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Review

Emerging risks from ballast water treatment: The run-up to the International Ballast Water Management Convention

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HIGHLIGHTS

- Potential impacts of the International Ballast Water Management Convention are discussed.
- Chemical ballast water treatment effectively reduces the risk of aquatic species invasions.
- Oxidative water treatment forms disinfection by-products that may harm humans and marine biota.
- The established risk assessment disregards multiple exposures and long-term sub-lethal effects.
- Holistic assessment of ballast water management needs to cover many additional factors.

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ABSTRACT

Uptake and discharge of ballast water by ocean-going ships contribute to the worldwide spread of aquatic invasive species, with negative impacts on the environment, economies, and public health. The International Ballast Water Management Convention aims at a global answer. The agreed standards for ballast water discharge will require ballast water treatment. Systems based on various physical and/or chemical methods were developed for on-board installation and approved by the International Maritime Organization. Most common are combinations of high-performance filters with oxidizing chemicals or UV radiation. A well-known problem of oxidative water treatment is the formation of disinfection by-products, many of which show genotoxicity, carcinogenicity, or other long-term toxicity. In natural biota, genetic damages can affect reproductive success and ultimately impact biodiversity. The future exposure towards chemicals from ballast water treatment can only be estimated, based on land-based testing of treatment systems, mathematical models, and exposure scenarios. Systematic studies on the chemistry of oxidants in seawater are lacking, as are data about the background levels of disinfection

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Risk assessment
Ballast water treatment

by-products in the oceans and strategies for monitoring future developments. The international approval procedure of ballast water treatment systems compares the estimated exposure levels of individual substances with their experimental toxicity. While well established in many substance regulations, this approach is also criticised for its simplification, which may disregard critical aspects such as multiple exposures and long-term sub-lethal effects. Moreover, a truly holistic sustainability assessment would need to take into account factors beyond chemical hazards, e.g. energy consumption, air pollution or waste generation.

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1. Introduction

Almost two thirds of traded goods worldwide are transported by ship (Kumar and Hoffmann, 2002). To ensure ship buoyancy, stability and manoeuvrability, oceangoing ships need ballast water. Based on an estimation that the world seaborne trade in 2013 amounted to 9.35 billion tons of cargo, the global ballast water discharges in 2013 are estimated to about 3.1 billion tonnes (David, in prep.). There is significant transfer of ballast water between different continents and oceans, and it has been known for decades that ballast water also transports organisms into new ecosystems, where, under favorable conditions, they can become invasive (Carlton, 1985; Williams et al., 1988). The introduction of invasive aquatic species into new environments has been identified as one of the four greatest threats to the world's oceans. When including terrestrial species, invasive species were identified as key factor in 54% of all known species extinctions as documented in the Red List database maintained by the International Union for Conservation of Nature (Clavero and Garcia-Berthou, 2005). Aquatic invasions are virtually irreversible and, once the newcomers are established, their impacts may also increase in severity over time. The transfer of invasive species does not occur only over larger distances, between continents, but also as a secondary spread in regional seas (David et al., 2013).

Invasive aquatic species can result in ecosystem changes and disruptions of ecosystem services (Vilà et al., 2010). Invasive species management in marine and coastal environments are major challenges. In European Seas alone, more than 1000 alien species are known. A list of the 100 most impacting species introduced into European waters was prepared within the project "Delivering Alien Invasive Species Inventories for Europe (DAISIE)" (Vilà et al., 2009). Ecological impacts were categorized, e.g. competition with native species, hybridization with native species, use of resources, or habitat modification. Among the top scorers of overall impact, for which ballast water could be identified as a major vector, are organisms from different taxonomic groups originating from different native ranges. Two species in particular, which were introduced by ballast water and are widespread in Europe, illustrate the possible impact of invasion: The first is the Chinese mitten crab (*Eriocheir sinensis*), a decapod crab, which is native in Asia. The crab, which reaches a size of approx. 7 cm body length, reproduces in marine waters, juvenile crabs migrate up to 1000 km upstream where the adults live for two years in lakes and rivers before they migrate back to the sea for reproduction. This invader was first recorded in Europe in 1912 in the Aller River (Germany). Mass development of this crab in several decades of the last century highlighted its negative impact. Fishermen were affected by the crabs preying upon fish caught in nets and they damaged fishing nets by rope cutting. It was also observed that the crabs clogged commercial water intakes and increased the river bank erosion by burrowing. A "beneficial" impact was also documented as the crabs are considered an Asian delicacy and are sold to Chinese restaurants. Today this species is found from Portugal to Norway and Russia (Gollasch and Rosenthal, 2006). A second example is the comb jelly (*Mnemiopsis leidyi*), which is a more recent case of a drastically impacting invasive species. This species originates from the East Coast of the USA and the Caribbean Sea and was introduced in the 1980s to the Black Sea where it caused, in combination with pollution and overfishing, a devastating reduction in fish catches (Shiganova and Bulgakova, 2000). Since then, the comb jelly spread further and is today also found in the Mediterranean, Baltic and North Seas, luckily without causing a comparable negative impact.

In 2004, the GloBallast programme – a cooperative initiative of the International Maritime Organization (IMO), the United Nations Development Programme, and the Global Environment Facility – undertook an initial scoping study on the global economic impacts of invasive aquatic species (Hassell, 2003; GEF-UNDP-IMO GloBallast Partnerships Programme and IUCN, 2010). Direct economic impacts due to currently known aquatic invasions, including costs from reductions in fisheries and aquaculture production, physical impacts on coastal infrastructure, loss of income for the shipping industry, and impacts on recreational areas and tourism, are estimated to exceed US$ 100 billion per