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METHODS FOR TREATING BALLAST WATER

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Abstract

A vessel sailing with ballast, or partially loaded, must use its ballast tanks, water currently being the most commonly used medium. An estimate of over 10,000 million tonnes of ballast water is transferred in the entire world each year, transporting 4,000 species of aquatic organisms a day. The most immediate way to confront this problem consists in taking measures on board the vessel through the appropriate treatment of ballast water. Facing the importance of this problem, the International Maritime Organization (I.M.O.) has developed the International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWM-2004), at the moment pending approval. In summary, the Convention obliges members to the "what" but not to the "how", recommending the exchange of ballast water by a "reballasting" method, technique which is not 100% effective. For this reason, important research efforts are being carried out throughout the world dedicated to finding a system that is 100% effective. The main methods currently being studied are the mechanical, physical and chemical ones.

Keywords: Vessel, Ballast, Waters, Contamination, Bioinvaders.

INTRODUCTION

As we know, vessels are designed and built to travel through water carrying the biggest possible amount of cargo and/or passengers. Hence, if a vessel travels with ballast or partially loaded, it must fully or partially fill its ballast tanks so that it can sail in good conditions of stability and safety.

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Water is the ideal ballast as it is an almost inexhaustible resource, which can be easily and cheaply obtained and, given that it is a liquid, it adapts to the shape of any tank. This turns it today, into the most commonly used medium for ballast.

It is estimated that over 10,000 million tons of ballast water are transferred worldwide per year. Each vessel has the capacity to transport from several hundred litres up to 100,000 tons of ballast water, according to the dimensions and purpose of the ship.

Ballast water is loaded at the source port to be discharged at the destination port, sometimes thousands of miles away, which has given rise to an involuntary introduction of exotic organisms (bioinvaders) in diverse areas of the world. In some places these organisms have managed to establish themselves, many times displacing the native species, with the consequent danger of causing zoological contamination. The invader species are a direct cause of 39% of all known extinctions as well as for the loss of biodiversity.

An estimate of over 4,000 species of aquatic organisms, in all their life cycles, are transported daily by ballast water in the entire world.

The studies fulfilled indicate that, normally, less than 3% of the species transported are able to establish themselves in the new regions. However, even if only one species is successful, it could seriously damage the entire food chain, the local ecosystem and their economies.

The most immediate way to confront this problem consists in taking measures on board the vessel through the appropriate treatment of ballast water.

Facing the importance of this problem, the International Maritime Organization (I.M.O.) has developed the International Convention for the Control and Management of Ships Ballast Water and Sediments (BWM-2004), on 13th February 2004 in London, with the participation of 74 countries.

This Convention will enter into force twelve months following the date in which it has been ratified by at least 30 states whose combined merchant fleets do not represent less than 35% of the world merchant shipping gross tonnage (GT). It will be applied, with a few exceptions, to all "ships" –be they of whichever type– operating in the aquatic medium, including the submersibles. However, said Convention, in summary, obliges members to the "what" but not to the "how" given that it recommends the exchange of ballast water through the "traditional" or "reballasting" method, technique that is not 100% effective, until an alternative is found and developed that is 100% effective.

Significant research efforts are being carried out by several scientific institutions around the world, determined to find the integral solution to the problem.

The main methods currently considered include:

— The mechanical ones (filtration, reballasting, dilution and cyclonic separation).

— The physical ones (ultraviolet, heat, ultrasonic, and copper and silver ion).

— The chemical ones (disinfectants and biocides).

The chemical treatments, oxidizers of the organic matter such as, for example, chlorine, are discarded for their use since the waters thus treated preserve a certain biocide nature that could subsequently affect other species. In addition, these can give rise to organochlorine compounds of a toxic and carcinogenic nature.

These methods are, therefore, excluded from our study.

METHODS

Mechanical treatment

Filtration

Filtration of ballast water while it is being loaded on board would enable the removal of large particles such as algae, yet it would not prevent microscopic organisms from being loaded. Residues would be left in the zone of ballast intake, but the cost necessary for this infrastructure could be very high.

Reballasting

The most natural method to avoid contamination would be to exchange the ballast water in deep waters, with sounds of 2,000 metres or more. This is considered to be the most efficient method to minimize the risk of transferring unwanted species. The deep water zones of the oceans contain few organisms, which furthermore have few possibilities of surviving when transferred to coastal or fresh waters.

In all cases, it is crucial to avoid surface waters, dredging operation zones and the zones known to have outbreaks of diseases or of plankton.

The main problem existing with reballasting, in terms of avoiding foreign species, is the difficulty to treat the sediments at the bottom of the tanks. If, when emptying a tank, we do not ensure that no sediments are left behind, then the operation is only successful in diminishing the number of species contained in the water, but it still holds the possibility of contaminating the water at destination. It is even well-known that some species proliferate when fresh water is loaded, making the problem worse rather than solving it.

Dilution

According to I.M.O. recommendations, the flow-through dilution method will be conducted in open sea by pumping ballast water into the tank and allowing the water to overflow, pumping at least three times the total volume of the tank. Since the water is introduced and discharged from the tank at the same time, this method does not entail significant risks as regards the stability of the ship, as there will always be enough water in the ballast tanks, even though it does entail the risk that the organisms not be entirely expulsed.

Theoretically, it would be ideal for the environment if at least 95% of the water in a tank were exchanged.

Cyclonic separation method

Ballast water enters the chamber with a circular flow, passing through the venturi-type passage found between the interior chamber and the separation chamber, with a centrifugal action. The centrifuge helical action propels the particles towards the wall and moves them towards the sediments chamber, going through the clean water towards the exit tube. The sediments are continuously purged through the sediments return pipe.

Some simple controls regulate the flow balance between the clean water and the sediments, and measure the ship's draft, as well as the pressure system to ensure an adequate discharge of mud into the sea. The descent of the pressure is minimal and only 5% or less of the ballast water flow is discharged with the mud.

Physics

Ultraviolet radiation

The effect varies according to the type of organism as some are very resistant to UV radiation, yet it can be very efficient when combined with filtration. It has no toxic or harmful secondary effects for the tubes, pumps or linings.

Ultraviolet radiation produces alterations to the DNA chains of the cells. Exposure to this radiation interrupts the normal replication of these chains and the organisms die or are left inactive.

A problem with this system involves the sediments in suspension. The clarity of the water, the period of exposure, and the energy of radiation exposed, are three factors that must be taken into account when using an ultraviolet radiation plant. These factors can be modified to treat large volumes of water fast and safely.

The treatment of ballast water with ultraviolet radiation requires the water flow to go through a treatment chamber in order to proceed to the disinfection of microorganisms. The treatment chamber must be placed in the water supply pump, between the first filtration system and the ballast tanks of the ship. An additional space on board is required for the control and power tapping used by this technology.

In order to compensate the turbidity of the water, a self-retracting system is placed to continuously adjust the radiation as a way to keep the system running and predetermine the level of radiation.

Ballast water heating technique

Temperatures higher than 40ºC during 8 minutes are mortal for practically all organisms. The ability to reach this temperature depends on whether sources of heat

can be made available on board to treat the ballast water during the journey.

The development of heat treatment technologies has enabled their use in the battle against the *zebra mussel.* Heating the water to temperatures of 36º to 38ºC during 6 hours kills the *zebra mussels* and the *Dreissena polymorpha*, which were developed during the end of the 1908s and, subsequently, contributed the bases for using these technologies in the treatment of ballast water.

The Australian Quarantine and Inspection Service (A.Q.I.S.) studied the efficacy of this technology on dinocysts contained in ballast water, coming to the conclusion that the cost of the energy necessary for its effectiveness would be exorbitant. This study has given rise to some alternatives to the direct use of heat in the treatment of ballast water inside the tanks. One of them is to use the residual heat arising from the main floor of the ship, connecting heat exchangers to the main engine. This yields big advantages regarding cost and energy consumption, but requires the reorganization of the entire internal pipe system of the ballast tanks. The latest studies suggest that placing heat exchangers within the ballast tanks themselves would be the best option.

The main factor to take into account regarding the efficacy of the system over possible bioinvaders is the time of exposure and the water temperature inside the tanks.

Ultrasonic

The ultrasonic treatment for liquids utilizes high frequency energy to cause a vibration in the liquid.

When the liquid becomes exposed to these vibrations, a physical phenomenon known as cavitation is produced consisting of the formation, expansion and implosion of microscopic gas bubbles in the liquid. As the ultrasonic energy enters the liquid, the gas bubbles grow until they reach a critical size and implode.

When such cavitation is sufficiently intense, it tears the cell membranes, liberating particles over the solid surface and destroying the organisms by collisions among the particles.

One of the influential parameters when using this technology regards the pressure in the interior of the tanks, the optimum one being 70 PSI.

Electrolytically generated copper and silver ions

Its efficiency rate is considered to be very high, but some organisms can increase their tolerance to the elevated concentrations of copper and silver making their utilization useless. It is also important to consider the environmental consequences of having concentrations of these elements in the water.

Due to these serious inconveniences this system has been discarded for its application.

COMPARING UV, HEAT AND ULTRASONIC TECHNOLOGIES

Each one of these three technologies is capable of treating the ballast water on board the merchant ships efficiently, with or without prefiltration. The first difference among them is the status of the technology applied and the operating conditions necessary to render the disinfection fully successful. As can be seen, the comparison among these technologies as regards their cost, benefits, advantages and disadvantages is complex.

A table is shown below detailing the factors to be taken into account regarding the efficacy of the three technologies of this study:

Table I.

Factor Being Evaluated	Ultravioleta	Heat	Ultrasonic
BIOLOGICAL EFFECTIVENESS	XXX	XXX	XXX
SPACE	XX	XXX	XX
ENERGY	X	XXX	XX
CHANGES	XX	XXX	XX
MAINTENANCE	XXX	XX	XX
SKILLS AND TRAINING	XXX	XX	XXX
TECHNOLOGY DEVELOPMENT	XXX	XX	X
COSTS	XX	XX	XXXX
SAFETY	X	XX	X
Keys: Low: X Moderate: XX High: XXX Very High: XXXX			

Self-elaborated

CONCLUSIONS

1. No method or system in use today, included those commonly used on board the ships, can entirely prevent the zoological contamination by ballast waters.
2. Most of the techniques currently existing designed specifically for treating ship's ballast water, require a change in the structural design of the ship for their installation on board.
3. The IMO has developed and sent a series of voluntary guides that are currently being used. These guides encourage us to minimize the introduction of unwanted aquatic organisms through maritime transport. At present, the best option for minimizing the introduction of bioinvaders is the reballasting and dilution method, technique recommended by the I.M.O.
4. The systems to treat ballast water on board the ships could provide more flexibility at the time of operating them with respect to those placed on land.

   The experiences derived from the treatment plants of residual waters on land provide the working principle of the plants on board the ships. However, the operational capacity associated to the use of the ships, including the high

flow of water and sediments of the ballast pumps, impose additional demands of the systems.

5. The management of ballast waters on a world scale demand, hence, a feasible and economical method that may perhaps be achieved by combining a mechanical treatment with a physical one.

   The most promising technologies to ensure the success of ballast treatment are the physical separation techniques. Filtration could displace all the materials of a given size, at the same time displacing many unwanted organisms from the ballast water. The installation of a pre-filtering system would be of 250 μm. The heat treatment technique is potentially acceptable as an alternative to filtration in the treatment of ballast water.
6. Further research will be necessary to establish, more efficiently, the mortality dose at critical temperatures as well as the time necessary to produce an acceptable mortality in ballast water organisms. An improvement in the equipment design is also essential in order to enhance the implementation of these on board the ships.
7. The ultraviolet radiation and acoustic techniques for treating ballast water have proved to be not entirely effective for treating a wide number of organisms, especially on board the ships.

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MÉTODOS PARA EL TRATAMIENTO DE AGUAS DE LASTRE

Un buque que navega en lastre o parcialmente cargado, debe usar sus tanques de lastre, siendo en la actualidad, el agua el medio más comúnmente utilizado como lastre. Se calcula que en todo el mundo se transfieren más de 10.000 millones de toneladas de agua de lastre cada año transportando 4.000 especies de organismos acuáticos al día. La forma más inmediata de afrontar este problema, consiste en tomar medidas a bordo del buque por medio del apropiado tratamiento del agua de lastre. Ante la importancia de este problema, la Organización Marítima Internacional (OMI) ha desarrollado el Convenio Internacional para el Control y la Gestión del Agua de Lastre y los Sedimentos de los Buques (BWM-2004), estando pendiente de aprobación. Aunque dicho Convenio, en resumen, recomienda el cambio de agua de lastre por el método de "relastrado", técnica que no es efectiva al 100%. Por ello están siendo realizados significativos esfuerzos de investigación, en todo el mundo, para encontrar un sistema efectivo al 100%. Entre los principales métodos considerados actualmente figuran: Los mecánicos (filtrado, relastrado, dilución y separación ciclónica); Los físicos (ultravioleta, calor, ultrasónico, e ión de cobre y plata); Los químicos (desinfectantes y biocidas). Los tratamientos químicos, oxidantes de la materia orgánica, como, por ejemplo, el cloro, están desechados para su uso ya que las aguas así tratadas conservan cierto carácter biocida que podría afectar posteriormente a otras especies. Además de que pueden dar lugar a compuestos organoclorados de carácter tóxico y cancerígeno.

METODOS

Mecánicos

Filtrado, Relastrado, Dilución y Separación Ciclónica

El filtrado del agua de lastre permitiría, a medida que se carga a bordo, eliminar grandes partículas pero no impediría la carga de organismos microscópicos.

El relastrado es el método más natural para evitar la contaminación sería realizar el cambio del agua de lastre en aguas profundas. Este se considera el método más eficaz para minimizar el riesgo de transferir especies no deseadas. El principal problema que tiene el relastrado, en términos de evitar las especies foráneas, es la dificultad de depurar los sedimentos del fondo de los tanques.

Según las recomendaciones de la OMI, el método de dilución por rebose se realizará en alta mar, introduciendo agua con las bombas de lastre y permitiendo que ésta rebose por la cubierta, al menos tres partes del volumen total del tanque. Como

el agua es a la vez introducida y sacada del tanque, este método no conlleva riesgos significativos en cuanto a la estabilidad del buque, aunque esto conlleva el riesgo de que los organismos no sean totalmente expulsados.

Con la separación ciclónica el agua de lastre entra en el interior de la cámara con un flujo circular, atravesando con una acción centrífuga el pasaje tipo venturi que se encuentra entre la cámara interior y la cámara de separación. La acción helicoidal centrífuga propulsa a las partículas hacia la pared y las desplaza hacia la cámara de sedimentos, atravesando el agua limpia hasta el tubo de salida. Los sedimentos son continuamente purgados a través de la tubería de retorno de sedimentos.

Físicas

Radiación Ultravioleta, Calor, Ultrasónica e Iones de cobre y plata

Cada una de estas tecnologías es capaz de tratar el agua de lastre a bordo de los buques comerciales con efectividad, con o sin prefiltrado. La primera diferencia entre ellas es el estatus de la tecnología aplicada y las condiciones de operatividad necesarias para tener éxito en la desinfección.

El efecto varía según el tipo de organismo ya que algunos son muy resistentes a la radiación UV, pero puede ser muy eficaz combinado con el filtrado.

La radiación ultravioleta produce alteraciones en las cadenas de ADN de las células. Una exposición a ésta, interrumpe la replicación normal de estas cadenas y los organismos mueren o quedan inactivos. Un problema de este sistema es el de los sedimentos en suspensión. La claridad del agua, el periodo de exposición, y la energía de radiación expuesta, son tres factores a tener en cuenta a la hora de utilizar una planta de radiación ultravioleta.

Las temperaturas superiores a los 40ºC durante 8 minutos son mortales para prácticamente todos los organismos. El poder alcanzar esta temperatura depende de que se pueda disponer de fuentes de calor a bordo para tratar el agua de lastre. El principal factor a tener en cuenta con vista a la efectividad del sistema es el tiempo de exposición y la temperatura de agua dentro de los tanques.

El tratamiento ultrasónico para líquidos utiliza energía a alta frecuencia para causar una vibración en el líquido. Cuando el líquido se ve expuesto a estas vibraciones se produce el fenómeno físico conocido como cavitación. Conforme la energía ultrasónica entra en el líquido, las burbujas de gas crecen hasta llegar a un tamaño crítico implosionando o cuál rompe las membranas celulares destruyendo los organismos.

Con Iones de cobre y plata generados electrolíticamente se consigue una efectividad muy alta, pero algunos organismos pueden aumentar su tolerancia a las concentraciones elevadas de cobre y plata haciendo inútil su utilización. También hay que valorar las consecuencias ambientales de las concentraciones de estos en el agua.

CONCLUSIONES

Ninguno de los métodos utilizados hoy en día puede prevenir totalmente la contaminación zoológica por las aguas de lastre.

La mayoría de las técnicas diseñadas específicamente para el tratado del agua de lastre en los buques existentes en la actualidad, requieren una modificación del diseño estructural del buque para poder ser instaladas a bordo. Además los sistemas a bordo de los buques para el tratamiento del agua de lastre podrían dar a éstos mayor flexibilidad a la hora de su manejo con respecto a los situados en tierra.

Actualmente, la mejor opción para minimizar esta introducción es el método de relastrado y dilución, que es el recomendado por la IMO.

La gestión de las aguas de lastre requiere, pues, un método factible y económico, que quizá pueda lograrse combinando un tratamiento mecánico con otro físico.

Las tecnologías más prometedoras para el éxito del tratamiento de lastre son las técnicas de separación física. La filtración podría desplazar todos los materiales de un determinado tamaño, a la vez que desplaza muchos organismos indeseables del agua de lastre. La instalación de un sistema de prefiltrado sería de 250 μm. La técnica de tratamiento por calor es potencialmente aceptable como alternativa a la de filtrado en el tratamiento del agua de lastre.