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BIOLOGICAL INVASION OF SEAS AND OCEANS

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ABSTRACT

Biological invasion is the entry of invasive species. Species are considered invasive when they become established in natural habitats, are agents of change, and threaten native biological diversity. Most invasive organisms from other ecosystems are transported around the world in the ballast water of ships.

In this paper for the Journal of Maritime Research, it will be explained to the audience which is the problem with these organisms transported in ballast water of ships, as well as prevent their invasion in other ecosystems and how to choose the right equipment to remove such species.

These invasive species densities are up to several thousand individuals per square meter, which can cause significant damage to hydraulic infrastructure such as hydropower centrals. Also in aquatic ecosystems can cause major disruptions in the food chain or food web dynamics, leading to displace native species. As is well known, the ballast is needed for many functions related to stability, manoeuvrability and propulsion of ships. The problem is that ballast water contains a soup of organisms. These organisms are composed of plankton (microscopic plants and animals), bacteria and viruses. This movement of organisms is now seen as one of the greatest threats to coastal ecosystems in the world. The ballast water organisms have a great environmental and economic impact. If ignored, a marine species could invade a new environment somewhere in the world every nine weeks. To combat this problem there are different solutions, each belonging to one of the largest companies in the marine sector. In the present circumstances of technological development, it is estimated that new generation of ballast water treatment systems, based on physical processes (such as in

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this paper presented) are the safest and most reliable to avoid transporting and unloading of organisms that ballast water contains.

This article concludes that a more suitable to fit onboard systems based on physical removal than those based on chemical, aggregations and storage of chlorine products and / or other chemicals where, if there is any leakage, may pose a risk to the safety of crew and vessel. Among the solutions discussed in this article for the Journal of Maritime Research, have been identified a number of disadvantages in each. The first is the unit cost and maintenance, in the case of using Ultra-Violet or inert gas is very high. The size and footprint are important determinants from the design point, and something that in practice all units showed. The simplicity of design, elimination of chemical additives, the small size and low maintenance costs are the parameters that should determine the adoption of a system or another.

Key words: Naval Engineering, Ballast Water, Biological Invasion.

STATE OF THE ART

One of the issues on the conservation of the marine environment, the most important being given in the naval world, is the elimination of the organisms found in ballast water of ships. Due to the volume of traffic and maritime trade, which has increased in recent decades, the need to assess the risks of invasive species has entered the scene. International data show that the proportion of invasions by biological agents is constantly increasing in a disturbing rate. This problem was first shown at the International Maritime Organization in 1988 and since then the Committees of Environmental Protection and Safety Committee of the International Maritime Organization, together with the technical sub-committees have been addressing this issue, focusing initially on standards and subsequently in developing the new Convention.

The first time that the scientific community recognized signs of introduction of species, was after the emergence of a mass of seaweed from Asia in the North Sea in 1903. It was not until the seventies when scientists began to revise the problem in detail. At the end of the eighties, Canada and Australia were among the first countries experiencing particular problems of unwanted species, bringing their problems to the attention of the Committee on Environmental Protection of the International Maritime Organization.

In 1991 the Committee for Environmental Protection, adopted Resolution 50, some rules to prevent the introduction of unwanted organisms and pathogens from the discharge of Ballast Water and Sediments, while the Conference on Environment and United Nations Development, held in Rio de Janeiro in 1992, recognized that the problem should be assessed as a major international concern.

In November 1993 the IMO Assembly adopted Resolution A.774 (rules to prevent the introduction of unwanted organisms and pathogens from the discharge of Ballast Water and Sediments) based on standards adopted in 1991. The Order enjoined Committees Environmental Protection and Maritime Security to maintain the standards under review with the intention of developing the international application of mandatory laws. In November 1997 the IMO Assembly adopted Resolution A.868, rules for the control and management of ballast water from ships to minimize the transfer of harmful aquatic organisms and pathogens.

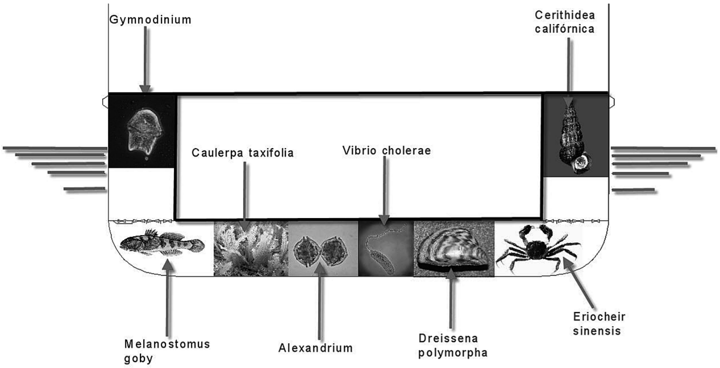

Figure 1: Example of biological organism that could be in ballast tanks.

When the international community was aware that he faced one of the greatest threats of seas and oceans of the world, since the introduction of invasive species into new ecosystems through ballast water had catastrophic effects on 13 February 2004 at the International Maritime Organization adopted the International Convention for the Control and Management of Ships "Ballast Water and Sediments, which requires all ships to implement a Management Plan" Ballast Water and Sediments, adopted by the Maritime Administration governments. The International Maritime Organization has defined in the Convention as follows:

• Ballast Water: water with suspended solids containing, loaded aboard a ship to control trim, list, draft, stability and stresses of the ship.

• Ballast Water Management: mechanical, physical, chemical or biological agents, whether used alone or in combination, to remove, or render harmless harmful aquatic organisms and pathogens present in the ballast water and sediments, or to prevent making or downloading them.

To combat this problem various solutions have emerged, splitting into three groups, depending on the mode chosen for the elimination of organisms:

• The first group would be the removal by mechanical means, to be included within the cyclonic separation and filtration.

• In a second group would be the physical media, such as ultrasound, cavitations, Ultra-Violet, heat, oxygenation and coagulation.

• The third group, chemical additions, electrolysis, ozone, chlorine and chlorine dioxide.

PROBLEMS CAUSED BY THE BALLAST WATER TRANSPORT

Studies in several countries show that many species of bacteria, plants and animals can survive in the ballast water and sediments carried in ships, even after journeys of several weeks. Subsequent discharge of ballast water or sediment into the waters of port States may result in the establishment of unwanted species which may seriously affect the existing ecological balance. If there have found other means of transferring organisms between geographically separated areas of the sea, the discharge of ballast water from ships appears to be one of the most important. Marine ecosystems are suffering from this phenomenon those results in the loss of biodiversity, caused mainly by organisms travelling in ballast water. The spread of disease can also result from the waters of port States receive large quantities of ballast water that contains viruses or bacteria, thus constituting a threat to the lives of human beings, animals and indigenous plants.

The problem with these unwanted elements in the ballast tanks has recently become a matter of considerable importance and, according to the International Maritime Organization is the fourth environmental problem that threatens the world's oceans, as the international traffic vessels has increased markedly in recent decades. And the trend continues.

Current studies estimate more than thirteen thousand million litres of ballast water being carried annually by merchant fleet worldwide, dragging rocks and sediment. Up to seven thousand different species, animals and vegetables, walk every day thousands of miles in the ballast water of ships and, with the unloading, reach a new destination for which will become a potential threat. This problem has already caused serious environmental and socioeconomic damage worldwide and therefore, this traffic has become a major vector for transferring marine organisms.

Unlike oil spill, the introduction of invasive species cannot be filtered or absorbed by the oceans. It could be said that, while in the first case, the impact of an oil spill decreases with time, in the second grows exponentially with it. After entering some species are virtually impossible to remove.

Shipping moves around eighty percent of goods transported annually and exchange three thousand to five billion tons of ballast water each year.

A ship can carry from a few hundred cubic meters to over a hundred thousand tons of ballast water, always depending on the size and type of vessel. This ballast water will be discharged by the vessel in or near the port of destination of the cargo, estimated at seven thousand the number of species transported across the ocean surface.

Most marine species carried in ballast water do not survive the journey: the loading and discharge of water and the atmosphere inside the tanks is generally hostile to the preservation of life of these species. Even for those species that survive the voyage and discharge, the chances of survival under the conditions of new marine environment, including the disappearance and competition with native species, are dramatically reduced.

The introduction of exotic species often result in most cases a dynamic impact on native marine populations and community structure where they are located. The main causes of such impacts are usually:

- Extermination of native species that have no defence system against such predators.
- Competition with other species occupying the same ecological niche and tend to be displaced.
- Alteration of habitat and consequent change in the structure of the communities where they settle.

Genetic pollution and reduction of marine biodiversity.

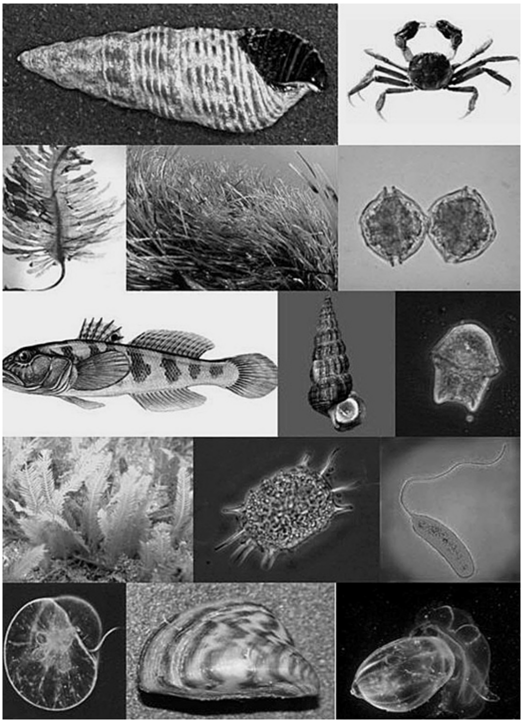

Figure 2: From left to right and from top to bottom: *Batillaria attramentarias*, *Eriocheir sinensis*, *Undaria pinnatífida*, *Poseidonia*, *Alexandrium*, *Melanostomus goby*, *Cerithidea califórnica*, *Gymnodinium*, *Caulerpa taxifolia*, *Odontella sinensis*, *Vibrio cholerae*, *Dinoflagelados*, *Dreissena polymorpha* and *Mnemiopsis* (Pérez and Vidal, 2010).

HOW TO SELECT A SUITABLE TREATMENT SYSTEM

It´s time to choose a treatment system. Several elements have to be analyzed. Assessing the vessel in question, it must be taken into account the following aspects that will be detailed below.

The requirements for ballast water treatment are directly related to the type of vessel. Those who are more dependent are the tankers (Mingorance *et al.*, 2009). For Suezmax, VLCC and ULCC where volume is the fifty-five thousand to ninety-five thousand cubic meters, the flow required will range from three thousand to six thousand cubic meters per hour. In a second step are the bulks, where Handy, Panamax and Capesize, will need to flow between 1300 and the three thousand cubic meters per hour.

The containers will have systems from two hundred fifty to eight hundred cubic meters per hour.

Passenger ships directly depend on the operating area, as its volume of ballast water is quite low.

It is necessary to know the salinity, temperature, concentration of water bodies in order to select the right system.

From the point of view of the treatment system, it could be made another classification. Currently available systems are divided into three groups.

The first would be the removal by mechanical means, to be included within the cyclonic separation and filtration. These methods may have problems of space if the volume of water to treat and / or the level of sediment are high.

In a second group would be the physical media, such as ultrasound, cavitations, Ultra-Violet, heat, oxygenation and coagulation.

The turbidity of water will be one of the parameters to take into account, as it directly affects the effectiveness and system performance.

The third group, chemical elements: electrolysis, ozone, chlorine and chlorine dioxide. Present the problem of disposing of the substances added and / or generated in various chemical reactions.

If the system uses filters, the pressure drop can go from one to four bars of pressure. Taking into account this data for new construction is not critical, but when it has to be adapted to a vessel in operation may lead to redesign pipes and pumps of the ballast system. The space required by these systems varies substantially for the same flow. We must also take into account the necessary piping. In many cases it may be a significant volume. If you are installing as a retrofit (means retrofit, upgrade mechanical equipment) on a vessel in operation shall be feasible for modular installation.

There are systems like the Ultra-Violet with very high fuel consumption, and if their operation is simultaneously to multiple systems of the ship, there may be power supply problems. It can become the main life-cycle cost of the system. Most of the systems will be handled with highly toxic elements. The system must have a safety manual, which will indicate how to properly store and use the additives.

It will be necessary to evaluate the cost of system acquisition, installation, and operational cost. These costs are difficult to assess and will depend on the type of ship and system. To evaluate correctly will be necessary to analyze:

- Power required.
- Cost of additives.
- Staff needed for the proper functioning of the system.
- Cost of maintenance.

RESULTS AND CONCLUSIONS

The globalization of transport (Schrooten *et al.*, 2009), a phenomenon which have raw materials or products manufactured anywhere in the world, involves the invasion of exotic, foreign or invasive species of invertebrates, algae, bacteria and viruses that are transported around the world ballast water of ships. Over a hundred thousand tons of ballast water is transported annually by ships from around the world. It spread species found in habitats that are not theirs. Some cause serious problems for ecosystems. Oceans of the world have begun to be biologically homogenized. The introduction of foreign organisms in ecosystems can lead to very significant losses of biodiversity. Once a species has been introduced, causing tremendous environmental damage, which leads to future spending millionaires to solve the problems that cause this kind. Commercial flow of goods into and out of access to the area of the bays is a vital part in the economies of the regions. However, the ships that bring these goods also discharge ballast water. The International Maritime Organization says that people can get sick or even die for marine pathogens introduced by ballast water. Since 1991 is working to create a mandatory regulation on the management of ballast water. Once the organisms are introduced into the ecosystem can be virtually impossible to eliminate in a short space of time can wreak havoc. The Conference on Environment and Development United Nations in Rio de Janeiro, acknowledged the situation and drive the need to assess appropriate measures, regulated in the discharge of ballast water to prevent the spread of organisms. Shipments of large volumes of sea water from one place to another, has been and is an international problem that has captured the attention of many countries and organizations like the United Nations, through the International Maritime Organization, devotes extensive efforts to control and mitigation of harmful effects they cause or origin in the marine environment where they are discharged. Following this, the technologies involved in the Ballast Water Treatment have received a boost in recent years which has resulted in a steady increase in the number of patents obtained.

When loading, it is necessary to ensure that only clean ballast water is taken, and minimize sediment loaded with water.

When selecting which procedures will be the discharge of ballast water and, therefore, sediments should be taken into account the following reasons:

- Monitoring of ballast water.
- Profitability.
- Safety of crew and vessel.
- Environmentalism.
- Possibility of operation.
- Activity.

Vessels should avoid taking ballast water in shallow areas, in areas where dredging to be conducted, and in areas that are affected by waterborne diseases ballast.

Since January of last year, according to the guidelines of the London Convention, ships of new construction shall comply with the rules of ballast water treatment.

As for water treatment systems for ballast, it must be noted that is considered most suitable for admission to board the next-generation systems than those supported by chemical means, with additions of chlorine products and other chemicals in causing which on a leak could endanger the crew and the ship itself. The simplicity of design, elimination of chemical additives, the small size and low maintenance costs are the parameters that should determine the adoption of a system or another. However, no system is suitable for all types of vessels. The requirements for ballast water treatment are directly related to the type of vessel. Those who are more dependent are the tankers. For Suezmax, VLCC and ULCC where volume is the fifty-five thousand to ninety-five thousand cubic meters, the flow required will range from three thousand to six thousand cubic meters per hour. In a second step are the bulks, where Handy, Panamax and Capesize, will need to flow between 1300 and the three thousand cubic meters per hour. The systems have sufficient container from two hundred fifty-eight hundred cubic meters per hour. Passenger ships directly depend on the operating area, as its volume of ballast water is quite low. Bulk carrier can then use any of the above systems, but from a dead weight greater than one hundred twenty thousand tons of systems using Ultra-Violet or chlorine will generate high volume and will be the hardest to adapt. It is the same in gas and chemical tankers, the limitation of space when the volumes of water to treat are high. And in the case of oil, the recommended system for all types of dead weight will be the addition of chemicals. This is similar to bulk carriers; from a dead weight over two hundred thousand tons of chlorine systems and Ultra-Violet will be too bulky. For container either system would be appropriate. It is necessary to know the salinity, temperature, concentration of water organisms in order to select the right system.

Then thus, in conclusion to this white paper for the Journal of Maritime Research, it is needed an intensive study of many conditions, and follow the development of policies to determine which system is right.

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INVASIÓN BIOLÓGICA DE LOS MARES Y OCÉANOS

ESTADO DEL ARTE

Uno de los temas sobre conservación del medio ambiente marino, a los que más relevancia se les está dando dentro del mundo naval, es el de la eliminación de los organismos que se encuentran en el agua de lastre de los buques.

Debido al volumen de tráfico y comercio marítimo, que se ha visto incrementado en las últimas décadas, la necesidad de evaluar los riesgos de las especias invasoras ha entrado en escena. Datos internacionales muestran que la proporción de invasiones por agentes biológicos está en continuo incremento en un porcentaje inquietante.

Este problema fue manifestado por primera vez ante la *Organización Marítima Internacional* en 1988, y desde entonces los *Comités de Protección al Medio Ambiente y de Seguridad Marítima* de la *Organización Marítima Internacional*, junto con los subcomités técnicos, han estado tratando este asunto, centrándose inicialmente en las normas y posteriormente en el desarrollo del nuevo *Convenio*.

La primera vez que la comunidad científica reconoció signos de introducción de especies extrañas, fue después de la aparición de una masa de Algas de origen asiático en el Mar del Norte en 1903. Pero no fue hasta los años setenta en que los científicos comenzaron a revisar el problema con detalle. Al final de los años ochenta, Canadá y Australia fueron de los primeros países que experimentaron problemas particulares por especies no deseadas, llevando su problemática a la atención del *Comité de Protección del Medio Ambiente* de la *Organización Marítima Internacional*.

En 1991 el *Comité de Protección del Medio Ambiente*, adoptó la *Resolución 50*, unas normas para prevenir la introducción de organismos no deseados y patógenos por la descarga del agua de lastre y sedimentos de los buques; mientras la *Conferencia sobre Medio Ambiente y Desarrollo de las Naciones Unidas*, llevada a cabo en Río de Janeiro en 1992, reconoció que el problema debía valorarse como una preocupación internacional mayor.

En noviembre de 1993, la *Asamblea* de la *Organización Marítima Internacional* adoptó la *Resolución A.774* (normas para prevenir la introducción de organismos no deseados y patógenos por la descarga del agua de lastre y sedimentos de los buques) basada en las normas adoptadas en 1991. La *Resolución* conminó a los *Comités de Protección del Medio Ambiente y Seguridad Marítima* a mantener las normas bajo revisión con la intención de desarrollar la aplicación internacional de las disposiciones legales obligatorias. En Noviembre de 1997, la *Asamblea* de la *Organización*

Marítima Internacional adoptó la *Resolución A.868*, normas para el control y manejo del agua de lastre de los buques para minimizar la transferencia de organismos acuáticos dañinos y patógenos.

Cuando la comunidad internacional fue consciente de que se enfrentaba a una de las amenazas más grandes de mares y océanos del mundo, ya que la introducción de especies invasoras en nuevos ecosistemas a través del agua de lastre tenia efectos catastróficos, el día 13 de Febrero del 2004 en la sede de la *Organización Marítima Internacional* se adoptó el *Convenio Internacional para el Control y Gestión del Agua de Lastre y Sedimentos de los Buques* que exige a todos los buques implantar un *Plan de Gestión de Agua de Lastre y Sedimentos* aprobado por la *Administración Marítima* de los *Gobiernos*. La *Organización Marítima Internacional* ha definido en la *Convención* los siguientes términos:

- Agua de lastre: el agua, con las materias en suspensión que contenga, cargada a bordo de un buque para controlar el asiento, la escora, el calado, la estabilidad y los esfuerzos del buque.
- Gestión del agua de lastre: procedimientos mecánicos, físicos, químicos o biológicos, ya sean utilizados individualmente o en combinación, cuyo fin será extraer, o neutralizar los organismos acuáticos perjudiciales y agentes patógenos existentes en el agua de lastre y los sedimentos, o a evitar la toma o la descarga de los mismos.

Para combatir este problema se han planteado diferentes soluciones, dividiéndose en tres grandes grupos, dependiendo del modo escogido para la eliminación de organismos.

- El primer grupo sería el de eliminación mediante medios mecánicos, dentro del que se incluiría la separación ciclónica y la filtración.
- En un segundo grupo estaría el de medios físicos, tales como *ultrasonidos*, cavitación, *Ultra-Violeta*, calor, desoxigenación y coagulación.
- Como tercer grupo, medios químicos: electrolisis, *Ozono*, cloración y dióxido de cloro.

RESULTADOS Y CONCLUSIONES

La globalización de los transportes, fenómeno por el cual se disponen de las materias primas o productos manufacturados en cualquier parte del planeta, conlleva la invasión de especies exóticas, extranjeras o invasoras de invertebrados, algas, bacterias, virus que son transportadas alrededor del mundo en el agua de lastre de los buques. Más de cien mil toneladas de agua de lastre son transportadas anualmente por los buques de todo el mundo. En ella se encuentran especies que se esparcen en hábitats que no son los suyos. Algunas causan problemas de gravedad para los ecosistemas. Los Océanos del mundo han comenzado a ser biológicamente homogeneizados. La introducción de organismos extraños en los ecosistemas que no les son propios puede conllevar pérdidas de biodiversidad muy significativas. Una vez que una especie se ha introducido, causa un tremendo perjuicio ambiental, lo cual deriva en futuros gastos millonarios para la solución de los problemas que aquella especie causa. El flujo comercial de mercancías dentro y fuera del acceso del área de las bahías es una parte vital en las economías de las regiones. Sin embargo, las naves que traen estas mercancías también descargan el agua de lastre. La *Organización Marítima Internacional* señala que la gente puede enfermar o incluso morir por patógenos marinos introducidos por las aguas de lastre. Desde 1991 está trabajando para crear una regulación obligatoria sobre la gerencia del agua de lastre. Una vez que los organismos estén introducidos en el ecosistema puede ser virtualmente imposible eliminarlos y en un corto espacio de tiempo pueden causar estragos. La *Conferencia sobre Medio Ambiente y Desarrollo de las Naciones Unidas*, en Rio de Janeiro, reconoció la situación e impulso la necesidad de evaluar medidas apropiadas, reglamentadas, en la descarga del agua del lastre para prevenir la extensión de organismos no autóctonos. Los traslados de grandes volúmenes de agua de mar de un lugar a otro, ha sido y es un problema que internacionalmente ha acaparado la atención de numerosos países y organismos como las *Naciones Unidas*, que a través de la *Organización Marítima Internacional*, dedica grandes esfuerzos a su control y mitigación de los efectos perjudiciales que éstas causan u originan en el medio marino donde son vertidas. Como consecuencia de lo anterior, las tecnologías involucradas en el *Tratamiento de Aguas de Lastre* han recibido un fuerte impulso en los últimos años, lo que se ha traducido en un constante incremento en el número de patentes obtenidas.

Al cargar el lastre se debe hacer todo lo posible para comprobar que sólo se toma agua de lastre limpia y reducir al mínimo los sedimentos embarcados con el agua.

A la hora de seleccionar cuales van a ser los procedimientos de descarga del agua de lastre y, por consiguiente, de los sedimentos, se deben tener en cuenta las razones siguientes:

- Vigilancia del agua de lastre.
- Rentabilidad.
- Seguridad de la tripulación y del buque.
- Ecologismo.
- Posibilidad de operación.
- Actividad.

Los buques deben tratar de no tomar agua de lastre en zonas de poco calado, en zonas donde se estén efectuando operaciones de dragado y en zonas que estén afectadas por enfermedades transmisibles por el agua de lastre.

Desde Enero del pasado año, según las *Directrices del Convenio de Londres*, los buques de nueva construcción deberán obedecer la normativa de tratamiento de agua de lastre.

En cuanto a los sistemas de tratamiento del agua de lastre, se tiene que destacar que se considera más apropiada la admisión a bordo de los sistemas de nueva generación, que aquellos sustentados en medios químicos, con aditamentos de productos clorados y otros causantes químicos en los que al producirse algún escape podrían poner en riesgo a la tripulación y al propio buque. La simplicidad de diseño, la eliminación de añadidos químicos, el tamaño reducido y los costes de mantenimiento bajos son los parámetros que deberían de determinar la adopción de un sistema u otro. Sin embargo, ningún sistema es adecuado para todos los tipos de buques. Los requerimientos de tratamiento de agua de lastre están directamente relacionados con el tipo de buque. Los que tienen una mayor dependencia serán los petroleros. Para los *Suezmax*, *VLCC* y *ULCC* donde el volumen va de los cincuenta y cinco mil a los noventa y cinco mil metros cúbicos, el caudal requerido irá de los tres mil a los seis mil metros cúbicos por hora. En un segundo escalón se encuentran los graneleros, donde los *Handy*, *Panamax* y *Capesize*, necesitaran caudales entre los mil trescientos y los tres mil metros cúbicos por hora. Los portacontenedores tendrán suficiente con sistemas entre doscientos cincuenta y ochocientos metros cúbicos por hora. Los buques de pasaje dependerán directamente de la zona que operen, ya que su volumen de agua de lastre es bastante bajo. Luego para graneleros se podrá utilizar cualquiera de los sistemas mencionados, pero a partir de un peso muerto mayor de ciento veinte mil toneladas los sistemas que utilicen *Ultra-Violeta* o generen cloro tendrán un volumen elevado, y serán los más difíciles de adaptar. Sucede lo mismo en gaseros y quimiqueros, la limitación de espacio cuando los volúmenes de agua a tratar son elevados. Y en el caso de petroleros, el sistema recomendado para todo tipo de peso muerto será el de adicción de químicos. Es una situación similar a los graneleros, a partir de un peso muerto mayor de doscientas mil toneladas los sistemas de cloro y *Ultra-Violeta* serán demasiado voluminosos. Para portacontenedores cualquiera de los sistemas sería apto. Es necesario conocer la salinidad, temperatura, concentración de organismos del agua para poder seleccionar el sistema adecuado.

Luego por tanto, como conclusión a este artículo técnico para el *Journal of Maritime Research*, es necesario un estudio intensivo de muchos condicionantes, y seguir la evolución de las directivas para poder determinar qué sistema es el adecuado.