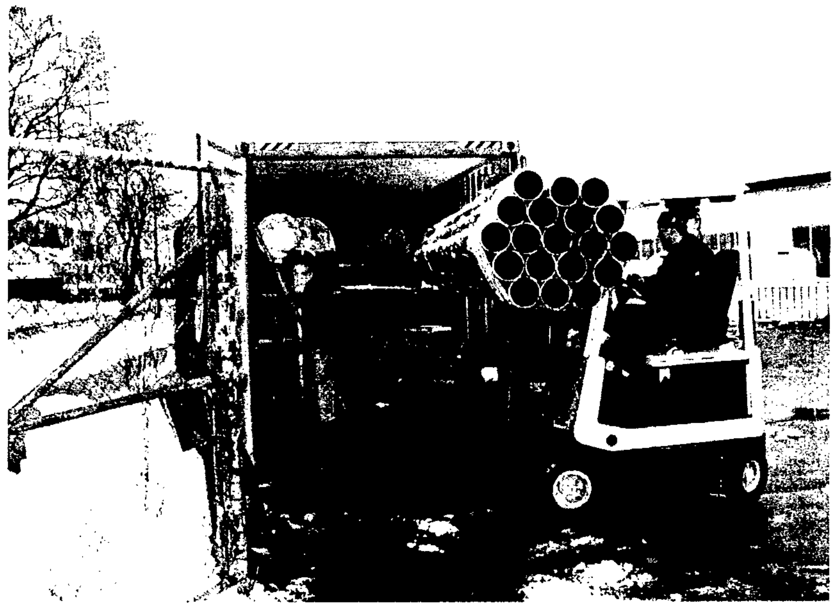
Final Target **<u>USCG Approval</u>**

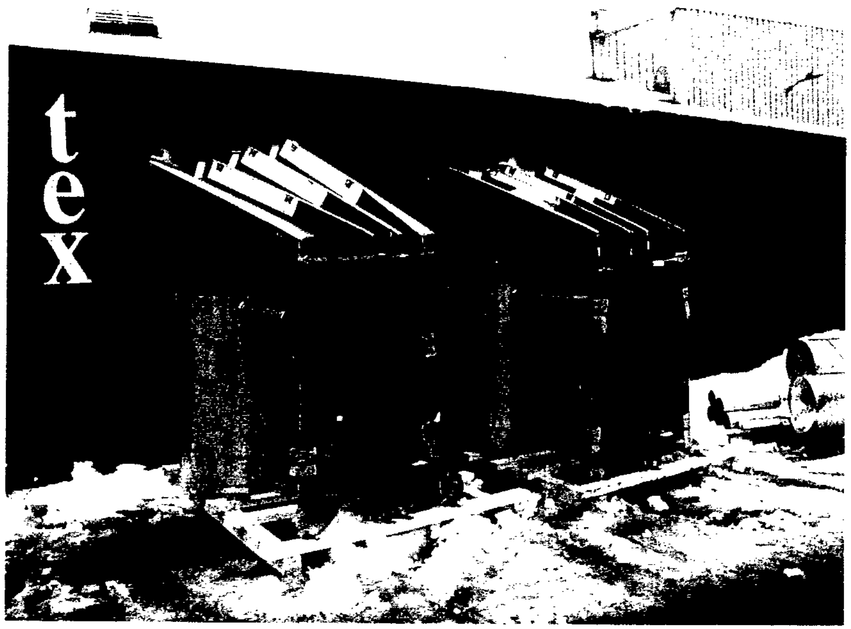
".....The NORWEGIAN SKY, NORWEGIAN WIND, and NORWEGIAN SUN are approved to continuously discharging treated wastewater effluent pr Title 33, Code of Federal Regulations, Part 159.309(b)......"

HOW DID WE DO IT ?





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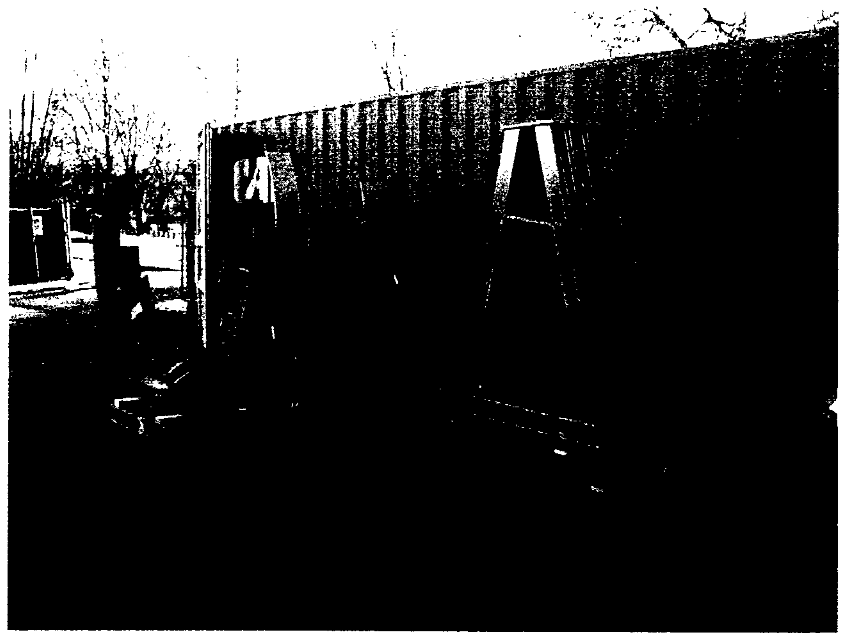
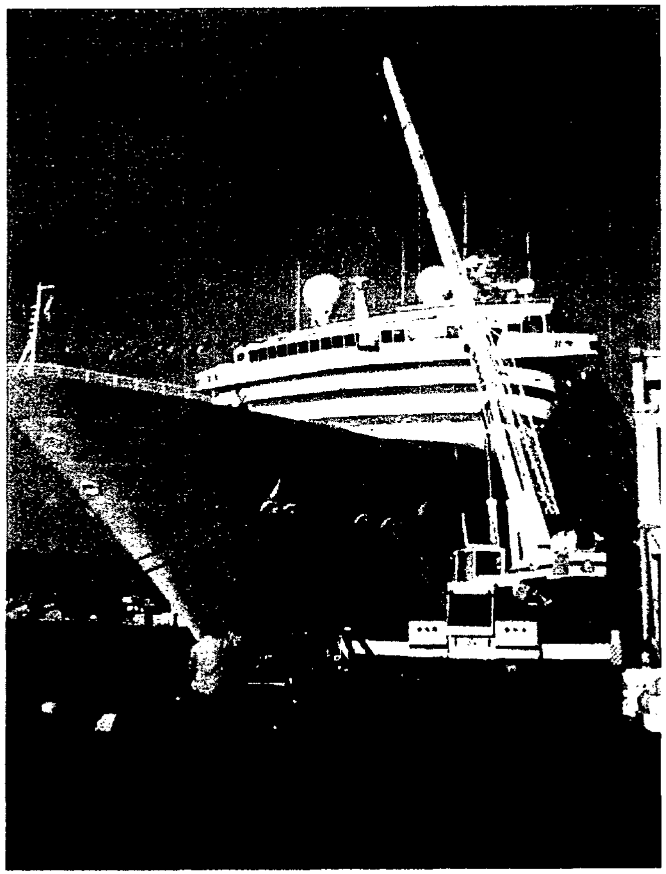
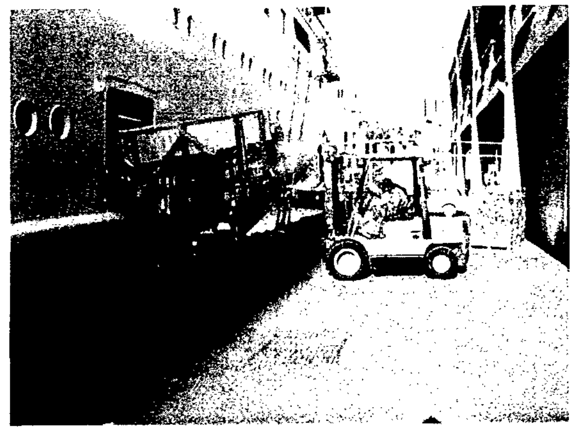
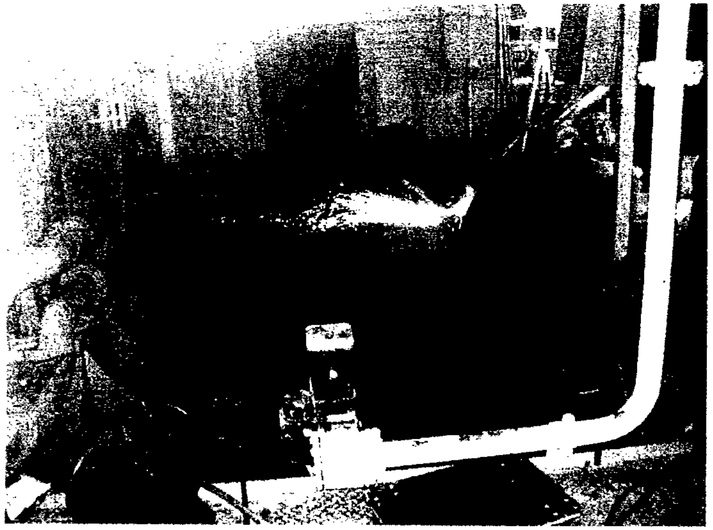
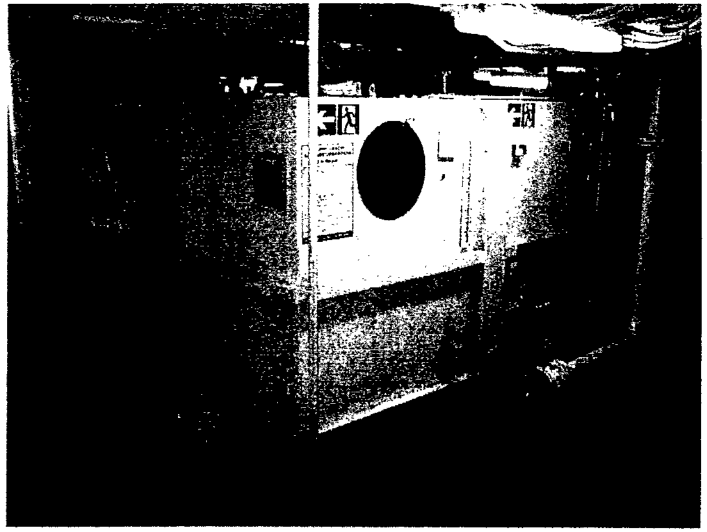


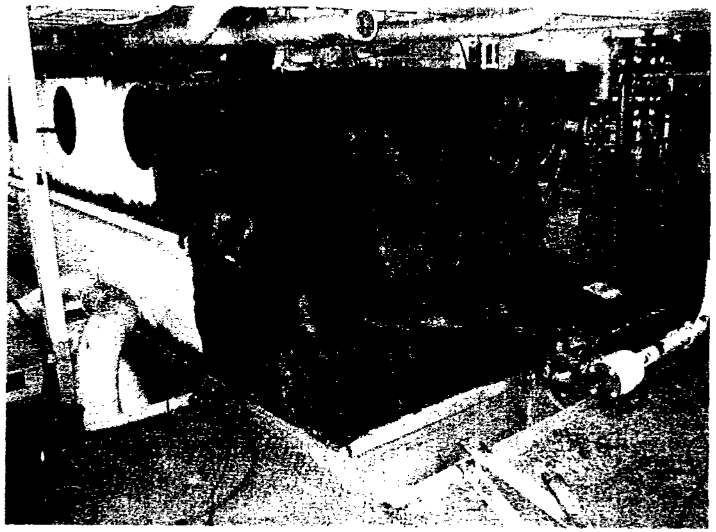
Port of Honolulu, Hawaii

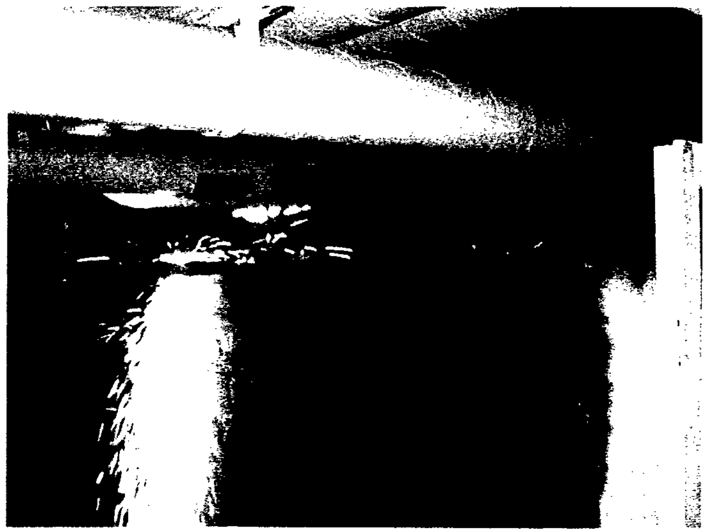




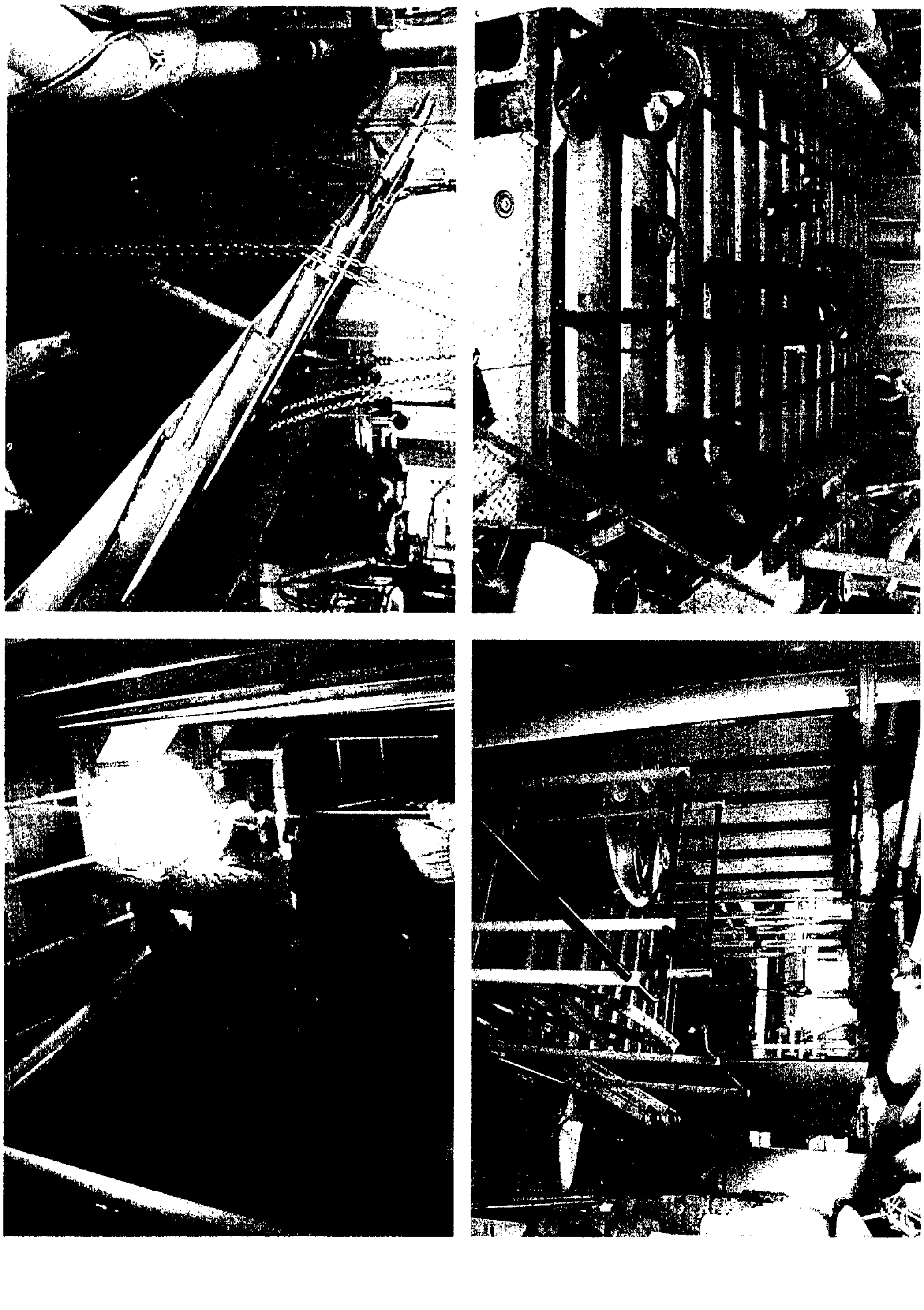




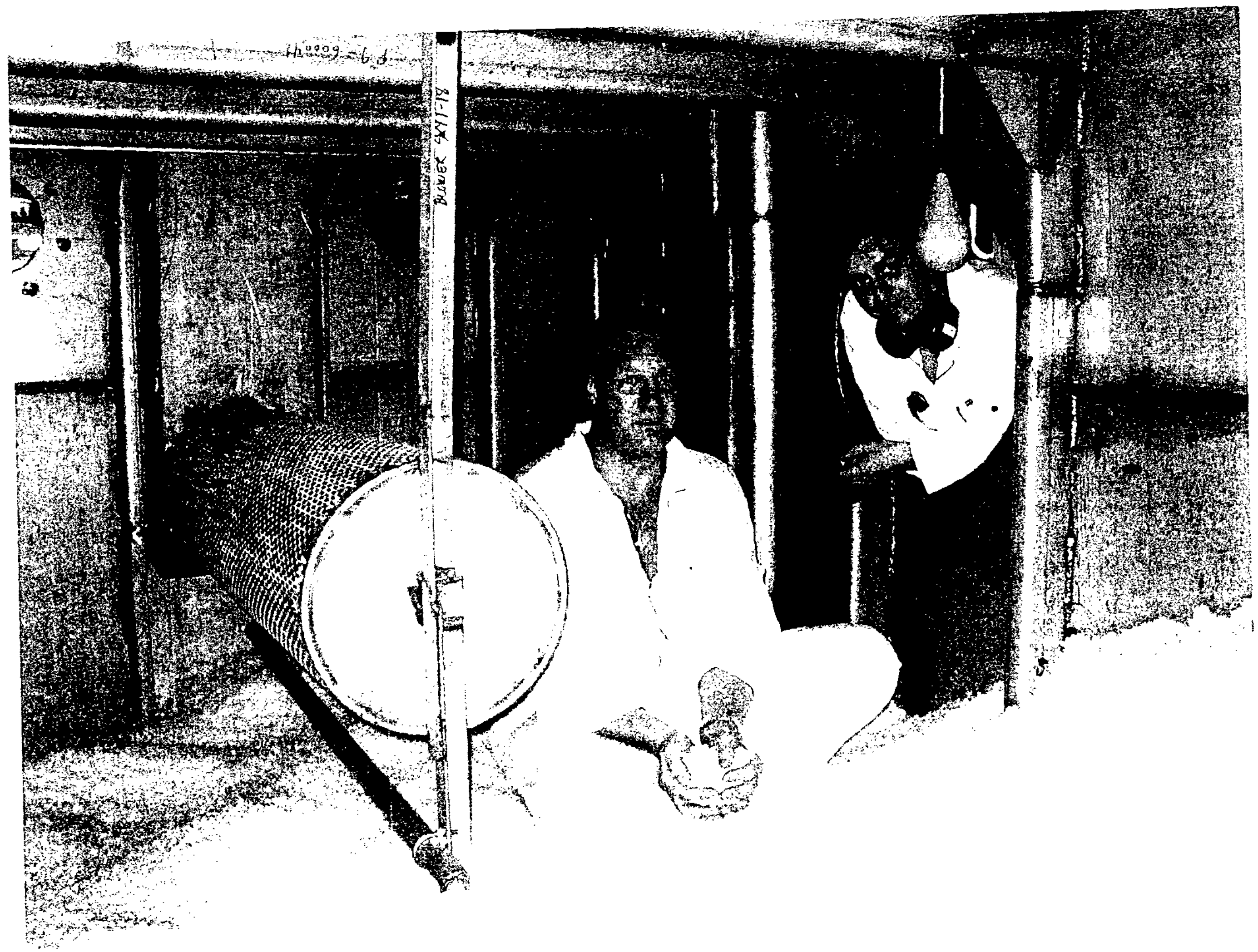




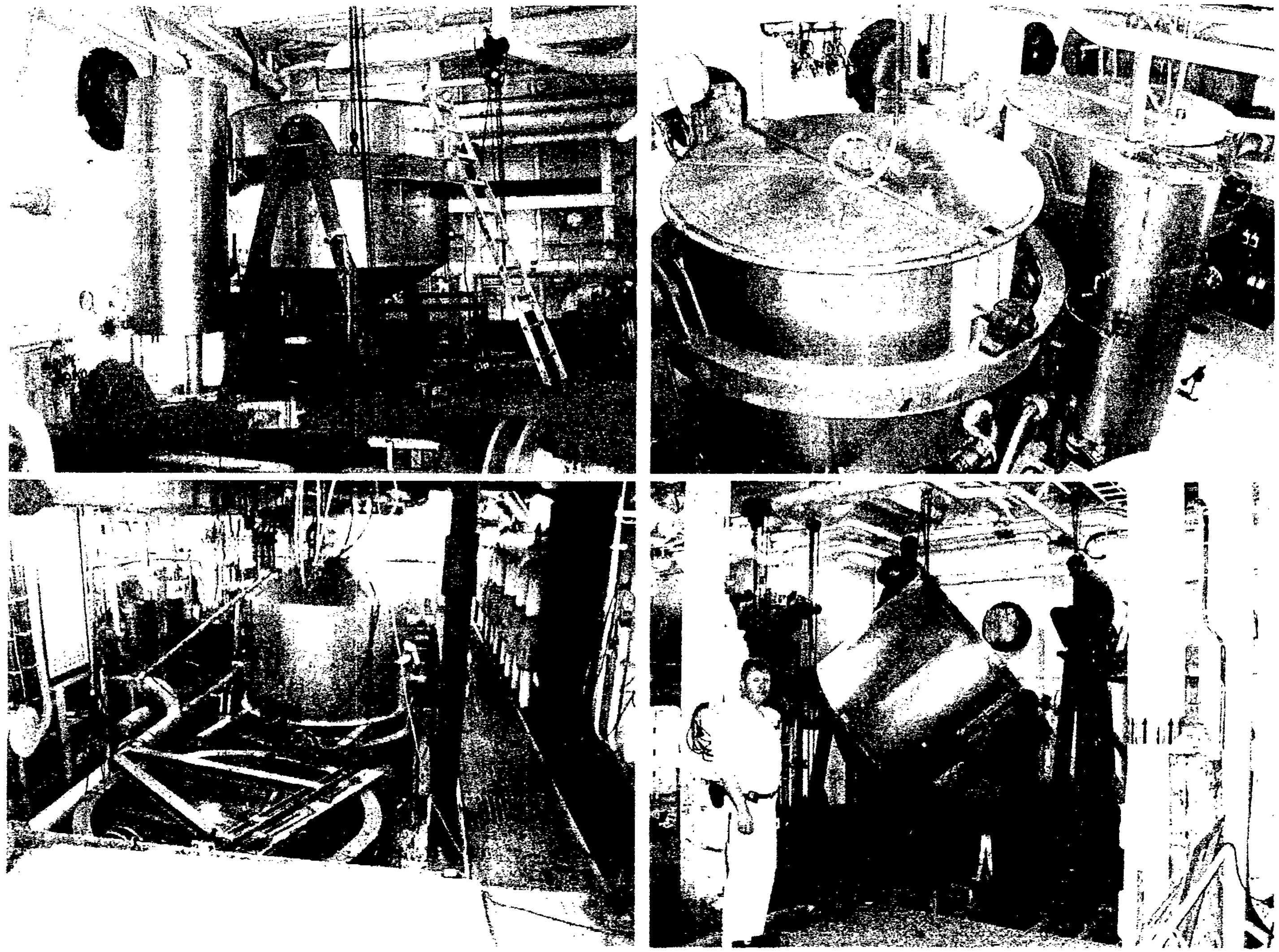
Norwegian SUN, SKY and WIND

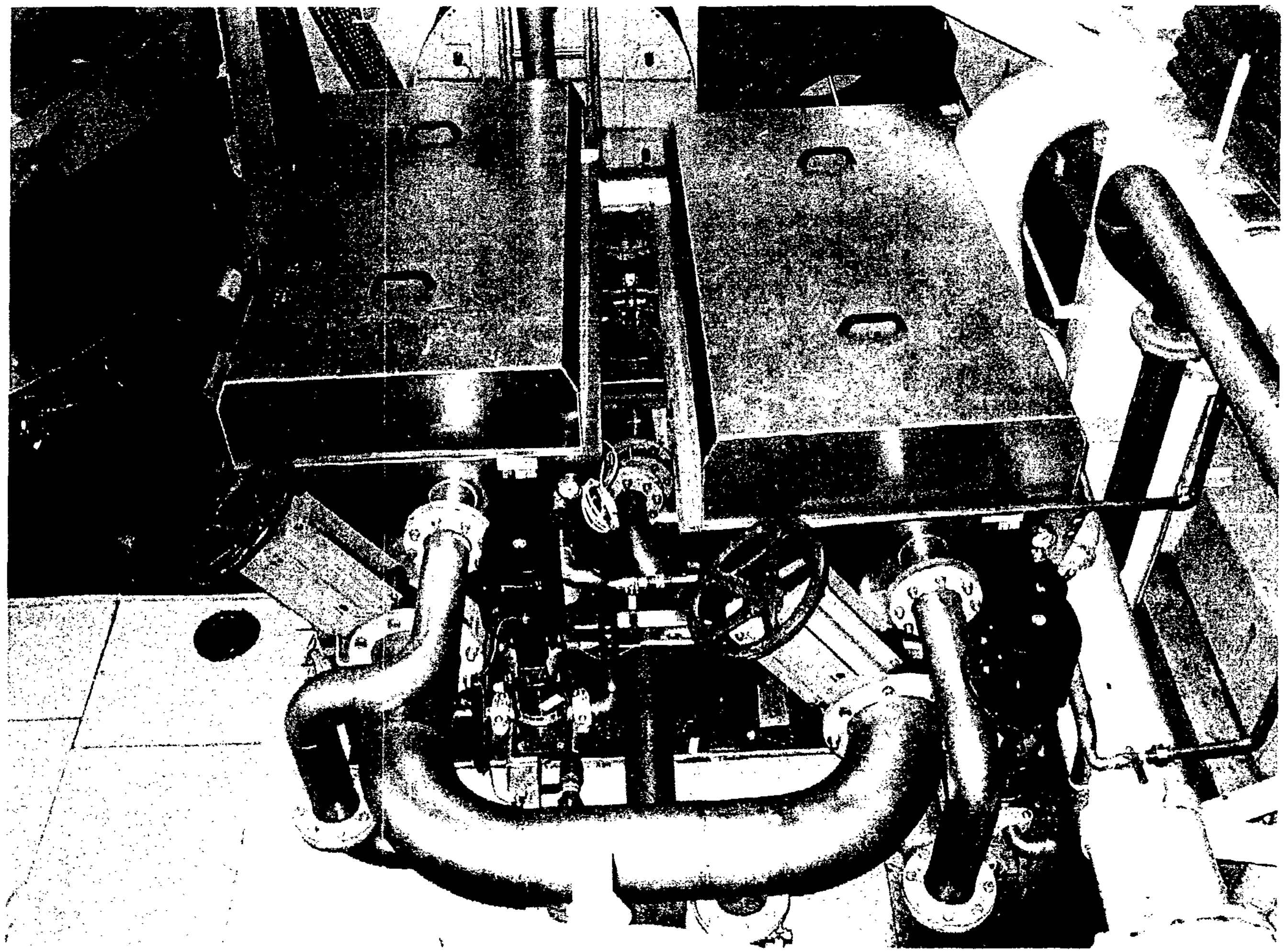


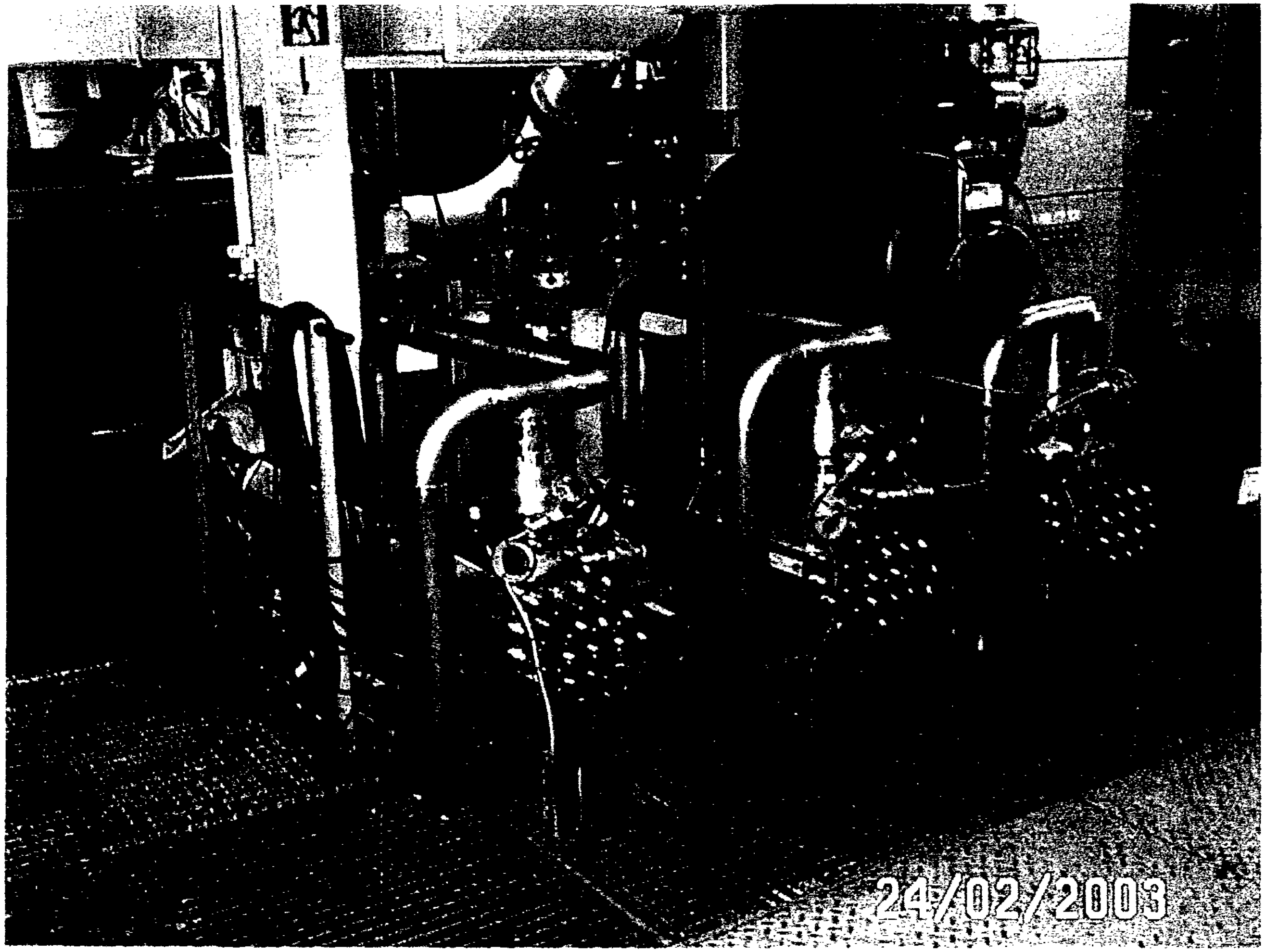
Norwegian SUN, SKY and WIND



Norwegian SUN, SKY and WIND



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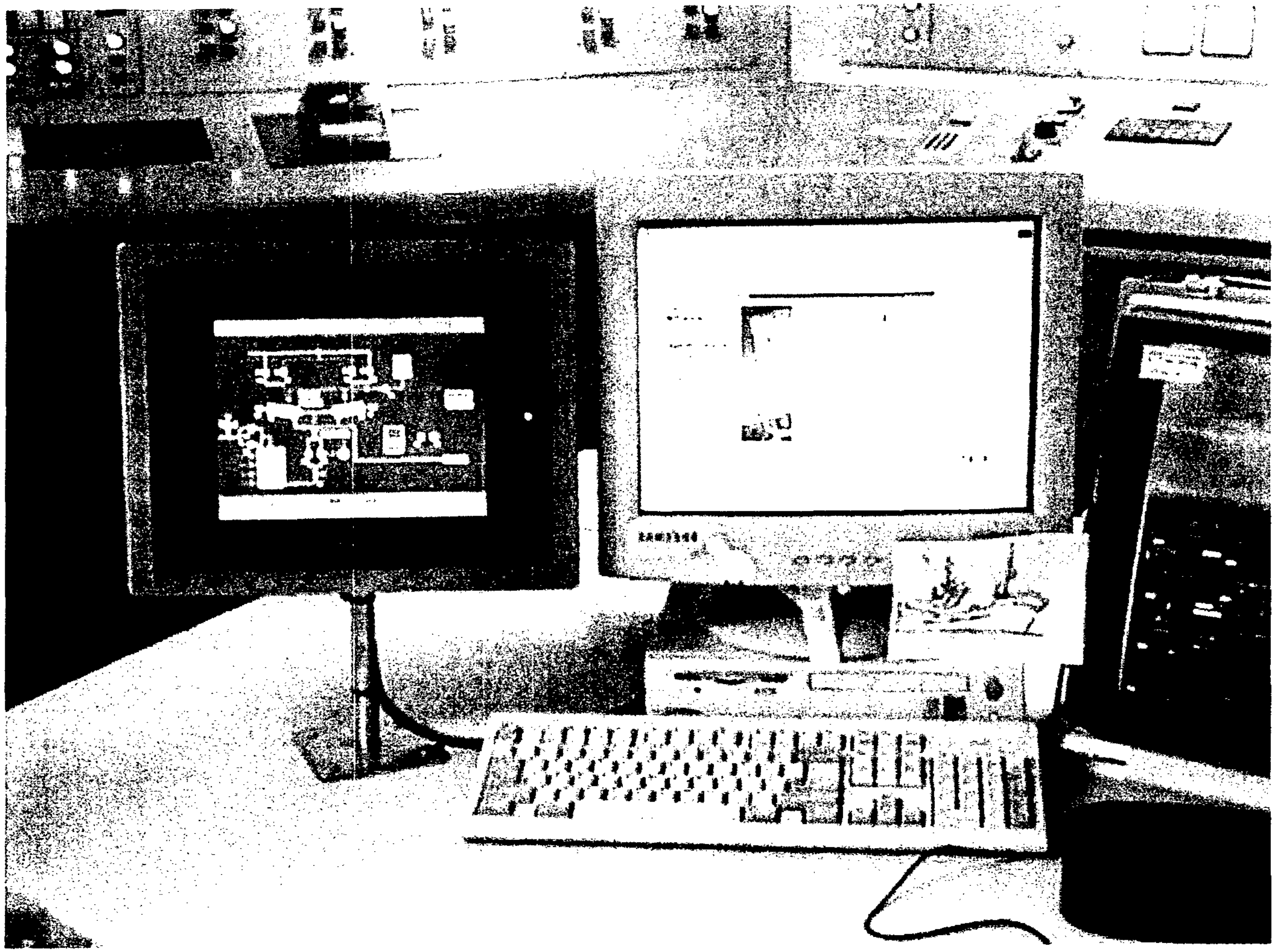


Start up and results

- *All three installations finished end of February*
- *Start up and tuning during early March*
- *Laboratory testing for USCG approval during late March, April and May*

Alaska discharge requirement

Parameter	***Average (5 samples) 30 days***	***Average (5 samples) 7 days***
TSS,mg/l	*30*	*45*
BOD_5, mg/l	*30*	*45*
pH	*6-9*	
Residual chlorine, mg/l	*< 10*	
Fecal coliform bacteria, FCB/100 ml	*< 30, < 10% of the samples with <40*	

The effort getting the USCG/Alaska approval

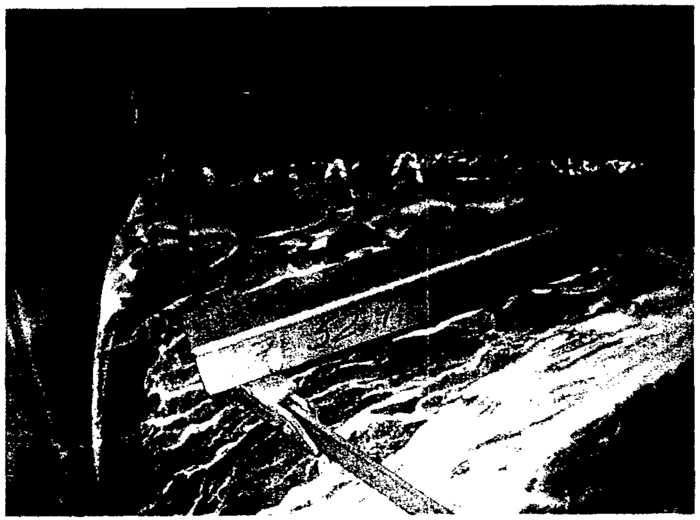
Challenge: Short time from start up to sailing to Alaska
SUN: Miami 12/4/03 -> Alaska 5/5/03
SKY: San Juan 20/4/03 -> Alaska 12/5/03
WIND: Honolulu 25/4/03-> Dry dock 5/5/03 -> Alaska 18/5/03

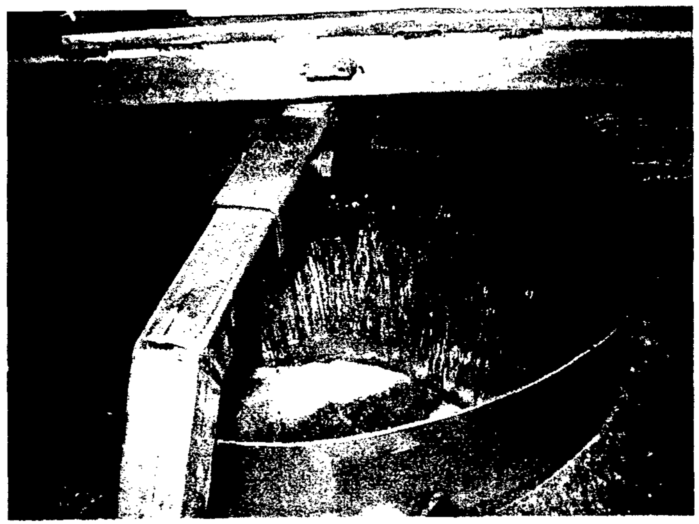
Caribbean:
Treated Waste Water samples from SUN and SKY were sent to Severn Trent Laboratories (STL) in MIAMI.

Hawaii:
Treated Waste Water samples from WIND were sent to Oceanic Laboratory in Honolulu

Alaska:
Treated Waste Water samples from WIND, SUN and SKY were sent to Analytica Laboratories in Juneau

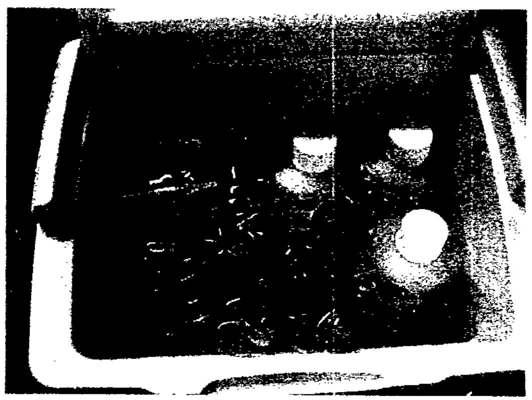
Norwegian SUN, SKY and WIND

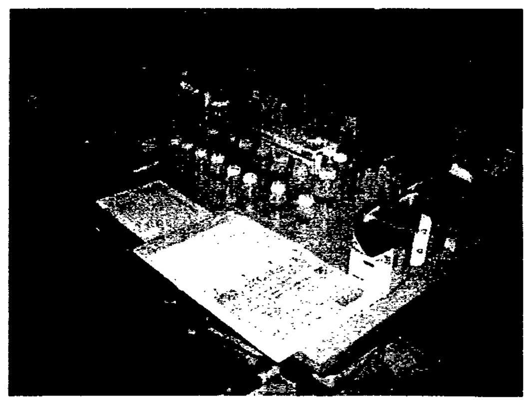




General results from March to May.

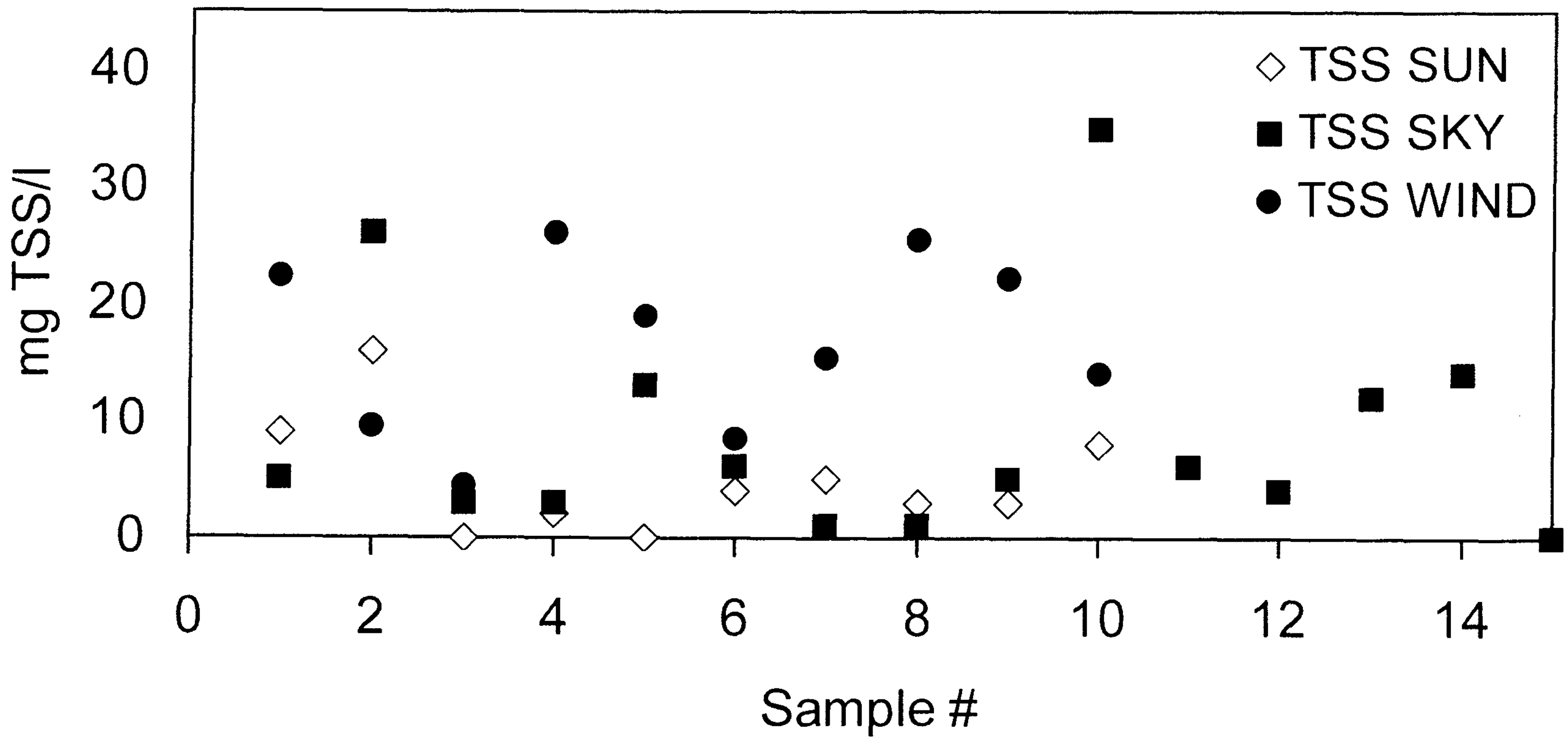
* *Hydraulic load:*	*700-900 m^3/d*
* *BOD_5:*	*average < 10 mg BOD_5/l*
* *TSS: average approx.*	*10 mg TSS/l*
* *pH:*	*average approx. 6,5*
* *Residual Chlorine:*	*BDL*
* *Fecal Col bacteria SUN/SKY:*	*BDL*
* *Fecal Col Bacteria WIND:*	*< 5 FCB/100 ml*



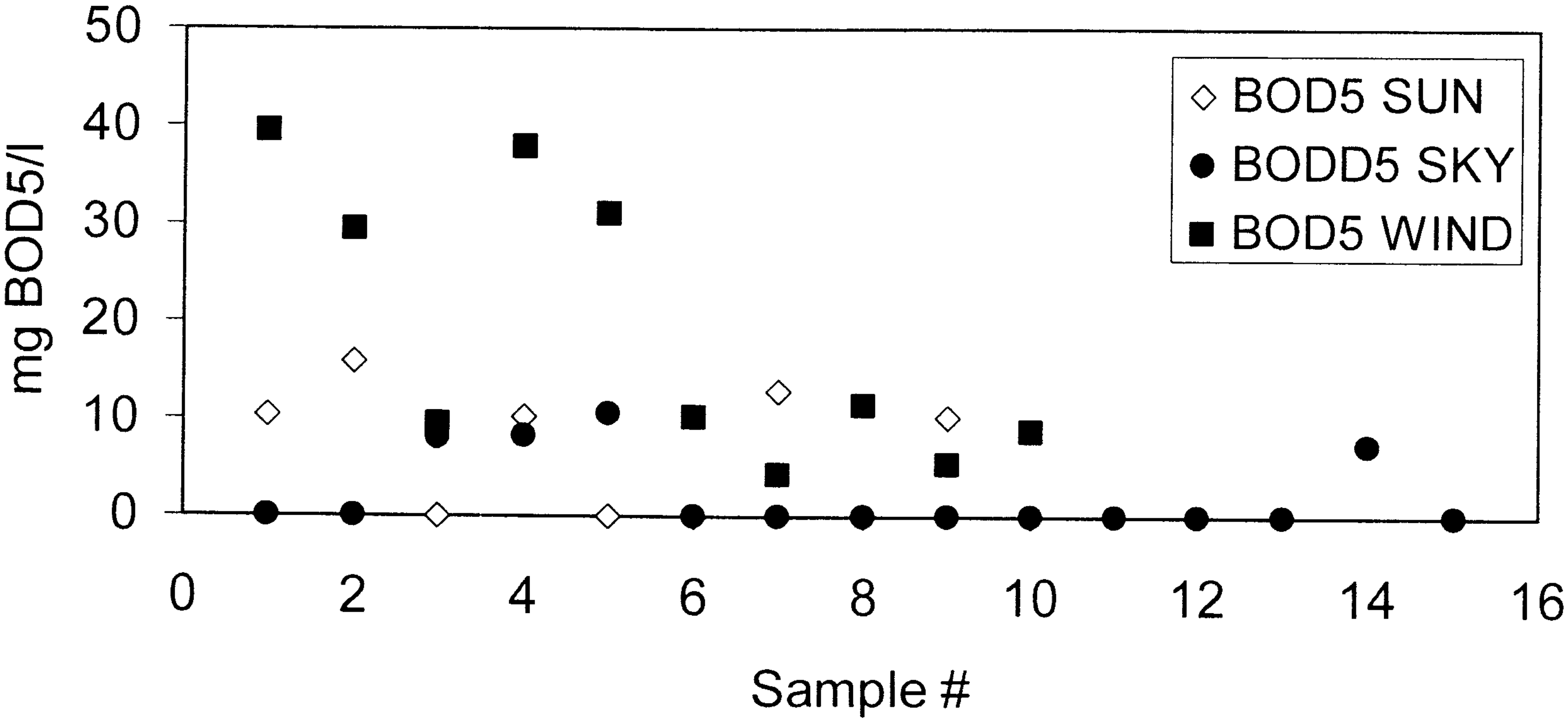


Norwegian SUN, SKY and WIND

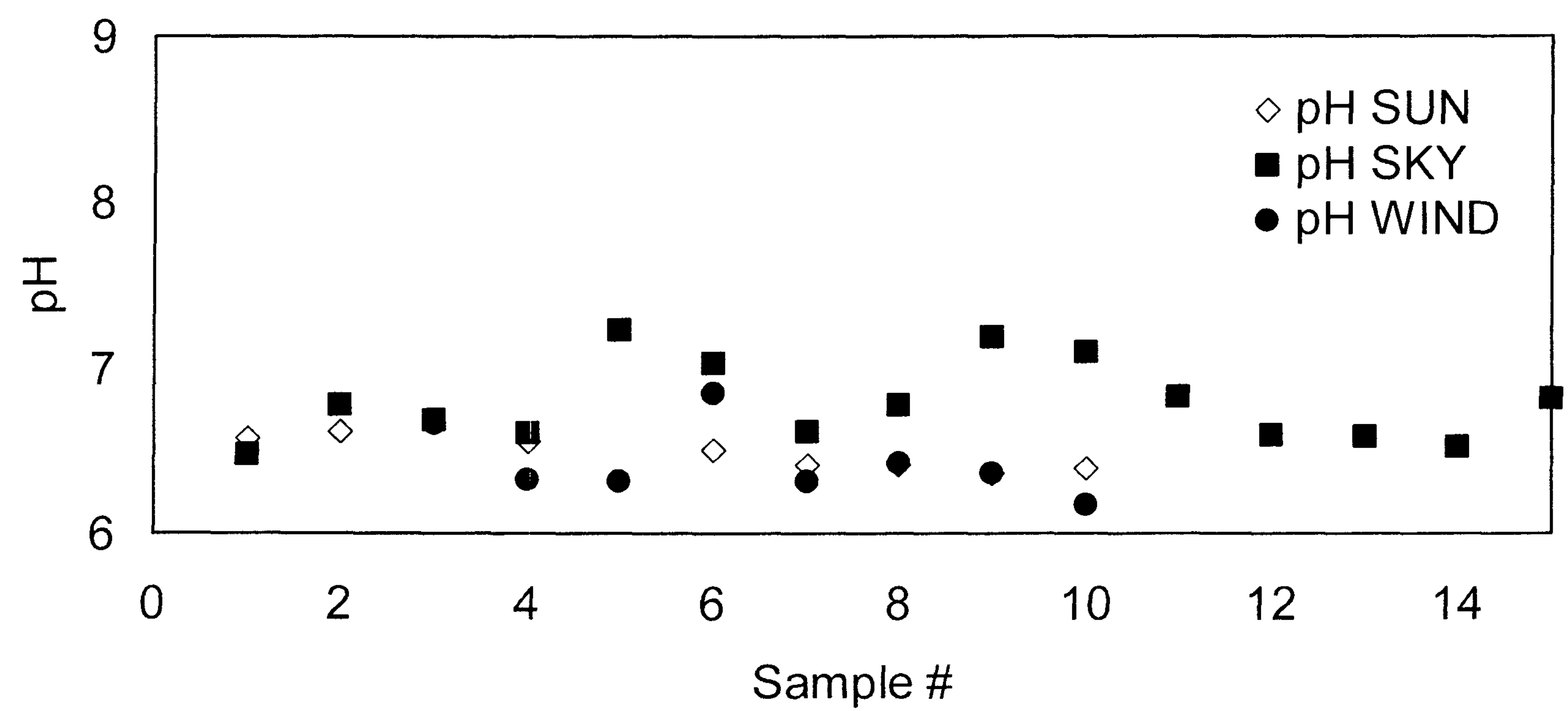
TSS results
March 19. to April 22.



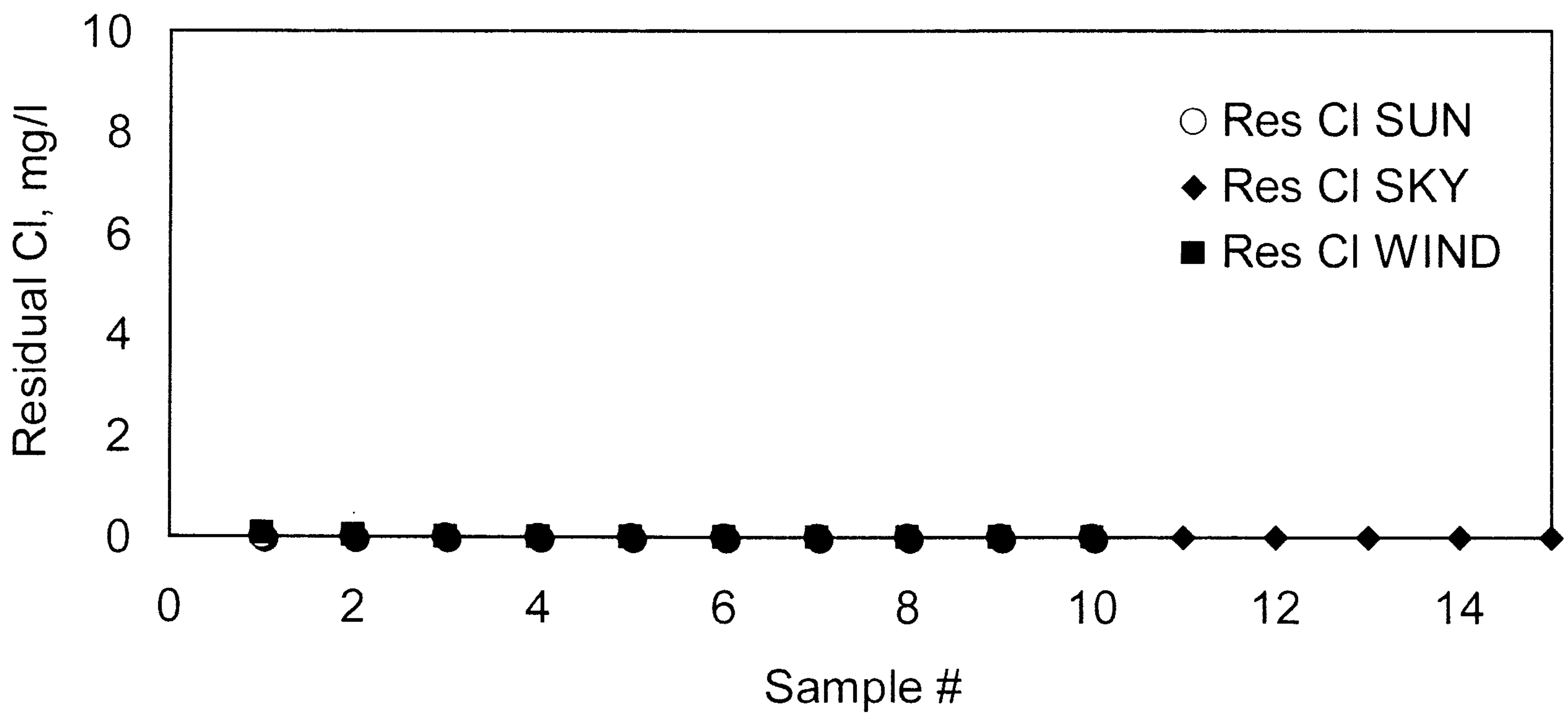
BOD_5 results
March 19. to April 22.



pH results
March 19. to April 22.

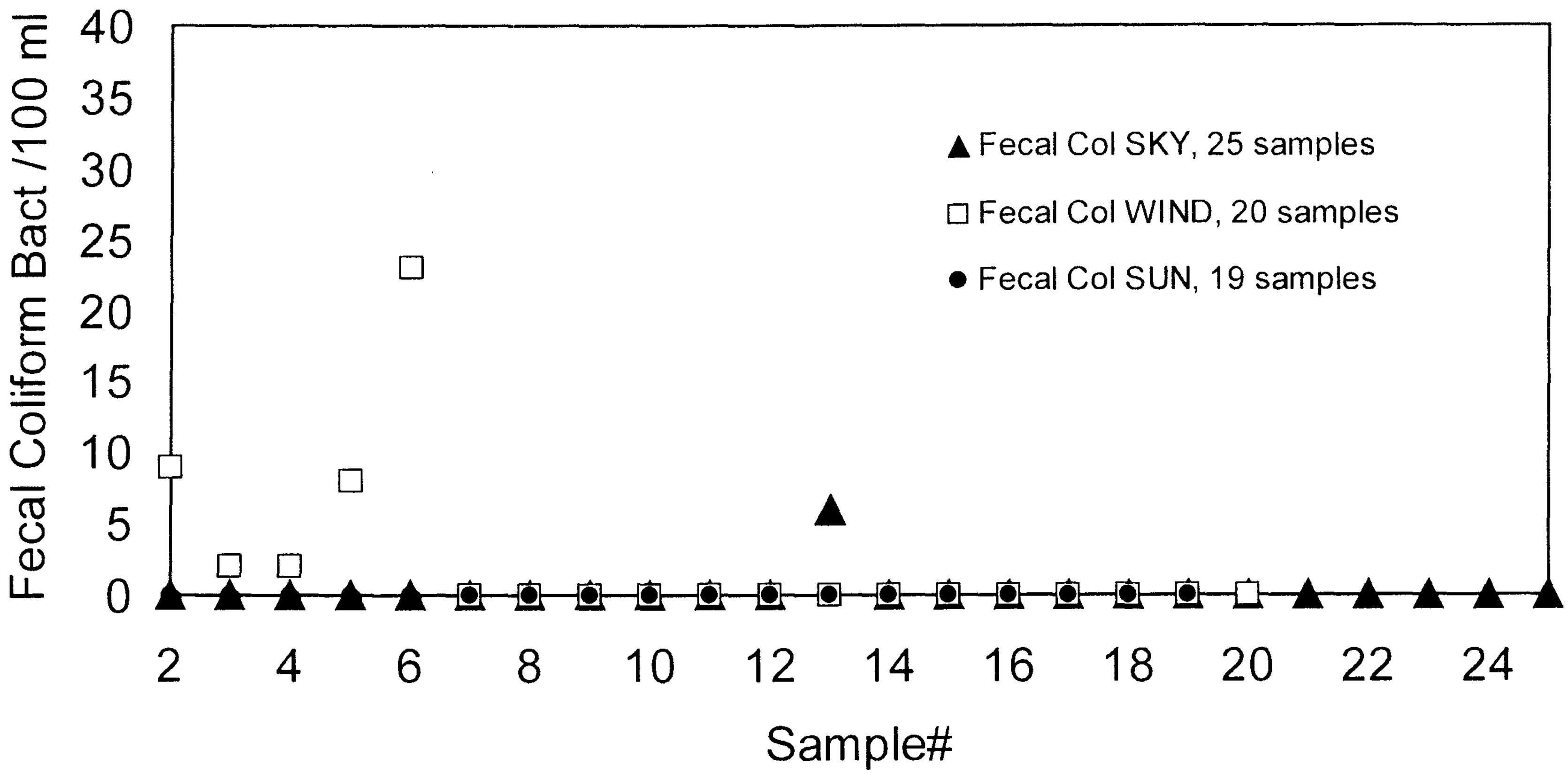


Residual chlorine results March 19. to April 22.



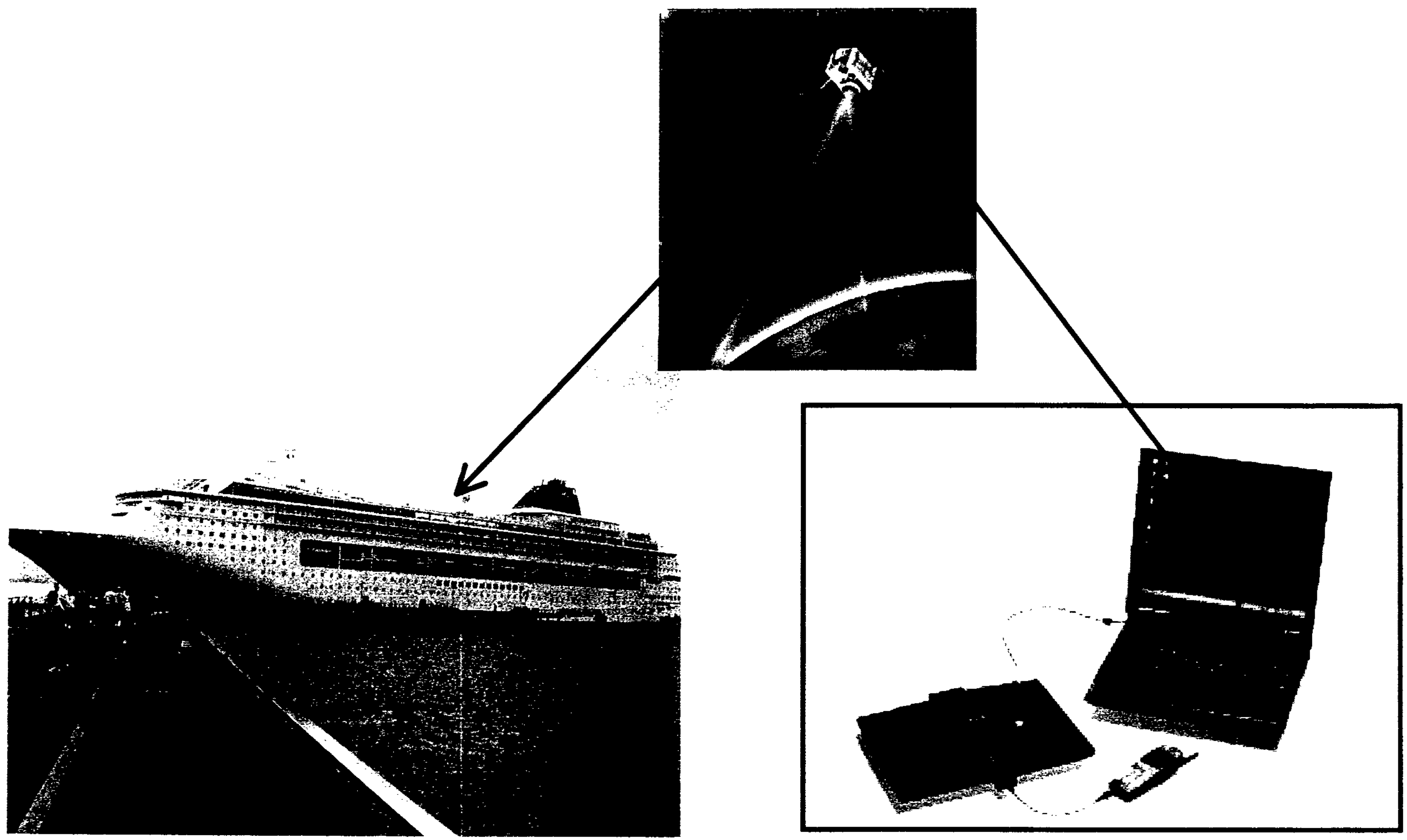
Norwegian SUN, SKY and WIND

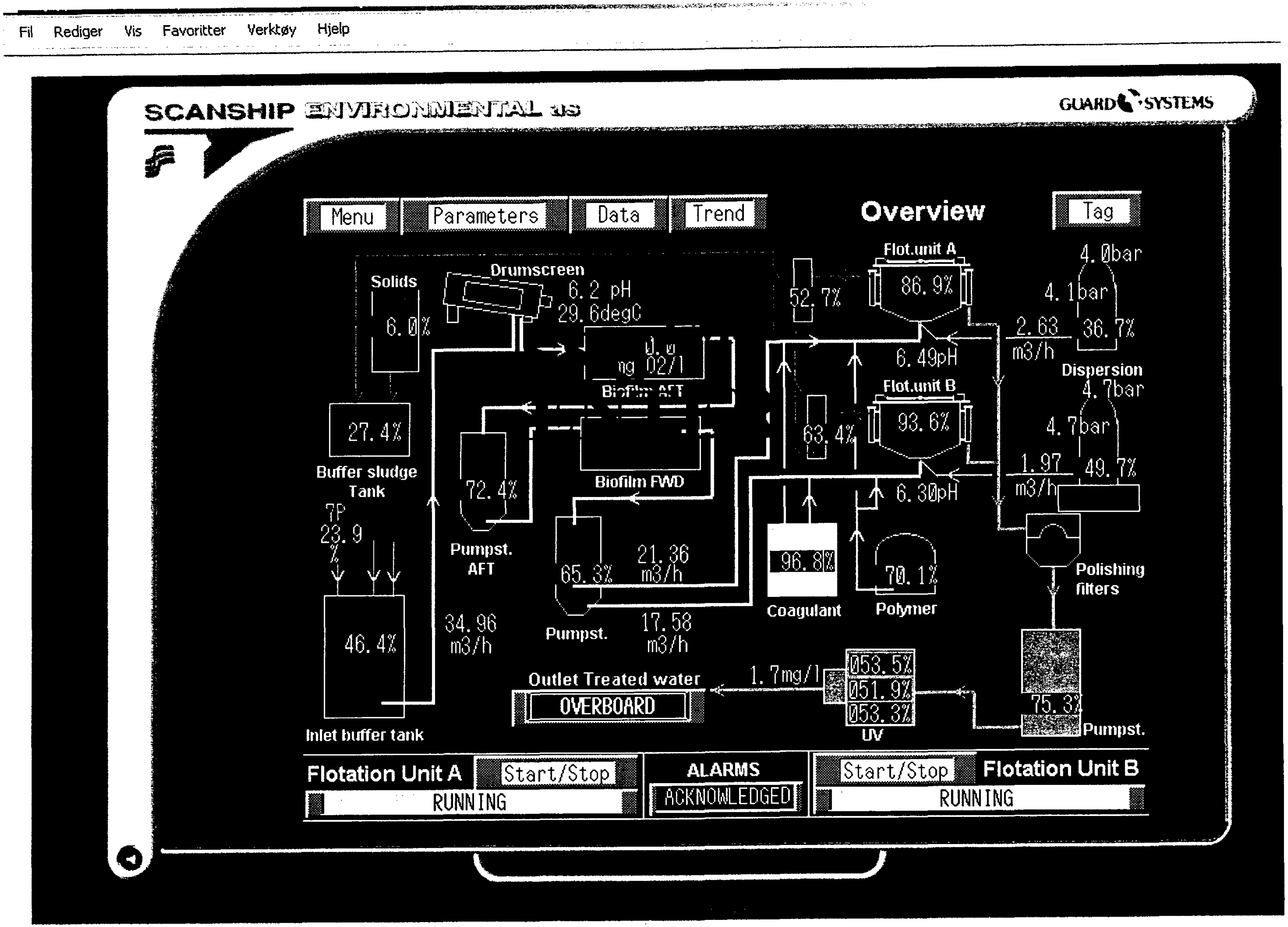
Fecal Coliform Bacteria results March 19. to May 29.



Norwegian SUN, SKY and WIND

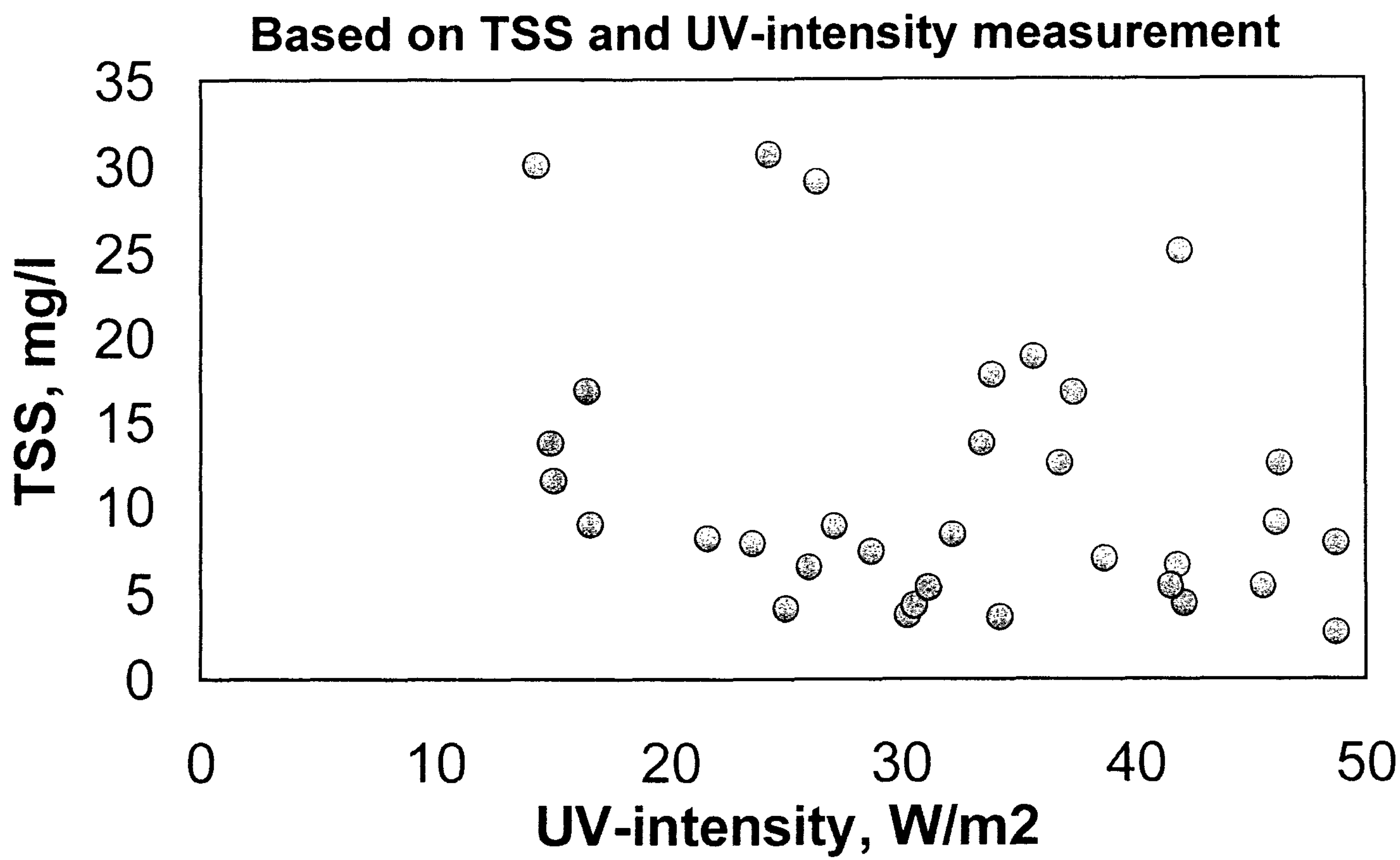
Ship to Shore Control: SSC™ => Online Internet Connection





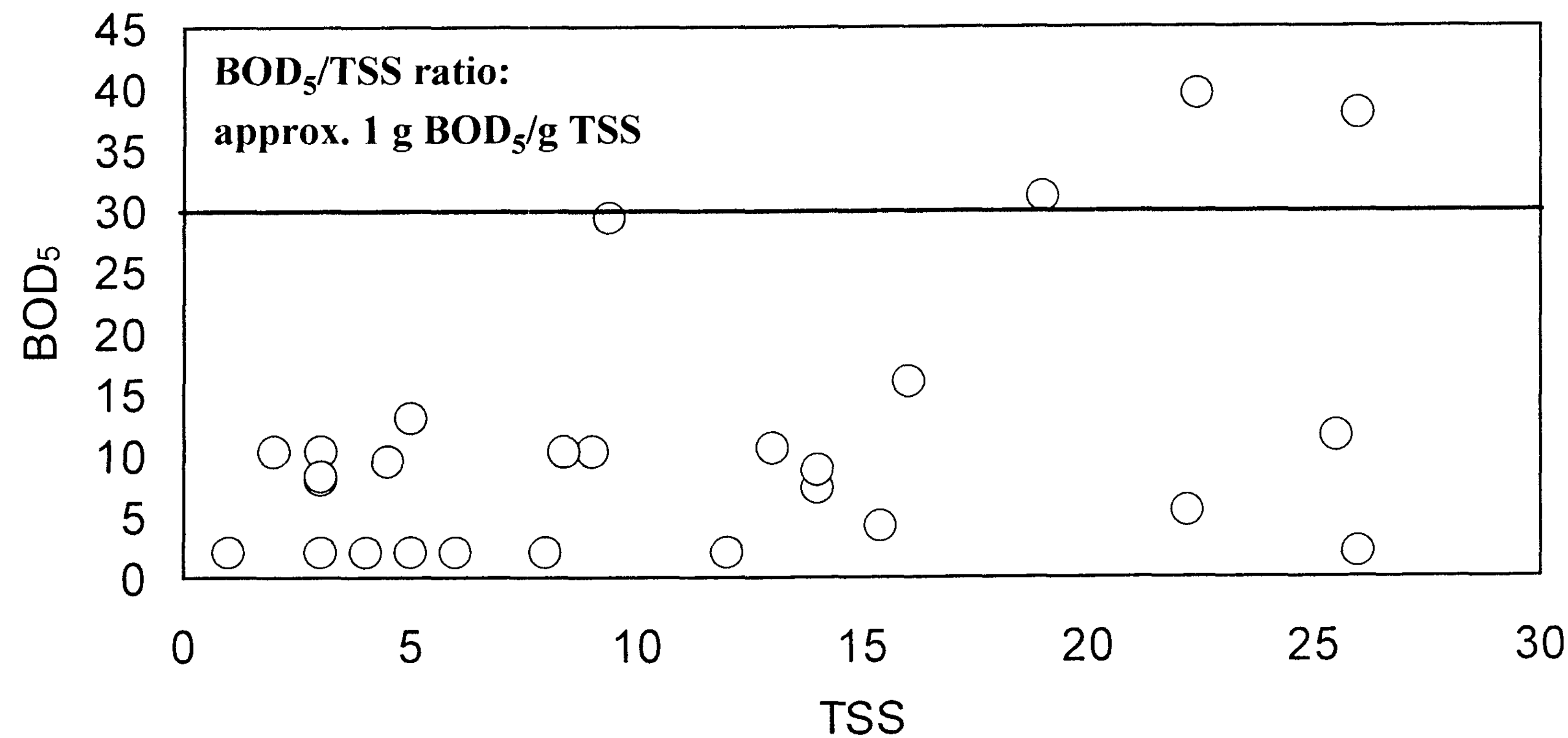
Fil Rediger Vis Favoritter Verktøy Hjelp
SCANSHIP ENVIRONMENTAL as
GUARD SYSTEMS
Menu
Parameters
Data
Trend
Overview
Tag
Solids
6.0%
Drumscreen
6.2 pH
29.6degC
27.4%
Buffer sludge Tank
72.4%
Pumpst. AFT
Biofilm FWD
21.36 m3/h
65.3%
Pumpst.
17.58 m3/h
34.96 m3/h
46.4%
Inlet buffer tank
52.7%
Flot.unit A
86.9%
6.49pH
Flot.unit B
93.6%
63.4%
6.30pH
96.8%
Coagulant
70.1%
Polymer
4.0bar
4.1bar
2.63 m3/h
36.7%
Dispersion
4.7bar
4.7bar
1.97 m3/h
49.7%
Polishing filters
75.3%
Pumpst.
Outlet Treated water
OVERBOARD
1.7mg/l
053.5%
051.9%
053.3%
UV
Flotation Unit A
Start/Stop
RUNNING
ALARMS
ACKNOWLEDGED
Start/Stop
Flotation Unit B
RUNNING

Effluent Control System: ECS™



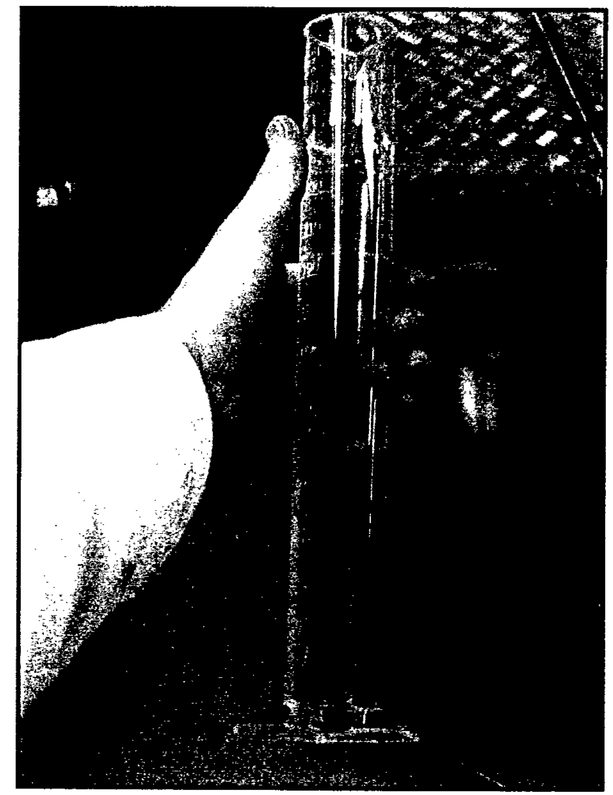
Norwegian SUN, SKY and WIND

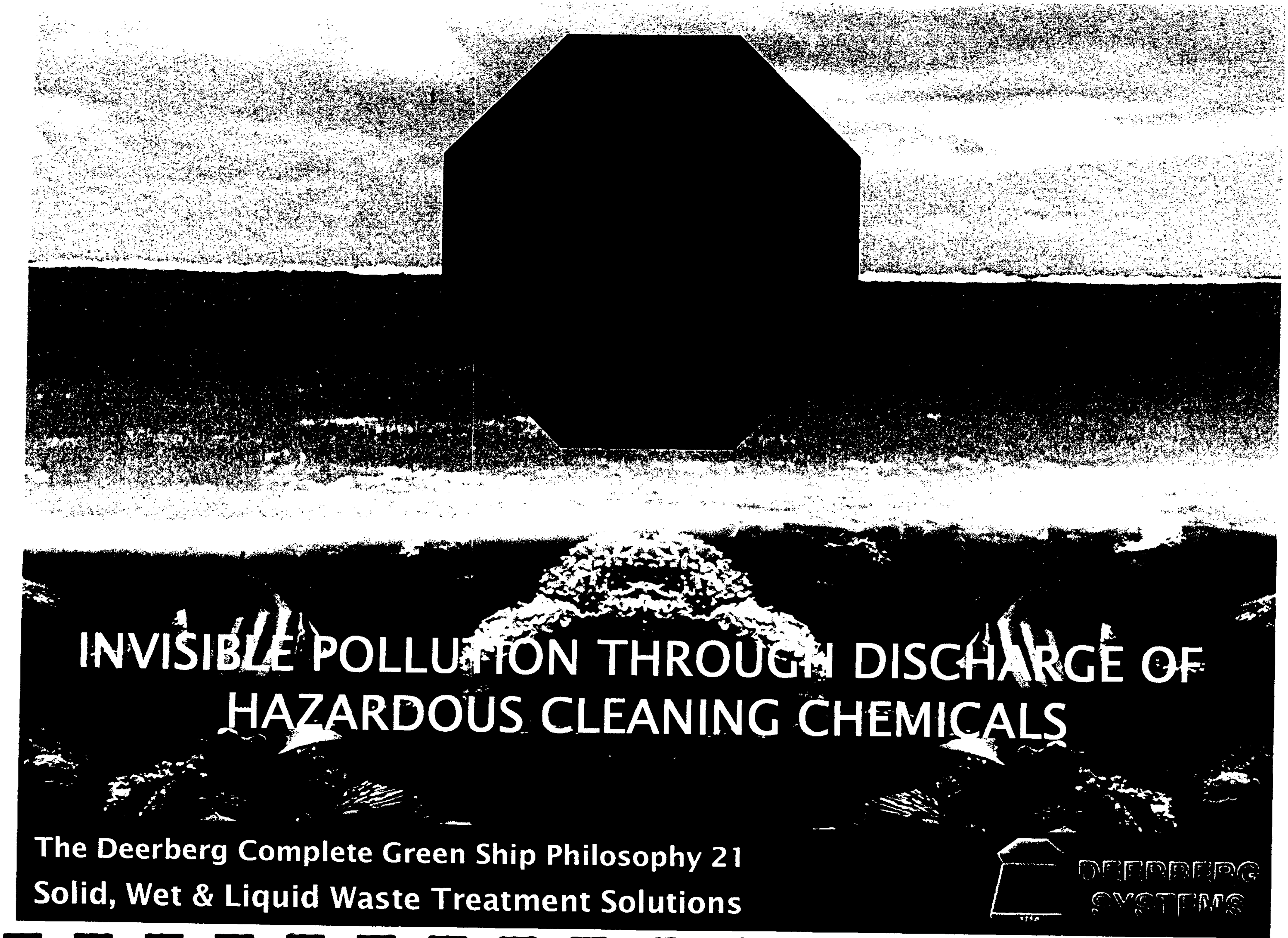
BOD_5/TSS ratio



Conclusion

- Short installation time
- Short startup time, approx.3 weeks
- USCG approval approx 2 month
- Quick and service friendly follow-up using internet




INVISIBLE POLLUTION THROUGH DISCHARGE OF
HAZARDOUS CLEANING CHEMICALS
The Deerberg Complete Green Ship Philosophy 21
Solid, Wet & Liquid Waste Treatment Solutions
DEERBERG
SYSTEMS

HEPBURN BIO SHIP CARE

Biodegradable, Biological Cleaning & Waste Treatment Products

MEETS THE ENVIRONMENTAL CHALLENGE

CHALLENGES FACING THE CRUISE INDUSTRY TODAY:

- PASSENGER SATISFACTION
- EFFICIENTLY OPERATING VESSELS
- REDUCTION OF OPERATING COSTS
- GROWING ENVIRONMENTAL PRESSURES

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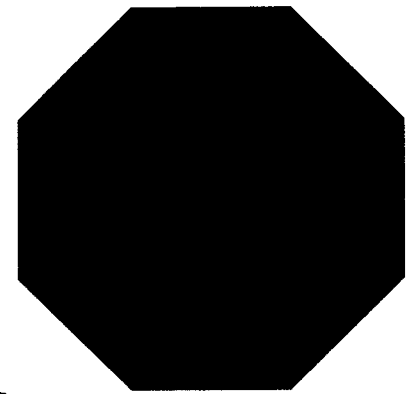
Solid, Wet & Liquid Waste Treatment Solutions

HEPBURN BIO SHIP CARE

Biodegradable, Biological Cleaning & Waste Treatment Products

- OCEANS AT RISK
  Ocean pollution is on the rise ......
- 60% coral reefs threatened
- One fourth are degraded beyond recovery–
- Average Cruise ship emits av. 200 tons chemicals per year
- Marine transport pollution into the sea accounts for 10% of all pollution into the oceans



THE OCEANS ARE THE CRUISE INDUSTRIES COMMERCIAL WORLD

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Solid, Wet & Liquid Waste Treatment Solutions

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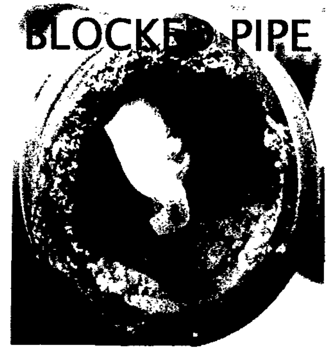
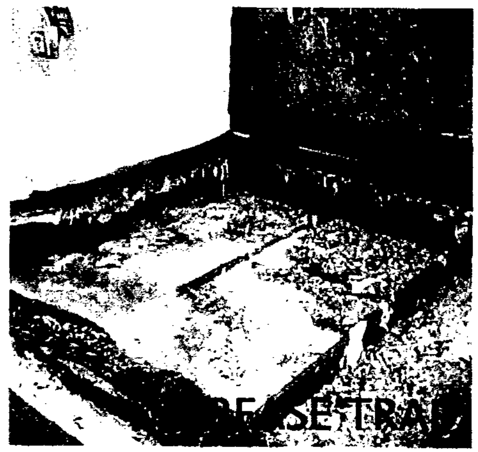
CONTRARY TO THE USE OF BIOLOGICAL AND BIODEGRADABLE CLEANING PRODUCTS,

<u>HAZARDOUS CLEANING CHEMICALS:</u>

- ➢ DAMAGE THE ENVIRONMENT
- ➢ KILL THE BIO MASS
- ➢ CREATE SMELLS OR BLOCKAGES
- ➢ PUT THE HEALTH AND SAFETY OF YOUR CREW AT RISK
- ➢ CAUSE STORAGE PROBLEMS
- ➢ CREATE HANDLING PROBLEMS





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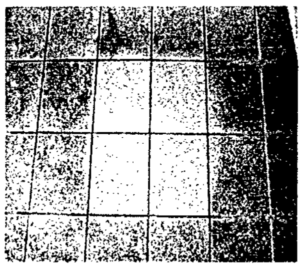
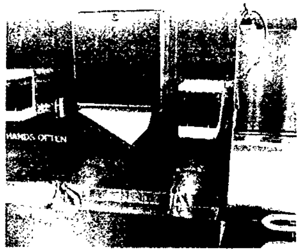
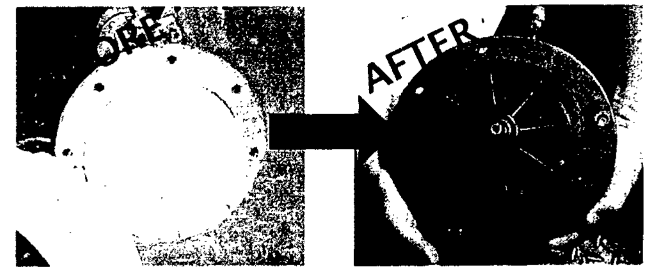


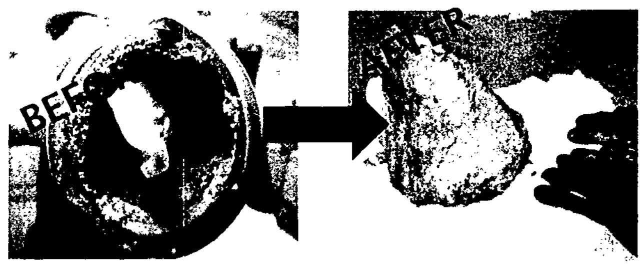


HEPBURN BIO CLEAN

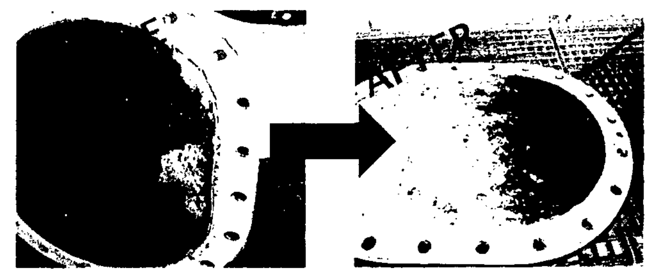
HEPBURN BIO WC CLEAN



HEPBURN BIO WC CLEAN

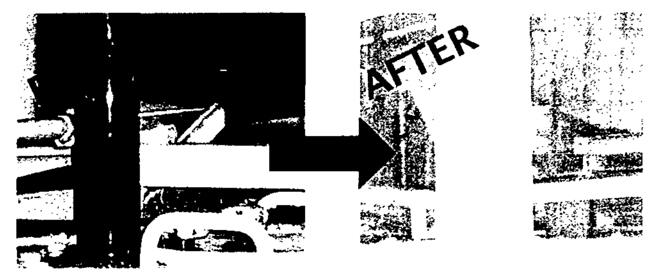


HEPBURN BIO WC CLEAN



HEPBURN BIO WC CLEAN

HEPBURN BIO ET



HEPBURN BIO ET

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Solid, Wet & Liquid Waste Treatment Solutions

DEERBERG SYSTEMS

HEPBURN BIO SHIP CARE

Biodegradable, Biological Cleaning & Waste Treatment Products

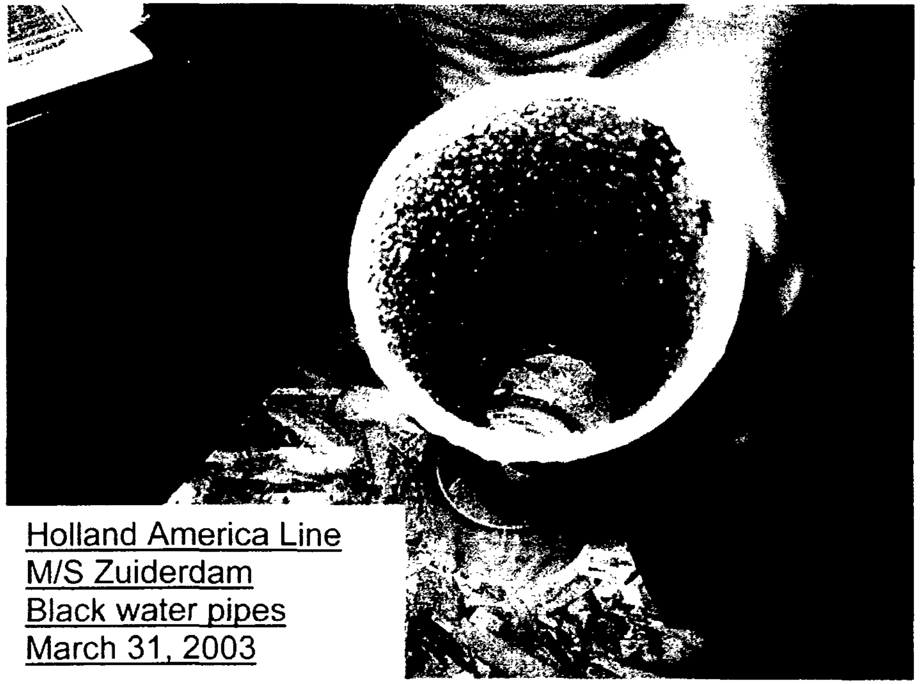
From: Novak, Mike (HAL)
Sent: Thursday, April 17, 2003 10:12 PM
To: Kruse, Stein (HAL); Groothuizen, Johan (HAL)
Cc: Softye, Richard (HAL); Roussel, Rene (HAL); Corbijn, Nico (HAL); Hogendoorn, Nanne (HAL); Boksem, Rob (HAL); Johnsen, Steinar (HAL); Fisker-Andersen, Jim (HAL); Van Leeuwen, Huib (HAL); Dorr, Hans (HAL); Rijkaart, Pieter (HAL); Koller, Jan (HAL)
Subject: Bio WC Clean in ZUDM

Stein:

Here is a photo of a black water pipe in ZUDM. This is dramatically different from what ZADM experienced in the same period of time. There is no scale build up at all. All one sees is the biomass on the wall.

Regards,

Mike



Holland America Line
M/S Zuiderdam
Black water pipes
March 31, 2003

HEPBURN BIO SHIP CARE

Biodegradable, Biological Cleaning & Waste Treatment Products

Change-over from Chemical Cleaning Products to Hepburn BIO Ship Care Products!

HOTEL DEPARTMENT	ENGINE DEPARTMENT	DECK DEPARTMENT
BIO WC Clean:	BIO ET / ET Activator:	BIO Clean:
Toilet and urinal cleaner. Degrades organic waste in pipes.	Waste treatment product to degrade all effluent greases, fat and human waste.	Multi purpose cleaner.
To be used in bathrooms, toilets, sinks, drains, showers, scuppers...	To be used in grease traps, waste water, STP´s	To be used for wood & steel decks, tables, chairs, BBQ, glass, plastic, tiles...
Saving: US$ 20.000,– per anno / ship	Saving: 25 % per anno / ship	Saving: 40 % cost 40 % labour per anno / ship

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Solid, Wet & Liquid Waste Treatment Solutions

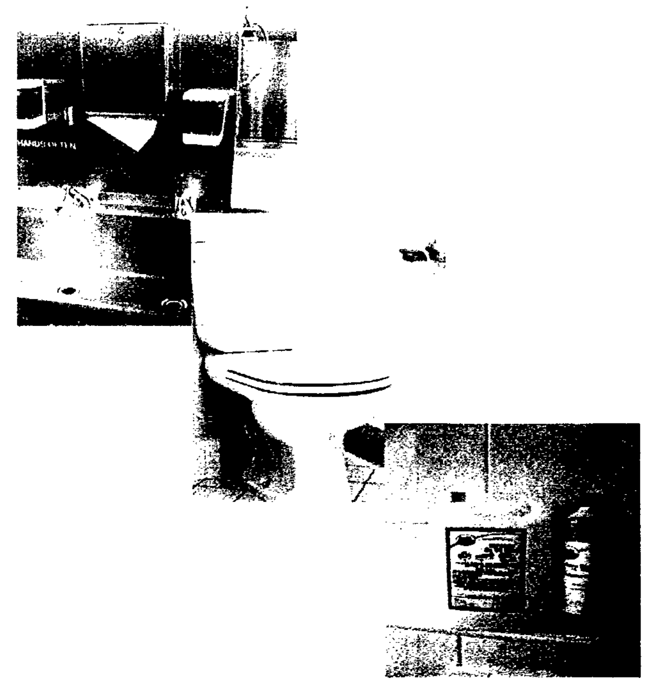
DEERBERG SYSTEMS

HEPBURN BIO SHIP CARE

Biodegradable, Biological Cleaning & Waste Treatment Products

CHEMICAL MANAGEMENT STRATEGIES

- REDUCE THE NUMBER OF PRODUCTS
  - USE APPLICATION STATIONS
  - USE MEASURED DOSES
  - APPLY AS DIRECTED
- REDUCE THE COST
- REDUCE THE CONSUMPTION
- REDUCE ENVIRONMENTAL RISK
- REDUCE PERSONAL COST



The Deerberg Complete Green Ship Philosophy 21
Solid, Wet & Liquid Waste Treatment Solutions

HEPBURN BIO SHIP CARE

Advantages of working in harmony with nature

PREVENTION IS BETTER THAN CURE - DEAL WITH THE PROBLEM AT ITS SOURCE - SUPPORT SUSTAINABLE DEVELOPMENT

Compliance	No risk to environment	Non Hazardous
Natural Products	Compatible products	Removes smells
Reduces Blockages	MSD work	Non abrasive
No risk to crew	No headaches	No Skin problems
Simplified routines	Committment	No risk to fixtures & fittings
Easy to store		

HBSC CAN OFFER YOU REDUCTION of Products, Logistics and Costs.

Cruise Lines are increasingly changing to HBSC Products.
Change is easy, adaptation of crew is a matter of weeks.

BIO Clean – Multi Purpose Cleaner, Light Cleaning, Dilution 1:9

BIO Clean – Multi Purpose Cleaner, Heavy Cleaning, Dilution 1:6

Glass Cleaner – Dilution 1:5

Air Freshener – Dilution 1:9

Sanitizer – Dilution 1:20

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Solid, Wet & Liquid Waste Treatment Solutions

Developments in Marine Environmental Compliance for the Future Warship – Wastewater Treatment for Type 23 Frigates

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Abstract
One of the major challenges faced by the Royal Navy is the maintenance and improvement of operational freedom and longevity for its warships. From an environmental perspective, a major imposition to this is posed by the introduction of increasingly more stringent marine environmental discharge legislation. QinetiQ's structured programme of research and development into wastewater treatment and management for the Royal Navy has resulted in the design, build and test of a biological membrane-based black and grey water treatment plant, aimed for retro-fit to Type 23 Frigates. The system has been designed to maximise environmental compliance whilst also bringing benefits in terms of retro-fit potential, long-term cost savings and risk minimisation. Trials of the plant proved extremely successful, and a replica system is now being trialled on an operational Type 23 Frigate, HMS Grafton. Analysis of final effluent from the plant, which was run using authentic black water from RN ships, and the system on HMS Grafton bears very good comparison with the very stringent effluent discharge targets set by the MOD. This plant has served a very beneficial purpose of de-risking generic membrane bioreactor plants for the MOD ahead of future installations onto ships of the Royal Navy.

1. Introduction

At the present time, regulations governing the quality of environmental emissions for international waters are defined by the International Maritime Organisation (IMO). These are presented in the IMO publication 'MARPOL 73/78' (1997 edition) [1], which represents the efforts of the International Convention for the Prevention of Pollution from Ships. This document is widely regarded as the international standard for environmental compliance by ships, and provides interpretations, articles, annexes and protocols for the regulation of ship generated pollutants, including; oil (annex 1), noxious liquids (annex 2), harmful substances (annex 3), sewage (annex 4), garbage (annex 5), and exhausts (annex 6).

Based upon the existing MARPOL 73/78 publication [1], UK Royal Navy ships observe, operate to, and achieve compliance with the protocols laid down within it. However, the maintenance of a 'watching brief' on environmental quality legislation on a global scale reveals that considerable policy shifts are either already underway, or are anticipated, which will give rise to increasingly more stringent operation and emissions legislation in the marine and coastal environments. The recognition by NATO navies that this may impose real challenges to the operational freedom and sustainability of military activities has resulted in the acceptance of the importance of improving environmental management approaches and technologies, and the development of strategies for achieving these aims.

In 1996, NATO Special Working Group 12 commissioned an industry-led advisory group (NIAG) to conduct a pre-feasibility study into 'the environmentally sound warship for the 21st Century' [2]. This study contributed significantly to the understanding of warships waste generation operations, processes and outcomes. For the first time on such a comprehensive scale, the study quantified all waste generation processes and arisings, made assessments of variations in production rates brought about, by example, by ships' staff movements and working hours, and identified each waste stream's key chemical and biological properties. Based upon these findings, the report then made an assessment of technologies suitable for the destruction or remediation of these waste streams, and concluded by identifying target emissions quality levels for liquid discharges, which were perceived to be achievable by the year 2005, using the identified technologies (see table 1).

The target levels presented in Table 1 were incorporated into the 'NATO staff target for an environmentally sound warship for the 21st century'. This was then utilised as a benchmark for achievement by the UK MoD, who set a two-stage target for UK NATO ships with the aims of reaching environmental compliance by 2005, and being considered environmentally sound by 2015. The adoption of this strategy by the UK Royal Navy represents a considerable departure from the RN's current waste treatment capabilities and approach, thus rendering existing equipments obsolete through inability to comply with target emissions levels.

As part of its commitment to ensure future environmental compliance and operational freedom for the fleet, the Royal Navy commissioned QinetiQ (previously DERA) to undertake a strategic package of research and development directed towards improving the understanding of environmental compliance issues, and identifying and developing solutions to fill technology gaps. QinetiQ's research into black and grey water treatment options commenced in 1997 with a study which identified membrane separation technology as holding most promise for achieving the anticipated NIAG standards [3] (Table 1). Physical test and evaluation of commercially available membrane technologies then followed, using a standardised test rig and authentic RN ships black and grey water. This process identified a flat sheet membrane in a submerged configuration, manufactured by the Kubota Corporation (Aquator Ltd, UK), as being the most promising approach at the time in terms of discharge quality (compliance), robustness, reliability, modularity and cost effectiveness [3].

The favourable outcome of this study facilitated the furtherance of the research, and QinetiQ were commissioned by MoD to undertake the complete design of a submerged-membrane black and grey water treatment system able to be retrofitted on to Type 23 Frigates. The design study, which was undertaken with support from subcontractors MBR Technology and Transvac Systems, aimed to modify the existing Type 23 wastewater 'collect and hold' system. Modifications included the incorporation of a biological membrane treatment system capable of meeting the NIAG 2015 target (see Table 1), and achieving a 45 day endurance, whilst minimising the changes to the existing systems. Following the completion of the system design, QinetiQ then undertook the construction of a full-scale technical demonstrator system, and conducted a series of trials to provide technical proof of principal and to de-risk the system prior to the ships fit. This paper details the design, construction and trials process and its key findings, and progress with ships installation and operation.

2. Submerged membrane technology

The biological treatment of sewage is brought about by a consortium of bacteria, which naturally colonise the waste stream, ultimately forming what is termed as an 'activated sludge'. These bacteria digest organic matter in the presence of oxygen to form carbon dioxide, water and sewage sludge. The sewage sludge consists of the less readily degraded, more refractory, organic components of the sewage. The water generated from the oxidation of organic matter can be readily be removed using suitable membrane technologies, thereby reducing the volume of the wastewater over time. Assuming that a sufficient level of filtration is achieved, the resultant water fraction may be discharged as 'clean' effluent, into receiving water courses or the sea, whilst the sewage sludge fraction progressively concentrates within the process tank, thereby increasing the proportion of suspended solids.

The materials used for these membranes generally consist of chlorinated polyethene with 0.4μm pores for liquid filtration. The types of membrane configurations that were considered for use on RN vessels included:

(1) Tubular Membranes, with the liquid waste flowing along the inside of tubular membranes, typically 10cm in diameter, and the permeate water passing through the membrane the outside as permeate.
(2) Hollow-Fibre Membranes, with the liquid waste flowing along the outside of the fibres, typically 3mm in diameter, and the water permeate passing through to the inside where it is removed (ie opposite to tubular membranes).
(3) Flat Sheet Membranes, whereby the liquid waste flows around the outside of the flat sheets and the permeate passes through to the inside where it is removed.

In addition to these fundamentally different membrane configurations it also possible to create additional variation depending on whether the membrane is directly immersed in the liquid waste (ie submerged-type) or, placed in a module external to the main sludge tank via a pump (ie side-stream-type).

Test and evaluation of different membrane configurations using authentic RN waste at QinetiQ Haslar suggested, at the time, that a submerged flat sheet membrane would be best suited to the RN requirements of efficiency, maintainability and the size footprint available. Flat sheet Kubota membranes were used for the technical demonstrator whereby cross-flow filtration is achieved using air-bubble induced water movement while filtering the water fraction from the mixed liquor of the bioreactor using a differential pressure across the membrane. A simple schematic of a flat sheet Kubota membrane submerged configuration is provided in Figure 1 and shows a series of laterally arranged, closely packed, flat panels, held centrally within the wastewater column of the bioreactor. The correct positioning of the membrane panels within the tank is critical to ensure membrane submergence and the correct membrane spacing in order for a flow of bubbled air, from beneath the membranes, to drive a liquid flow of 0.5 ms^{-1} across the membrane surface. During optimum system performance the liquid flow created by the air bubbles is circulatory throughout the tank. In addition to the physical mixing of the sludge, the bubbled-air also provides a source of oxygen for the bacteria to maintain efficient aerobic digestion, and also helps to scour the membrane surface, thereby preventing blockage of the pores in the membrane by creating a cross-flow.

The concentration of organic matter within the wastewater process tank greatly influences the efficiency of the treatment process. If the sludge contains relatively low levels of organic matter, then there will be insufficient biological activity to digest the incoming waste. Conversely, if the sludge contains excessively high levels of solid matter, then insufficient oxygen will partition into the viscous liquor to maintain the aerobic process. In this respect, the concentration of suspended matter (Mixed Liquor Suspended Solids, or MLSS) also represents the key operating factor for system endurance. Membrane manufacturers typically recommend that an MLSS limit of 25,000mgl^{-1} should not be exceeded in the process tank in order to avoid damage to the membranes, and to maintain effective aerobic biological treatment. This value was therefore utilised in the design calculations of the Type 23 system in order to interpret what size of process tank would be required to achieve a 45-day endurance.

3. Type 23 Frigate - System Design Considerations and Requirements

3.1. Existing Type 23 Plant Description

The existing wastewater management system onboard recently built Type 23 Frigates is based upon a simple collect-and-hold solution. Influent black water is transferred under vacuum from the ship's heads to the vacuum collection tank where is it periodically transferred into either of the port or starboard holding tanks, each of 8000 litres. A photograph of the existing port and starboard holding tanks currently used on Type 23 Frigates is provided in figure 2. Grey water arising from the forward part of the ship is collected into a dedicated holding tank of 18,000 litres which periodically discharges to the port 8,000-litre holding tank of the collect-and-hold system. Grey water arising from the Aft end of the ship however is collected under gravity and discharges directly into the starboard 8,000-litre tank of the collect-and-hold system. When capacity is reached the system discharges untreated wastewater, via the port holding tank, either directly overboard, when outside of restricted sea areas, or to shore-based reception facilities. With a full crew compliment onboard of 185 personnel, the collect-and-hold system achieves between 5 and 7 days endurance before the contents need to be discharged to sea beyond 12 nautical miles or to shore reception facilities.

3.2. Design aims of the Type 23 Plant

It is clear that the existing collect-and-hold arrangements fail to meet the Royal Navy's future aspirations, either for operational freedom or for operational longevity. The revised design programme, based upon RN future requirements and previous QinetiQ research, therefore aimed to:

'Interface, into the existing ships system, a cross flow membrane treatment system that will treat grey and black waters to an acceptable standard for continuous marine discharge whist in deep water or in port. The new system is to incorporate sufficient sludge storage capacity to enable the vessel to remain at sea for a period of up to forty-five (45) days without having to make a marine discharge of any surplus sludge'

Further to these aims, there was also a requirement to minimise risk and cost by utilising as much of the existing collect-and-hold system and associated parts as possible. Where the addition of new equipments or technologies was necessary, these were to be selected from commercially available technologies (COTs). In addition, to provide confidence to ship builders and integrators and to ease retrofit capability, the new plant design was to be sized such that it did not impinge on any area outside of the exiting sewage treatment plant (see figure 2). The new system also had to be totally assembled in-situ, within the compartment space, with very limited disturbance to the ship and without a shipping route through the hull of the vessel.

Simple calculations, based upon estimated total flows for black and grey water per person per day were determined. The calculations suggested a daily throughput of black water of $3m^3$ day^{-1}, and a total grey water flow of $27m^3$ day^{-1} giving a total daily flow of $30m^3$ day^{-1} for a crew compliment of 185. However, to accommodate natural variations brought about by the daily activities of the ships' crew, the system was designed to cope with peak flows of up to 150% normal flow, and conversely, to operate effectively during periods of very low flow, brought about, for example, by periods of shore leave.

3.3. Design Modifications of the existing plant to a bioreactor

The following engineering alterations were required to incorporate a submerged-membrane, biological, wastewater treatment system into the existing Type 23 collect-and-hold plant. In order to appreciate fully the discussion involved reference to the schematic of the technical demonstrator, with wastewater flow direction (figure 3), and a corresponding photograph of the demonstrator at QinetiQ Haslar (figure 4) are recommended.

Enlargement of existing port and starboard holding tanks

To meet the 45-day endurance criterion the total working volume capacity of the existing port and starboard holding tanks had to be increased from 12,000 litres to 16,000 litres (ie final total volume of $20m^3$). This modification would be expected to keep the suspended solids (MLSS) below 25,000 mg/l and would also accommodate the 220 membrane panels. This was achieved by extending vertically the mid-section of each tank by 0.5 metres.

Inclusion of an additional mixing / balancing tank

A new tank, the mixed liquor balancing tank, of 4.5 m^3 capacity, was designed for inclusion between the existing port and starboard tanks (see figures 3 and 4). This provided sufficient balancing volume to accommodate variations to the influent flow rate, and to allow for mixing of all incoming black and grey waste streams prior to entering the bioreactor. This latter aspect effectively prevents shock loadings of either organic-rich (i.e. undiluted black water), or organic-poor (i.e. undiluted grey water) influent from entering the bioreactor and disrupting the biomass, to the detriment of treatment efficiency.

Incorporation of membranes to port holding tank
Provision in the port holding tank was made for the internal framework designed to hold four membrane modules each accommodating a total of 55 membrane panels, each with a surface area of ~0.4m^2, under which is fitted an air diffusion system. The system was designed to maintain an effective passage of air past the membranes during system operation. Permeate hoses were connected from each membrane panel, via pipework situated in the roof of the tank. This permitted the removal of permeate water that passed through the membrane units to be discharged overboard via the ships low-level discharge pipework. To gain maintenance access to the membrane units, the port tank was also re-designed to include 5 access hatches (figure 4).

Provision of air to bioreactor tank
To maintain aerobic metabolism within the system, and to maintain membrane surfaces in good working order, it is essential that a volume of approximately 180 – 200 m^3 hour^{-1} of air be supplied to the bioreactor tank. The provision of air from the ships existing low pressure air system was found to have insufficient capacity to sustain the volume required. Dedicated air blowers (one duty, one standby) were therefore identified from a commercial source and included within the system design.

Designation of starboard holding tank
The starboard holding tank, with its increased volume holding capacity, was re-configured to perform the function of a sludge balancing and dentrification tank. The mode of operation allows freshly mixed watewater (black and grey) that arrives into the starboard tank from the MLBT to be mixed into recycled sludge arriving from the bioreactor tank before being pumped back into the bioreactor tank for continued treatment. This denitrification tank allows the oxygen concentration to drop as a direct result of the continued aerobic respiration of the activated sludge until the metabolism of these facultative organisms in the sludge switches to oxidise BOD using nitrates as the electron acceptors. The product of the denitrification stage is to reduce nitrate concentrations, by converting the nitrates to nitrogen gas, while continuing to oxidise BOD organic matter without the additional requirement of pumped air.

Inclusion of waste screening and screenings collection
A key element in the prevention of system failure in a submerged membrane system is the adequate provision of waste screening prior to the bioreactor. A previous QinetiQ study aimed towards characterisation of Royal Navy waste streams found variable quantities of 'alien' objects in both black and grey water streams, including litter, personal hygiene items, and foodstuffs. Clearly, if items such as this enter the bioreactor they could give rise to serious operational difficulties. In order to prevent this occurrence, a 3mm screening device was incorporated after the recycle tank, with a dedicated receiving vessel, for all wastewater entering the bioreactor tank. Matter retained upon the screen periodically transfers into the receiving vessel where it is de-watered and stored until the end of the ships mission. Initial problems of hair build-up on the screen required increased resources onboard the ship to manually clean at regular intervals. However, recent modifications to the ship system have incorporated a new screen with a rotating-sieve cutting mechanism to provide a continuously cleaned screen to 3mm, which does not require manual cleaning.

Additional buffering capacity for Aft Grey water
During initial trials of the prototype bioreactor on HMS Grafton it was realised that the proportion of grey water from the aft part of the ship was significantly greater than that of the forward part of the ship. Forward grey water arrives at the bioreactor via an 18 Tonne holding tank whereas the aft grey water is delivered direct to the bioreactor from the laundry, shower and galley washing facilities. Additional modifications to the HMS Grafton bioreactor were

therefore required to allow the level in the MLB Tank and the denitrification tank to run down to low levels before the grey water in the forward holding tank was treated. This policy ensured that up to 8 Tonnes of buffering capacity was accommodated within the bioreactor for the aft grey water. This system also required a PLC to continually monitor the change in levels to ensure that the most optimum permeate flow rate was always selected.

4. System Testing of the Modifications

The fundamental aims of the trials process were to: (1) assess the mechanical integrity of the system, and to de-risk unknown elements of the plant, including the air blowers, the membrane panels and the membrane units for robustness and efficiency, (2) test the practicality of the theoretical design, and the functionality of its novel automated nature, and (3) establish absolute operating parameters for efficient plant operation, and effluent compliance to legislation such as MARPOL 73/78 Annex 4 and targets defined in the NATO Industry Advisory Group (NIAG) report.

To achieve these aims, a series of combined theoretical and physical research studies were undertaken both for the new system design package, and for a scale-demonstrator model, which was constructed and operated at QinetiQ Haslar. The theoretical Finite Element Analysis study element identified no generic difficulties with the system design configuration, or locations of system elements within the wastewater compartment as a whole. This was not entirely surprising considering that the new system is a modification of the existing collect and hold plant. However, the study did make a recommendation for the modification of bolting arrangements at the feet of the port and starboard holding tanks to prevent shearing in extreme operational scenarios.

The noise and vibration assessment was undertaken solely for those equipments which generated a noise output and were new to the existing collect-and-hold system including the air blowers and the permeate pumps. The assessment, undertaken on the technical demonstrator at QinetiQ Haslar, in accordance with NES 810 (part 2) found that the recognised safety level for machinery spaces onboard RN ships of 90 decibels was not exceeded. The effects of heel, brought about by the motion of the vessel at sea, are of particular concern in systems, which comprise fluid holding vessels, due to shifts in centre of gravity brought about by movement of a liquid mass. Although the Finite Element Analysis did not find any structural concerns for the modified system caused by heeling, it was also important to consider the process implications in terms of treatment efficiency. Theoretical tests showed that the membrane panels would remain submerged within the waste stream at all states of heel, while only more extreme angles of heel would the air flow past the surface of the membrane be effected. It is considered unlikely however that excessive heel in one direction would occur for a significant period of time, and a prompt return of the air supply across the panels would resume the scouring process with no effect upon the integrity of the membrane.

4.1. Analytical Results of Permeate Discharge

Throughout the duration of the trials, the system was loaded with authentic RN derived black water, which was obtained from Type 23 Frigates based at Portsmouth Naval Base that were operating with a vacuum collect-and-hold wastewater system. Grey water was artificially prepared to replicate the key chemical, biological and physical characteristics of grey water, which were identified as part of a previous QinetiQ wastewater characterisation study [4]. The waste loading profiles were designed such that they would effectively mimic those likely to be experienced by the system when in normal operation onboard the Type 23 Frigate. These included flows of 1.5 $lmin^{-1}$ black and 7.1 $lmin^{-1}$ grey water from 00:01 to 09:00 hours, 10:00 to 14:00 hours and 16:00 to 23:59 hours, and periods of higher flows of 6.3 $lmin^{-1}$ black and 100 $lmin^{-1}$ grey water from 09:00 to 10:00 and 14:00 to 16:00 hours (~30m^3 total per day). Data from HMS Grafton during operations in tropical climates has also shown that the grey water production rate can significantly increase over these values provided above. Also, every third weekend during the trials, the working volumes of each waste stream were reduced in order to represent periods of reduced crew compliment, such as shore leave. The total working volumes were therefore reduced to one third of the above volumes to achieve this.

The technical demonstrator plant was run continuously for a period of 82 days, 55 of which were considered to represent a plant in fully operational, post-commissioned mode which was greater than the aim of 45 days endurance. Also during this period the mixed liquor suspended solids (MLSS) of the activated sludge remained below the set limit of 25,000mgl.$^{-1}$ Table 2 shows the analytical determinands monitored over this period from the permeate water discharge of the bioreactor with comparison to the MOD target set in the NIAG report for 2015. Typically the 2015 limits represent half the concentration of the 2005 target provided in table 1 also with the MARPOL 73/78 Annex 4 limits.

The biological oxygen demand (BOD) is a measure of the amount of oxygen consumed by the microbiological species present through respiration over a 5 day period. The permeate monitored over the 54-day trial was shown to have BOD's of <4.0 to 5.8 mgl^{-1} which was well within the limits to be set for MARPOL Annex 4 and the most stringent NIAG 2015 target (ie 50 and 15mgl^{-1} respectively). These BOD values were also well within the most stringent current marine discharge legislation of Dade County, Florida at 30mgl^{-1}. Chemical oxygen demand (COD) is a more rapid test and is a measure of the maximum oxygen that would be required to oxidise the total organic matter present. COD values were found to vary from 38 to 145 mgl^{-1} which was also found to be within the NIAG 2015 target of 150 mgl^{-1}. MARPOL 73/78 Annex 4 does not require COD to be determined. Faecal coliform bacteria would not be expected to pass through a correctly functioning membrane bioreactor due to the pore sizes of 0.4μm, before slime-layer reduction to ~0.01μm, being less than typical bacterial sizes at 1-3+μm. From table 2 it was evident that no coliform bacteria were present in the permeate water discharged from the bioreactor which readily met both the NIAG 2015 and MARPOL 73/78 Annex 4 limits of 1 and 2 cfu.ml^{-1}, respectively. Suspended solids (ie 8mg.l^{-1}) were also well within the MARPOL 73/78 Annex 4 limit and NIAG 2015 target of 100 and 50 mg.l^{-1}, respectively. BOD, faecal coliform counts and suspended solids represent the key, priority determinands required to meet the recently ratified MARPOL 73/78 Annex 4 levels, which emphasised the effectiveness of making the retrofitted bioreactor compliant to the forthcoming legislation. Other determinands were also found to be within the stringent NIAG 2015 target and included pH, total organic carbon, total nitrogen and oils and grease (cf table 1 and 2). Total dissolved solids and total solids have, in the opinion of the authors and MOD been incorrectly specified, as these are comparable to limits set on drinking water by the UK Drinking Water Inspectorate. Moves are already underway to lobby NATO Special Working Group 12 to issue an addendum to change these limits. Besides this only total metals and total phosphorous were just outside the very stringent MOD-imposed, NIAG 2015 target. On the whole this retro-fitted bioreactor plant demonstrated compliance to the recently ratified MARPOL 73/78 Annex 4 legislation as well as the most stringent local marine discharge legislation designed to curb the impact of the cruise ship industry (ie Dade County, Florida).

A replica of this trials plant has also been producing similar effluent quality on HMS Grafton since its installation in late 2001.

5. Conclusions and Recommendations of the study

The positive outcome of the system design, construction, operation and environmental compliance assessment concluded that:

i. The system achieved the design aims of incorporating a biological wastewater treatment system into the existing compartment space, utilising much of the existing on-board equipments, and minimising disturbance to the ship

ii. The system achieved compliance against all of the key priority analytical determinands of the permeate discharge that were identified in the NIAG study (Tables 1 and 2).

iii. The system achieved at least a 45-day endurance without the need for de-sludging of the bio-reactor tank.

The successful achievement of all of the original system aims brought about the recommendation that the plant be included within the Type 23 Frigate fleet retro-fit programme. Trials of a replica bioreactor system fitted onto HMS Grafton have been ongoing since late 2001 and results suggest that a similar quality of permeate is also achieved with this plant. Results from incorporating this technology into a Royal Navy Type 23 Frigate has already sufficiently de-risked this technology to permit the MOD to consider bioreactor technologies for subsequent ship installations to other platforms.

References

1. MARPOL 73/78 Consolidated Edition, 1997. Printed by the international Maritime Organisation (Sales No. IMO-520E), ISBN 92-801-1435-2.
2. NIAG-D(96)1. NATO Industrial Advisory Group, Pre-feasibility Study on a NATO Environmentally Sound Ship of the 21st Century. Document NIAG-D(96)1 1996.
3. Lesley D and Earwicker S (1997). Towards the environmentally independent fleet – a review of biological and membrane technology for waste water management. DERA Report No. DERA/SSES/CR971034, 42pp.
4. Kenny S, Wood S, and Woodruff D (2000). Type 23 Frigate. Modification of a vacuum sewage system to a bio-membrane system. DERA Report No. DERA/MSS/TR99, 46pp.
5. Kenny S, Smith G, Wood S, Sutcliffe K and Woodruff D (2002). Developments in marine environmental compliance for the future warship – wastewater treatment for Type 23 Frigates. Journal of Defence Science, Vol. 7, p 131-146.

Acknowledgements

The authors wish to acknowledge the technical and financial support of MOD, MAES IPT, Abbeywood, Bristol.

Determinand	Units	NIAG 2005 Target [2]	Current MARPOL 73/78 [1]
Biochemical oxygen demand	mg/l	30	50
Chemical oxygen demand	mg/l	300	ND
Faecal coliforms	No./100ml	200	250
pH	1-10	6-9	ND
Suspended solids	mg/l	100	100
Total dissolved solids	mg/l	500	ND
Total solids	mg/l	500	ND
Metals combined	µg/l	100	ND
Total organic carbon	mg/l	100	ND
Total nitrogen as organic and ammonia	mg/l	40	ND
Total phosphorous	mg/l	10	ND
Oil and grease	mg/l	5	ND
Total chlorine	mg/l	Not Allowable	ND
Solid Wastes	n/a	Not Allowable	Variable

ND = Not Determined

Table 1. NIAG anticipated levels for discharge

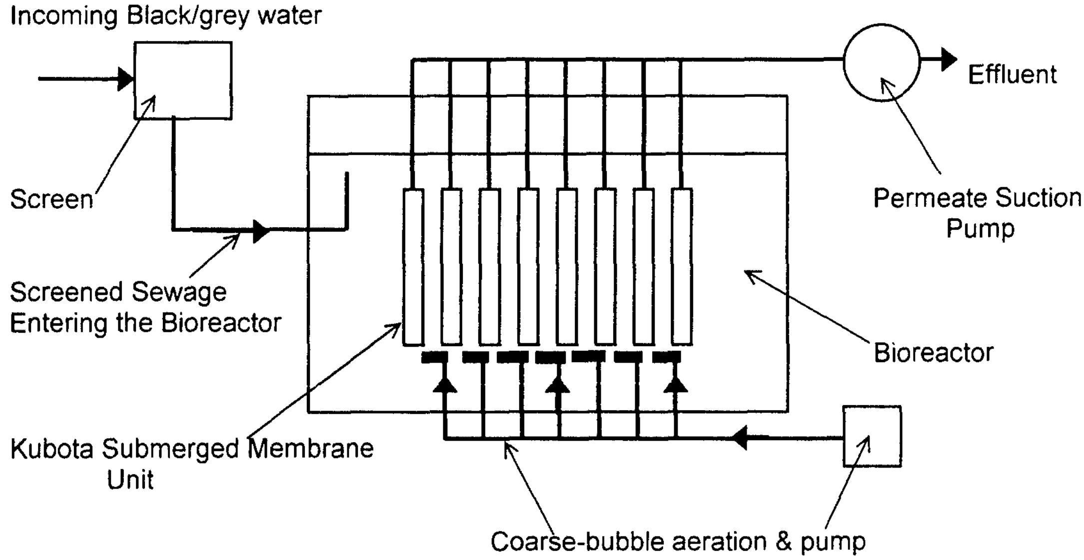


Figure 1. Schematic of the membrane configuration in a Kubota waste management process plant.

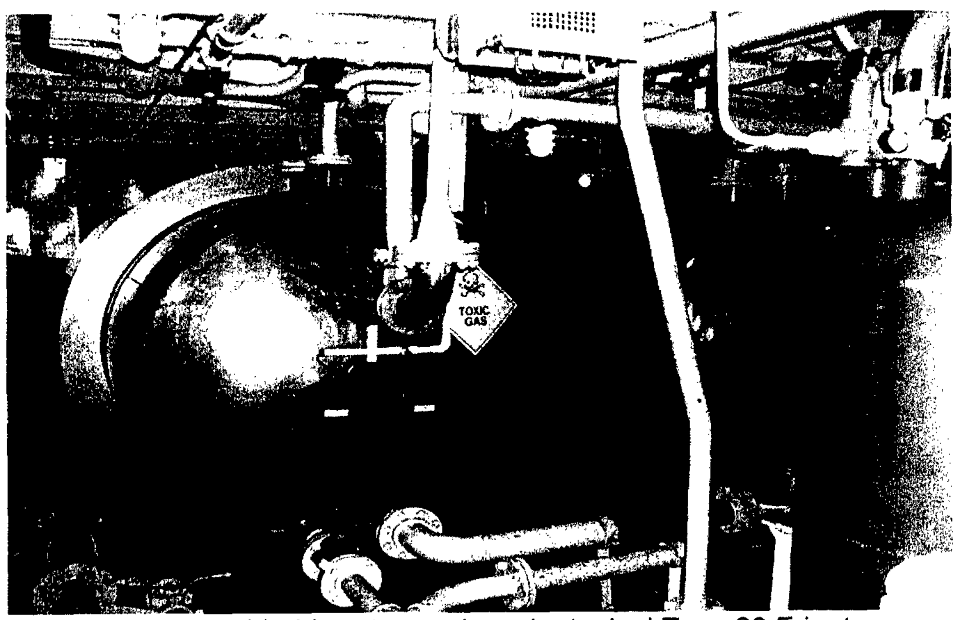


Figure 2. Existing collect-and-hold system onboard a typical Type 23 Frigate

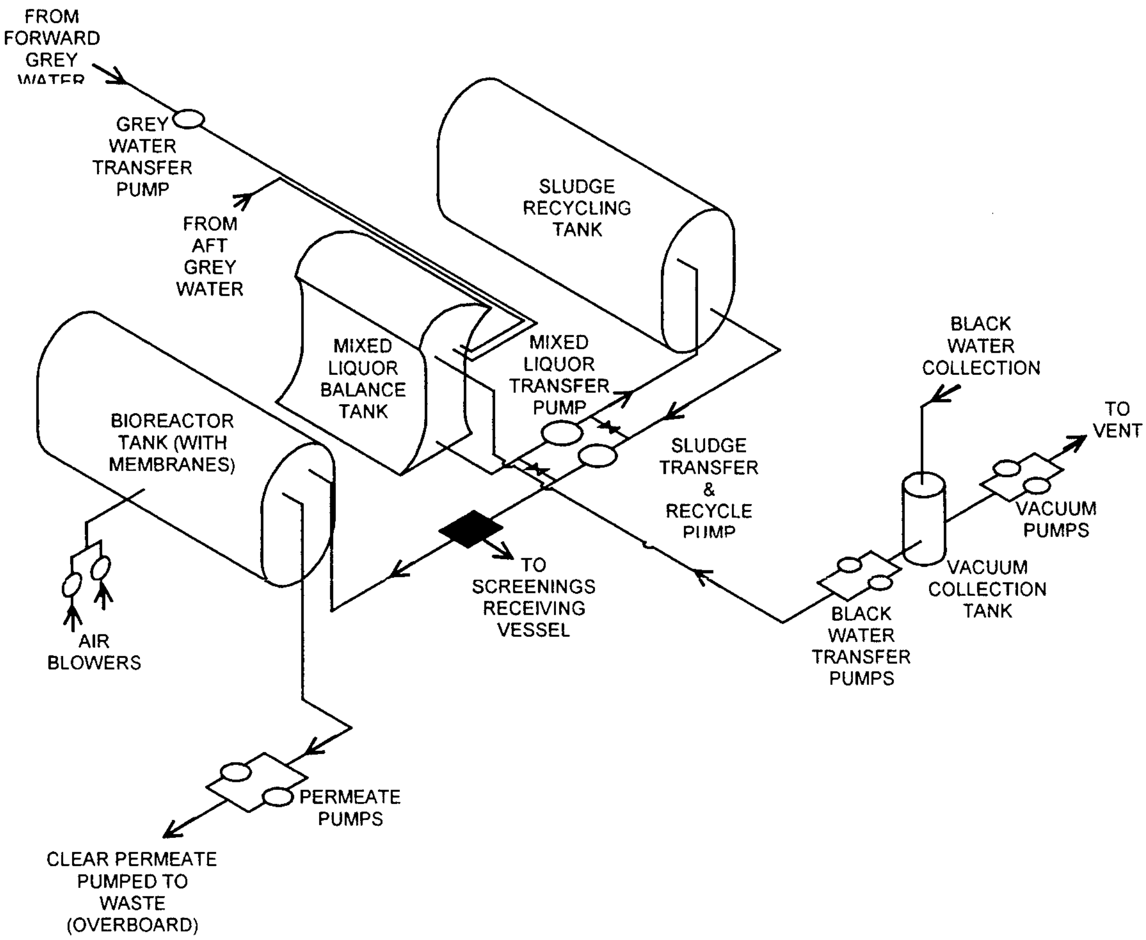


Figure 3. Modified system design (expanded for ease of reference)

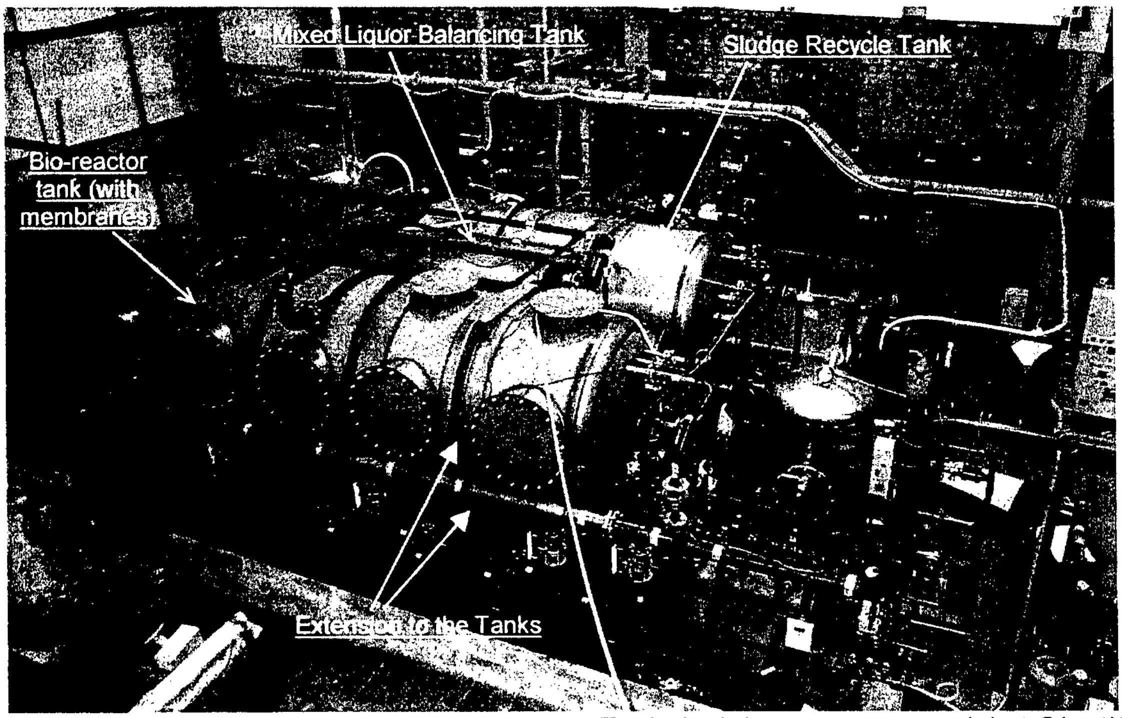
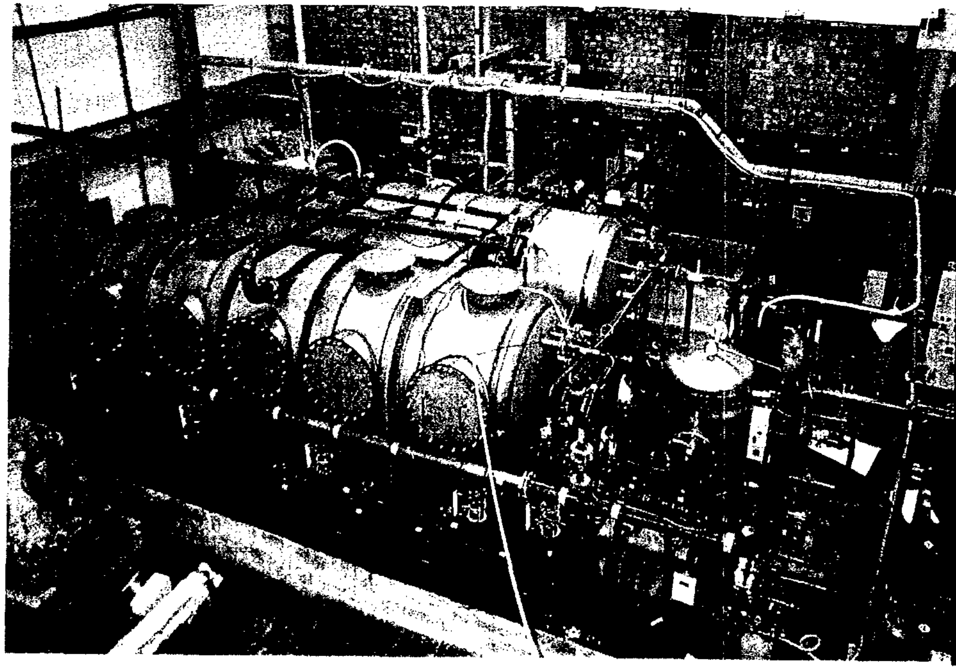


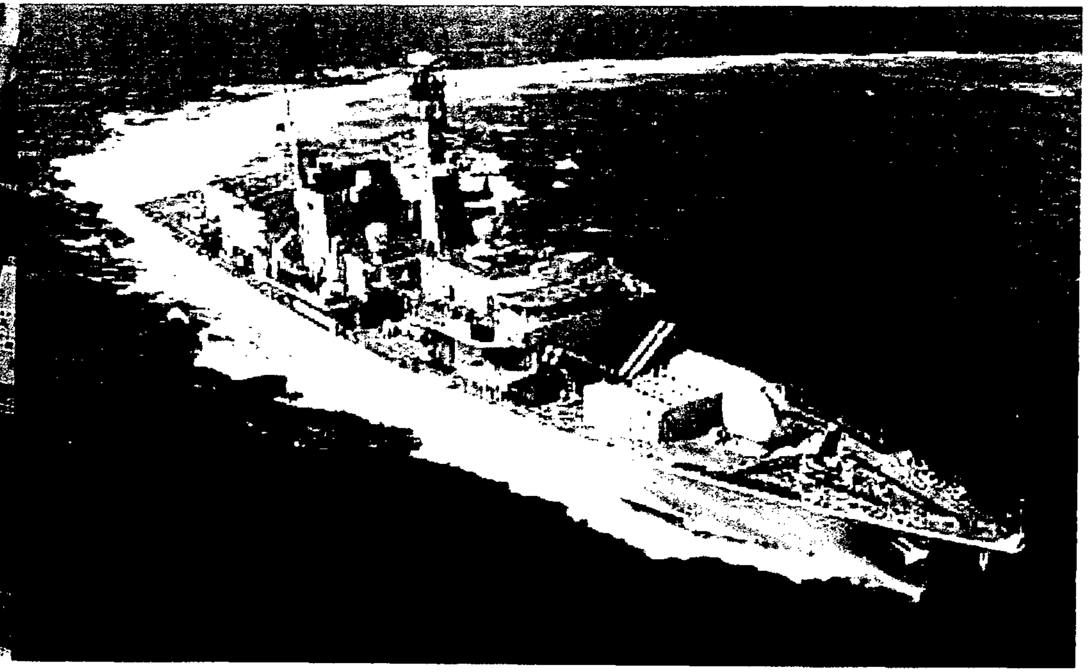
Figure 4. Technical demonstrator model at QinetiQ Haslar

Determinand	Units	Days 1-21	Days 22-40	Days 41-54	Mean concentration	NIAG 2015 Target [2] *
Biochemical oxygen demand (BOD)	mg/l	<4	5.8	<4	4.6	15
Chemical oxygen demand (COD)	mg/l	110	38	145	97.6	150
Faecal coliforms	No./ml	0	0	0	0	1
pH	1-10	6	6.4	6	6.13	6-9
Suspended solids	mg/l	16	3.5	4.5	8	50
Total dissolved solids	mg/l	590	630	730	650	250
Total solids	mg/l	600	660	750	670	250
Metals combined	µg/l	78.7	84.6	79.6	80.9	50
Total organic carbon	mg/l	21	14	23	19.3	50
Total Nitrogen (as organic and ammonia)	mg/l	2.4	<1	48	17.1	20
Total phosphorous	mg/l	7.3	3.8	7.7	6.2	5
Oil and grease	mg/l	2.3	2.5	2.9	2.5	2.5
Total chlorine	mg/l	0	0	No data	0	Not permissible

* NIAG 2015 target = 50% of NIAG 2005 target [2]

Table 2. Analytical results of the permeate water collected from the land-based bioreactor trials





Environmental Compliance for the Future Warship - Wastewater management for an RN Type 23 Frigate

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Environmental Sciences Dept,
QinetiQ Ltd, Gosport, Hampshire

Drivers

- Ship-board Black and Grey water treatment
  - Comply with current and anticipated future legislation
    - Environmental independence
  - Help to reduce the cost of off-loading wastes in ports
    - 'Duty of Care' causing these costs to rise.
  - 2002 NATO policy on terrorism
    - Restrict ease of use of bowsers alongside RN ships.
  - Improve health and safety on board
    - Reduced-gases such as H_2S is not formed

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Legislation - Liquid Effluent from Ships

- MARPOL Annex IV (Currently imposed on a national level, to be implemented globally Sept 2003, and will apply to existing ships from 2013)
  - Black water
    - >12nm can be discharged raw
    - 4 - 12 nm Maceration/Disinfection
    - <4nm IMO approved Sewage Treatment Plant
  - Grey water
    - Can be discharged anywhere
- Other Local Legislation
  - Dade County, Florida
  - Alaska, etc

} Applies to Black <u>AND</u> Grey Water

MOD Target for Royal Navy Vessels

- In 1996 NATO Special Working Group 12 commissioned an Industry-led Adivsory Group (NIAG) to conduct a prefeasibility study into “The environmentally sound warship for the 21st century.” This study:-
  - Enhanced understanding of waste generation on ships
  - Assessed technologies for destroying or remediating these wastes
  - Identified target quality levels for liquid discharges, which were incorporated into the “NATO staff target for an environmentally sound warship for the 21st century.” The MOD are aiming to achieve target levels.

Comparison of Liquid Effluent Discharge Requirements

	Royal Navy NIAG 2015 Target	'Dade County' Florida Legilsation	MARPOL 73/78 Annex IV
Biochemical Oxygen Demand (mg/l)	15	30	50
Chemical Oxygen Demand (mg/l)	150	-	-
Faecal Coliform Bacteria (No./ml)	1	0	2.5
Suspended Solids (mg/l)	50	40	100
Total Dissolved Solids (mg/l)	250	(500 chlorides)	-
Metals (combined) (µg/l)	50	(Individual)	-
pH	6-9	6-8.5	-
Oil and Grease (mg/l, ppm)	2.5	30	-
Total Organic Carbon (mg/l)	50	-	-
Total Chlorine (mg/l)	Not permissible	0.5	-

RN Requirements and Constraints

- Demonstrate treatment of ~27m^3 grey water and 3m^3 black water per day for a 185pe Type 23 Frigate for 45-days.
- Proof of principle using full-scale technical demonstrator
- Retrofit potential to RN ship (through small hatch <1m^2)
- Use existing “Collect and Hold” tanks for fall back option.
- Small footprint, simple modular design, low maintenance
- Use of COTS technology
- Effective remediation of RN-specific waste streams
- Compliant to Defence standards (DEFSTAN and NES)
- Compliant to current environmental legislation and NIAG

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QinetiQ's Experience

- Membrane Bioreactors are currently being adapted into a range of municipal waste applications.
- These Bioreactors can treat both black-water (sewage) and grey-water (hand basins, showers, galley washings, laundry), as well as effluent from tanneries, dairy, food processing, etc.
- QinetiQ currently design, build and trial prototype waste treatment systems, working with industry where necessary.
- QinetiQ has been trialing various membrane bioreactor systems for the MOD since 1997.

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Membrane Bioreactors

- Combination of biological treatment and physical separation used for the remediation of waste effluents
- Waste effluent enters a bioreactor where biological digestion occurs (Aerobic or Anaerobic)
- The clear filtrate of the mixed liquor passes through the membranes (<0.01μm) (bacteria = >1μm)
- Resulting permeate can be readily disposed and is also clean enough to be considered for re-use
- Suspended matter is retained in bioreactor where it is degraded further

Types of membranes for Cross-Flow Filtration

- Tubular (40-100 litres m^{-2} hr^{-1})
- Hollow fibre (30 litres m^{-2} hr^{-1})
- Flat Plate and frame (12-25 litres m^{-2} hr^{-1})

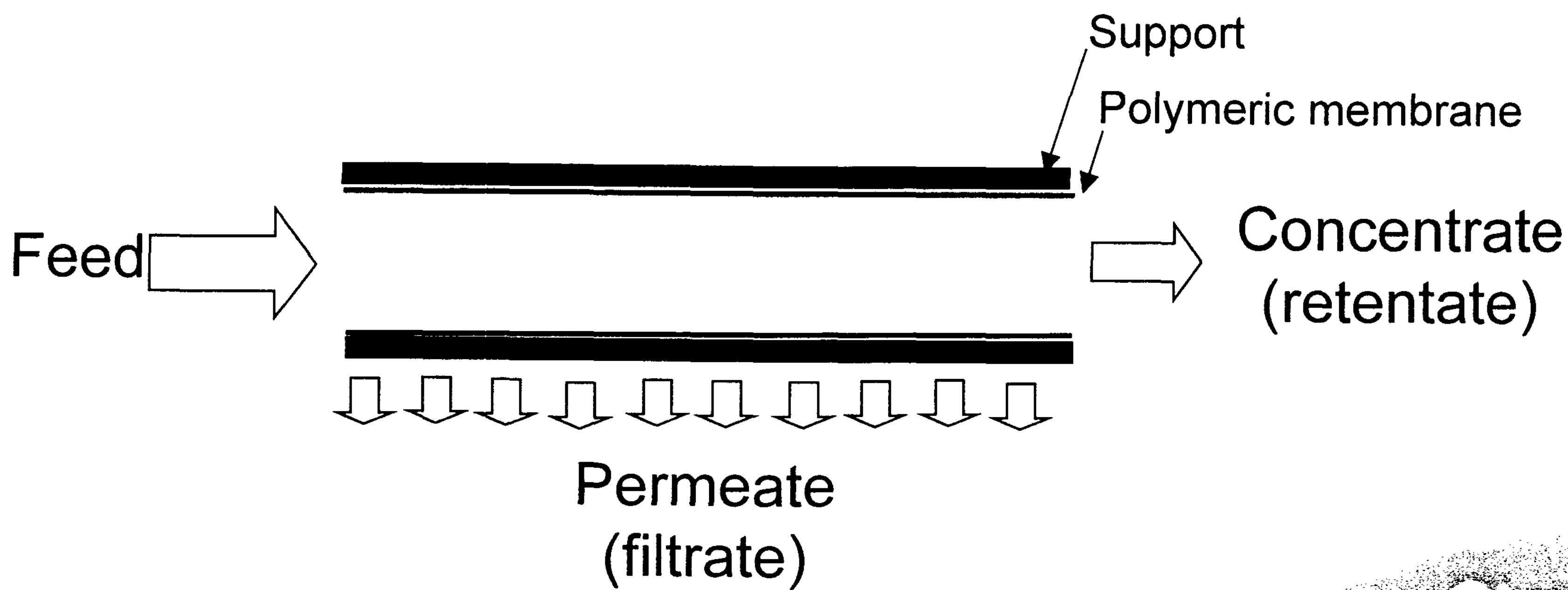

Plate and Frame Membrane Configuration

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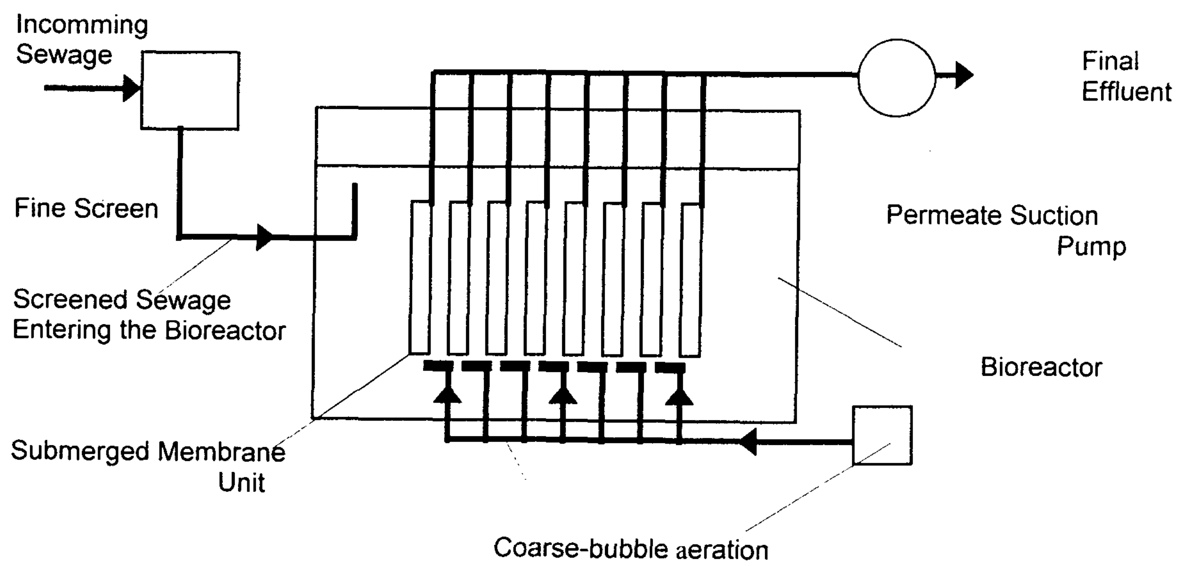
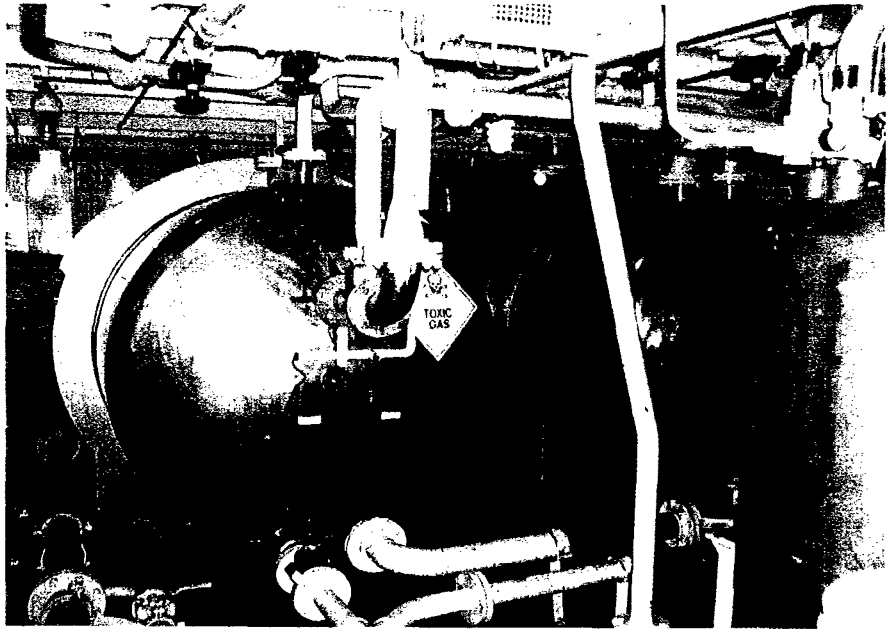
Low Maintenance MBR Configuration

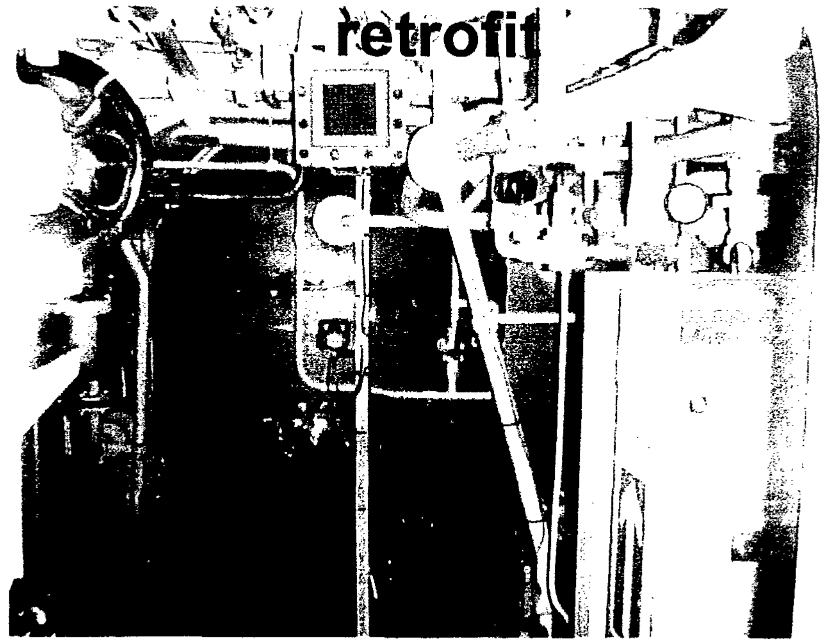


T23 Frigate - Collect & Hold

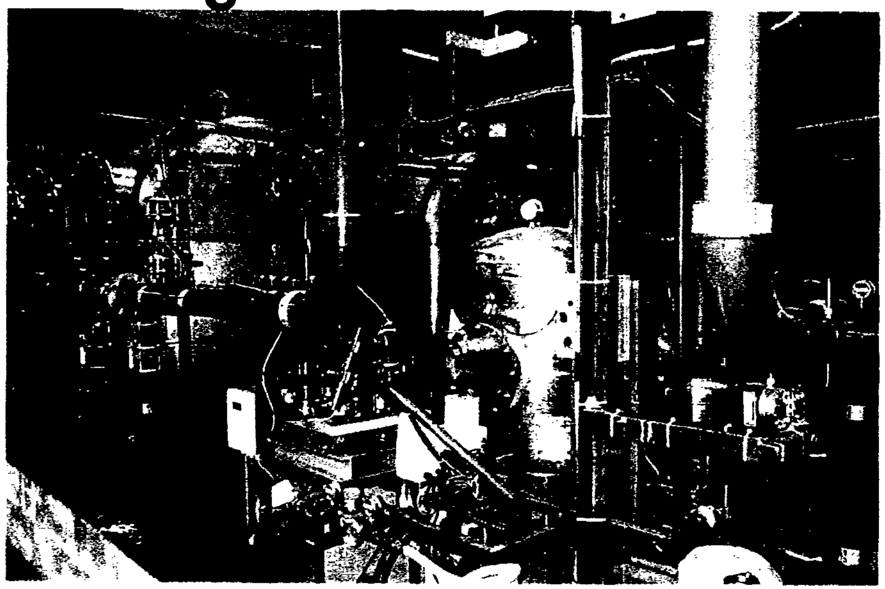


T23 Frigate - Bioreactor retrofit

12



T23 Frigate - Bioreactor TD



T23 Frigate - Bioreactor schematic

Grey
input

Bio-reactor tank

Mixed liquor balance tank

Black water input

Denitrification tank

Air blowers

Vacuum collection tank

Permeate output

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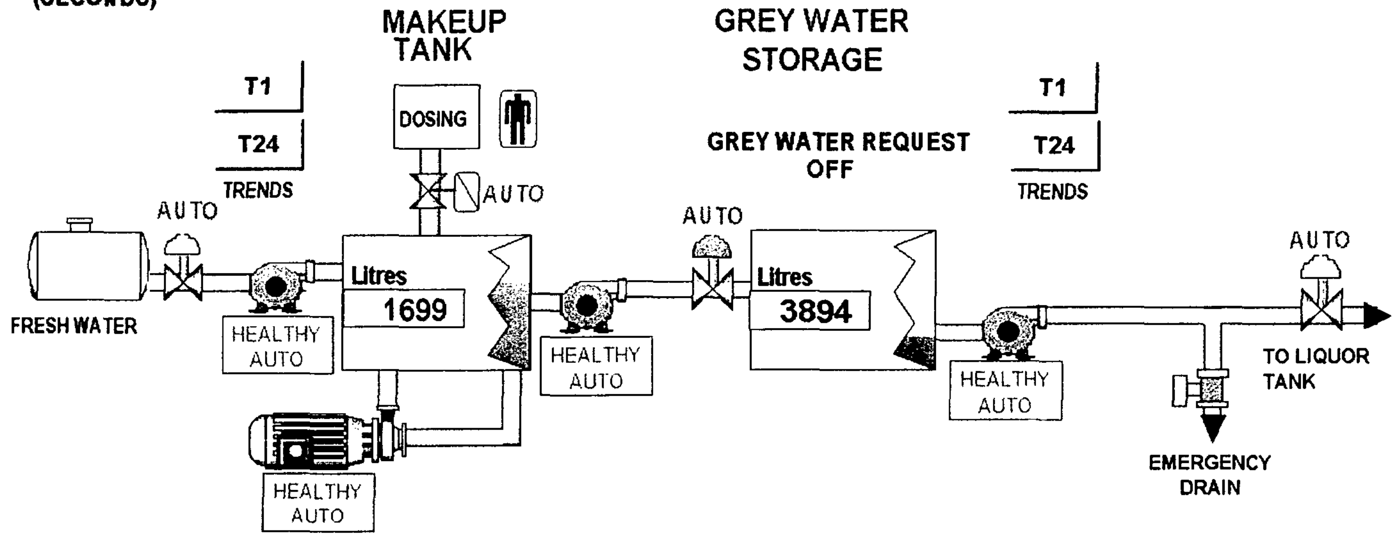
Automatic Grey & Black Water Generation for Trials Reflecting Typical RN Production Rates Using SCADA

DOSING TIME FOR FULL TANK MAKEUP (SECONDS) **60**

GREY WATER SYSTEM

09/11/02
11:40



ESTIMATED DELIVERY RATE FROM MEASUREMENT **300** LITRES / MIN

DAILY PERIOD	00:01 - 09:00	09:01 - 10:00	10:01 - 14:00	14:01 - 16:00	16:01 - 23:59	DAILY TOTAL
MAKEUP DELIVERY TIME (Mins)	1.7	11.1	1.7	11.1	1.7	
ESTIMATED VOLUME DELIVERED (Litres)	510	3330	510	3330	510	
No OF BATCHES	8	2	4	4	8	
TOTAL DELIVERY FOR PERIOD (Litres)	4080	6660	2040	13320	4080	30180

STATUS | HELP | SYSTEM | SETUP | MENU | RESET

RN Black and Grey Water - Waste Loading

- The various waste streams are loaded into the system at the rate and time that would be expected over a typical 24 hour period in the Royal Navy
  - These values below reflect normal black/grey water generation rates on board a Type 23 Frigate.

Time:	00:00 - 09:00	09:00 - 10:00	10:00 - 14:00	14:00 - 16:00	16:00-00:00
Black m^3 Water	0.81 m^3	0.38 m^3	0.36 m^3	0.76 m^3	0.72
Grey Water	4.3 m^3	6.7 m^3	1.9 m^3	13.3 m^3	3.8 m^3

1.9 m^3 → 13.3 m^3: +1400%

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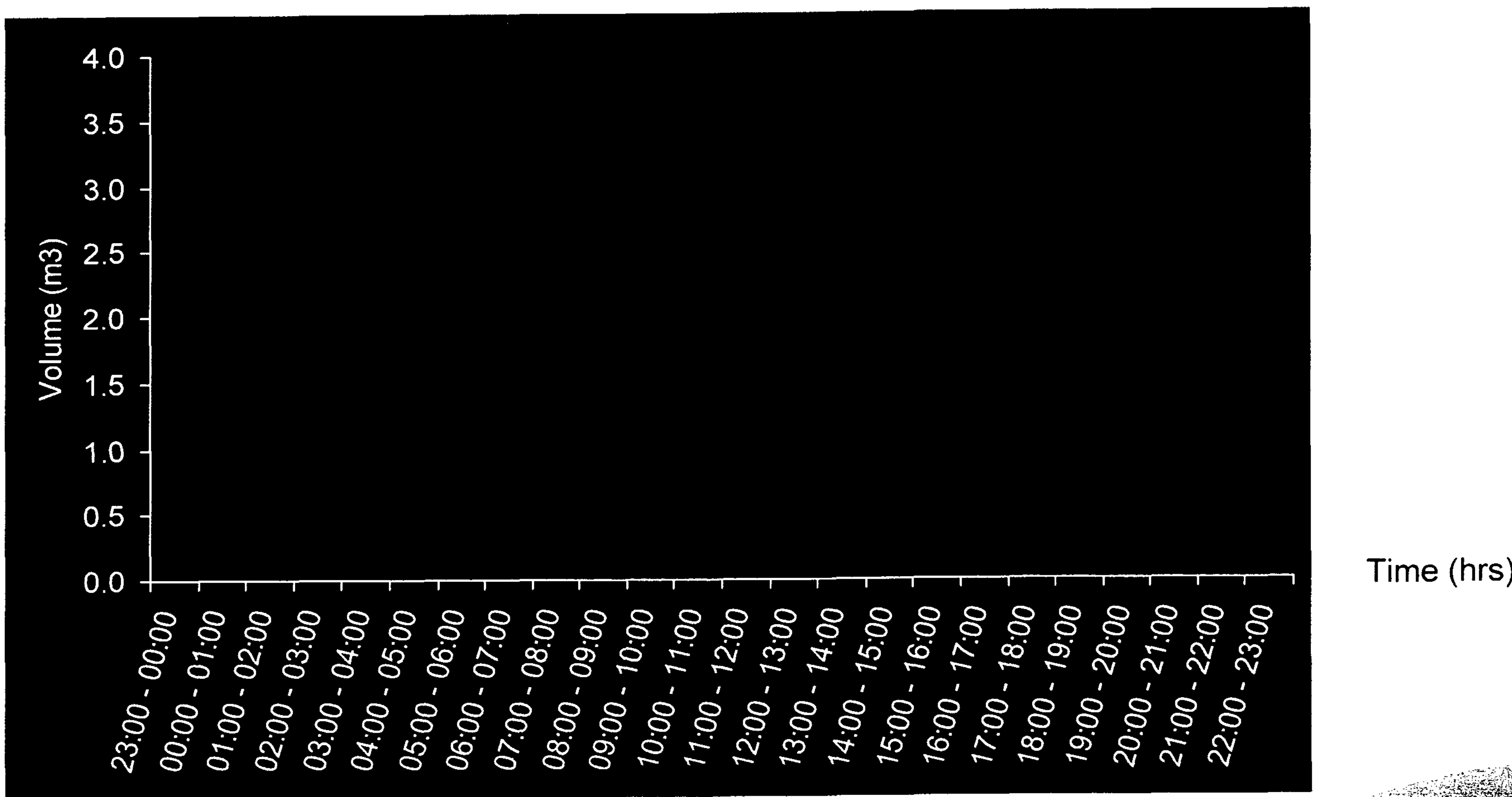
Total Black & Grey water generation for HMS Grafton in Tropical Conditions ($\sim 34 m^3/day$)



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Results of the Technical Demonstrator trial at QinetiQ Haslar

- Membrane bioreactor TD was successfully run using RN-waste production rates for 54 days before de-sludging was required.
- Compliance was achieved for the permeate discharge for all key determinands during the 45-day trial.
  - BOD = 4.6mg/l, COD = 98 mg/l, Faecal Coliforms <1cfu/ml, Suspended solids 8 mg/l.
- Results encouraged the MOD to consider membrane bioreactor technologies for future RN ship installations, such as Type 23 Frigates.

QinetiQ

Liquid Effluent from Bioreactor TD for recent 45-day trial

	Activated Sludge	Bioreactor Permeate	Royal Navy NIAG 2015 Target	MARPOL 73/78, Annex IV
Biochemical Oxygen Demand (mg/l)	830	2.1	15	50
Chemical Oxygen Demand (mg/l)	10903	57.7	150	-
Faecal Coliform Bacteria (No./ml)	2.9×10^5	<1	1	2.5
Suspended Solids (mg/l)	10110	3.3	50	100
Total Dissolved Solids (mg/l)	735	567	250	-
Metals (combined) (µg/l)	-	54	50	-
pH	-	7.7	6-9	-
Oil and Grease (mg/l)	-	3.3	2.5	-
Total Organic Carbon (mg/l)	519	4.4	50	-

Additional Modifications considered for HMS Grafton retro-fit of membrane bioreactor to the 'Collect & Hold' tanks

- Improved removal of hair from the black/grey water
  - Rotating Screens with cutting edge proved better in subsequent trials at QinetiQ at removing hair than simple pressure-based screen-cleaning systems.
- Provision of additional buffering capacity within the Denitrification tank (DT) for the un-buffered Aft grey water on HMS Grafton.
  - Forward grey water is only treated when the levels in the MLBT and DT have reduced to a minimum level, thereby providing up to $8m^3$ buffering capacity within the MBR for the Aft grey water.

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Conclusions

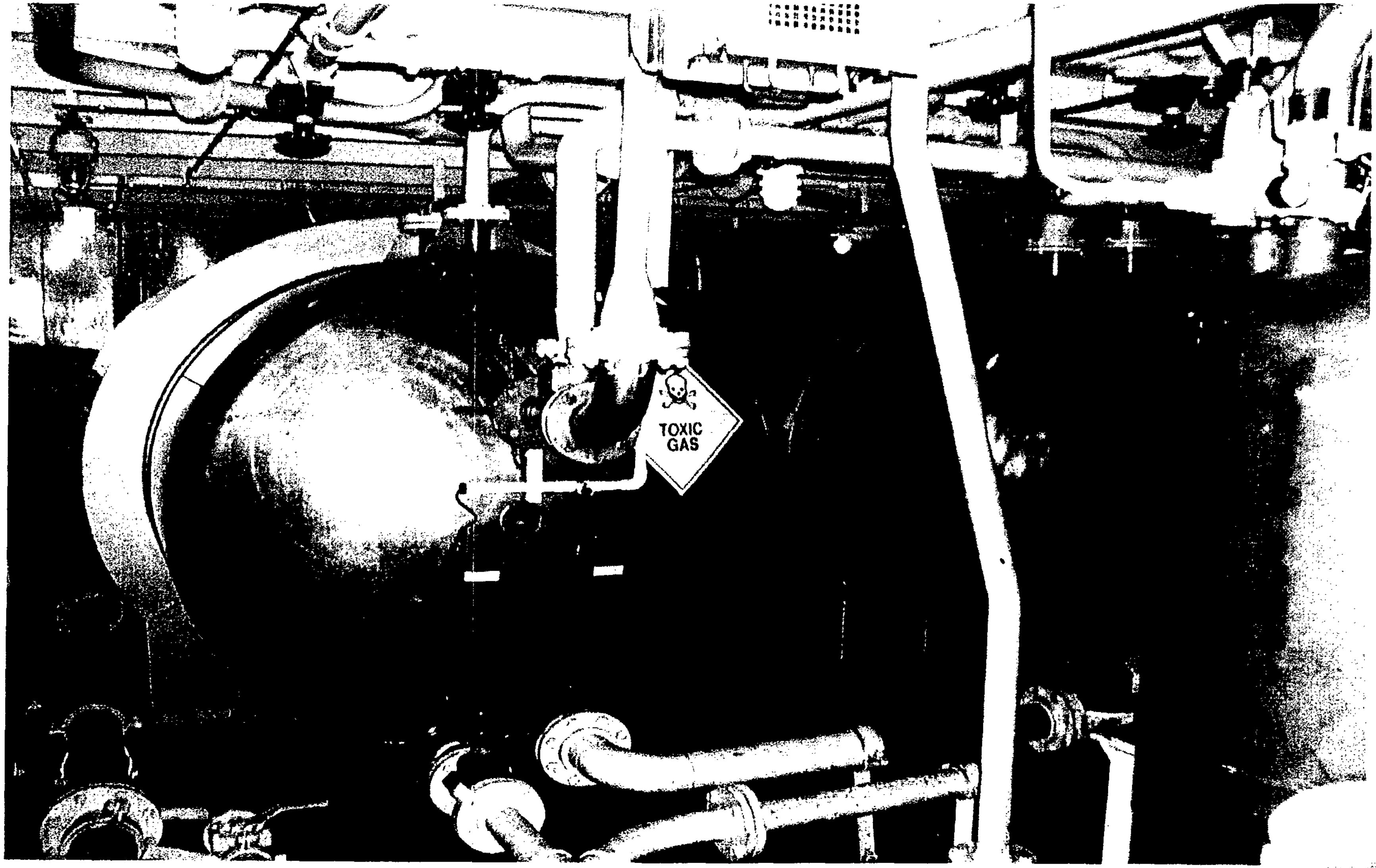
- Membrane technologies evaluated in 1997 and results led to most appropriate design for the Type 23 retro-fit being a submerged flat sheet membrane bioreactor.
- Full scale technical demonstrator designed, built and successfully trailed for 54-days at QinetiQ Haslar in 1999/2000 exceeding existing legislation.
- MOD (MAESIPT) commissioned retro-fit of this technology to HMS Grafton as a trials plant for late 2001.
  - MBR has been operating for most of this time with some modifications recommended over this period.

Forthcoming Programmes

- Addition of the salty water fraction of a bilge-water separator to a black and grey water membrane bioreactor
  - Salt tolerances
  - Potential COD increases in the permeate
- Food waste digestion
  - Enzyme treatment
  - Cellulose removal

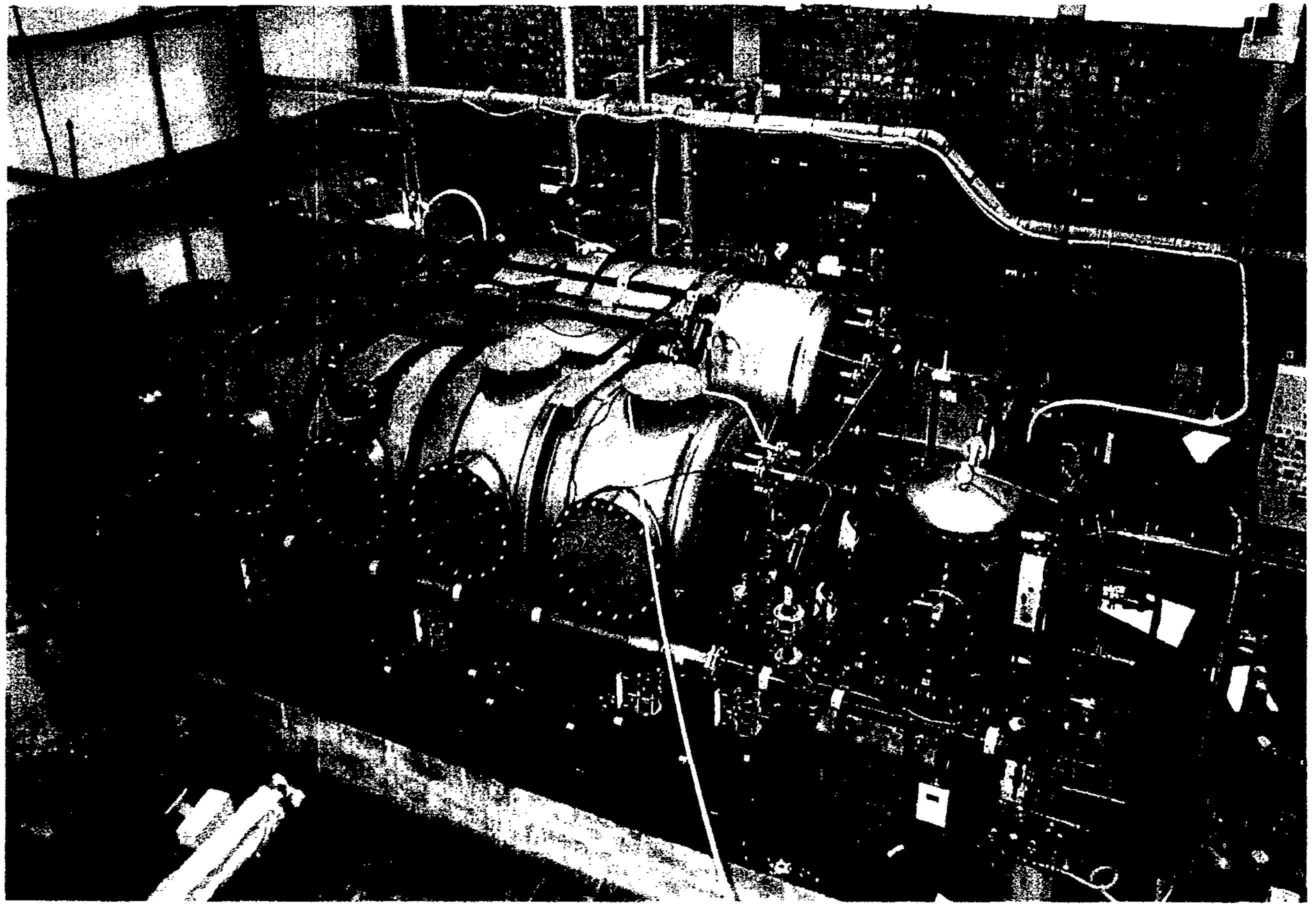
QinetiQ

Type 23 Collect and Hold Tanks



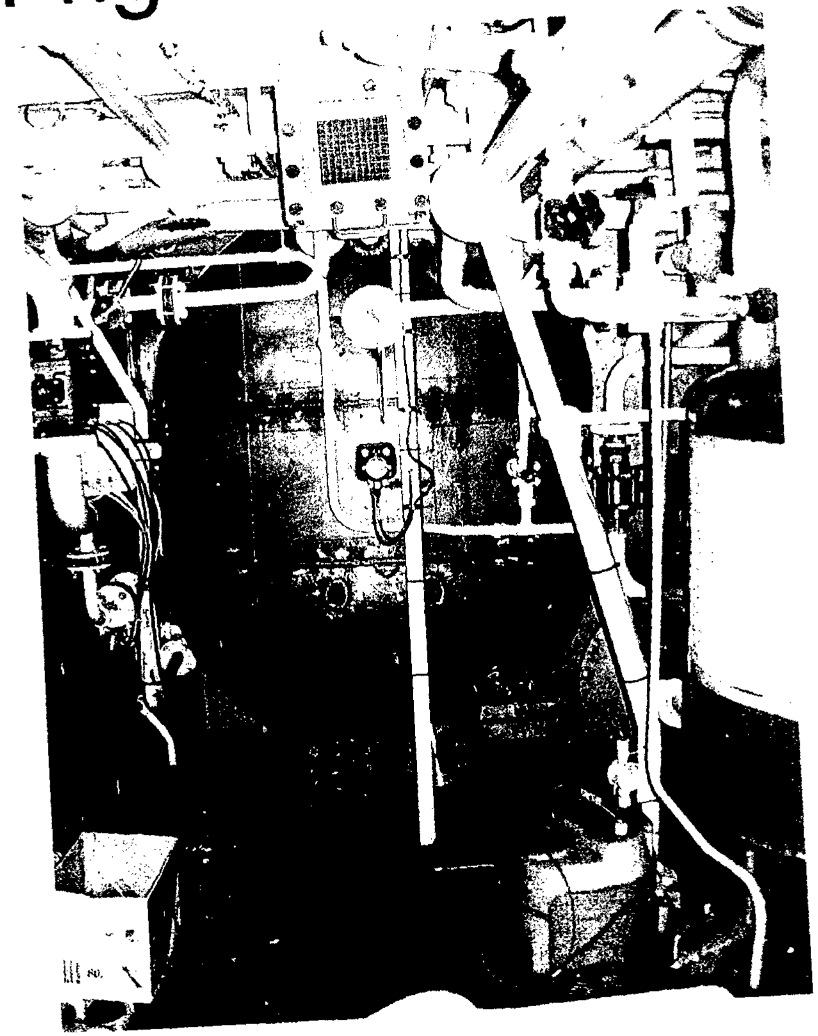
QinetiQ

Technical Demonstrator of Type 23 MBR trialled at QinetiQ Haslar

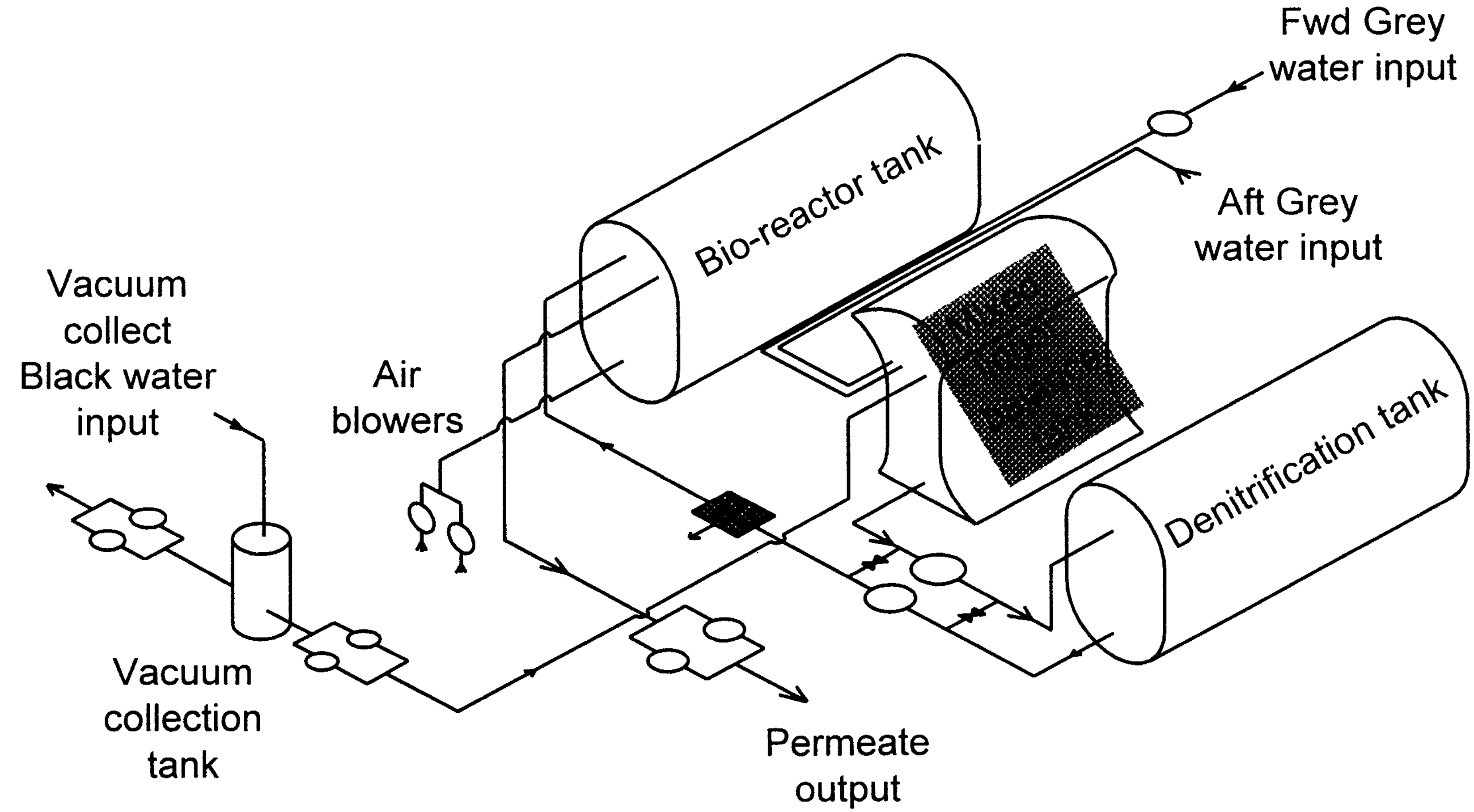


QinetiQ

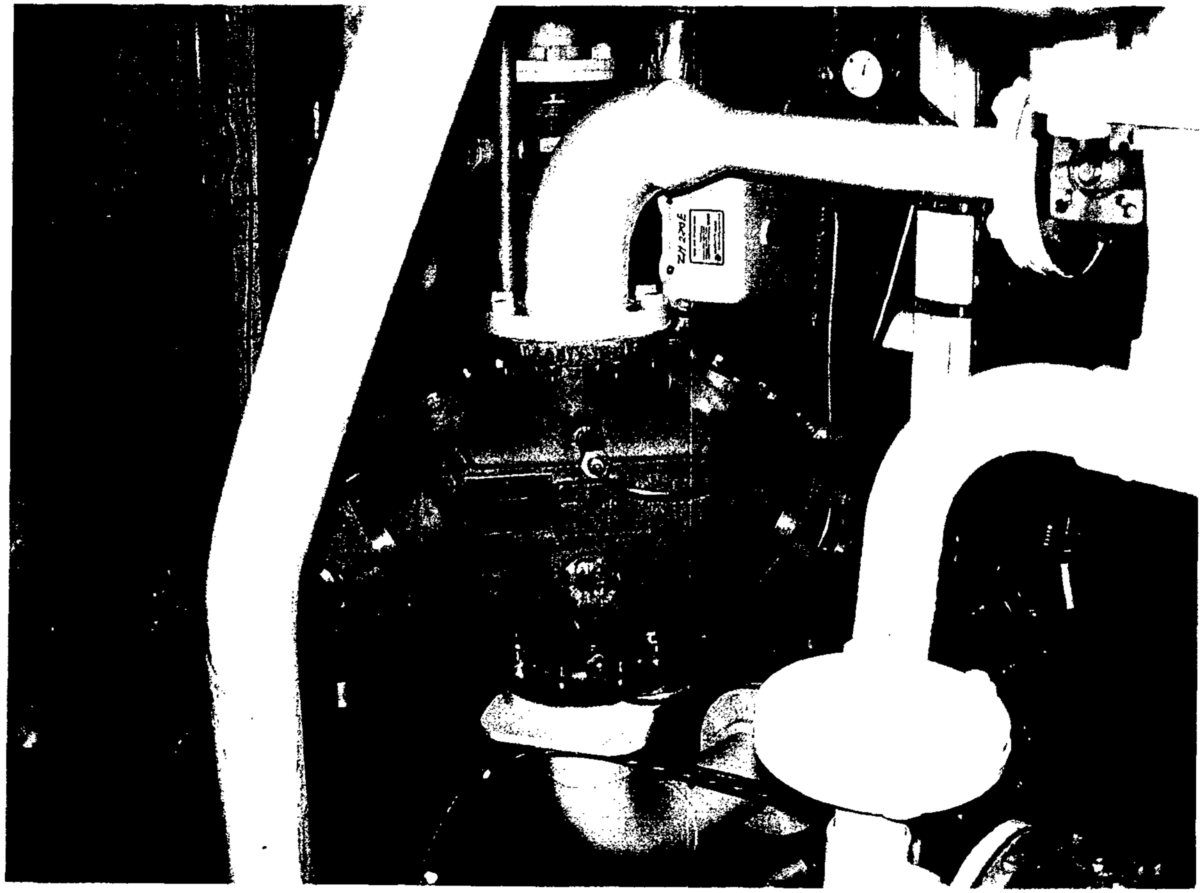
Retrofitted Membrane Bioreactor to the Type 23 Frigate HMS Grafton

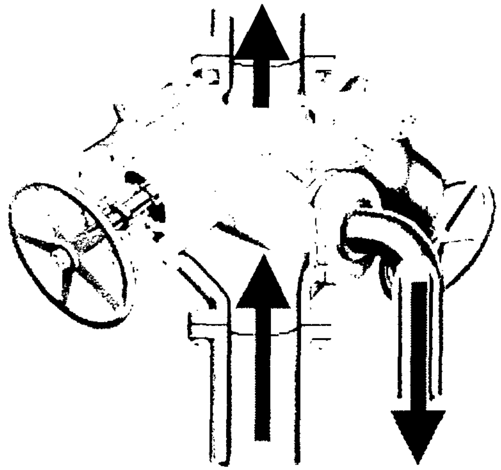


Type 23 Membrane Bioreactor Schematic

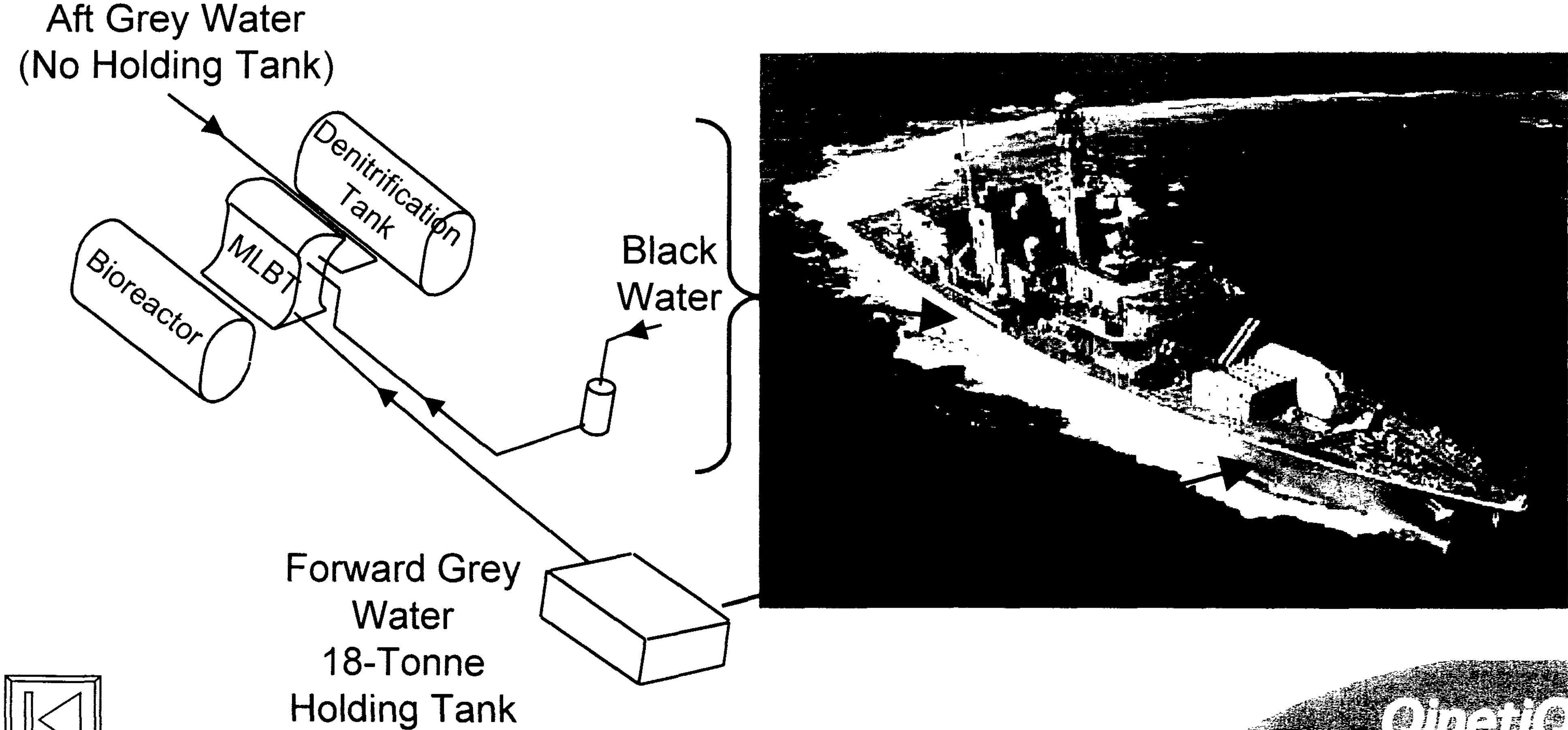


MBR screenings - Rotating screen cutter





Waste Water Generation Considerations on Type 23 Frigates - Additional Buffering capacity required for Aft Grey water



QinetiQ

MARISAN

I.S.I.R.

MEP

Marine Environmental Partners Inc.

New Technology for Rules Fulfilling

Environmental Issues

ANNEX IV of MARPOL 1973/78 in force from 27th September 2003.

New local regulations (e.g. AS 46.03.460÷ 46.03.490, Dade City Code of Ordinances Ord. 2001-0768 Ch. 98-91÷ 98-102) for discharges implement more stringent regulations for environmental protection.

Class Requirements

Sewage :

treatment + 2 days retention

Grey Water:

2 days retention

Forthcoming new regulation will prescribe :

ENVIRONMENTALLY SOUND SHIP

Complete treatment of polluted waters

Waste Water to be treated

In order to comply with international and national requirements soon to be introduced for overboard discharges, all sanitary waste water must be treated:

- SEWAGE
  - SANITARY GREY WATER
    - GALLEY GREY WATER
      - LAUNDRY GREY WATER

Waste Water Characteristics

Due to the variability of situations onboard cruise ships, the only fixed data are:

UNKNOWN real quantity

UNKNOWN real chemical/physical characteristics

Technical Solutions

To be in line with present Rules.
Technical selection:

- HOLDING TANKS + LATER OFFLOAD
- ADVANCED BIOLOGICAL TREATMENT
- BIOLOGICAL TREATMENT + POLISHING

HOLDING TANKS

Benefits

- No Treatment
- No Maintenance
- Easy operations
- No Foot-print

Disadvantages

- High International waters pollution
- Limited Discharge
- Sludge sedimentation
- Explosive gases production

ADVANCED BIOLOGICAL TREATMENT

Benefits

- Unrestricted Effluent discharge

Disadvantages

- Sensitivity to Flow Changes
- Sensitivity to Chemical additions
- Dedicated personnel
- High Foot-print

BIOLOGICAL TREATMENT + MEMBRANE POLISHING

Benefits

- Unrestricted Effluent discharge

Disadvantages

- Sensitivity to Flow Changes
- Sensitivity to Waste Water Quality
- Skilled personnel
- High running costs

Evolutionary Treatment plant MUST:

- handle all waste water + (optional) HVAC condensate
- receive multiple streams, deliver one
- work ON / OFF
- have no problems with peak loads, sea-water, any type of chemical products
- have a reduced foot-print
- be fully automatic and equipped with self-diagnostic system
- be easy to operate, with low maintenance and low costs

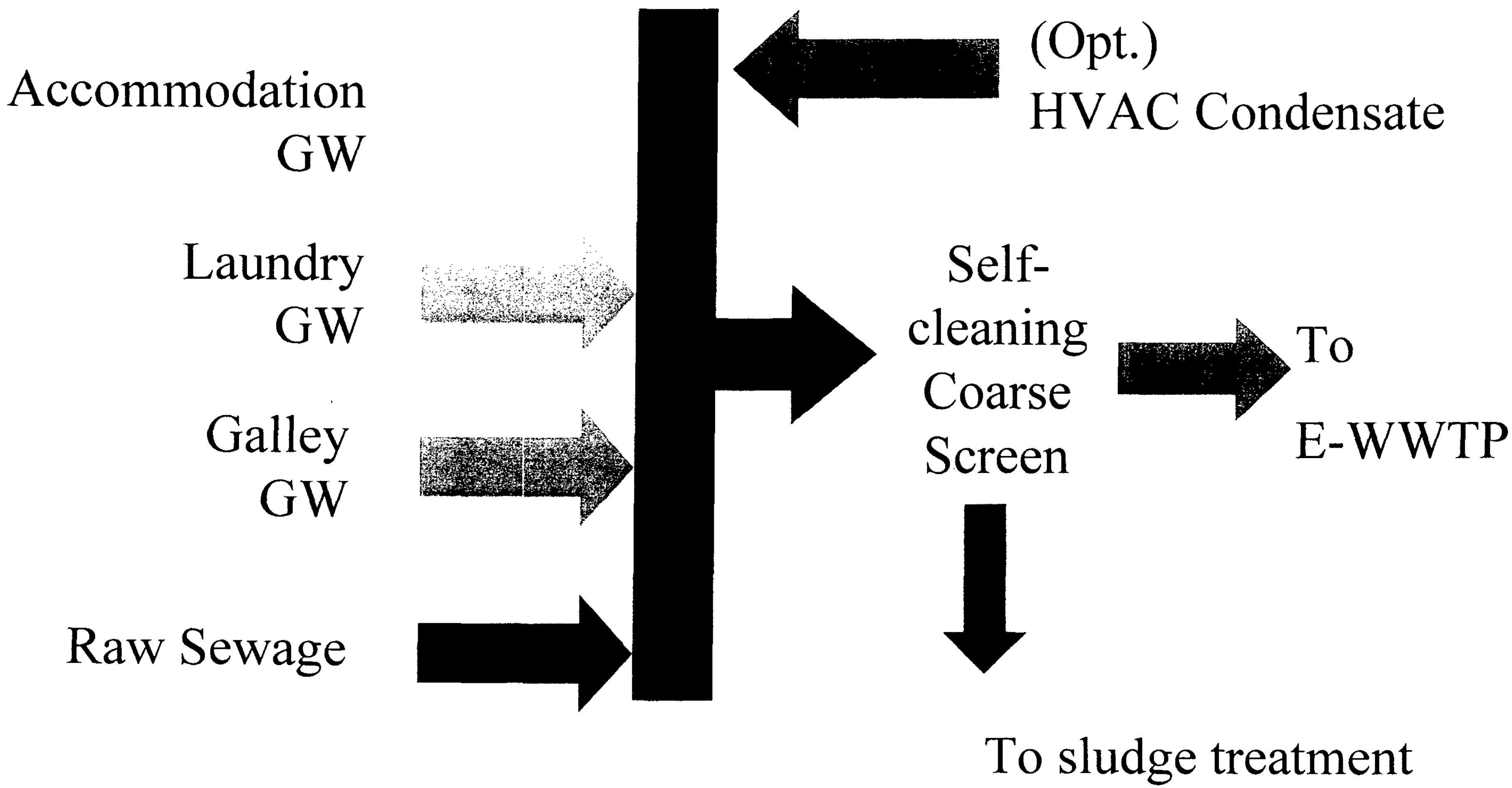
EVOLUTIONARY WASTEWATER TREATMENT PLANT

Single Solution for Multiple Problems

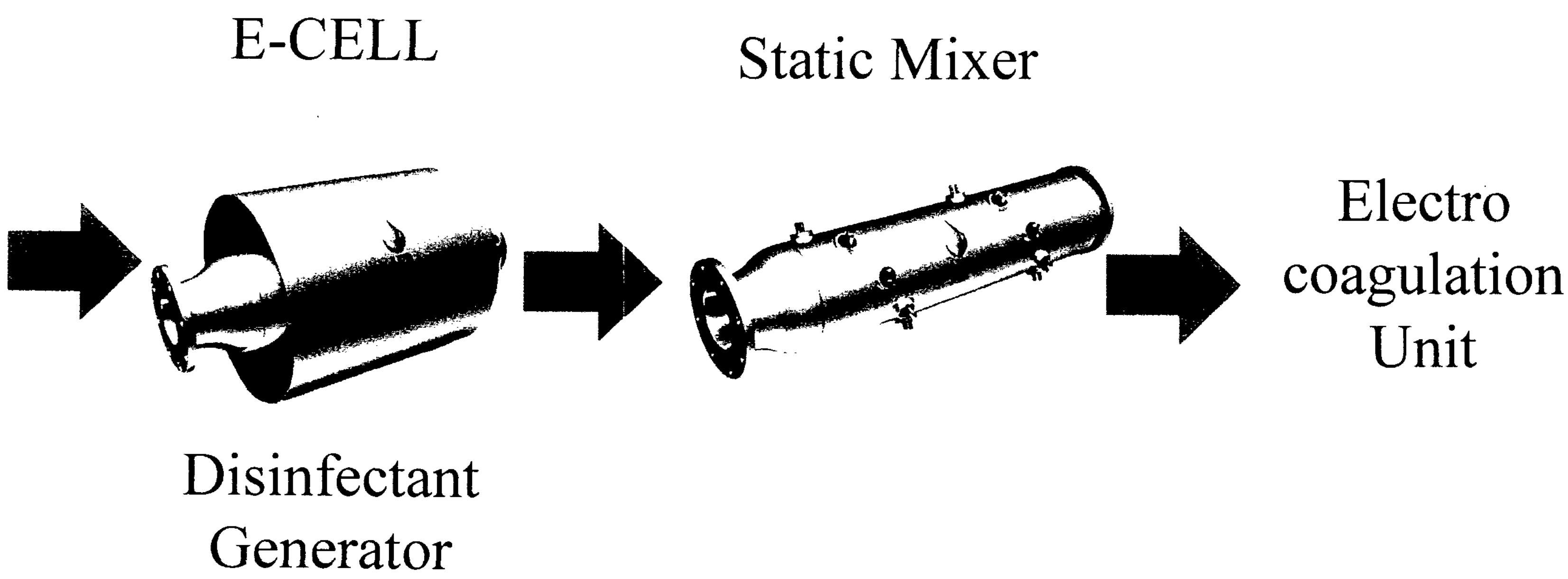
Working Principles

- The Plant functions according to the physical and chemical characteristics of wastewater produced onboard.
- The Plant is realised with modular components concept which will allow maximum flexibility.
- Plant is not affected by flow changes and any type of chemical products.

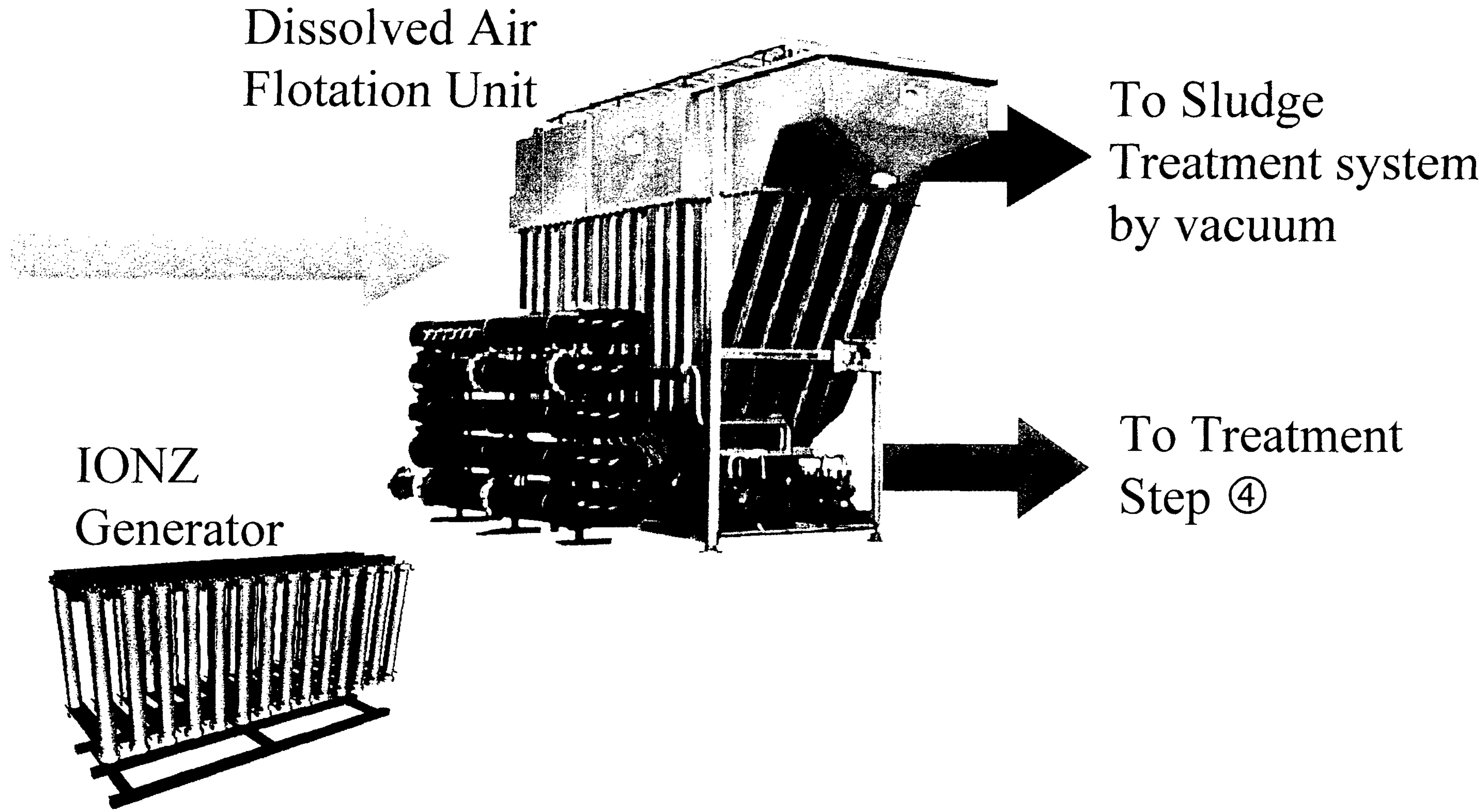
Treatment Step ①



Treatment Step ②



Treatment Step ③



Treatment Step ④

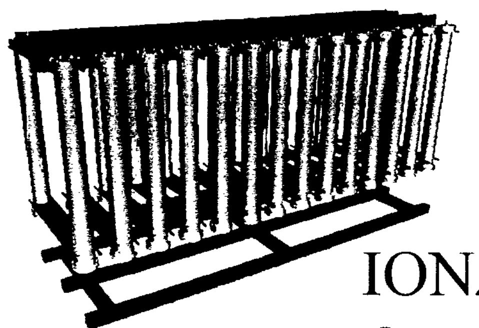
ONE
ntact
nk

IONZ
Contact
Tank

Duplex
Manual
Filter

UV-C

Low Level
Ozone
Generator



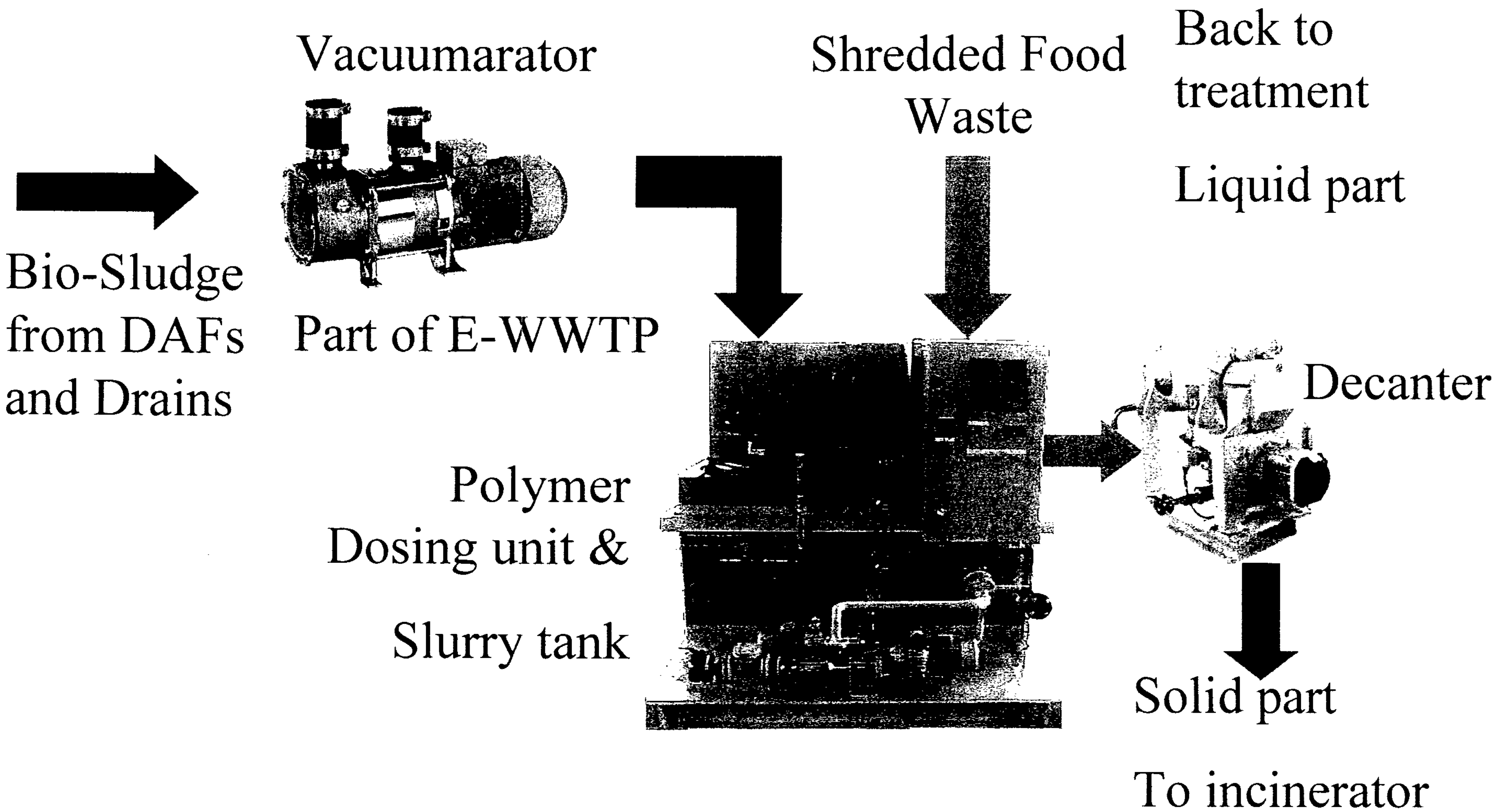
IONZ
Generator

CLEAN
EFFLUENT

Solved Problems

1 Influent restrictions	→	All wastewater can be treated
2 Start-up time	→	On / Off capability
3 Peak Load Management	→	Buffer tank
4 Required installation space	→	Reduced footprint
5 Crew training	→	Easy to operate
6 Dedicated Technician	→	Automatic monitoring & Adjustment

Bio-Sludge & Optional Food Waste Treatment



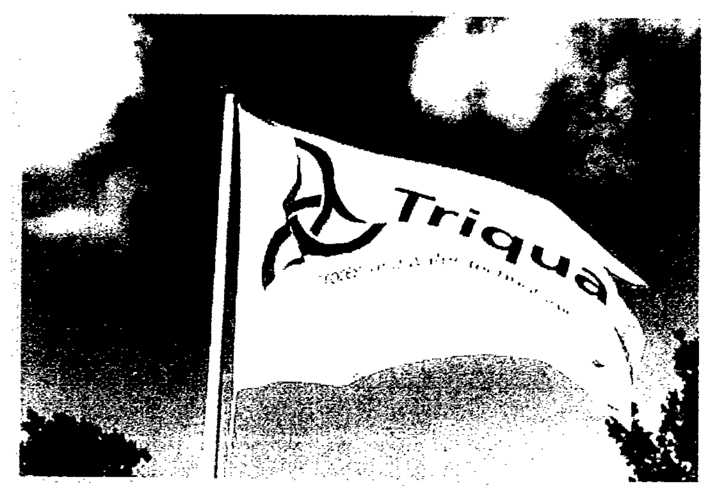
MemTriq®Marine

Advanced wastewater treatment on land and on board

Lex van Dijk

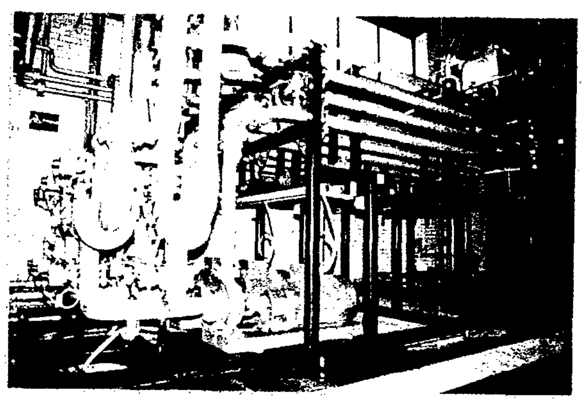
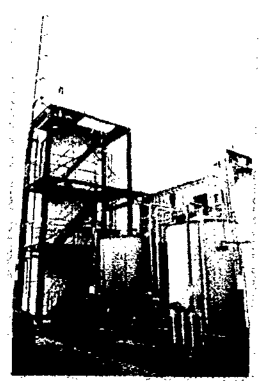
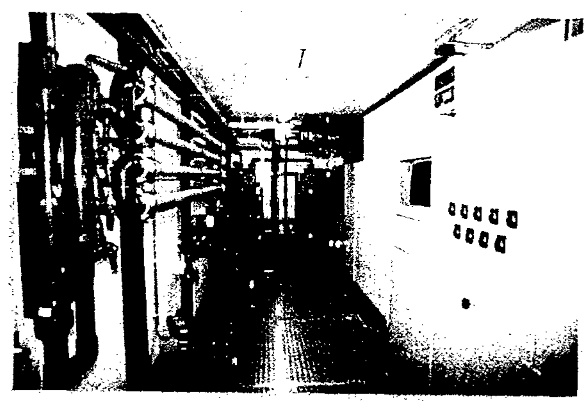
Presentation outline

- Triqua
- The MemTriq®Marine
- Treatment of bilge water (land based)
- Treatment of ship wastewater
  - Goals for water treatment
  - Requirements
  - References
- Experiences
- Developments
- Summary

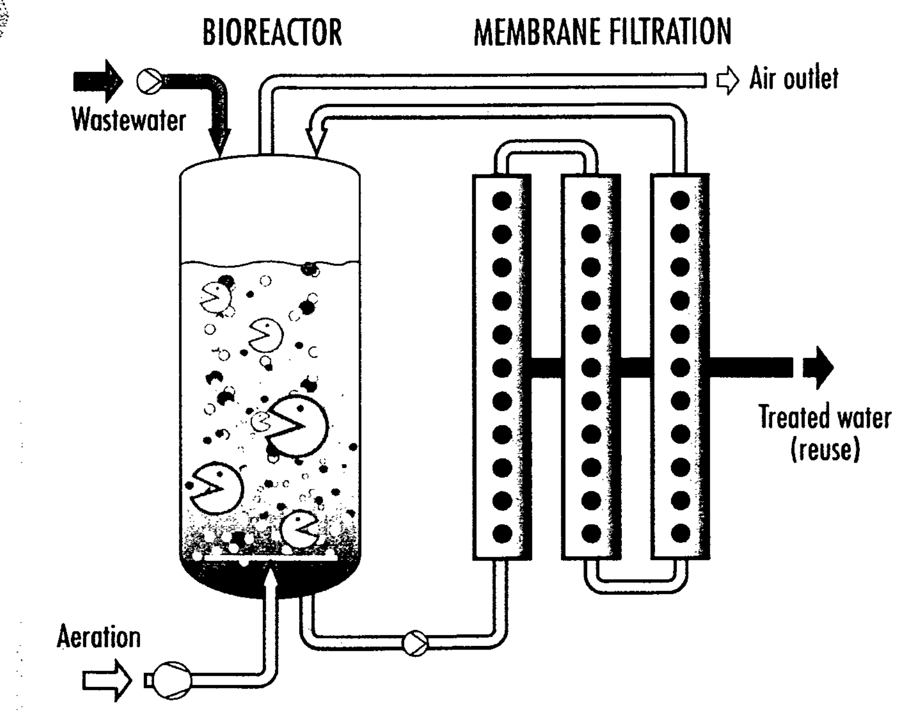


Triqua

- More than 50 running plants round the world
- 100 % focused on water treatment
- Long term experience in land based wastewater treatment systems
- 5 years experience in turn-key membrane bioreactor wastewater treatment on-board

The optimal solution

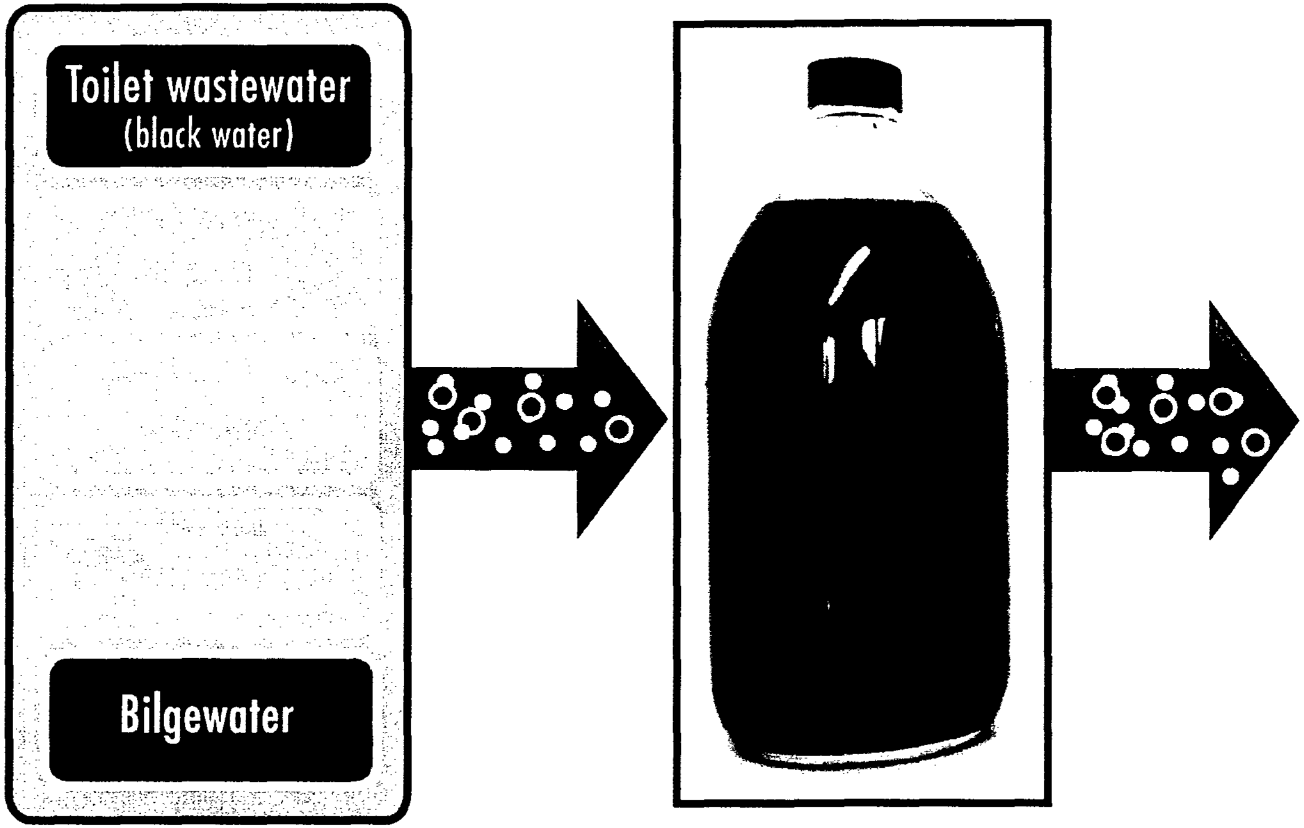


MemTriq®Marine technology

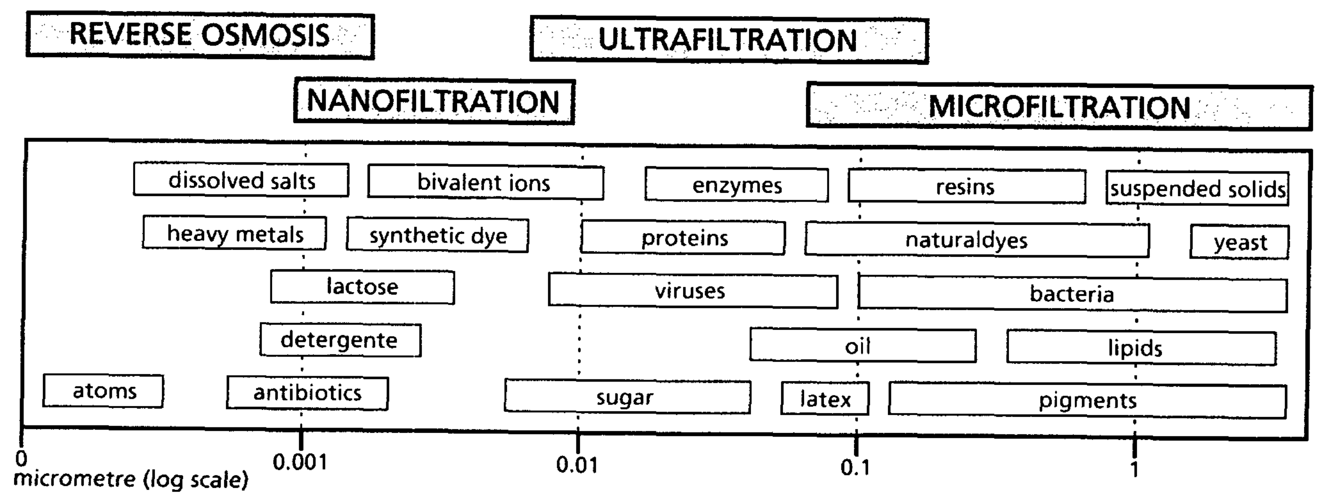
Characteristics of MemTriq®Marine

- Facility to treat different types of wastewater
- High quality of treated water
- Hygienically safe water without dosing chlorine chemicals
- External membranes
- Waste reduction of 97 - 99 %
- Simple operation and reliable system
- Flexible design

Treatment of all types of wastewater



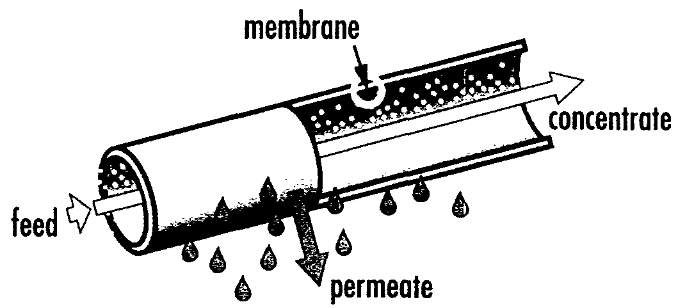
Hygienically safe water without the need for chlorination

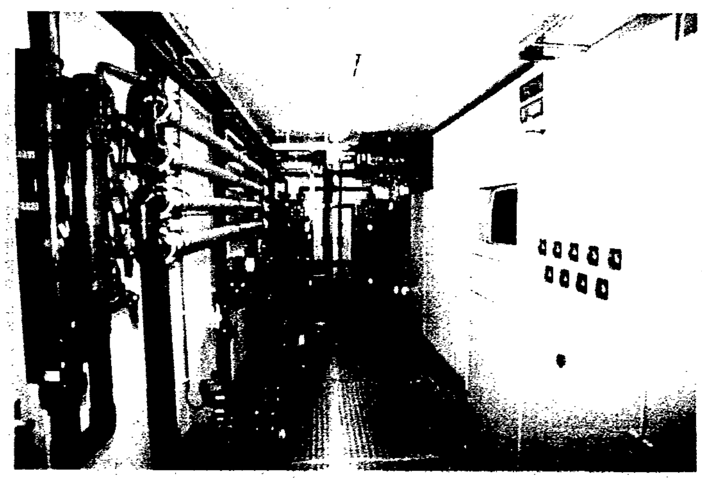


MemTriq®Marine operates with ultra-filtration membranes

Advantages of external membranes

- Independent of biomass characteristics and concentration
- High fluxes
- No black flush necessary
- Standard membranes
- Easy access and replacement
- Reliable operation



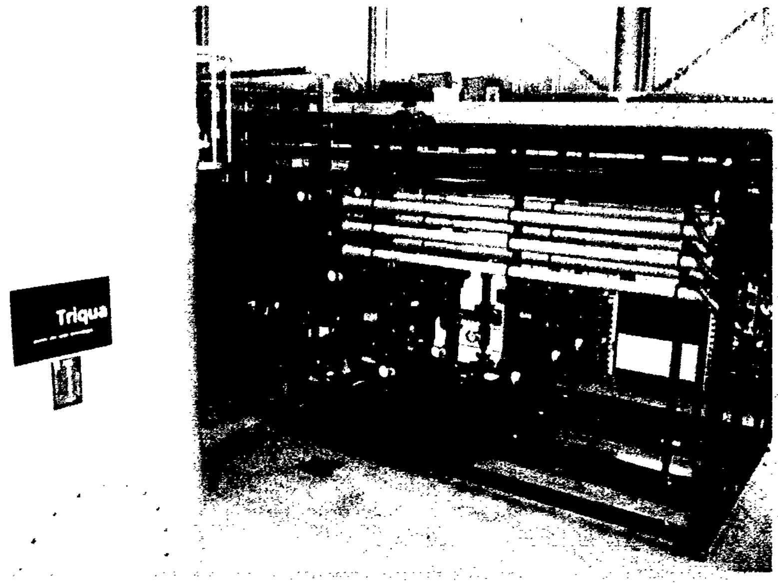


Bilge water treatment (1)

- Dutch navy site in Den Helder (NL)
- Central treatment of bilge water and water from fuel/seawater displacement
- Pre treatment by conventional oil/water separator
- Discharge not allowed any more:
  - phenols
  - PAH
  - mineral oil

Bilge water treatment (2)

- The unit in Den Helder at the Dutch navy



Bilge water treatment (3)

- **Results**

	Feed	Treated water	
Flow	3 - 5	-	m^3/h
COD	1.200	< 200	mg/l
Kj-N	25	< 10	mg/l
phenol	2,5	< 0,1	mg/l
mineral oil	80	< 1	mg/l
MAH	500	< 0,5	mg/l
PAH	500	<0,2	mg/l
heavy metals	2 - 4	< 1	mg/l

Water treatment on ships

- **Goals for water treatment**
  - Complying with existing and future regulations
  - Treatment of all liquid waste on-board
  - Chemical free
  - Total green ship management philosophy (zero discharge)

Water treatment on ships

- **Requirements**
  - Flexible design
  - Simple operation
  - Small footprint
  - Proven technology
  - Minimal production of additional waste
  - Treatment of different types of wastewater

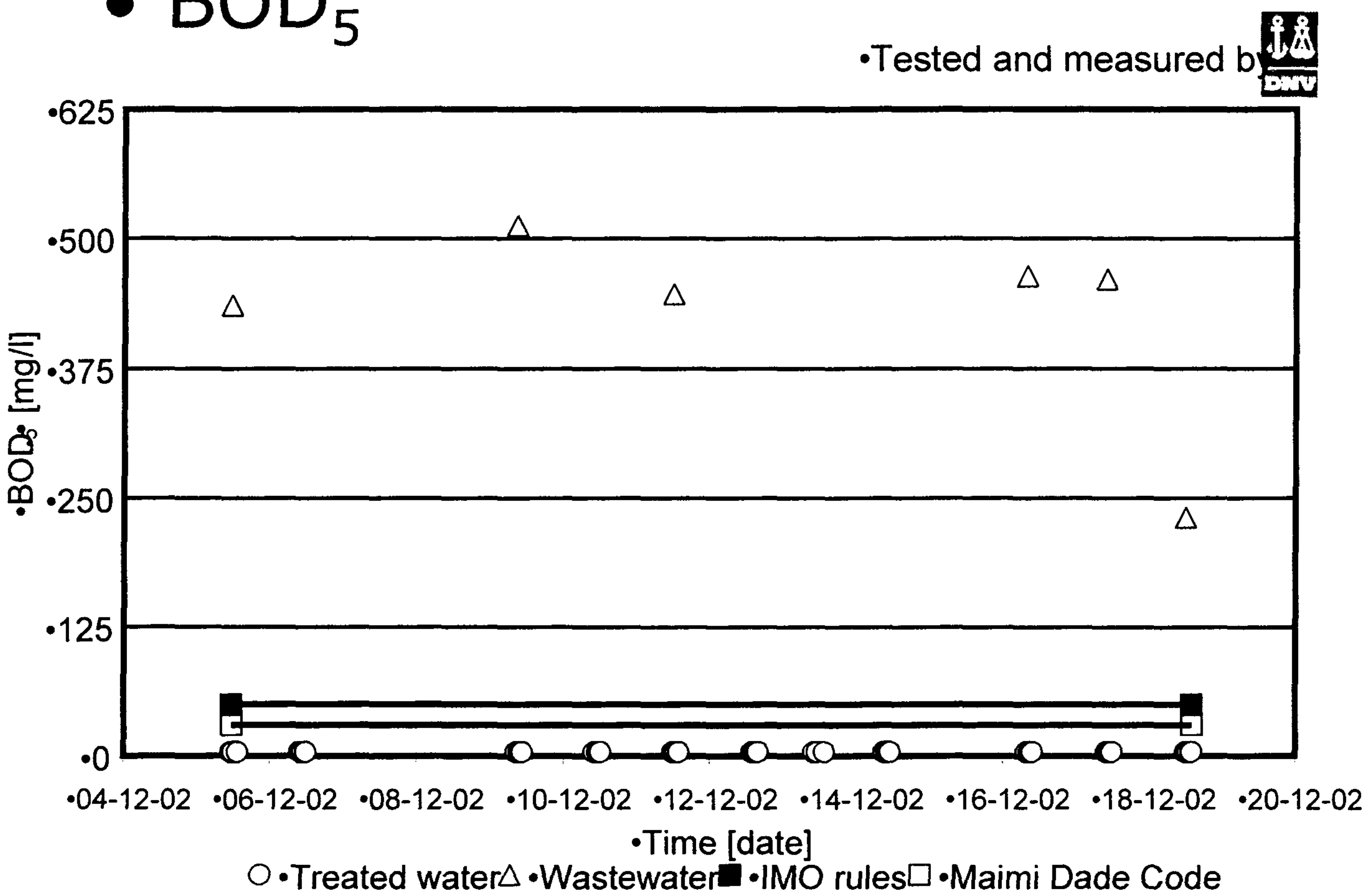
Feed water

- **Different types of water**

	Volume (l/person/d)	BOD (mg/l)
Black water	25	2.500
Grey water	250 - 350	200 - 600
Food waste drainage	3	20.000
Mixture	275 - 350	500 - 900

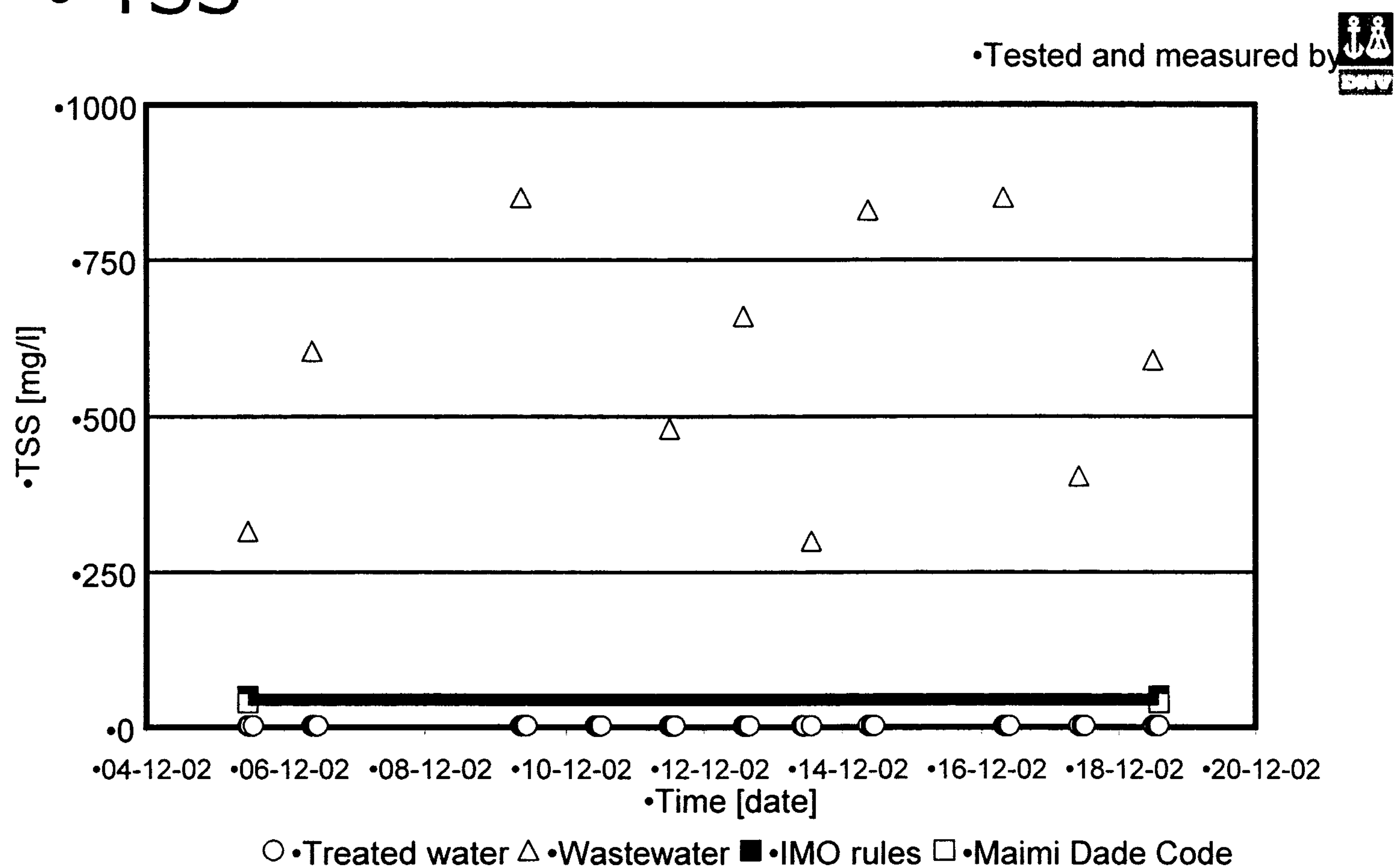
Treated water

- BOD_5



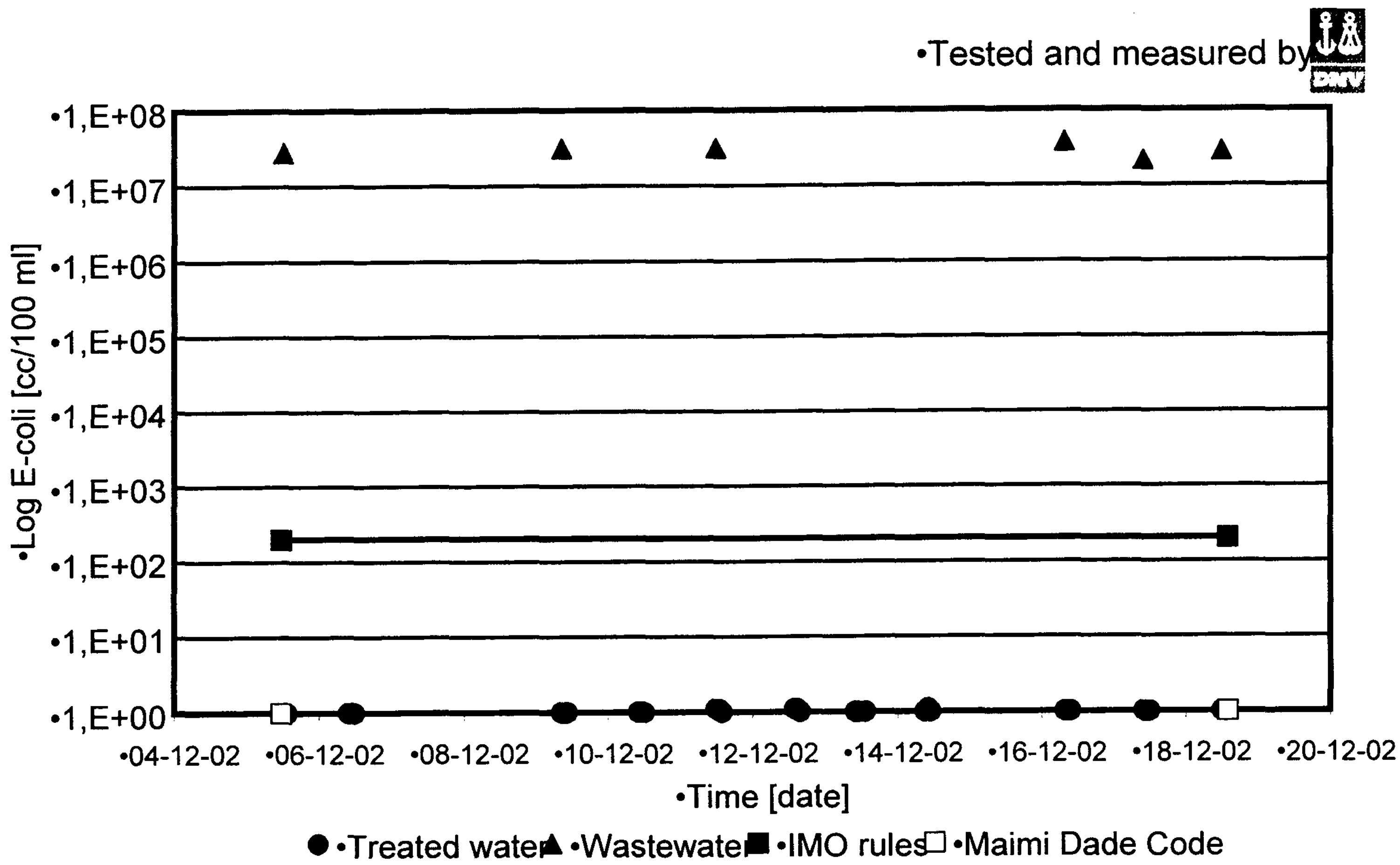
Treated water

- TSS



Treated water

- Feacal coliforms



High quality of treated water

Parameters		Inlet	MIAMI DADE CODE	MemTriq®
BOD_5	mg/l	650	30	< 3
TSS	mg/l	500	40	b.d
Fecal Coliform	cc/l	10^7	b.d.	b.d

DNV Type Approval, CE, MED

RMR

Very limited sludge waste

Additional waste:

- Pre treatment — 0,3 %
- MemTriq®Marine — 1,0 %
- Advanced sludge treatment with DigesTriq® — ↓ 0,2 %

Total result of waste treatment:

- Total clean water: — 99,5%
- Total waste: — 0,5%

Simple operation and reliable system

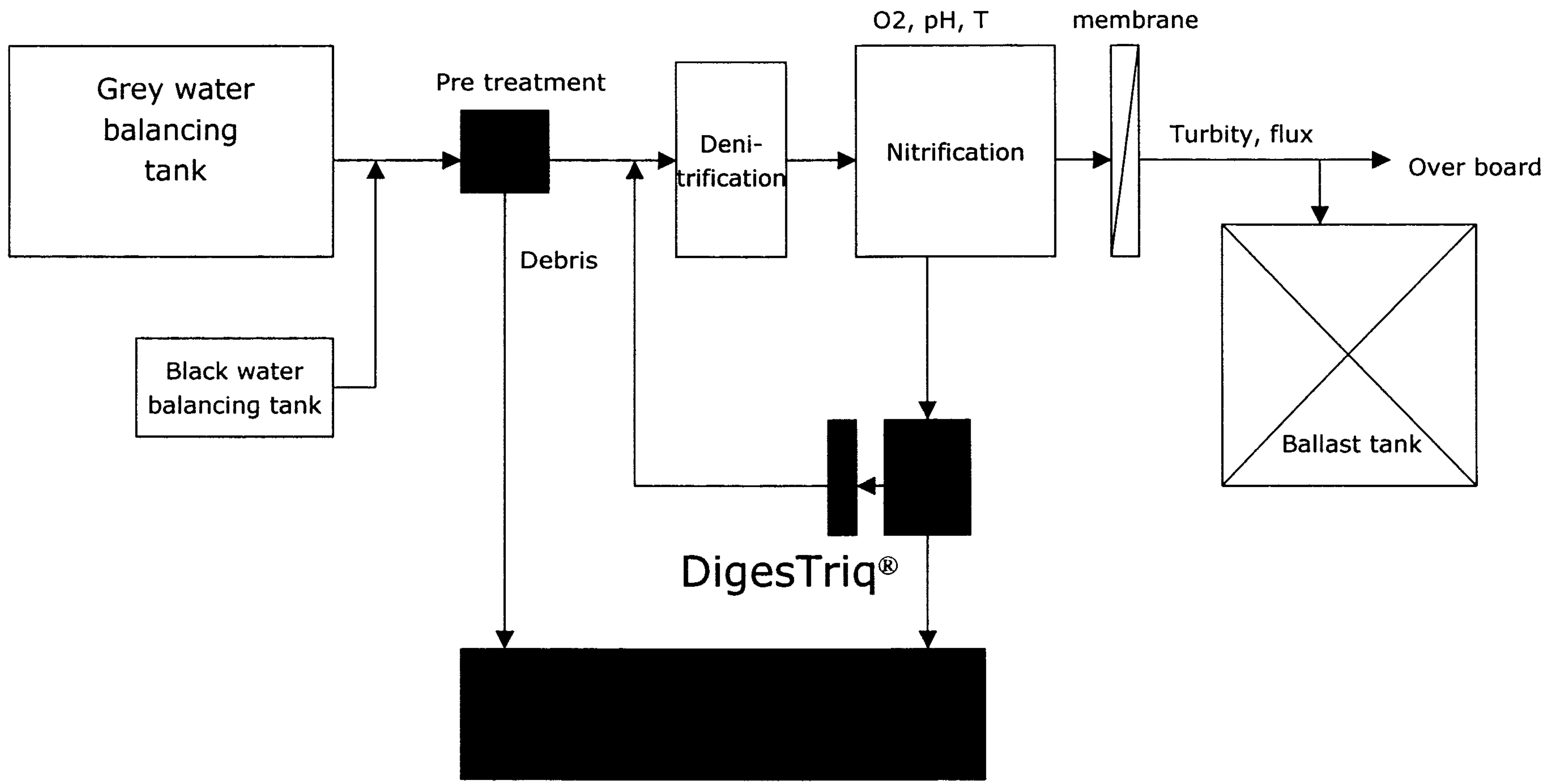
- No high skilled operators
- Easy access to unit
- Standard equipment
- Proven technology

Design aspects

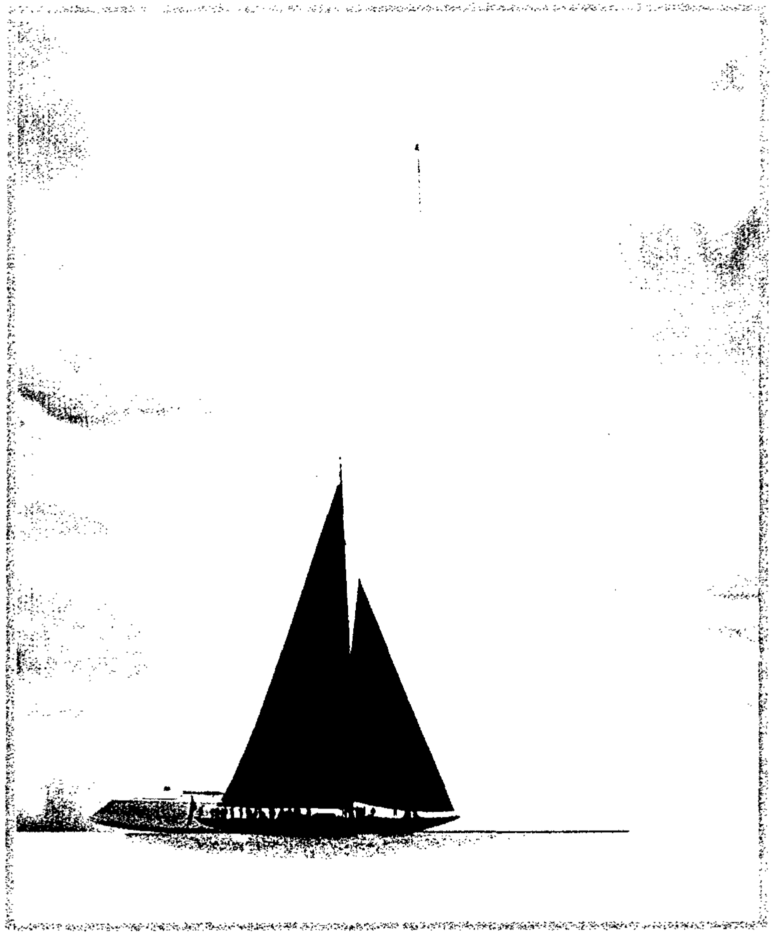
- Wastewater holding tank:
  - Balancing hydraulic load and organic load
- Pre treatment:
  - Grease trap
  - Pre-filtration
- Controlling the treated water quality:
  - Bioreactor (pH, O_2,T)
  - Membrane system (turbity, flux)
- System upgrade with de-nitrification/nitrification and P-removal
- DigesTriq® for thermophilic sludge digestion

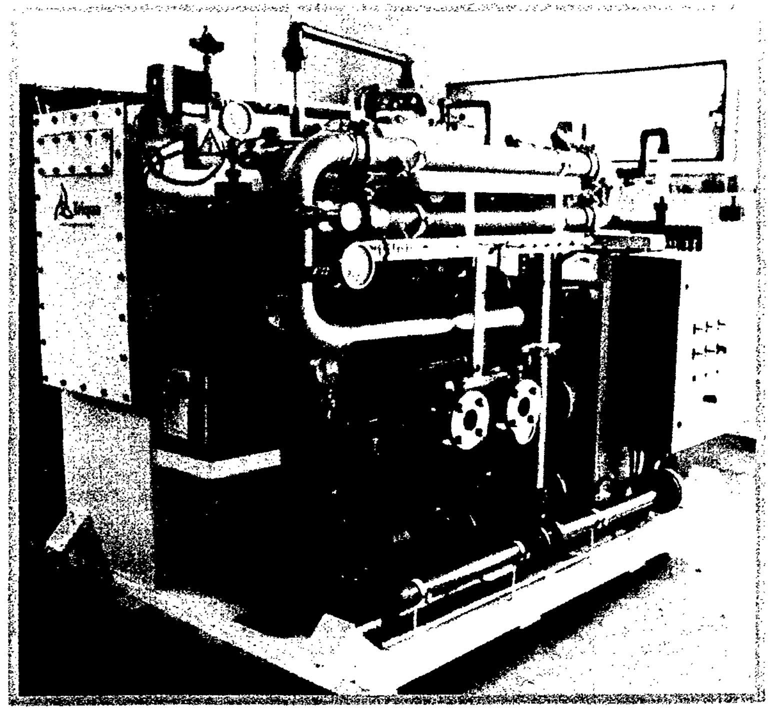
Design aspects

MemTriq® Marine

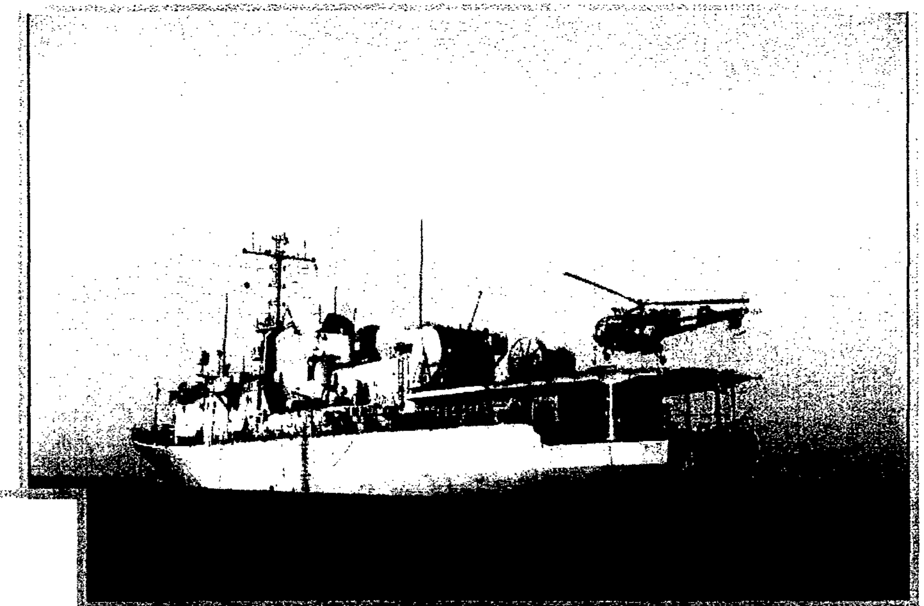


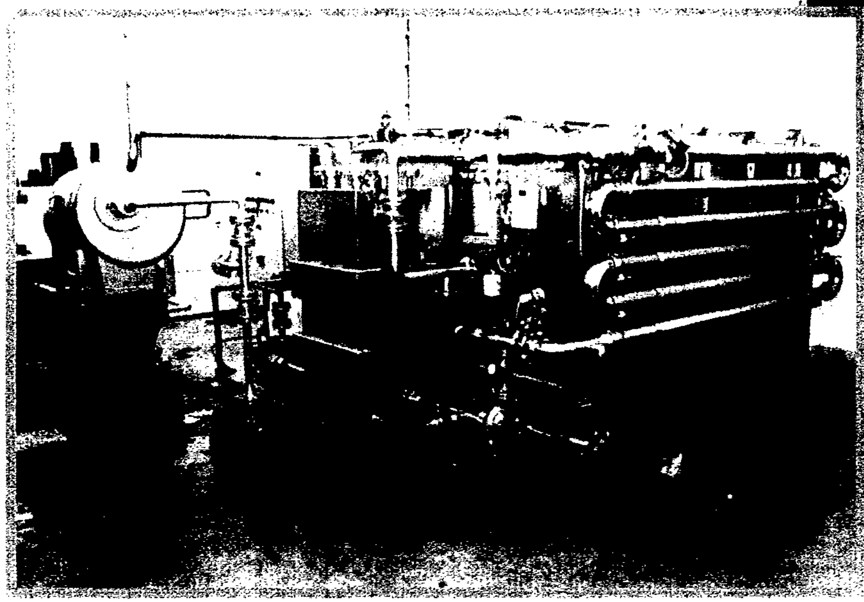
Small size units (25 - 100 p.e.)



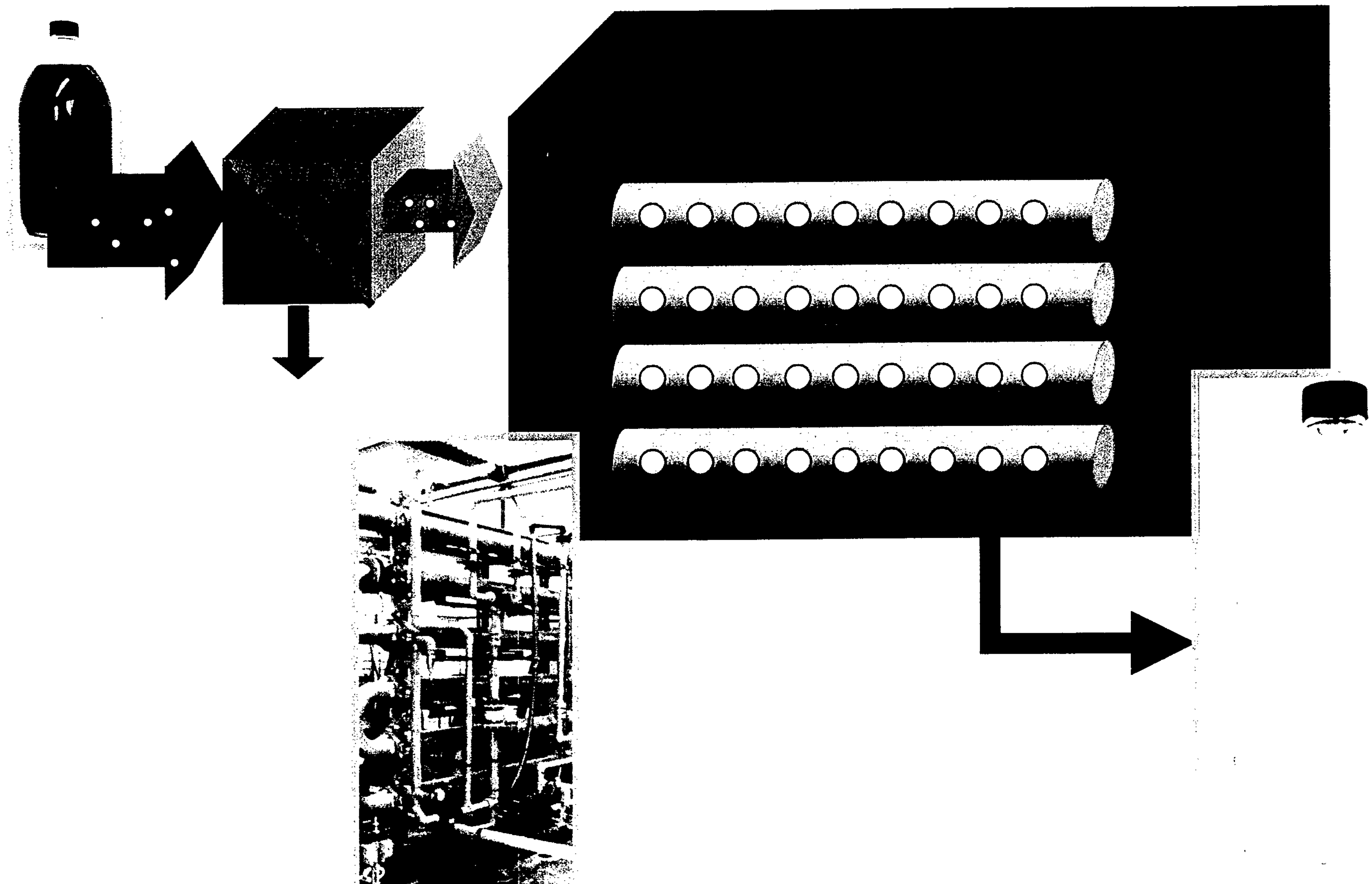


Medium size units (100 - 500 p.e.)

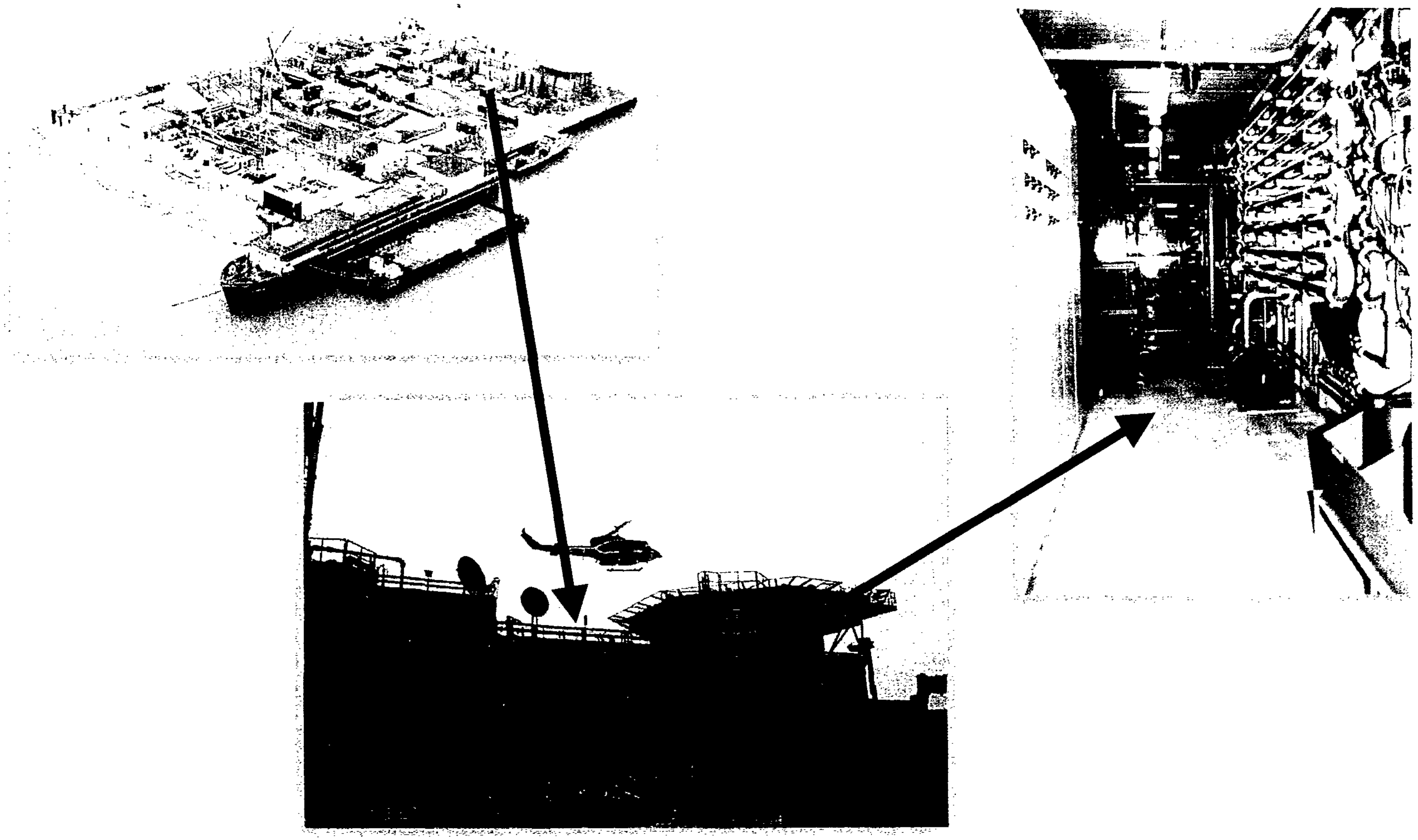




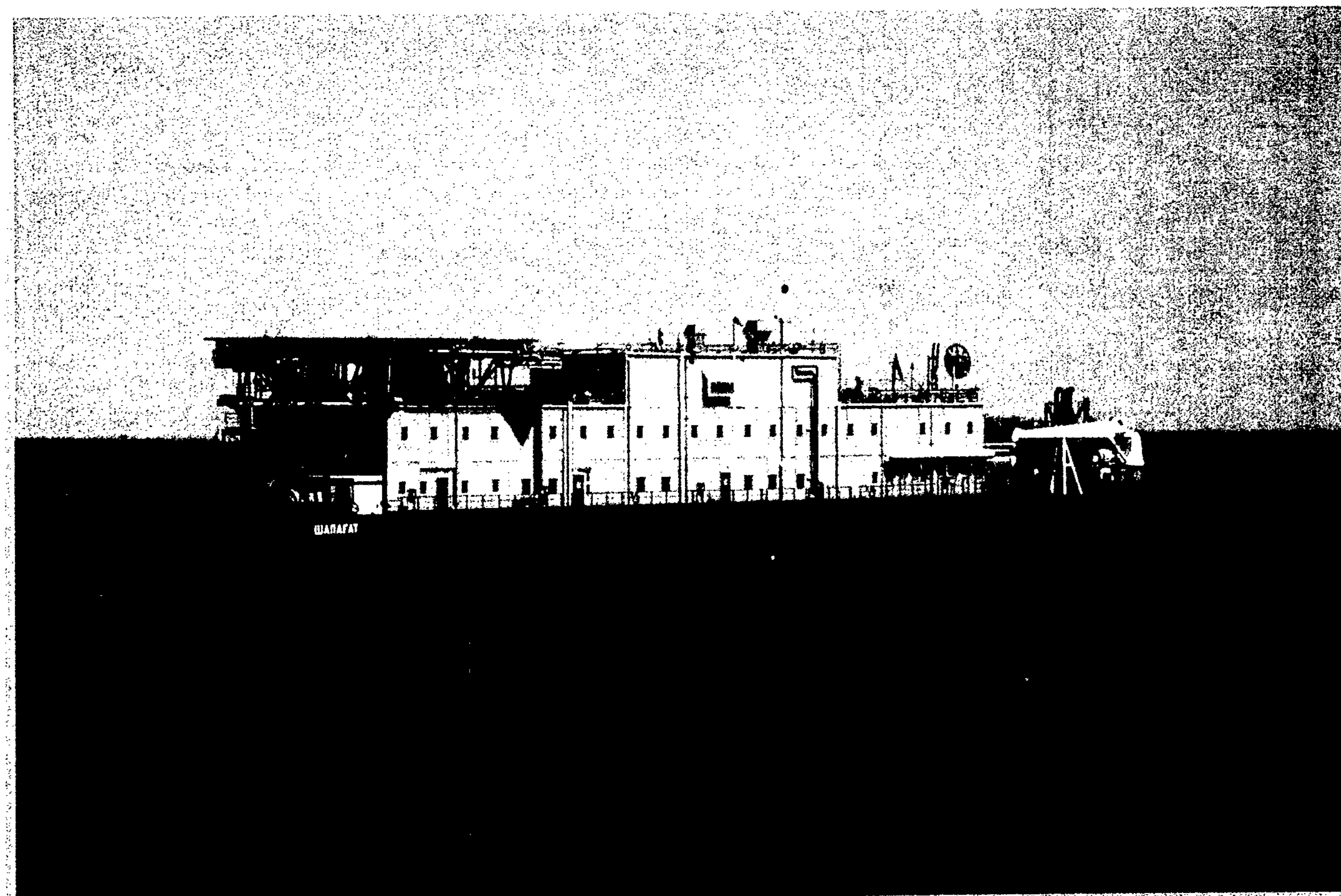
Large size units (500 - 5.000 p.e.)



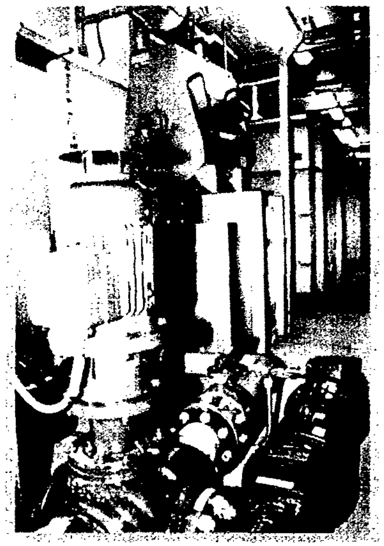
Offshore applications

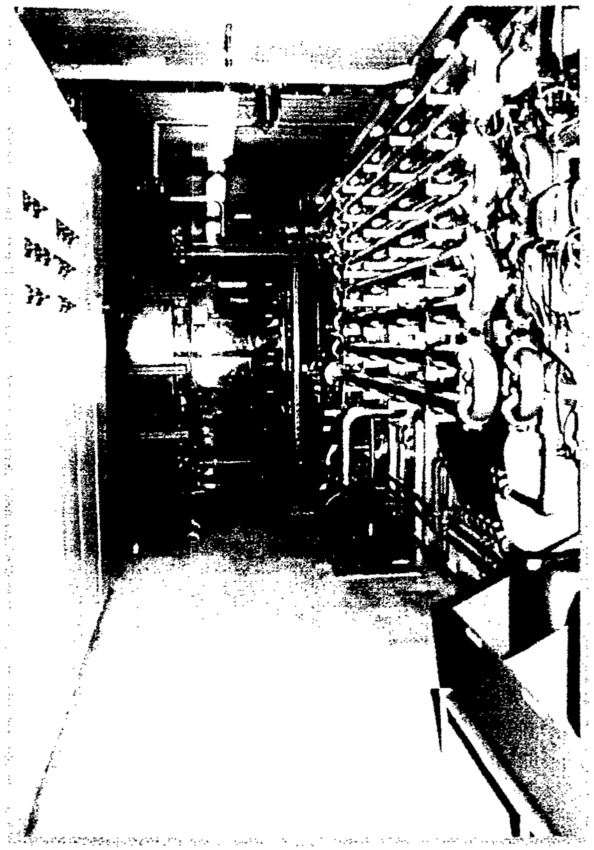


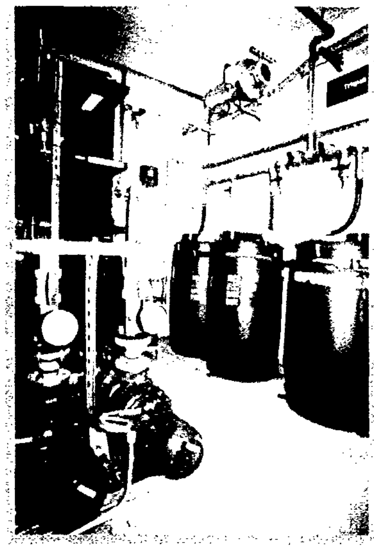
MemTriq®Marine on barges

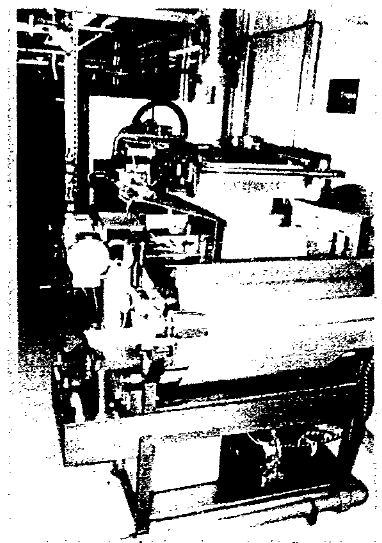


The off-shore application inside


Pre treatment


MemTriq®Marine


Post treatment

Sludge treatment


Off-shore project in Caspian Sea

- Extreme severe discharge standards
- Permanently controlled by authorities
  - COD < 10 mg/l
  - BOD < 5 mg/l
  - tot-N < 15 mg/l
  - Faecal coliform absent
- Criticality # 1
- 3 units in operation
- Permanent on-line controlled in NL

Experiences

- Proper pre-treatment is very important
- Use of sea water for toilet flushing can influence ultra-filtration membrane capacity
- Upgrading the system for N and P removal
- Interface with Solid Waste Treatment (SWT)

New developments

- Further decreasing of sludge production
- Co treatment of bilge water
- Up grading systems for N and P removal
- Size reduction by enhanced oxygen transfer
- Water reuse

High lights

- Treatment of all liquid waste on-board
- Complying with existing and future regulations
- No use of chemicals
- Flexible design
- Simple operation
- Small footprint
- Proven technology
- Minimal production of additional waste

Summary

- Severe discharge limits and the request for a reliable system
- Advantages of the MemTriq®Marine:
  - Excellent quality of treated water
  - Small foot print
  - No use of chemicals
  - Very limited sludge production
- MemTriq®Marine can be upgraded for future standards
- Proven system

Eule & Partners
International Consulting

Maritime Conferences

• The Maritime Environment •

" Ballast Water and Waste Water Treatment Aboard Ships and in Ports"

Supplement

Summary of the Conference on "Ballast Water and Waste Water Treatment Aboard Ships and in Ports" in Bremerhaven, Germany on 11^{th} – 13^{th} June 2003

The International Conference on "Ballast Water and Waste Water Treatment Aboard Ships and in Ports" was held on 11^{th} – 13^{th} June 2003 in the Best Western Hotel Naber, Bremerhaven, Germany.

The Conference had been initiated and was organized by Eule & Partners International Consulting, Glückstadt, Germany.

The Conference was sponsored by the Senator for Economy and Ports of the Hanse City of Bremen, the US Navy Office of Naval Research International Field Office in London, UK and Deerberg-Systems in Oldenburg, Germany.

This was the third conference held in Bremerhaven one of the major German seaports belonging to the Hanse City of Bremen. All different trades of the maritime industry, whether it is the Shipping Industry with several shipping lines, the shipyard of NDL, or the fishery industry are located here. Bremen and Bremerhaven for many years have undertaken major efforts in the area of environmental protection of our ports, the sea and the shores.

The Senator of Economy and Ports of the Hanse City of Bremen hosted a reception aboard the Sailing Vessel "Seute Deern" on the first day of the conference.

In the world of maritime application of waste management systems Deerberg-Systems is a well known company and the world-wide leading supplier for Total Waste Management Systems for the Cruise Industry. Mr. Deerberg had initiated a series of workshops for the Cruise Industry, Ship Owners, Shipyards, Suppliers and Manufacturers to discuss together the requirements and the way ahead for Liquid Waste Treatment. The results were presented at this conference.
Deerberg-Systems hosted a Dinner for all participants on the first evening of the conference aboard the Sailing Vessel "Seute Deern".

The US Navy Office of Naval Research International Field Office is committed to fostering and facilitating collaboration in Science, Technology, Research and Development between the United States and their professional counterparts in Europe, Africa and the Middle East. The US Navy Office of Naval Research International Field Office is linked with international scientists and engineers through conferences, workshops, visits and personal research to identify key opportunities in Science & Technology, to assess Science & Technology activities and accomplishments and to exchange information and ideas in areas of mutual interest.
The US Navy Office of Naval Research International Field Office is based in London.

The objectives of this conference were:

1. Provision of a forum for representatives from industry, ship owners, academia, governments, maritime and harbour authorities and shipyards for discussion and exchange of information on policies, trends and development of regulations for the treatment of ballast water, waste water and sewage on ships and in ports.
2. Presentation and discussion of technologies and equipment for the treatment of black, grey and oily water as well as ballast water and sewage generated on board of ships.
3. Presentation and discussion of advanced waste water treatment technologies, future research and adaptation of current and future technologies for ship systems
4. Discussion of management aspects related to waste water and ballast water treatment.
5. Recommendations for latest technology applications on ships and in ports.

6. Recommendations to industries and governments for policies and international collaboration.

Mr. Jörg Schulz, the Mayor of the City of Bremerhaven opened the conference by welcoming the participants to the seaport city of Bremerhaven. He stressed the importance the city attached to this international conference contributing to the environment of our seas and ports.

Frau Sybille Winther representing the Free Hanse City of Bremen held the keynote address. She pointed out the efforts Bremen has undertaken over the years in international fora in support of the Maritime Environmental Protection issues.

Around 90 Experts in this area from 13 different Nations (Denmark, Finland, France, Germany, Greece, Israel, Italy, Monaco, The Netherlands, Norway, Sweden, the United Kingdom and the United States) attended the conference. They represented the whole range of interested groups in this field, i.e. Ship Owners, Shipyards, Navies, Port Authorities, Incentive Organizations, Academia, System Engineering Companies, Equipment Manufacturers.

Deerberg-Systems from Germany, Maritime Environmental Partners Inc. from the United States, the International Maritime Organisation (IMO), Dr. Voigt Consulting from Germany as well as the Royal Netherlands Institute for Sea Research (NIOZ) were exhibiting their products.

The Conference was organized in three Sessions:

Session 1 – POLICIES, REGULATIONS, MANAGEMENT and ORGANISATION

Session 2 – BALLAST WATER (Chairmen: Dr. Matthias Voigt, GE – first day and Capt. Cornelius de Keyzer, NL – second day)

Session 3 – BLACK AND GREY WATER, OILY WATER, SEWAGE and SLUDGES (Chairman: Mr. Jochen Deerberg, GE)

The conference participants were well aware of the current discussions in the European Commission, in the IMO and other fora on the regulations for ballast water and waste water treatment on the high seas as well as in special areas. They were also aware of the more restrictive regulations that have been established by many coastal regions and even local authorities. This impacts on the shipping industry in general but particularly on the Cruise Industry that visits environmentally sensitive sea areas quite frequently.

The papers for the conference were selected with the intention to contribute knowledge and to provide an expert forum for discussion of these matters involving the regulatory authorities as well as the concerned industry.

The key observation in this conference was the fact that the increasing awareness of the need for maritime environmental protection has now been firmly established in the maritime industry and as such the need for clear universal regulations has become more urgent. The industry concerned with Liquid Waste Treatment therefore urges MARPOL nations to ratify the Annex IV to the MARPOL Convention.

A number of incentive schemes have emerged in the maritime industry to award ships and ship owners with a certificate for compliance with the environmental rules and even beyond the basic requirements. Capt. Bahlke from GAUSS in Germany reported on the criteria for the UN launched

"Blue Angel" certificate for environmentally compliant products, now being applied in Germany to ships. Capt. Braren, ship owner in Germany briefed the conference on his ships having been the first ships that were attributed the "Blue Angel" award.

It is hoped that these awards at some time can be consolidated and a proliferation on different criteria can be avoided.

The issue of **ballast water treatment** has gained significant visibility in the recent past. It is expected that IMO will agree an initiative that will establish a regulatory basis for ballast water treatment during this and the next year.

Capt. De Keyzer in his lecture dramatically showed that proper ballasting is required to maintain ship's stability and integrity and that ballast water exchange on the high seas especially at high sea states is a dangerous endeavour. He therefore ruled out the ballast water exchange as a viable solution for ballast water treatment on a regular basis.

On the other hand around 10-12 billion tons of ballast water containing the "unwanted species" is carried around the worlds annually and the requirement for treatment is obvious in order to avoid ecological and economical damage.

The lectures in this conference demonstrated that industry has made great efforts in developing technologies that could cope with the problem. In general it is recognized that no single technology will do the job but that a combination of technologies and/or processes is required - mechanical, chemical or electrical.

The approach to ballast water treatment generally breaks down into treatment in-line, i.e. during the intake of ballast water or its discharge and then on the other hand in in-tank treatment during the ships voyage. The most difficult problem is the surviving of biological matter in the sediment in the ballast water tanks. It appears that technologies will mature over the next couple of years as experience is gained and applied.

Another issue concerning ballast water treatment is the development of standards and standard test procedures to establish common criteria and the tools for certification of efficacy of the different technologies and applied processes.

A very interesting proposal was made by Prof. M. Champ, US, who suggested that a neutral international Marine Testing Board for the Certification of Ballast Water Treatment technologies should be established by all industrial parties involved to judge and to progress technologies in this important area.

Overall it was felt that ballast water treatment is well on its way but there is still a need for further work and discussion, especially on standards and test procedures for the certification of treatment technologies and processes.

The other major part of the conference was dedicated to **grey- and black water and sewage and sludge treatment.**

Thanks to Mr. Deerberg, Owner and CEO of Deerberg-Systems in Germany an initiative was started to bring together the concerned industry, i.e. ship owners, shipyards, suppliers and manufacturers, to discuss and develop a way ahead in the area of Liquid Waste Treatment (LWT). The results of these workshops that had developed from the 2nd Deerberg Environmental Workshop for the Cruise

Industry in conjunction with the SMM in Hamburg in September 2002 were presented at the conference.

After an introduction by Mr. Deerberg, Mr. Storari from Carnival Cruise Lines interpreted the results from the ship owners point of view, i.e. emphasising that the specifications developed during the workshops did not limit the options on one particular technological approach to LWT, but established targets that needed to be discussed between the owners, the shipyards and the suppliers to select the appropriate technology for a new building or retrofit.

Mr. Mammes from the Meyer Werft in Germany explained the specifications that had been drafted in the workshops. These will be published after approval by the Cruise Industry.

The view of the manufacturers was presented by Mr. Van Dijk, Triqua, NL, who briefed the conference on the checklist for LWT technologies that goes along with the specifications.

All of the results are contained in a report that was handed out by Deerberg-Systems to the participants of the conference.

The conference agreed that bringing together the partners in the industry to establish a common set of requirements for LWT technologies was a great achievement and had now created a common platform to work from.

Further lectures in the conference dealt with particular systems and technologies for LWT and showed clearly that there are already very mature systems for shipboard operation.

The very interesting aspect of retrofitting systems on ships in service was presented by Messrs. Badin and Wien of Scanship Environmental AS, NO for the retrofit on a cruise ship and by Dr. Smith, QinetiQ, UK for the same on a Navy frigate. There were a large amount of similarities in both retrofits. The conference recognised the difficulties associated with the retrofitting in existing spaces even during or in very short time before a cruise of the ship. The presenters were recognised for their achievements in this area.

Another aspect which was presented by Capt. Baer, Deerberg-Systems, GE was that the environmental conditions on a vessel could be significantly improved by introducing bio-degradable cleaning products on the ships. This not only had an effect on a more environmentally friendly maintenance of the ship, but also on significant cost- and labour savings due to less clogging of pipes and greater cleanliness of holding tanks.

Overall it was concluded that the conference had been very successful and had demonstrated the progress in the area of ballast water and waste water treatment over the last two years.

The participants used the conference extensively to conduct business discussions.

The social events, the luncheons, the reception hosted by the Free Hanse City of Bremen and the dinner hosted by Deerberg-Systems offered many additional opportunities for discussions amongst the delegates.

The exhibitions by Deerberg-Systems from Germany, Maritime Environmental Partners Inc. from the United States, the International Maritime Organisation (IMO), Dr. Voigt Consulting from

Germany as well as the Royal Netherlands Institute for Sea Research (NIOZ) have helped visualizing the systems, technologies and products addressed during the conference.

Organizationally and socially the conference worked very well. The Best Western Hotel Naber in Bremerhaven offered excellent conference facilities and support.

In summary the conference was very well received by the Participants, who also expressed their desire, to attend future conferences in the area of maritime environmental policies and technologies. The Conference Organizer announced that another conference including the subjects of ballast water and waste water treatment was planned for 2004 at about the same time.

Klaus D. Eule
Conference Organizer

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