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BALLAST WATERS: PROBLEMS AND PERSPECTIVES

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Review

Abstract

This paper analyses the dangerous consequences of contamination of coastal waters by nonindigenous sea species spread by ship's ballast waters. It specifically points out that the measures currently recommended to avoid the danger are merely palliative and a radical solution is yet to be seen. Furthermore, the impacts of some nonindigenous species that have already been spread, whether accidentally or intentionally, are being outlined as well as a possible approach to the treatment of ship's ballast waters. Notwithstanding the actual selection of the treatment, treatment of ballast waters still on board ships seems to be imposing itself as the solitary solution with any realistic chances for global success. Finally, a pledge is being made that each coastal country conduct a research on its own species resilience to biocidal treatment and thus contribute in finding a radical solution to this global problem.

1. PRELIMINARY CONSIDERATIONS

The idea of the danger that ships' ballast waters are bringing, i.e. spreading, with them is slowly but consistently making its way to the public. Most of the involved, however, do not react adequately. Nevertheless, the problem being rather complex, insufficiently scrutinized, while the solutions that are in sight point without exception to additional expenses, such a lukewarm reaction does not surprise. So far as there is no solution, there are no costs, and at the same time "*navigare necesse est*", which leaves no room for expectation from the world shipbuilding or shipping business to make larger investments into research projects in order to reach a radical solution. As long as the international community will tolerate it, finding of a solution will be put aside while at the same time palliative measures, that disguise the problem rather than solve it, will be offered.[1]

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2. PALLIATIVE SOLUTIONS

In order to protect the coastal seas from contamination with nonindigenous sea species, as a relatively efficient measure, exchange of ballast sea water at open sea during voyage in ballast is being offered, in two variants: a) sequential method and b) flow-through method.[2]

The sequential method anticipates gradual pumping of sea water out of and in the ballast tanks. Taking into consideration that such a procedure influences ship's stability, bending moment and sheer forces on ship's hull, it endangers ship's safety. Therefore, it has to be carried out under favourable weather conditions as well as favourable weather forecast.[3] Certain types of ships will not be able to perform it even under such (favourable) circumstances.

The flow-through method anticipates topping up of ballast tanks during the voyage in ballast, which actually represents continuos flow of sea through tanks during deep sea passage. The topping up is done by ballast pumps, while the sea water is overflowing through manholes, which must remain open all the time, Such a procedure significantly decreases the risk to ship's safety compared to the previous one, but it is energy and time consuming. It has been experimentally proved that the tanks have to be recirculated four times in order to replace 98% of initially loaded ballast water.[4] Since this procedure has to be accomplished at deep sea, still under favourable weather conditions, the ship may easily end up in a situation when the process that has been started cannot be completed due to lack of time.

This indicates another fault pertaining to both methods: there is no way of monitoring the process and everything relies on master's statement. In addition, the method may present a risk, it is relatively long and favourable weather conditions are required?!

Both methods insist upon exchange of ballast waters at ocean and therefore they are labelled: "ocean ballast exchange". Assuming that bringing of nonindigenous species into deep sea waters has been proved to leave no consequences (?) there is still an outstanding ques-

tion of what about the ships which perform voyages in ballast not in the ocean but, for example, sail from Black or Red Sea to Adriatic? Could these methods be equally acceptable if they turn to be "Mediterranean ballast exchange"? Or perhaps sea species from Black or Red Sea are not nonindigenous from the Adriatic? These methods offer no answer to these and many other questions, which are being brought out from the analysis, these methods offer no replies, which is exactly why they are merely palliative solutions.

3. (UN)REALIZABLE RADICAL SOLUTIONS

A ship which would not require ballasting in certainly a most desirable solution, since it actually excludes the problem. Even to consider such a solution, it would be necessary to imagine a futurist project of a merchant ship, unconventional in shape and with rather limited dead-weight. For middlesize and larger merchant ships, considering present power sources, such a solution is unrealizable.

Pumping out of ballast waters into port tanks upon ship's arrival at port is a simple technical operation and there should be no problems in applying such a solution to existing ships. Thus, ship's crew, i.e. shipowner, would not have to worry about disposal of ballast waters and consequently the liability. The question is only at what price? Here, the cost for ship's delay should be taken into calculation, as well as the cost for discharge of ship's ballast water into port tanks. Such expenses have not been evaluated yet, the cost for such a port installation can only be estimated, which would still be estimated,[5] which would still be insufficient to calculate total expenses once such an installation is put in operation.

There is another aspect of such a radical solution to be considered at this point, and which is rather unaffected by the cost. Port tanks have a limited capacity. They will, therefore, after some time, have to be emptied, and where else would the stored ballast water go but into the sea. By that time this water would have to be safe for environment, otherwise the whole procedure would turn to be just a useless expenditure. This means that before pumping out it would have to be sterilized. Whatever the procedure, the effect of it, having in mind the sterilization grade as well as the means and the energy consumed by volumetric unit, would be the same, whether the water is treated ashore or on board. For treatment of the water on board, however, there are no major logistic problems, while for such treatment in port installation these will obviously be rather impressive. Still, there is a dilemma of the cost for more smaller units compared to those for one big unit. This is a major point to be thoroughly analysed with a complex approach to the problem, besides the very procedure.

4. THEORETICAL CONSIDERATIONS OF NONINDIGENOUS SPECIES

From the early beginning of modern oceanography in 19th century the importance of introductions of nonindigenous species in local habitats had been recognized. For the first time this accounted for a positive force of revival of local ecosystems, and alien species were used for explanations and proofs of water movements at larger scales ("zoocurrents")[6]. Recently, man has been recognized to be responsible for worldwide introduction, both accidentally and intentionally, of large number of marine species that subsequently started reproducing populations far away from their native areas.[7]

There are two major hazards related to introduction of nonindigenous species to local environment: ecological and toxic.

Ecological hazard: Some of introduced species coming into an open unexploited ecological niche reproduce enormously and, having no competition, cause damages in the ecological chain and influence the change of large portion of marine biocenoses. In respect to human activities this could cause damages primarily in aquaculture and fisheries[8], but also it could be a nuisance causing economic damages due to rapid colonization of water pipes, filters and other installations as it happened, publicly best known, in the case of introduction of zebra mussel (*Dreissena polymorpha*) in Laurentian Great Lakes[9]. The total costs of damages reached a sum of 5 billion dollars.

Toxic hazard: Introduction of new (unwanted) species into a local environment can cause toxic effects on humans. Some marine species of phytoplankton, especially species from the genus *Gymnodinium, Alexandrium*, are responsible for the human illness, paralytic shellfish poisoning (PSP) and diarrheic shellfish poisoning (DSP)[10]. In addition, some viruses, bacteria and higher organisms (*Cnidaria*) could be responsible for unexplained cases of intoxicated fisherman, bathers and tourists.

Introductions of alien species can occur naturally or accidentally. Natural patterns are mostly harmless and depend upon sea-current regime. Organisms were always transported from one to another ecosystem. Problems start when man opens now way of communication. The best example is opening of Suez Channel that caused changes, primarily, in Levantine fauna and flora, but also in other parts of the Mediterranean Sea[8]. Though purposeful introductions are negligible by the number of cases, accidental introduction are more numerous and cause sometime great damages and represent a health hazard. This could be from acquarious and aquaculture escapes, fouling organisms and ballast water transportation.

Organisms brought in by ships are numerous because their survival in ballast water during the normal transportation time is very high[11]. This is pronounced by the fact that many marine organisms produce cysts that are very resistant to unfavourable environmental conditions. It is a common knowledge that with ballast water at least fourteen established species have been introduced in Australian waters and some of them are already responsible for long term ecological effects[12]. Among the spectacular increase in the last 20 years of accidental species introduction in European coastal waters many are linked with marine transports. It has been noted that more than 23 species are introduced, and many of them were spread out in large geographical areas of the Mediterranean, too[13].

What lessons should we learn? The main conclusion is that we can not predict exactly how some species will behave when introduced into a new environment. Because of this unpredictability every possible precaution should be taken to prevent the introduction of species from one ecosystem to another. In these days of rapid means of transport, especially fast ships, it is easy for marine organisms to be carried across the world either purposely of inadvertently. How to prevent this continual transfer of species from one ecosystem to another is a major problem.

Because of great variety of biological taxa and their very different biological cycles that they show during transportation in ballast water, it seems that the only reasonable measure would be to treat ballast waters on board. Experimentation with different treatment methodologies could be applied in model systems in land laboratories. The species used for experimentation of treatment success should represent those examined from ballast waters, coming from neighbouring regions and from very distant ones, too. Also, experimental species must represent various biological taxa having different life cycles. Nevertheless although those species that might be introduced do not exist in local ecosystem, the experimental one should be from local fauna and flora, but selected from same orders or genera like those of expected alien organisms.

5. APPROACH TO THE TREATMENT OF SHIP'S BALLAST WATERS

As it has been previously stated, the exchange of total quantity of ballast during sea passage, besides presenting a problem to ship's seaworthiness, does not offer a reliable protection from spreading unwanted species into the waters of the port of call. Even repeated washing out of ballast tanks would not suffice - species remain accumulated in the ballast thank sludge making thus such a great effort, danger and costs an insufficient protection.

Special treatment of ballast waters is a more reliable way, it should be carried out aboard during sea passage, or at port, but in this case the water would have to be discharged into special treatment units. Both ways will cause extra complications, especially high expenses. The very technology of water treatment should not differ in principle no matter whether the water is being treated still onboard or in special port installation. The only difference is that the unit that would be placed on board should be adjusted to work in special circumstances - particularly safety-wise, while at the same time the unit ashore would not be subject to so many restrictions, especially concerning its dimensions. Moreover, the unit ashore could use cheaper chemicals or in smaller concentrations but with more energy consumption etc. Therefore, the decision on the ballast waters treatment, particularly on choosing the approach to solution of the problem still on board or off board, should be brought upon a detailed analysis of the technical possibilities for water treatment, keeping in mind the cost that such treatment would incur.

Based on the experience with treatment of drinking water, as well as with conditioning of pool or industrial cooling water, a selection of adequate disinfection system, i.e. sterilization of ballast waters, could be made. But the specific properties which make a significant difference in the very approach to such treatment, should be taken into consideration too. First of all, there are the species the appearance of which in ballast waters proves to be the major problem. The means or the way of treatment should be adjusted to such species, most part of the experience with the disinfection processes being connected to other species, primarily to fresh-water algae or to mushrooms. There has been some experience in treatment of cooling water in circulating cooling systems of thermo-electric power plants condensers which are situated at the coast. However, here we are dealing mostly with protection from sea growth (shells + algae), but in circulation systems, which means in systems with fast flow-through. There are mechanical, physical and chemical systems for water treatment, such as filtration, usage of UV rays or ozone for disinfection, as well as various chemicals, e.g. chlorine and its combinations, hydrogen peroxide, various biocides based on ammonium products etc. At this point, a special attention should be paid that with usage of some chemical and additional damage is avoided resulting from discharge into the waters of port of call of the treated water which still contains a large amount of dangerous chemicals instead of unwanted species. For this reason the installations which would be placed ashore, including the collecting basins and water treatment basins, are seemingly more suitable - it would be easier to control the outflow or perform additional treatment of waters. However, having carefully considered all parameters and problems in ensuring that all ships are liable for discharge of

ballast waters, including the problems of costs and particularly time table for discharging, it seems that the only acceptable solution is installation of ballast water treatment units on board ships. This conclusion exactly is the greatest obstacle - there is the problem of finding space for the unit and eventual chemicals, the problem of its capacity, maintenance, safety, and of course, total expenses.

Numerous research works have been conducted, and many are still in progress. The expenses for treatment of waters on larger ships, over 40.000 DWT, amount to as high as several million U.S. dollars per voyage[14], which is in practice out of question. The problems lies in, for example, quantities of hydrogene peroxide required to obtain 1% solution which is necessary for total elimination of the presence of *Gymnodinium catenatum* in approx. 50.000 tons of ballast water, which makes a cost of about USD 2.000.000. Consequently, usage of enormous quantities of chemicals for disinfection cannot be the right solution; the possibility of usage of other, physical and mechanical, means for water treatment should be carefully considered too, such as filtration, heat treatment, change of pH factors or redox-potential, combination of various chemicals in smaller concentrations etc.

The major problem which keeps showing up in the processes of disinfection of ballast waters is the application of chemical on other species besides those that we wish to be treated, which leads to larger scale of chemicals consumption. Besides, these waters are usually turbid, i.e. the transparency of these waters is rather low, which further eliminates one of the most convenient means = ultraviolet rays. The problem, thus, has to be given a more complex scrutiny, combinations of standard water treatment methods are required, including eventually filtration, settling and addition of chemicals which are efficient even in smaller quantities. This, nevertheless, has to be analysed in relation to the kinds of microorganisms to be expected.

6. CONCLUSION

The dangerous consequences of contamination of coastal waters by nonindigenous sea species spread by ships' ballast waters have caught the attention of the scientists and experts to the full extent. The problem is certainly a global one, but it specifically influences the Mediterranean countries, the Mediterranean being a land-locked small sea with numerous ports. A realizable radical solution is still out of sigh. Any solution would simultaneously bring the consequence of increased investment value of ship and ships' exploitation costs. Therefore, it is not likely that the shipping and shipbuilding industry will eagerly involve themselves into all-consuming research work and overtake the financial burden for finding a final and radical solution. The initiative, it appears, remains exclusively with the governments of coastal countries which are bound to co-operate within IMO and encourage research in their own environments, exchanging between them scientists, equipment, even finances, wherever necessary. At same time it does not necessarily have to be nonindigenous species that are being under research, but primarily indigenous species of same orders which can easily be cultivated in laboratories, and only when some results have been achieved the research work should be expanded and done on nonindigenous species, should it be necessary. Such a concept would definitely cut the effort and the cost of the research works. Besides, each coastal country would be given an opportunity to investigate resilience of its own species to biocidal treatment, and this on its own would still make an important contribution to general efforts in finding a radical solution to this global problem.

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