Emission to water

This leaflet contains information related to emissions to water from shipping based on research work within the BONUS SHEBA project. The purpose is to populate knowledge and experience established from science and make the information more available. It has been prepared by Karl Jivén, IVL, on behalf of the Interreg CSHIPP project platform.

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THE BONUS SHEBA PROJECT

The BONUS project SHEBA brought together lead experts from the fields of ship emissions, atmospheric, acoustic and oceanic modelling, atmospheric and marine chemistry logistics and environmental law[1] to provide an integrated and in-depth analysis of the ecological, economic and social impacts of shipping in the Baltic Sea and to support development of the related policies on EU, regional, national and local levels.

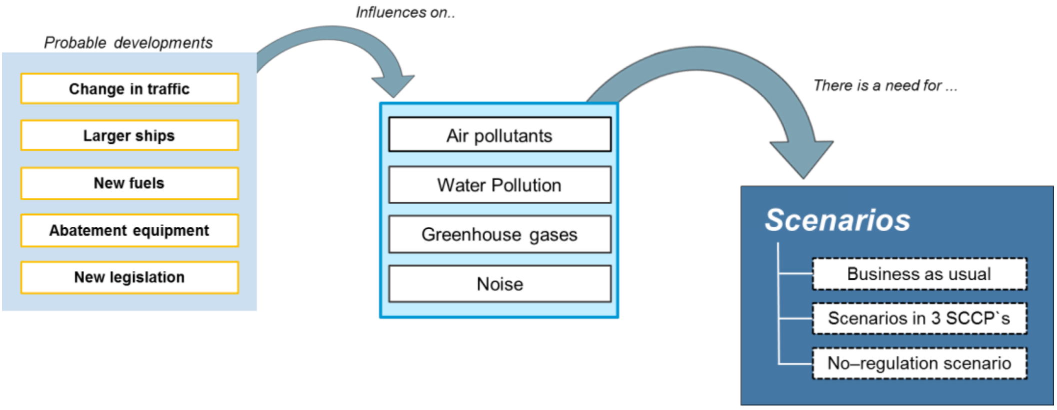

Figure 1 The model used for finding what the future air emissions will look like.

The Baltic Sea is one of the world's most trafficked sea areas and of great importance for both global and regional seaborne trade. Various ship types are constantly in route with cargo from or to the area. Also, passenger traffic in the Baltic Sea is extensive with ferries operating year-round covering many destinations. There are around 100 ports in the Baltic Sea located in fresh to salt water, of different size and with varying type of traffic. Although shipping is one of the most environmentally friendly modes of transport referring to CO_2 emissions to air per tonnes of cargo, shipping like all industries cause environmental impact which is affecting the Baltic Sea. The countries surrounding the Baltic Sea all use the area as waterway, for fishing, recreation and tourism and it is essential for their economies and development. To support a sustainable development of shipping in the area, a quantification of shipping's contribution to the environmental impact has been conducted within the BONUS SHEBA project.

The SHEBA project, which was an EU-BONUS funded project, has analysed the following sources and pathways of shipping induced pollution to the marine environment:

- Noise pollution
- Emissions to air (NOx, SOx, CO_2)
- Particulate matter (PM)
- **Emissions to water** (Bilge water, Ballast Water, Sewage, Grey water, Stern tube oil, Biofouling vs Antifouling paint and Food waste).

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EMISSIONS TO WATER

Ships emit pollution and contaminants from different sources such as antifouling paint, black- and grey water, propeller shaft lubricants etc. Ballast water can contain invasive species and/or toxic contaminants used to eliminate invasive species. Black, grey and bilge water contain nutrients and contaminants. Scrubber water contains acidifying chemicals and contaminants.

In BONUS SHEBA we have identified in total over 600 different chemical contaminants that are likely emitted from shipping. It should be noted that a chemical mixture can be more toxic than the individual contaminants, and shipping emits a very complex mixture of chemicals to the sea. This is why research on water pollution by ships is needed.

Load factors for pollutants from sewage, food waste, bilge water, scrubber water, ballast water, stern tube oil, operational oil discharges and antifouling paints have been produced and a spatio-temporally resolved inventory of pollutants for the entire Baltic Sea has been calculated. The first simulations with a 3-d oceanic model utilising the spatially resolved emissions and deposition of pollutants from air have been performed.

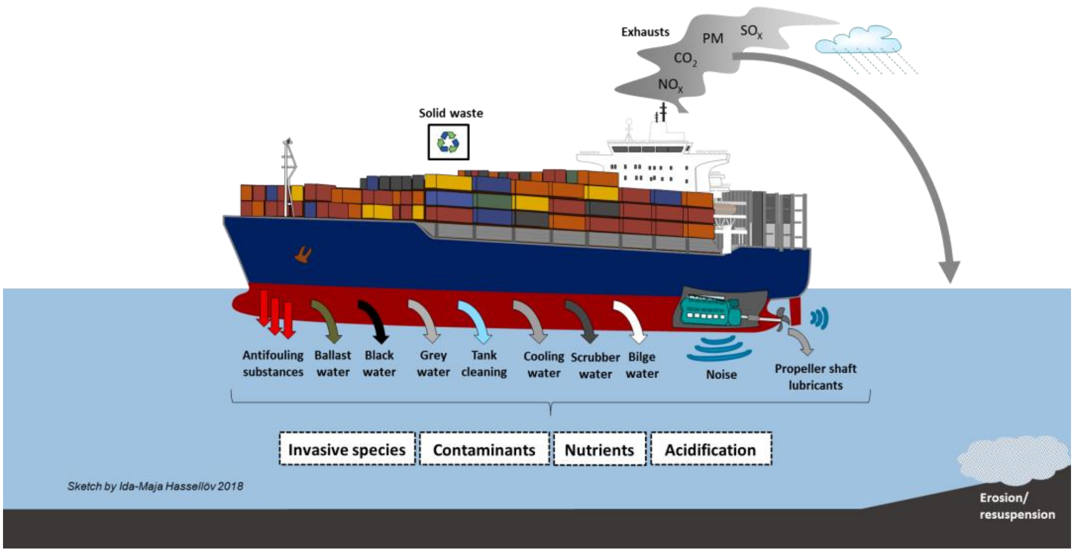


Figure 2 Shipping and water pollution – overview of emissions

Table 1 Glossary for commonly used expressions related to emissions to water from ships

Antifouling substances	Substances used to prevent undesirable accumulation of organisms on ship hulls
Ballast water	Water stored in ballast water tanks used for stability mainly in case of non-laden voyages
Grey water	All streams of waste water except for toilet water. Possible sources are devices like showers, dishwashers or washing machines.
Black water	Sewage water containing organic matter, pathogens and nutrients.
Bilge water	Water collected in the lowest area of a ship (bilge) from condensation, leakages during work or inflow from the sea. Often a mixture of fresh water, sea water, oily components and others. Must be pumped out of the ship regularly.
Cooling water	Water used for cooling the engines.
Propeller shaft lubricants	Lubricating oils used for operational reasons at the propeller of a ship
Scrubber water	Water used for removing SO_x and particulate matter (PM) from exhaust
Tank cleaning	Process of removing remains of every kind of liquids transported in tanks

NUTRIENTS - SEWAGE/ GREY WATER/ FOOD WASTE

The nutrients nitrogen and phosphorus stimulate plankton growth and promote so-called algal blooms. When these plankton die and sediment to the sea floor, bottom water oxygen is used to biodegrade the plankton, which results in bottom water with low oxygen (hypoxia). Bottom animals living in such areas either die or migrate away. These areas are also called *Dead sea floor areas*.

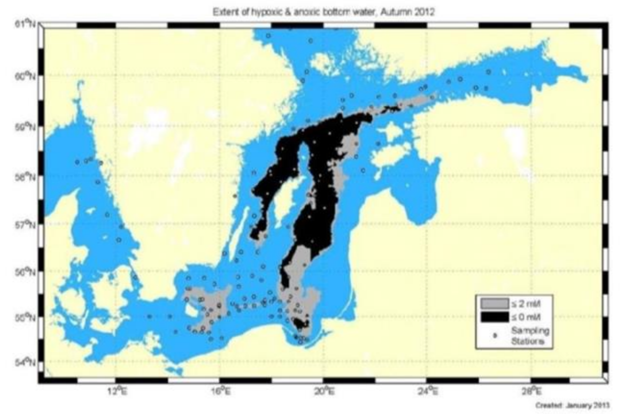


Figure 3 Extent of hypoxic & anioxic bottom water, Autumn 2012

Figure 4 Algal blooming in the Baltic Sea.

The primary source of **nitrogen** from shipping is nitrogen oxides (NO_x) produced in the engine combustion process. NOx is emitted via the ship exhausts and subsequently deposited to the sea water. **Phosphorus** is primarily emitted directly to the sea via black water and grey water.

According to the results produced in BONUS SHEBA, the nutrient emissions from shipping give small increases in plankton growth but stimulate different plankton groups in different ways. The groups' diatoms and flagellates are stimulated with a few percent by the shipping emissions, but cyanobacteria are actually not favoured due to the high nitrogen to phosphorus ratio in the emissions. The shipping-induced plankton growth results in an increased area of hypoxic sea floors. As an example, the SHEBA project estimated that the increase in areas of hypoxia in the *Arkona basin*, the *Bornholm basin* and the *Gdansk Bay* was 1.2 %. This hypoxia is also assessed to correspond to a 1.2 % reduced catch of cod and a loss of landed cod corresponding to a value of 1,4 million per year Euros.

Sewage/ Grey water and Food waste all contain nutrients (Nitrogen and Phosphorous) that. if entering the Baltic Sea, can make status in the already eutrophicated areas worse.

Sewage/ Grey water/Food waste is produced during daily activities on-board and with amounts dependent on the number of persons on the ships. Data produced within SHEBA show that the unregulated greywater from large Cruise ships and RoPax contain approximately the same amounts of nutrients as in the sewage that currently is being regulated in Annex IV -Sewage (where Baltic Sea currently is the only special area under this Annex).

OCEAN ACIDIFICATION

Ocean acidification is a result from a lowered pH in marine waters. The pH can, for example, be lowered due to the dissolution of carbon dioxide (CO_2) in the atmosphere into carbonic acid (H_2CO_3) in the sea. The increased concentrations of CO_2 in the atmosphere from fossil fuels hence make the seas more acidic.

Many marine organisms cannot cope with a lowered pH and are threatened with extinction, for example many coral reef species.

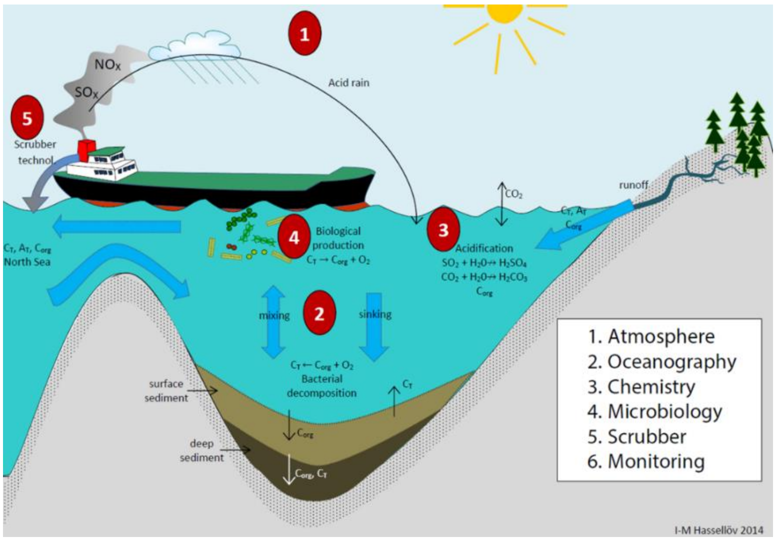


Figure 5 Ocean acidification

Shipping contributes to ocean acidification by emitting acidifying substances to air (CO_2, SOx and NOx). In order to reduce the SOx emissions to air, scrubbers are used. The scrubbers wash away the substances from the exhausts by dissolving them into water. However, the scrubbers' wash water contains large amounts of acidifying substances and other contaminants from the exhaust gasses and have a very low pH.

If so-called Open loop scrubbers are used the scrubber water is then emitted directly to the sea. If Closed loop scrubbers are used, the scrubber wash water is re-circulated, but a so-called bleed-off of scrubber water is emitted to the sea and sludge is produced that needs to be handled by port reception facilities.

Analyses in BONUS SHEBA shows that the use of scrubbers will likely increase due to regulations of SOx emissions. However, the shipping-induced ocean acidification will still be small in the Baltic Sea. Researchers in BONUS SHEBA also participated in the ShipH project, where 100% of the shipping fleet where assumed to use open loop scrubbers and the resulting reduction in pH was between 0.001 and 0.003 pH units over a period of 30 years. It should be kept in mind, however, that the modelling was performed using low spatial resolution and it cannot be ruled out that extensive use of scrubbers may give rise to larger impacts in semi-enclosed areas such as harbours and coastal areas.

Seawater scrubbing is a type of Exhaust Gas Cleaning System (EGCS) that reduces the emissions of SOX to the atmosphere by washing the exhausts with seawater. However, the scrubbing process produces acidic and toxic waste water that, when operating in open-loop mode is discharged directly back to the sea. Another option is to operate in closed mode where the wash water is reused in the scrubbing process after the addition of a buffer (e.g. caustic soda).

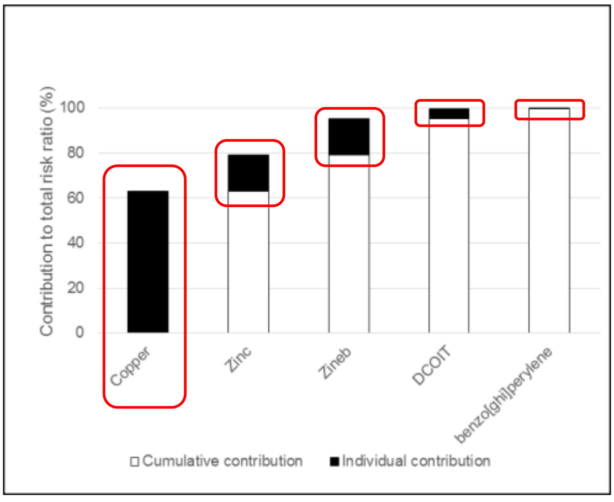
The outcome of the SHEBA project will support development of related policies on EU, Baltic Sea region as well as national and local levels. The ship- and port operators are important actors in making shipping a more sustainable transport solution.

BIOCIDES FROM ANTIFOULING PAINT

Antifouling compounds are used in antifouling paint and are meant to prevent fouling on ship hulls (biofouling). These compounds are of great environmental concern as they are highly toxic and some of them are not biodegradable, where copper and zinc are dominating. The compounds studied in BONUS SHEBA are copper, zinc, copper pyrithione, zinc pyrithione, DCOIT and zineb.

Figure 6 Antifouling applied during dry-docking

SHEBA results show that locally the concentrations of chemicals from antifouling paints in the Baltic Sea can lead to adverse effects on the marine environment. The emission inventory on the load and distribution of shipping-originated copper has shown that >99% of the ca. 300 t copper emitted annually by shipping originates from the antifouling paints. Furthermore, the oceanic model shows that the highest concentrations of copper are not always where the shipping lanes are located but near the largest harbours where ships spend most of their time.



When chemicals were ranked based on their risk for the environment, four of the antifouling compounds came out as the chemicals contributing most to the cumulative environmental risk. Copper and zinc were the two top chemicals contributing most to the overall environmental risk from chemicals.

Copper and zinc are almost exclusively emitted from antifouling paint. Furthermore, the shipping emissions of copper and zinc resulted in increases in those geographical areas where the Environmental Quality Standards for these compounds were exceeded. Both these observations underline the environmental problem of the current use of copper and zinc in antifouling paint.

Figure 7 Contribution to cumulative environmental risk in the shipping lane north of Bornholm. For example, copper contributes to approximately 60% of the total chemical risk.

INVASIVE SPECIES

Invasive species are problematic since they can eat, outcompete or parasite on the native species in an ecosystem. Furthermore, they can spread disease to humans.

To eliminate invasive species carried by ballast water, different types of ballast water treatment systems are used. These treatment systems use different methods to kill the organisms in the ballast water, such as UV light, filtration and chemical disinfection (using active compounds/biocides). Hence, treated ballast water contains toxic contaminants.

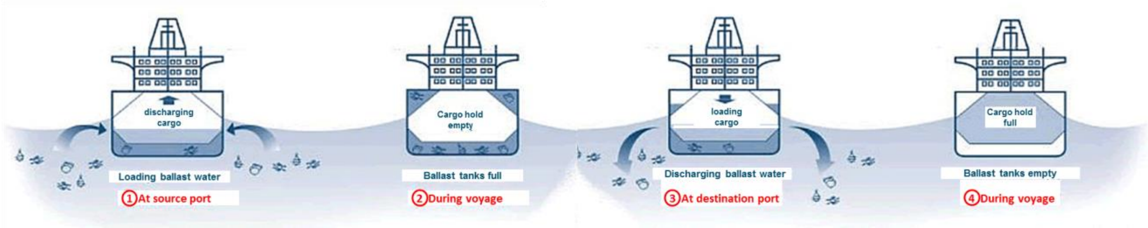


Figure 8 Ballast water cycle through a voyage.

The ballast water management convention (International Convention for the Control and Management of Ships' Ballast Water and Sediments), of the International Maritime Organisation (IMO) aims to minimize the problem on invasive species transfer by ballast water. However, at the same time it induces the emission of toxic contaminants from ballast water.

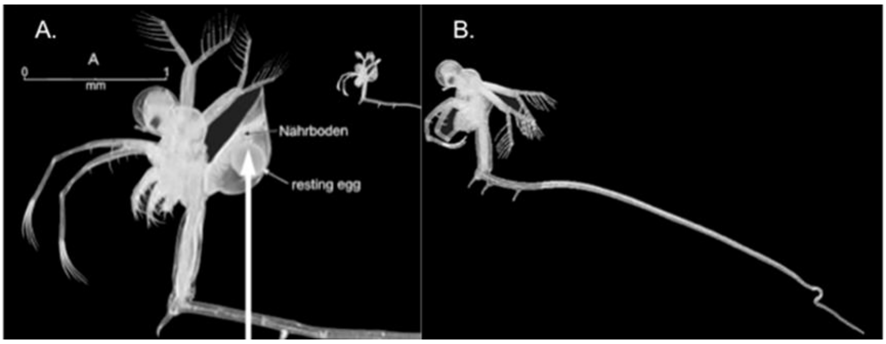


Figure 9 The predatory cladoceran Cercopagis pengoi (fishhook waterflea), introduced to the Baltic Sea from Ponto-caspian area (Black and Caspian Sea), has impacted the ecosystem as it preys on fish food (copepod and cladoceran species) affecting both smaller crayfish and fish. Photo © Dr. MacIsaac, Great Lakes Institute for Environmental Research, University of Windsor, Canada

Figure 10 Round goby (Neogobius melanostomus) is a wide spread invasive species in the Baltic Sea potentially impacting the structure and function of the coastal ecosystems. Photo: Riikka Puntila/HELCOM