REDUCING THE RISK OF INVASIVE ORGANISMS BY CLEANING THE BALLAST WATER OF SHIPS

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Ships need ballast water for their stability and manoeuvrability. This water is not pure, but it contains a sample of the local ecosystem at the place of intake. Within a few days to weeks, vast quantities of water are shipped from one continent to the other. At the port of destination, ballast water is often pumped overboard, including the organisms it still contains. The receiving ecosystem is not always well adapted to the reception of newly introduced species. Such new species sometimes develop into a plague, pushing native species to the edge of their existence. The International Maritime Organisation of the UN has declared that from 2009 onwards ballast water has to be free of organisms to minimize the risk of introduction of invasive species. NIOZ is involved in the development of the proper test protocols for the evaluation of ballast water treatment installations and for compliance control measurements by the port authorities.

Ships transport 5-10 billion tons of ballast water annually all over the globe, loaded with a enormous variety of organisms. These organisms belong to the natural ecosystem in the port of origin but are often not present in the ports of destination at the end of a ship's journey. In hundreds of cases around the world, this has resulted in severe damage to the receiving ecosystem because the non native organisms developed into a pest. This can have a high impact on the ecosystem, resulting in a decrease of stocks of commercially valuable fish, shellfish species and occasionally outbreaks of diseases like cholera. To minimize these risks for the future, the International Maritime Organization (IMO) of the United Nations (UN) has adopted a Ballast Water Convention in 2004. This Convention states that starting in 2009 for ships with a ballast water capacity below 5000 m^3 to finally all ships (> 50,000 in number) in 2016 should install a certifeied Ballast Water Treatment (BWT) equipment on board. NIOZ has the ambition to become the European test centre for the certification of BWT equipment. To achieve this, we have developed new and adapted our existing automated analyzing methods for phytoplankton, zooplankton and bacteria for this special purpose. This was done in a collaborative experimental study with the German firms Hamann AG and Degussa AG. The SEDNA BWT installation

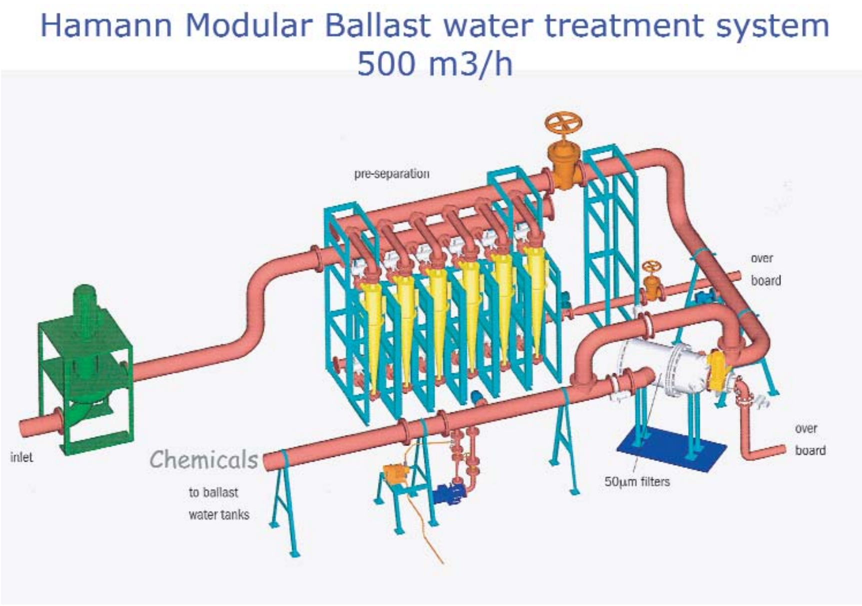

Fig. 1. Schematic configuration of the Ballast Water Treatment system SEDNA (Hamann AG, Hollenstedt, Germany).

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Fig. 2. The Ballast Water Treatment system temporarily installed at the NIOZ harbour.

of Hamann AG was used as a test instrument (Fig. 1) and the NIOZ harbour as the land-based test site (Fig. 2).

The IMO Ballast Water Convention includes very challenging standards for the test methods. For proper testing, brackish test water should contain minimum densities of two size-classes of plankton: at least 10^5 organisms per m^3 for organisms larger than 50 mm and at least 1000 organisms per ml for organisms between 10 and 50 mm, With exception of the winter season, these densities of organisms are present in the natural community of the Wadden Sea.
The cleaning efficiency of the BWT system should be very high since the maximum allowed numbers of organisms in the treated ballast water at discharge are extremely low: For the organisms larger than 50 micrometer, the maximum is 10 viable organisms per m^3 and for the smaller organisms between 10 and 50 micrometer, a maximum of 10 viable organisms per ml is allowed. Also for the presence of humans pathogenic bacteria (*E. coli, Enterococcus* and *Vibrio cholerae*) in treated ballast water, extremely low maximum numbers are defined.

Based on pilot studies, it became evident that there is no single step solution to treat ballast water to remove both sediment and biota. Moreover, the treatments should be effective to a huge variety of organisms, as well as to the resting stages of various species which under normal conditions are capable of surviving prolonged unfavourable conditions. Also, the ballast water should not only be organism free but also non-toxic for the receiving ecosystem when it is discharged. The SEDNA unit of Hamann consists of a primary cleaning method using six hydrocyclones in combination with filtration over a self-cleaning 50 micrometer filter . This primary phase reduces the number of organisms and suspended sediment particles in the water. The final treatment step involves the use of the active chemical mixture PERACLEAN Ocean, manufactured by Degussa AG (Hanau, Germany). The two active ingredients are hydrogen peroxyde and peroxyacetic acid. Both compounds are initially very toxic when added to the ballast water, but they disintegrate within a few days. This should result in harmless concentrations of these compounds when the ballast water is discharged.

At the beginning of the tests at the NIOZ harbour in 2004, no well-described test methods were available. Thus we had to develop these methods according to the requirements laid-out in the IMO ballast water convention and the methods developed for our fundamental research on plankton. In practice sampling devices and sample volumes had to be adapted taking into account the extremely low thresholds of maximum allowed densities of organisms after treatment. For the large organisms, a new type of sampling net was designed to concentrate the organisms from several m^3 of ballast water after it had been in the tanks. For the small organisms the required sample sizes fitted well with the volumes used for semi-automated plankton counting by flow cytometry. In addition, the Convention refers to the presence of viable (living) organisms rather than total organisms. To differentiate between live and dead plankton, a newly developed staining method using the dye SYTOX Green was successfully applied. This method is based on the integrity of the cell membrane which is intact in life cells but is distorted when cells are exposed to stress, e.g. caused by physical damage or chemical treatment (Fig. 3).

The physical components of the SEDNA system (hydrocyclone and filters) turned out to be effective in reducing the numerical abundance of the larger organisms but a secondary treatment with chemicals was still necessary to reduce the number of living organisms in the smaller size class to below the tolerated maximum of 10 organisms ml-1. The bacteriostatic compound of the chemical (H_2O_2) delayed the regrowth of total bacteria with ca. 10 days.

Currently the draft protocols, test results, and instrumentation for testing developed at NIOZ are communicated with various national and international agencies. Upon agreement by IMO and in collaboration with specialized classification societies for ships, it is our goal to develop these protocols further to official guidelines used for certification together with our international partners in Europe, the United States and Asia.

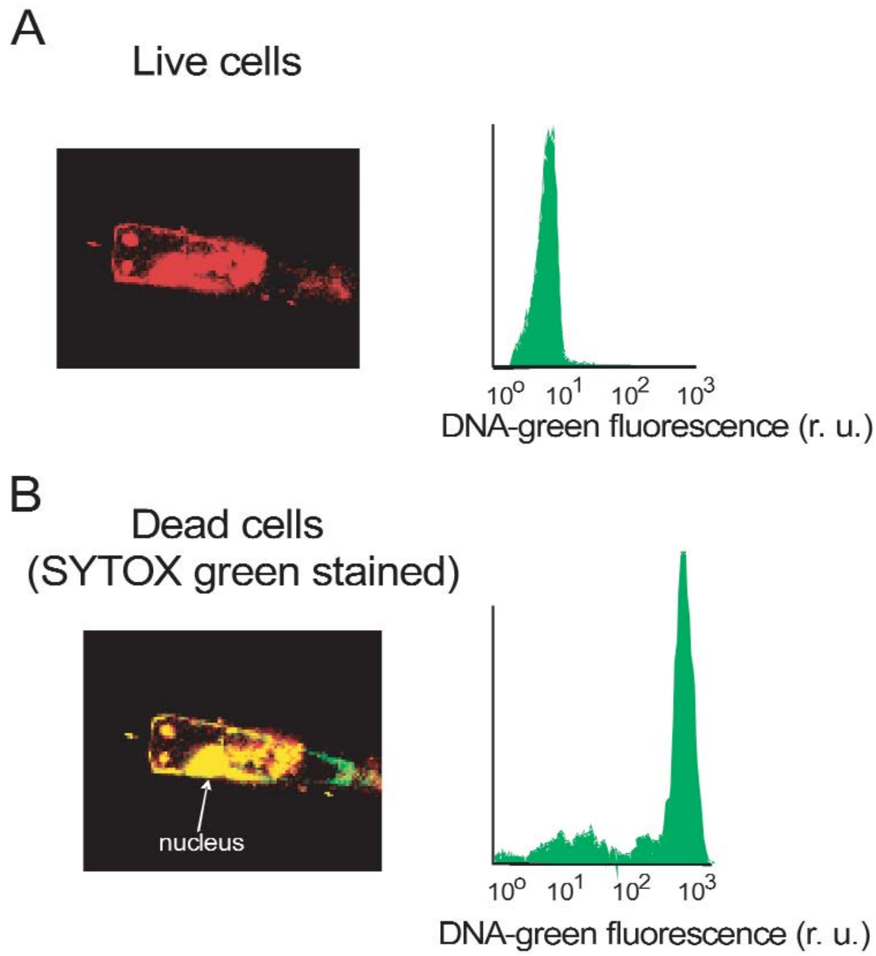

Fig. 3. The nucleic acid stain SYTOX Green does not enter live cells (A) but dying or dead cells are green-yellow stained (B). The fluorescence (in relative units) of the SYTOX-stained DNA in readings by flow cytometry is more than two orders higher in the non-viable cells.