Extending the drydock interval

Hydrex White Paper No. 11
Extending the Interval Between Drydocking to Ten Years - From a hull protection and fouling control point of view, a ten year drydocking interval is perfectly feasible and very economical

Captain Charles Assifuah Master’s Thesis
“Evaluating the potential for the use of Ecospeed antifouling system on the hulls of merchant ships”

Coming soon - A new book
Surface Treated Composites WHITE BOOK - A proven, non-toxic, cost-effective alternative technology for underwater ship hull protection and biofouling control

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Greetings and welcome to the third issue of the Journal of Ship Hull Performance for 2012.

Much has been said and continues to be said on the subject of a longer drydock interval. In days gone by, ships had to drydock every year. Then it became twice in five years with a maximum interval of 36 months. The concept of underwater inspection in lieu of drydocking (UWILD) emerged which made it possible for some ships to go for five years in between drydockings. Now the classification societies have gone further and attempted to permit a seven and a half year interval between drydocking for certain ships under specified conditions.

Due to advances in technology, the inspections, repairs and maintenance which demanded a shorter drydock interval have largely become unnecessary. However, there is one major thorn in the side of extending the drydocking interval to seven and a half years and longer: the underwater hull, its protection and the control of biofouling. When conventional coatings are used such as biocide leaching antifouling systems or silicone fouling release coatings, even a five year interval is more than they can cope with. They become ineffective and accumulate fouling. Since they are not suitable for in-water cleaning due to their soft and toxic nature, the fuel penalty rises and rises and it becomes very expensive to continue to sail. Some operators do carry out in-water cleaning on these coatings despite the great hazard to the environment but this then depletes the coating and it becomes even less effective.

This has been the conundrum in the drive to extend the drydock interval.

Hydrex White Paper No. 11, “Extending the Drydock Interval to Ten Years” offers a tested and proven, viable, environmentally benign alternative which could extend the drydocking interval to ten years or more, at least from the hull protection and biofouling control point of view.

This White Paper is reprinted in full in this issue of the Journal.

Almost by accident we came across an experienced mariner, Captain Charles Assifuah, who went back to university mid career to study for a Master’s degree in International Maritime Studies at Southampton Solent University’s Maritime and Technology Faculty. The title of his thesis is “Evaluation of the potential of Ecospeed Antifouling System,” and it has now been accepted and he has been awarded his MSc. We found out about Charles Assifuah and his studies only when he came to us to ask for information...
about Ecospeed, which of course we provided. Nevertheless we were astounded and delighted to read his final thesis. This is an entirely independent study with no support or suggestion whatever from Hydrex or Ecospeed.

With the permission of the author we have published a somewhat abridged version of the thesis (it was too long to publish in full). It includes a survey of the industry on the subject of underwater hull protection and fouling control and is in general of interest to anyone involved with ships' hulls, their protection, fouling and its effect on fuel consumption, and all related environmental factors.

We are in the process of publishing a Surface Treated Composites White Book which is a recompilation of the subject matter of the Hydrex White Papers and Journal of Ship Hull Performance issues to date, all completely revised and updated.

The White Book will be available first in printed form but electronic versions will also be prepared and made available in due course. This book should be completed in the next month or two. A description of the White Book can be found in this issue of the Journal.

We hope you will find the material in this Journal useful and encourage you to contact us with any feedback, comment or contribution.

Good reading,

Boud Van Rompay
CEO, Hydrex.
Part I. Introduction

Drydocking a ship is a complex, expensive, time-consuming and stressful activity, regarded by most shipowners, operators, officers and crew as a necessary evil.

Time spent in drydock is time spent out of service. It is becoming increasingly difficult to find drydock time available when and where one would like it, particularly for larger vessels. Thus drydocking often takes a vessel well away from its normal operating route.

Many different activities need to be scheduled for accomplishment during a drydocking and these activities may interfere with each other. The weather can be an important factor, particularly since drydocking usually involves painting.

That drydocking is necessary is not in question. In order to keep ships operating safely and efficiently for 25 years or more they have to be taken out of the water periodically for inspection and any needed repair. What is in question is how often this needs to occur. Technology is advancing and conditions which were prevalent twenty or thirty years ago are not necessarily the same today.

Currently the usual interval between mandatory drydocking for most ships is two and a half to five years, depending on type and age of ship. This has been extended to seven and a half for certain ships and under certain conditions.¹

A ten-year drydocking interval is a dream for most shipowners, operators, officers and crew – one which, if it could be attained, would reduce operating expenses and help make the shipping industry more viable.²

¹ DNV “Assessment of Ships and Managers for the Acceptance of Extended Interval Between Bottom Surveys in Drydock,” (January 2011).
The challenge to extending the drydock interval

The main challenges to a seven and a half, ten or even twelve year interval between dockings are hull corrosion protection and fouling control.3 The continual attack by salt or fresh water, cavitation, oxidation, abrasive particles (gravel, lava, sand), ice and occasional solid contact renders these parts of a ship particularly prone to damage, erosion, corrosion and general reduction or weakening of the steel, aluminum or other material from which they are made. Salt water is potentially more damaging than fresh.

The accumulation of biofouling in the form of plant and animal life which naturally adheres to any submerged object, man-made or natural, reduces the hydrodynamic smoothness of the hull and can also damage the protective coating and even the hull itself. This in turn adds friction or drag to the hull and propellers. The result is that more fuel must be burned to achieve the ship’s cruising speed. The rougher the hull and propellers become, the higher the fuel penalty incurred. This not only shows up in higher costs to the operator but also in increased environmental impact through additional noxious gas and particulate matter emissions resulting from the higher fuel consumption. With conventional coatings, the longer the interval between drydocking, the rougher the hull is likely to become until at around the ten year mark it becomes necessary to thoroughly clean the hull of all fouling, blast it back to bare metal and reapply the entire coating system consisting of multiple layers of different types of paint.4

In addition to this fuel penalty, biofouling on the ship’s hull has recently come to be regarded increasingly as a vector for the translocation of invasive, non-indigenous marine species from one environmental zone to another. Precautionary guidelines and regulations have been or are being proposed and enacted to combat this threat. In general terms, the more fouled the hull, the greater the risk of spreading NIS.5

Answering the challenge

The protection of the hull over a ten or even twelve year period can be accomplished with currently available coatings if the appropriate system is used. Certain types of coating become smoother over time as a result of in-water cleaning, rather than rougher as is the case with conventional hull coatings.6

This leaves biofouling control as the perceived largest challenge to an extended drydock interval. The concern is that conventional approaches to hull protection and fouling control will not perform over that period and that the fuel penalty incurred from increased hull roughness would therefore make a drydock interval of ten or twelve years too expensive in terms of added fuel costs, especially with the price of fuel as high as it currently is, and that this will result in increased GHG emissions. Also that the spread of NIS would increase. The challenges are mainly commercial and environmental.

This White Paper presents the case for a system of hull protection and fouling control which can easily last for ten or twelve years without any need for drydocking and can keep the ship’s hull well protected and virtually free of biofouling for that length of time, becoming

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smoother not rougher over time, thus avoiding the fuel penalty and preventing the translocation of NIS.

The type of system described herein is non-toxic and environmentally benign. It is also cost-effective and will, when standardly applied and maintained, result in considerable savings for both owner and operator over the service life of a ship when compared to conventional coating systems.\(^7\)

Since hull protection and fouling control are considered the biggest challenges to a longer interval between mandatory drydocking, this White Paper focuses on these without going into detail on other aspects of mandatory drydocking such as tail shaft removal and other inspections and repairs required by IMO or State regulations and classification societies.

**Part II. Why drydock at all?**

A car has to go to the garage for service or repairs. An airplane goes to the hangar for routine inspection, service, maintenance and repairs. A ship is a highly complex vehicle with a large number of structural, mechanical and other parts which need to be kept in good working order so as to ensure its efficient and safe operation. The number of different systems, motors, watertight structures and all the other units and equipment involved in just keeping the ship afloat and getting safely from point A to point B is considerable. Add to that the internal workings of different types of ships such as the hotel facilities of a cruise ship, the weapons and communications systems of a warship, the tank and pumping equipment of a VLCC and you can see that any ship would need to have a pit stop from time to time in order to keep it running at optimum.

Of course, many conversion, maintenance and repair jobs can be done with the ship afloat and even operating normally. And they are. Development of advanced

underwater repair and maintenance procedures have made it possible for many of these activities that used to require drydocking to be done with the ship still afloat.8 Straightening bent propeller blades, repairing leaking or damaged stern tube seals, removing and replacing bow thrusters, welding a damaged hull, repairing rudder cavitation damage, as well as hull cleaning and propeller polishing or cleaning can all be done without requiring the ship to drydock. This of course avoids many of the headaches connected with drydocking and can save a great deal of expense.

There are still a few maintenance and repair operations which cannot be done with the ship still afloat and therefore require drydocking. One such operation is pulling the tail shaft for inspection and maintenance/repair/replacement. Modern ship design has made it possible to extend the period for this, however.

Increasingly there is pressure on ship operators to take steps to eliminate or reduce the spread of invasive aquatic species via ship hull fouling.910 Before too long, vessels arriving at their destination with a heavily fouled hull may find themselves required to drydock their ship to have the fouling removed before they enter State waters or a port, or simply be turned away.

Above all there is underwater hull painting which can only be done in drydock. This includes repair of the coating system, renewing a biocidal antifouling system, reapplying a fouling release coating and all the various painting operations which conventional hull coating systems seem to demand.

**IMO, State and classification society required drydocking**

Also, as with cars, trucks, airplanes, trains and other vehicles, over time a number of laws and rules have been enacted which require, usually for the safety of crew and passengers but also for the protection of the environment, that certain routine inspections or surveys of ships be carried out in order for the vessel to continue to operate legally.

In addition to this, insurance companies have developed over time methods of classifying ships in terms of their risk. In order for the insurance companies to provide insurance, they needed to know how much of a risk a ship was. This led to a classification system using letters and numbers. From this have developed a number of classification societies who have the expertise required to carry out this inspection and classification and to verify a ship’s compliance to international (IMO) and individual States’ laws and regulations.11

These classification societies have also developed systems of rules of their own and their services are employed by shipowners to verify and certify that their ships meet the various requirements that they are supposed to. The classification societies become involved at the planning stages of a new ship, survey the ship during construction, certify it upon completion and then carry out routine surveys and inspections periodically while the ship is in service to make sure that it remains “in class.” In the case of an accident occurring, the applicable classification society inspects the damage and determines the seaworthiness of the vessel and what repairs must be carried out either in situ or in drydock or both to get the vessel back up to the class requirements.12

The IMo, individual States and the classification societies require that ships undergo surveys or inspections at regular intervals, some of which must be carried out in drydock so that the underwater parts of the ship can be inspected, the integrity of the hull checked and a number of other examinations and inspections performed which are difficult to carry out with the vessel still afloat. Such surveys require periodic drydocking, although in certain cases some of these

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inspections can be replaced by Underwater Inspection In Lieu of Drydocking (UWILD). The frequency of such drydocking depends on the type of ship (e.g. passenger or cargo), the age of the ship and a number of other factors.

For example, following is a quote from Merchant Marine Circular No. 204 from the Panama Maritime Authority, under whose flag a healthy proportion of the world fleet sails, based on the IMO’s Safety of Life at Sea (SOLAS) convention 74 amended. This circular concerns “Outside Ship’s Bottom inspection and Dry docking Interface Periods for Panamanian Flagged Vessels.”

3. The Panama Maritime Authority notifies to all Ship Owners/Operators, Legal Representatives and Recognized Organizations that the outside ship’s bottom inspection periods for the Panamanian Flag registered ships, are as follows:

3.1. Cargo ships of 500 Gross Tonnage and above:

3.1.1 In accordance with the International Convention for the Safety of Life at Sea 74, as amended (SOLAS 74) Regulation I/10(a)(v), all cargo ships in possession of a Cargo Ship Safety Construction Certificate require a minimum of two inspections of the outside ship’s bottom during any five year period of validity of the relevant certificate.

3.1.2 Cargo ships of 500 Gross Tonnage and above shall be subject to a minimum of two inspections of the outside ship’s bottom, during the

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3.1.3 Ship Safety Construction Certificate. One such inspection shall be carried out on or after the fourth annual survey in conjunction with the renewal of the Cargo Ship Safety Construction Certificate. Where the Cargo Ship Safety Construction Certificate has been extended under SOLAS as amended, regulation I/14(e) or (f), this five-year period may be extended to coincide with the validity of the certificate. In all cases the interval between any two such inspections should not exceed 36 months.

No extension will be permitted on the period of 36 months between any two such inspections.

3.1.4 The inspection of the outside of the ship’s bottom and the survey of related items, should include an inspection to ensure that they are in a satisfactory condition and fit for the service for which the ship is intended.

3.1.5 Inspections of the outside of the ship’s bottom should normally be carried out with the ship in a dry dock. However, consideration may be given to inspections of the ship’s bottom not conducted in conjunction with the renewal survey to be carried out with the ship afloat in case of ships others than bulk carriers and oil tankers less than 15 years of age.

3.1.6 Inspections with the ship afloat should only be carried out when the conditions are satisfactory and the proper equipment and suitably trained staff is available.

Prior authorization from this Administration to be granted by the Panama Seguma Office is necessary to complete an alternate inspection with the ship afloat.

3.1.7 Where an inspection of the outside of the ship’s bottom is not completed within the periods specified above. To restore the validity of the Certificate should be carrying out the appropriate survey which, in such circumstances, should consist of the requirements of the survey that was not carried out, but its thoroughness and stringency should have regard to the period of time beyond the survey due date. The Administration will investigate why the survey was not carried out within its lapse of time and consider further action, if necessary.

3.2. Cargo ships of less than 500 Gross Tonnage:

3.2.1 Irrespective of the navigation area this group of ships shall be subject to a minimum of two outside ship’s bottom inspections during any five year period following the same instructions applicable to Cargo ships of 500 Gross Tonnage and above. The required inspections of the ship’s bottom for the renewal surveys of the Cargo Ship Safety Certificate under the provisions of the Decree 45 of the Republic of Panama could be carried out with the ship afloat.

Prior authorization from this Administration to be granted by the Panama Segumar Office is necessary to complete an alternate inspection with the ship afloat.

3.3. Passenger ships:

3.3.1 Irrespective of the navigation area passenger ships shall be subject to two outside ship’s bottom inspection with the ship in a dry dock in a five (5) year period (60 months). In all cases the period of time between these two bottom inspections in
dry dock shall not exceed 36 months. The remaining bottom surveys of these ships can be carried out as underwater surveys. Consecutive underwater surveys will be allowed for these ships.

3.3.2 The required inspections of the ship’s bottom for the renewal surveys of the Passenger Ship Safety Certificate can be carried out with the ship afloat.

3.3.3 Inspections with the ship afloat should only be carried out when the conditions are satisfactory and the proper equipment and suitably trained staff is available, and previous authorization has been issued by this Administration through the Panama Segumar Office.

3.3.4 Operators of Panamanian Passenger ships of less than 15 years of age will make the request for underwater survey in lieu of dry dock directly to the ship’s Recognized Organization. The Recognized Organization will evaluate the request and, after considering all relevant information, make a recommendation to this office. If the request is approved, the underwater examinations will be performed according to the Recognized Organization procedures, by personnel of companies certified by the Recognized Organization to do these surveys and to the satisfaction of the attending surveyor.15

This excerpt form the Panama Maritime Authority Circular is used only as an example of prevailing regulations regarding ship bottom surveys and drydocking.

Full details of the regulations regarding drydocking can be found online and in various documents issued by the IMO, by States and by the classification societies. Some of them are universal in scope, being governed by international law, while others vary from State to State and classification society to classification society.16

Some ships are required to drydock twice in any five year period, the longest interval being 36 months. Others may waive one of those drydockings and have an underwater inspection instead. More recently the classification societies have made it possible for many ships less than 15 years old to extend the interval to seven and a half years before mandatory drydocking.17

**Drydocking and paint**

This then brings us to the biggest single item which causes a ship to go to drydock voluntarily: PAINT (or perhaps one should say, PAINT and BIOFOULING, since it is really a combination of the two).

The major reason for voluntary drydocking of a ship is that the hull needs to be cleaned of biofouling and the paint coating repaired or replaced.

The major reason for voluntary drydocking of a ship is that the hull needs to be cleaned of biofouling and the paint coating repaired or replaced.

Although there are claims that antifouling paint or fouling release coatings will keep a ship fouling free for five years or longer, ship operators’ experience on the whole with the post-TBT coating systems varies considerably from these claims. Instead, a few months or a year after a ship has launched with a new or replenished or patched paint coating she is already experiencing noticeable drag due to fouling, the fuel efficiency is dwindling and the operator finds himself having to spend a great deal more money on fuel compared to initial sea trials. The longer a conventional coating system goes without full reblasting and recoating, the rougher the hull becomes and the higher the fuel penalty climbs, reaching as much as 25-40% after ten years or so just as a result of hull coating degradation, not even factoring in biofouling.18

When the fuel efficiency drop becomes noticeable, the operator has a few options:

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1. Ignore the fouling, spend a great deal more money on fuel to overcome the increased drag, emit a higher volume of GHG and risk the spread of non-indigenous invasive species
2. Have the hull cleaned in the water
3. Drydock the ship and have the hull cleaned and the coating repaired/patched/renewed or replaced entirely.

The problem with option 1 is obvious. Much higher fuel costs raise the overall cost of shipping. The spread of invasive species may not be a concern to the ship operator but will become so as States and the IMO impose regulations to prevent such a spread. The same applies to GHG emissions which are obviously higher as more fuel is consumed in getting the ship from A to B and will soon become the subject of regulation.

With conventional hull coatings, either biocidal or fouling release systems, option 2 (much cheaper than option 3), presents new problems. With biocidal antifouling coatings, even light in-water cleaning creates a pulse discharge of biocides which is hazardous to the environment both in terms of water pollution and sediment contamination. Trying to clean a biocidal coating will also deplete the coating, reducing its effective life. Because these coatings are relatively soft, the cleaning roughens the hull surface itself and thus defeats the economic purpose of the cleaning – to improve fuel efficiency.19

In the case of fouling release coatings, again, unless the cleaning is very light and there is only a biofilm present, the coating will be damaged by the cleaning and will then be ineffective or less effective in preventing fouling from attaching or in releasing it easily.

Unless a ship operator commits to hull grooming or very regular cleaning which does not permit more than a slime layer to accumulate before the hull is cleaned, then a fuel penalty varying between about 7% to 40% or considerably more in the case of heavy calcareous fouling will accrue.20

The alternative will be to drydock every year or two to have the hull properly cleaned and the coating system repaired, replenished or replaced. This may be good for paint sales but is not economical for ship operators.

This section on paint applies specifically to biocidal antifouling paint systems and “non-stick” fouling release paint systems. It does not apply to certain hard Surface Treated Composites (STCs) which can be effectively

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cleaned in the water without damage to coating or environment.

**Section summary**
Ships do need to drydock periodically for certain repair and maintenance operations which can only be done with the ship out of the water. In fact, these activities are rather few and most needed repair and maintenance can be carried out with the ship afloat.

There are international, State and classification society regulations which require ships to drydock periodically for inspection and certificate renewal. The period varies from twice every five years to once every seven and a half years. Bottom surveys can also be carried out underwater under certain circumstances.

The main reason a ship has to voluntarily go to drydock is to remove accumulated biofouling and repair or replace coating systems. This applies to biocidal antifouling and fouling release coating systems. The longer a vessel operates without reblasting the hull and reapplying the coating system, the rougher the hull becomes and the higher the fuel penalty incurred.

If hull fouling is allowed to accumulate beyond a slime layer, then the threat of spreading invasive aquatic species increases and steps need to be taken to prevent this spread. This may require drydocking the ship.

The need to drydock to clean off biofouling and repair or replace the coating system is not applicable to Surface Treated Composites (STCs) since these are expected to last the life of the ship and can be cleaned in the water without negative effects to coating or environment. In the case of NIS, the ship can be fully cleaned before sailing and will thus arrive at the destination port without macrofouling.

**Part III. Drydocking issues**
There are a number of issues associated with drydocking which contribute to its reputation as a necessary evil. Some of the main ones are listed here, not particularly in order of magnitude.

1. Having to go to drydock at all
2. Finding a convenient drydock which is capable of doing any work required to a high standard and which is available for any given vessel when it is time for that vessel to go to drydock
3. Interrupting normal ship operations for what can be a considerable length of time in order to get the ship into drydock, the work done and the ship undocked again
4. The extensive and costly preparations which may be needed prior to drydocking, depending on the type of ship (a naval vessel, for example, may have to unload all of its ammunition before entering drydock, cargo vessels and tankers discharge their loads and the tanks must be clean and gas free, etc.)
5. The cost of the drydocking itself including the drydocking fees, outside contractors and all the various specialists required to carry out the work
6. The possibility of damage occurring to the ship in drydock or as a result of docking or undocking, hazards to crew and drydock employees and other dangers involved.

It is worth having a look at these points so that one can see clearly the advantages of drydocking less frequently and for shorter periods of time.

1. **Having to go to drydock at all**
The reasons for drydocking have been covered in the previous part of the White Paper. There is no complete avoidance of drydocking. However, any factors which can make those visits as infrequent as possible are welcomed by all shipowners and operators.
Ships in drydock.
2. Finding a convenient drydock which is capable of doing any work required to a high standard and which is available for any given vessel when it is time for that vessel to go to drydock

Ships often follow set routes. For example, a cruise ship may routinely cruise the West Coast of the United States and Canada, visiting Alaska and back to Long Beach. Lack of a suitable drydock or shipyard on that route may force the ship to go through the Panama Canal to a US East Coast or Gulf Coast facility. This adds unwelcome extra time and expense to the procedure of drydocking. However, it may be necessary due to conflicting schedules, lack of the right size drydock or necessary services or low quality of workmanship or a number of other factors.

The larger the ship, the fewer drydocks there are that can service it and the further out of the way it may have to go for drydocking.

Whether the ship’s route is set or not, it is more the exception than the rule that there will be the necessary drydock facility available just when and where it is most convenient.

3. Interrupting normal ship operations for what can be a considerable amount of time in order to get the ship into drydock, the work done and the ship undocked again

What is a ship’s daily revenue? For the owner, what is the daily time charter fee? For the operator, how much lost revenue and profit does an inactive day for a ship represent? Even military ships have a value associated with being in operation or potential operation, whether or not their country is at war.

Not having a ship available for a number of days or weeks or even longer can be extremely costly to the owner and/or operator of that ship or to the taxpayer.

This is a fixed, calculable sum for any given ship. If it spends two weeks in drydock, it loses twice as much revenue as it would if it undocked after one week. If a ship drydocks once in ten years it saves half of what it would spend if it has to drydock twice in the same period of time.

If drydocking is at all avoidable, then the owner or operator or both benefit financially by being able to keep the ship working and earning its daily income.

4. The extensive and costly preparations which may be needed prior to drydocking, depending on type of ship (a naval vessel, for example, may have to unload all of its ammunition before entering drydock, cargo vessels and tankers discharge their loads, etc.)

One may think of drydocking as simply sailing to the drydock, having the ship towed in and then emptying out the dock so that the ship is ready for service, repair, maintenance. However, extensive and costly preparation is required to get a ship ready for drydock, varying in extent by type of ship, but much more in all cases than one might imagine.

Cargo vessels of any kind need to have the cargo discharged ahead of time. Tankers need to have their tanks empty, clean and gas free. That means finding a suitable place to unload. In the case of cargo that needs to be delivered in Singapore before the vessel can drydock in Shanghai, and where the next port of call is Colombo, one can see that the drydocking will be very inconvenient and expensive. Passenger vessels need to discharge their passengers. Warships must unload all their ammunition and any potential security threats from having the ship in drydock would need to be taken care of.

Living arrangements need to be made for the crew while the ship is in drydock. Electric power, water, sewage and a hundred and one other things need to be prepared for so that the ship can be drydocked.

These preparations involve time, money and stress.
for the officers, crew, operator and owner of the ship.

5. The cost of the drydocking itself

Drydocking fees vary greatly from one shipyard to another. Some examples will give an idea of orders of magnitude. Quotes for drydocking a Panamax bulk carrier in three different shipyards in China ranged from $570,000 to $647,000 for 20 days with all repairs. A 12-day stay in drydock for the ship ended up costing $238,000 after considerable expert negotiation.21

The actual cost of drydocking can also greatly exceed initial estimates as new repairs are found to be needed, the weather holds up work (particularly exterior painting) and for a number of other reasons. It is not at all unusual for the owner to pay a bill which is much higher than the original quote. In any event, even the best and smoothest of drydockings are still very costly.

... even the best and smoothest of drydockings are still very costly.

6. The possibility of damage occurring to the ship in drydock or as a result of docking or undocking, hazards to crew and drydock employees and other dangers involved

This point does not require much amplification. Ships are designed to live in the water, not on dry land. All of their dynamics are based on being afloat. Taking a ship out of the water and supporting it on wooden blocks is a tricky and hazardous operation and one which preferably occurs as infrequently as possible.

These are some of the general issues connected with any drydocking. They are enough to encourage shipowners and operators to welcome anything which can make drydocking as infrequent an event as possible in their lives.

Paint specific issues

There are, however, other issues connected with current practices regarding underwater hull coating and their relationship with drydocking.

1. Conventional biocidal and fouling release coatings do not last very long and are very much subject to degradation. They need to be repaired and replaced.22 The tendency is to spot blast and patch these coatings for the first two or three drydockings and then eventually, when the coating is unbearably rough, to blast the hull back to bare steel and replace the whole system, perhaps after ten or twelve years. The patching and repair done in drydock contributes to the coating degradation and the fuel penalty steadily increases over the ten or twelve year period in between complete replacement of the entire coating system.

2. The frequent repair and replacement of toxic coatings is harmful to the environment. The toxic waste that comes off a hull coated with a biocidal coating tends to make its way back into the local marine environment, pollutes the water and contaminates the sediment. The ultra high concentrations of heavy metals and various toxic substances around any shipyard testify to this. Frequent reapplication of hull coatings also results in high VOC emission. The regular repair and replacement of hull coatings in drydock constitutes an environmental hazard.

The regular repair and replacement of hull coatings in drydock constitutes an environmental hazard.

For these reasons, a long-lasting Surface Treated Coating is a better choice. It is applied once and lasts the life of the hull with only very minor touch-ups required in drydock (typically less than 1% of the wetted surface area, which adds up to a few cans of paint) and is environmentally benign. It can be cleaned repeatedly in the water without harm to coating or environment.

And it becomes smoother with each in-water cleaning, avoiding the paint degradation associated with other types of coatings.

21 Idwal Marine Services "DRY-DOCK MANAGEMENT" (2012).
Part IV.
How to avoid hull paint driven drydocking

How to avoid having to go to drydock frequently in order to repair or replace damaged, worn or depleted underwater hull coating systems is so simple it seems to have escaped the shipping industry’s broad notice:

1. At newbuild or at next drydocking a long-lasting, extremely durable and tough non-biocidal, non-leaching underwater hull coating is applied after the hull has been blasted to Sa 2.5.

2. Routine in-water hull cleaning is thereafter used to keep the hull free of any macro-fouling and most microfouling.

This system works on the basis of replacing chemicals with good old-fashioned elbow grease and employs more people – good for local economies. Since the cost of this system is overshadowed by the savings from a reduced fuel penalty and from avoiding repeated applications, it is economically sound for shipowner and operator.

The answer is really that simple. But since it may appear to be too simple, further explanation is provided.

The most durable, most resilient, toughest, best protecting underwater hull coatings are glassflake based surface treated composites (STC). They have been proven to stay on the hull in the harshest of conditions (2.5 meter ice mixed with volcanic lava in Antarctica, for example). Applied to rudders they even prevent cavitation damage to the steel. They work well on steel, aluminum and glass-reinforced plastic hulls. In order for them to adhere properly they require grit blasting of the hull to Sa 2.5. A good profile is key to their success. Once properly applied they are guaranteed to last for ten years intact and are expected to last the full service life of the hull – 25 years – requiring no more than very minor touch-ups during routine dry-docking. The STC is applied to the entire wetted surface area, including all niche areas. The only exception is the propellers which at this time are best left uncoated and cleaned regularly.23

The routine cleaning of the underwater hull needs to be tailored to each vessel. Warmer waters and longer times in port or at anchor mean faster and heavier fouling and therefore more frequent cleaning. Colder waters, shorter times in port, operating in ice and similar factors usually mean that the ship will foul less and will require more infrequent cleaning.

From an economic point of view, with cleaning

organized efficiently so that even the largest ships can be fully cleaned including all niche areas in 6-12 hours, one can afford to clean once every month or two and still save a great deal of money with this system of hull protection, compared to conventional systems. (Underwater cleaning is described in great detail in Hydrex White Paper No. 5 “Underwater ship hull cleaning: cost-effective, non-toxic fouling control,” published in July 2011.)

When one takes into account the total cost of ownership of the ship, the savings really mount up: fuel savings from reduced drag; savings on costs of drydocking and repairing or replacing the hull coating system; saving on off-hire expenses while ships are in drydock for repainting. Those are some of the financial savings. There are also major environmental savings. The absence of toxic chemicals emitted into the water column and contaminating the sediment is only one part of it. The improved fuel efficiency from a smooth hull means lower CO2 and other air emissions. Not having to blast off and replace toxic paint coatings helps eliminate pollution around shipyards. Not having to repaint regularly means reduced VOCs. Keeping a hull and niche areas clean eliminates the spread of invasive aquatic species via ship hull fouling.

The infrastructure for in-water cleaning on an industrial scale is in its infancy. But there was no network of fuel stations or even of highways when the internal combustion engine driven automobile was introduced but this did not prevent it coming into wide-spread use. The increase in demand for internet services is leading to greater and greater availability of wi-fi networks. Thus as the demand for fast, efficient and economical in-water cleaning grows, so will the supply. The infrastructure is easy to establish. It is not a major obstacle to overcome.

The restrictions placed by certain ports and States on in-water cleaning were designed to prevent water and sediment contamination by heavy metals and biocides from antifouling paint and to prevent the distribution of invasive aquatic species by macrofouling from badly fouled ship hulls. They are not needed in the case of non-toxic coatings and the regular cleaning of ships’ hulls where only a slime layer or weed or grass are present or any macrofouling has been picked up in the local area. Many ports and States permit in-water cleaning of non-toxic hull coatings where the fouling is limited to a biofilm and/or where the fouling has been picked up locally.24

**Part V. Conclusions**

There are many reasons for ships to extend the drydock interval to seven and a half, ten or even more years. An extended drydock interval would help reduce the cost of shipping and be of great benefit to the environment.

The main barrier to this drydocking interval extension is fouling control. An associated but lesser barrier is hull corrosion protection. It should probably be stated as underwater hull protection and fouling control as these are two sides of the same coin.

Current practices consist mainly of the use of biocidal antifouling coatings with a much smaller reliance on fouling release coatings. For a number of reasons, neither of these types of coatings is suitable for in-water cleaning. These types of coatings will not control fouling sufficiently over an extended period and need to be drydocked fairly frequently for coating replenishment, repair or replacement or an excessive fuel penalty will accrue.

One possible answer is very frequent “hull grooming” of fouling release coatings if it can be demonstrated that this does not pose a water pollution problem. However, these types of coatings tend to be fragile, suffer from mechanical damage and then cease to work, thus requiring a trip to drydock to repair the coating. They also have the liability of fouling more

seriously if the ship is laid up, and then in-water cleaning by the usual mechanical brush approach will definitely damage the coating.

The obvious answer is the application of a very tough, long-lasting but chemically inert, nontoxic surface treated composite. This type of coating will last more than ten years without need of replacement or major repair and is expected to continue to provide full hull protection for the life of the ship. It is not biocidal nor “non-stick” but requires routine in-water cleaning to keep it free of fouling. This cleaning is easy and cost-effective in terms of fuel savings and is environmentally safe.

Proper preparation of the hull and correct application of an STC coupled with a regimen of in-water cleaning of the hull, the niche areas and the propeller are an economically viable means of extending the drydocking period to seven and a half, ten or even more years while preserving the integrity of the hull and keeping the ship fouling free.

In addition to the economic benefits, this system has many environmental benefits which include the elimination of pollution of the water column and contamination of sediment, the reduction of CO2 and other air emissions, the reduction of VOCs and the elimination of the spread of invasive aquatic species via hull fouling.
In 2012, Captain Charles Assifuah studying for his Master’s degree, MSc International Maritime Studies, Shipping, Ports and Environment, under the supervision of Dr. Anthony Gallagher, Senior Lecturer and MSc Programme Leader, International Maritime Studies, and Dr. Paul Wright, Academic Leader, University Teaching and Learning Fellow, at the School of Engineering, Construction and Maritime Studies, at the Maritime and Technology Faculty of Southampton Solent University in Southampton, UK, submitted in part fulfilment of the Degree of Master of Science in International Maritime Studies–Shipping, Ports and Environment at Southampton Solent University in March 2012 a thesis entitled “Evaluation of the potential of Ecospeed Antifouling.”

Captain Charles Assifuah is an experienced sea officer and Master Mariner (Unlimited) Class 1 Deck Watchkeeping Officer with certificates of competency from the Singapore Maritime Academy, Singapore, and MCA, UK. He has served as an officer at sea for nine years on a variety of ships including container vessels and general cargo ships and as a harbor pilot in Singapore.

Captain Assifuah explained his reasons for choosing this particular subject matter for his Master’s thesis:

“REASON FOR CHOOSING ECOSPEED ANTI-FOULING SYSTEM AND EVALUATING ITS POTENTIAL AS A GREENER COATING FOR CLEANER SEAS.

“Coming from a shipping background, I knew how much a ship’s hull performance was essential if any ship owner or operator was to achieve major savings on fuel. Savings in fuel are mainly dictated by the amount of fouling on a ship’s hull at any point in time and as such antifouling systems of all sorts and kinds are applied to the hulls of ships when they are newly built and periodically during drydocking to alleviate or reduce this inevitable menace to the barest minimum.

“However the vast number of antifouling systems in use today have detrimental effect on the marine environment by virtue of the biocides which they employ. In the process of time, these biocides leach into the seas and cause detrimental effects to the marine organisms as they enter the food chain through biomagnification and bioaccumulation. As I kept researching for a suitable antifouling system that will protect the ship’s hull from...
marine biofouling and at the same be non-toxic to the marine environment, I came across Ecospeed antifouling system.

“Ecospeed being a hard, biocide free coating which can be cleaned in the water without damaging the coating but rather improving its texture and making it more hydrodynamically smooth, proved to be the way forward. It also helps in tackling the issue of transfer of NIS when the hull is periodically cleaned using state-of-the-art equipment that was manufactured in conjunction with this system. This is why I decided on this research project to reach out to shipowners and operators to inform them about Ecospeed and to find out from them whether they are willing to use this system given its tremendous environmental and economic benefits.”

It should be noted that this thesis was carried out without any solicitation, encouragement or funding from Ecospeed or Hydrex beyond providing information as requested. The study is therefore entirely independent and unbiased.

Due to the length of the thesis, excerpts have been published here with full permission and approval of the author.
Abstract

The ban on the use of tributyltin (TBT) and legislative pressures suggest that there is the need for a different, environmentally friendly antifouling system. The hulls of merchant ships and even other marine structures including platforms and jetties also experience these harsh biofouling conditions because of the environment they work in. There are currently a number of ways for preventing or reducing the growth of these organisms on the hulls and most of them usually come in the form of coatings (paints). Biofouling adversely affects the hydrodynamics of the ship’s hull causing an increase in the power required for propelling the ship which leads to a higher consumption of fuel. The effect of different seawater conditions on chemically active paints is highlighted and the booster biocides commonly used in replacement of TBT containing compounds are elaborated. It has to be emphasized that the side effects and these biocides’ impacts on the environment are not fully realised or understood. The latest technologies currently available owing to a much better understanding of biofouling and the biological principles involved are also stressed. Considering the factors that contribute to biofouling, it is imperative that very effective means whereby the organisms that attach themselves to the hulls are eliminated or prevented from thriving on the hulls without the use of chemicals, will be the most desired option. Because of IMO’s ban on the use of TBT, any alternative antifouling system that is suggested needs to be environmentally friendly and also have a long life span. Reviews of the development of antifouling systems for preventing marine biological fouling, and antifouling coatings’ timeline are also mentioned. The two main antifouling systems presently used widely are the Tin-free self-polishing copolymer (SPC) and foul release (FR) technologies, however many other options have been suggested. Modern approaches to environmentally effective antifouling systems and their performance are highlighted and this dissertation seeks to evaluate the potential for the use of Ecospeed antifouling system on the hulls of merchant ships and also make a comparative analysis with the main existing options.

List of Acronyms and Abbreviations

A/F Antifouling
AFS Antifouling System
CO2 Carbon dioxide
FR Foul Release
FRC Foul Release Coatings
GHG Greenhouse Gases
ICMCF International Congress on Marine Corrosion and Fouling
IMO International Maritime Organization
MEPC Marine Environmental Protection Committee
NIS Non Indigenous Species
PARCOM Paris Commission
RPM Revolutions Per Minute
SP Self Polishing
SPC Self Polishing Copolymer
TBT Tributyltin
TEU Twenty Equivalent Units
USD United States Dollar
VOC Volatile Organic Compounds
Wt Weight

List of symbols

C Carbon
cm Centimeter
g gram
Kts Knots
L litre
m metre
N Nitrogen
O Oxygen
T tonnes (metric)
1.1 Rationale

This dissertation seeks to evaluate the potential for the use of Ecospeed antifouling system on mainly large merchant ship hulls. Fouling is a phenomenon which is very much prevalent in the marine environment and is basically the unwanted growth of organisms on a surface (Chambers L.D. 2008).

Marine biofouling has been a problem for the shipping industry for quite a number of years because of its rapid growth on submerged hulls and until now, there is still the search for an effective and appropriate antifouling option in tackling this menace. The accumulation of foulers such as algae and barnacles increases the drag on moving vessels, thereby increasing the fuel consumption and emissions, and reducing the vessel’s manoeuvrability. Recently, the use of ship hulls as a key vector for the transportation of alien species between ports has highlighted the environmental requirement for maintaining a clean hull during service. Merchant ships need to resist the harsh salt-water environment, which is highly corrosive to unprotected surfaces. (Chambers L.D. 2008).

Apart from preventing corrosion, coatings on ships are used for a wide range of functions as well as the prevention of biofouling on the hull. The International Maritime Organization convention on antifouling described an antifouling system as ‘a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms’. The two main types of antifouling coating technology currently used widely are the Foul Release (FR) and the Self-Polishing Co-polymer (SPC) coatings. The FR coatings are non-biocidal and control fouling through the coating’s surface energy which weakens and deprives the organisms’ anchoring capabilities on the hull and removes them as the ship reaches a critical speed (Yebra, D.M. et al. 2004). Biofouling however cannot be prevented when the vessel is dockside and these coatings are not suitable for certain operational profiles. The SPC coatings control the biofouling by the leaching of biocides (Chambers L.D. 2008). This is a very effective delivery system for a variety of operational profiles, however, it has detrimental effects on the marine environment. The most effective biocide to date, tributyltin (TBT) was found to have a large secondary effect on non-target organisms and has subsequently been banned worldwide (Chambers L.D. 2008). The return to copper-based antifoulants has recently come under scrutiny as have the second generation of biocides designed to be environmentally ‘safe’. TBT-based SPCs are known to be toxic to the marine environment and have been banned completely from usage whilst copper-based SPCs are known to be resisted by some algal species. For the FR coatings, the fouling cannot be removed if the vessel does not attain the critical speed and could result in translocating NIS.

It is dicey to brand any biocide as safe since a number of factors such as practical applications amongst others need to be considered. It is clear that the washing of ships’ hulls is a major source of introducing these chemicals into the waterways as this was seen with TBT’s effect on non-target organisms (Chambers L.D. 2008). The coating/environment and the coating/substrate interfaces are of equal importance and this combination of required function is essential for its effectiveness (Chambers L.D. 2008). The development of antifouling systems has come a long way and the last ten years has seen an increase in the development of environmentally acceptable alternatives. Figure 1.2 clearly illustrates how these parameters interact with different layers in an antifouling coating system (Chambers L.D. 2008).
**Fig. 1.1** Key interactive parameters affecting an antifouling coating system. Source: (Chambers L.D. 2008).

**Fig. 1.2** Schematic of Antifouling system showing the interactive parameters and the coating layers. Source: (Chambers L.D. 2008).
1.2 Aim and Objectives

The aim of this project is to evaluate the potential for the use of Ecospeed antifouling system on merchant ships.

This aim is to be achieved through the following objectives:

1. To identify the range of antifouling options currently available for merchant shipping.
2. To make a comparative analysis of the Ecospeed antifouling system to the main options mentioned above.
3. To conduct a survey on ship owners and operators to determine their willingness to use the Ecospeed antifouling system.
4. To synthesize findings into recommendations for future best practice.

Chapter 2
Literature review

2.1 Introduction

The accumulation of unwanted plants, animals and microorganisms on submerged surfaces in sea water is usually known as marine biological fouling or marine biofouling (Yebra, D.M. et al. 2004). When it comes to merchant ships, these biofouling problems are very well known as it negatively affects the whole operation of the ships in various diverse ways.

Because of the roughness that is created on the hull, the vessel experiences a higher resistance as it glides through the water and with this additional weight caused by the fouling, the manoeuvrability of the vessel is hampered creating reduction in speed which will mean a higher fuel consumption and increase in emissions of harmful compounds (Yebra, D.M. et al. 2004). Fuel consumption could be increased to as much as 40% and the total overall voyage cost could mount up to an additional 77% (Yebra, D.M. et al. 2004).

When ships incur fouling very fast, there will be the need to clean it up and this is usually done at the dockyard. This means that enormous amount of time will be wasted and a large amount of waste will be generated as well. There will also be high tendencies of introducing non-indigenous species into the environment where the cleaning will be carried out.

Various solutions to curb this problem have been suggested since man first took to sea, and among the exhaustive list of solutions, tributyltin self-polishing copolymer TBT-SPC is known to be the most effective in tackling the fouling menace (Yebra, D.M. et al. 2004). Unfortunately, the TBT-SPC systems have an adverse effect on the environment. For example, defective shell growth in oysters due to even very low concentrations of TBT have been reported. In dogwhelks it is also reported that there is the development of male characteristics in female genitalia (imposex) (Yebra, D.M. et al. 2004). Many other species have also suffered deformations of one kind or the other and the debilitation of the immunological defences in fish and accumulations in mammals catapulted the development of national and international regulations by the IMO, some of which are the elimination of the use of free TBT holding compounds, restriction of the use of these compounds on vessels less than 25m and restriction of the release rates of these compounds from the paints (Yebra, D.M. et al. 2004).

On 5 October 2001, a meeting held by IMO and its member states banned the application of TBT based antifouling paints from 1 January 2003, and the presence...
of such paints on the surface of vessels from 1 January 2008 (IMO, 2002). An extract of the Antifouling Convention is attached in Appendix A. Some member states and paint manufacturing companies started putting measures in place even before the global application of the resolutions of the convention reached certainty, with regional legislation being developed in the same direction (Yebra, D.M. et al. 2004). Some of the major shipping companies such as Maersk Line also reacted swiftly by beginning a fleet-wide conversion to other suitable options (Yebra, D.M. et al. 2004).

This chapter seeks to combine all main topics related to antifouling technology, and will elaborate on the marine fouling process and the development of antifouling systems. The sea water will be fairly described and its variables will be highlighted. The antifouling option with the most potential will be presented and evaluated against the existing options.

### 2.1.1 Fouling

The growth of unwanted marine organisms and other biological matter on the submerged part of vessels is termed fouling. This includes barnacles algae and other lower class unicellular and multicellular flora and fauna. They usually settle on the surface (IMO, 2002).

#### 2.1.1.1 Why ships need antifouling

The submerged areas of an unprotected hull are likely to accumulate 150kgs of marine biological fouling per square metre in less than six months after the vessel is put to sea. For bigger vessels such as Very Large Crude Carriers (VLCC’s), the fouling could amount to 60,000 tonnes since they have a submerged area of approximately 40,000 square metres (IMO, 2002). The attachment and settlement of this fouling increase the drag on the vessel as it glides through the water. This increases the friction which reduces the vessel’s speed significantly with an increase in the consumption of fuel, and is detrimental to the manoeuvrability of the vessel. About 40 to 50% increase in fuel consumption is incurred as a result of fouling on the hull since the vessel’s movement is hampered by excessive resistance. A vessel will therefore sail faster if it is clean and will require relatively less energy. Antifouling systems are therefore required to be applied on the hulls of vessels to reduce or eradicate fouling (Almeida et al., 2007).

An effective antifouling system can represent great savings to shipowners and operators in a number of ways which include:

- Significant and direct savings in fuel because the hull is kept free of fouling organisms
- Since the antifouling system guarantees long term use, drydocking interval for the vessel will be considerably extended
- Because the vessel need not spend much time in the docks, it will be available more often for commercial use (IMO, 2002).

### 2.2 Development of Anti-fouling Systems

Lime was predominantly used in the early days and then compounds of mercury such as Dichloro dithenyl trichloroethane (DDT) were incorporated and used to act as antifouling by painting it on the vessel’s hull. The 1960’s saw more efficient and cost-effective systems using metallic compounds and during the 1970’s most seagoing vessels had TBT, the organotin compound, painted on their hulls (IMO, 2002).

The ingredients or components of the organotin based paints which were used earlier dispersed with paint in the resinous matrix and leached out destroying the organisms that had fouled the hull. The biocides leached very fast as the rate of release was not controlled initially. They were rendered ineffective in about 18 to 24 months as all the biocides became depleted by this time (Almeida et al., 2007).
2.2.1 Free association paint

2.2.1.1 Self-Polishing Paints

Self-Polishing Paints were developed during the latter part of 1960’s and were considered to be a substantial breakthrough in antifouling paints. The polymer base and the organotin compound are chemically bonded together in this system. The rate of leaching of the biocides in these paints is achieved because it is controlled as the release of biocides only occurs when the peripheral surface layer of the paint reacts with seawater. A layer by layer release of the biocides is stimulated, which means that after the surface layer is depleted, the next layer begins to release its biocides when it reacts with seawater (IMO, 2002).

Because of the uniformity of the leaching rate, it has a relatively longer life span which enabled the vessels coated with this system to run for almost 60 months before repainting. The emergence of the Self-Polishing paints containing TBT was undeniably a noteworthy success with the shipping industry, but this success was detrimental to the environment (CEFIC, 1995).

2.2.1.2 Self-Polishing Copolymer System (SPC)
2.2.2 Tributyltin (TBT) Free Systems

![Image](image_url)

**BIOCIDES DISPERSED IN RESINOUS MATRIX**

*Fig. 1.6 The dispersal of biocides at the seawater-paint interface at a controlled rate. Source: (CEFIC, 1995).*

2.2.2.3 Foul Release (FR) Approach

Foul release coatings (FRCs) function due to a low surface energy which inhibits an organism’s ability to cling to the surface. The smoothness of the coating makes it difficult for the organisms to stick and remain on the hull when the vessel is steaming beyond a critical speed of about 10-20 kts (Chambers, L.D. et al. 2006). Silicone-based polymer and fluoropolymer are the two main FRC’s currently in use and the thickness of the coatings controls the coating modulus with the silicone compounds being more successful because less energy is required to break the bond between the foulant and coating (Chambers, L.D. et al. 2006).

This approach however is unable to counteract biofouling whilst the ship is stationary or moored alongside a jetty or dock and can allow the establishment of these foulers which may later on be translocated if not dealt with. The oils contained in some silicone-based paints are also known to be toxic and as such might pose a problem to aquatic life in the long term (Chambers, L.D. et al. 2006). FRC’s can therefore not be considered as a remedy in curbing the fouling problems and even require certain operational profiles to be effective coupled with increases in fuel consumption in order to attain the required speed to dislodge the foulers (Chambers, L.D. et al. 2006).

2.3 The environmental concerns about biocides in antifouling

The use of biocides in antifouling systems has recently come under immense scrutiny and certain countries have already banned its use. In San Diego, France and other parts of the world it is shown that the growth, development and reproduction of marine life such as sea urchins, crustaceans, oysters and scallops are hampered due to concentrations of dissolved copper from copper-based antifouling paints (Chambers, L.D. et al. 2006). Traces of TBT are still seen in sediments in which TBT once accumulated such as shipyards and the vicinity of ports.

There are a number of regulations worldwide restricting the release rates as well as the amount of copper and other biocides as a way of reducing pollution. Countries such as Denmark and Sweden have banned the use of products containing biocides such as Diuron and Irgarol (Chambers, L.D. et al. 2006) and in California and other parts of the coast of the USA and Canada legislation is underway to completely ban copper-based paint (Hydrex, 2011).
Even though copper in minute quantities has very useful nutrient properties for plants, it has many dangers attached to it as well and might even pose a risk to drinking water supplies which might lead to acute poisoning of babies. Diseases such as cirrhosis could be easily contracted and such incidence has been recorded in Germany in the 1980’s. (Chambers, L.D. et al. 2006). There is therefore no effective alternative to TBT and according to OSPAR’s working group on diffuse source, the ones that are supposed to replace TBT are known to have similar unwanted environmental effects as TBT (Chambers, L.D. et al. 2006).

### 2.4 Antifouling System Timeline

<table>
<thead>
<tr>
<th>Anti-fouling systems time line</th>
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<tbody>
<tr>
<td><strong>Resin or pitch used on ship hulls.</strong></td>
<td>1900</td>
</tr>
<tr>
<td><strong>Copper-based paints containing mercury oxide, arsenic halogen compounds.</strong></td>
<td>1960s Long-life anti-fouling paints provide protection to hulls for up to 24 months.</td>
</tr>
<tr>
<td><strong>Introduction of free association TBT-based anti-fouling paints</strong></td>
<td>1970s Self-polishing anti-fouling paints containing TBT hailed by shipping industry. Anti-fouling toxin is partly released by a reaction with seawater and paint polishes away layer by layer, continuously exposing new layer to seawater. Biocide delivery rate is more or less constant. Ships can now drydock just once every five years.</td>
</tr>
<tr>
<td><strong>Introduction of self-polishing co-polymer TBT-based anti-fouling paints.</strong></td>
<td>1980s Worrying side-effects of TBT on oysters (deformities) identified in France. TBT-related imposex recorded in English coastal waters. Various countries ban TBT on boats less than 25 metres long.</td>
</tr>
<tr>
<td><strong>Introduction of non-stick coating for small vessels. Various tin-free alternatives developed.</strong></td>
<td>Early 1990s IMO Resolution recommends Governments ban TBT on vessels less than 25 metres in length; TBT leaching from paint should be less than 4 microgrammes per cm square per day. Japan, New Zealand, Australia ban use of anti-foulants containing TBT. Impeex found in dog whelks, attributed to TBT. United States, Canada, Australia, Sweden, the Netherlands impose TBT release rate restrictions.</td>
</tr>
<tr>
<td>1995</td>
<td>IMO creates MEPC working group on harmful effects of anti-fouling paints.</td>
</tr>
<tr>
<td>1997</td>
<td>Japan bans production of TBT-based anti-fouling paints.</td>
</tr>
<tr>
<td>1998</td>
<td>MEPC agrees to draft mandatory regulations to ban organotins used in anti-fouling systems; MEPC approves draft Assembly Resolution setting out time scale to do so.</td>
</tr>
<tr>
<td>1999</td>
<td>IMO 21st Assembly adopts Resolution on phasing out organotin compounds acting as biocides in anti-fouling systems.</td>
</tr>
<tr>
<td>2001</td>
<td>Diplomatic conference adopts International Convention on the Control of Harmful Anti Fouling Systems on Ships</td>
</tr>
<tr>
<td>2003</td>
<td>Date for prohibiting application of organotin compounds acting as biocide in anti-fouling systems</td>
</tr>
<tr>
<td>2008</td>
<td>Date for complete prohibition on organotin compounds acting as biocides in anti-fouling systems</td>
</tr>
</tbody>
</table>

*Table 1.1 Antifouling system timeline. Source: (IMO, 2002)*
2.5 Development of International Regulations

The Paris Commission (PARCOM), which is an international organisation formed by treaty, was among the bodies that bade IMO consider and take appropriate measures under the applicable instruments to inhibit the use of TBT compounds on seagoing merchant vessels. Pollution prevention of the North East Atlantic is of a major concern to PARCOM and in 1988 the Marine Environmental Protection Committee (MEPC) which is one of the senior technical bodies of IMO first highlighted the detrimental effects of TBT in antifouling paints (IMO, 2002).

The use of legislation in the prohibition of TBT was successful as a substantial decline in TBT contamination occurred and recuperation from malformed growth in oysters was seen as well as reductions of the imposex condition in dogwhelks (IMO, 2002). In 1992, it was emphasised that it is essential for IMO to work on the antifouling issue during the Rio Conference and Agenda 21 of chapter 17 which was instituted by the same conference, it appealed to states to take measures to minimise pollution from organotin based compounds in antifouling paints (UNCED 1992).

2.5.1 MEPC's work on TBT

The development of a different antifouling system using mechanisms that are less harmful such as cleaning methods, non-stick mechanisms and electrochemical mechanisms was encouraged by the IMO. It also called on member states, competent organizations, industry programmes and all other states that are concerned to foster and encourage the promotion of scientific and technical research for the development of appropriate antifouling systems that are less toxic (IMO, 2002). An International convention on the Control of Harmful Antifouling Systems on Ships (AFS Convention) was adopted by a diplomatic conference in 2001 and in 2003 and application of compounds containing organotin that act as biocides in antifouling systems was prohibited. This compound was completely forbidden in 2008.

2.5.1.1 MEPC's Continued work on TBT

MEPC was given the results of a monitored study during the 1990's that proved the toxicity of TBT to marine fauna and flora. Data and materials containing information on current alternative options as well as their relative effectiveness and the harm they posed to the marine environment by these options was offered. At its 38th session in 1996, the MEPC created a correspondence group to examine the problems involved (IMO, 2002). The main conclusions drawn based on comments from the 12 countries and four nongovernmental organizations which participated and reported back to MEPC at its 41st session in April 1998 were that the precautionary approach need to be applied and the use of less harmful antifouling systems was to be encouraged. Any alternative system is to be comparatively less harmful to the environment (IMO, 2002).

The need for provisional measures was necessary prior to the total ban on TBT anti-fouling systems. The provisional measures consisted of restricting systems containing TBT to bigger ships at the start, barring TBT systems on vessels having about 2.5 years or less docking interval, putting restraint on certain classes of vessels such as fishing boats, equipment used for dredging, offshore equipment and vessels that usually operate in particularly sensitive sea areas (IMO, 2002).

The use of antifouling coatings for protection from the marine environment has a long history. By considering the historical and current approaches to antifouling systems, this review will assess the effectiveness of the main broad spectrum of modern antifouling options used, make a comparative analysis of the Ecospeed antifouling system and evaluate its potential for application on merchant ships’ hulls.

…..
2.8 Other Alternative Antifouling Systems

2.8.1 Electricity

The system that employs electricity operates by producing a difference in electrical charge between the hull and sea water which then initiates a chemical process that inhibits fouling. This system is known to be more efficient than the tin free paint systems in inhibiting fouling, but it is comparatively expensive, not very durable and can be damaged easily. There is also the tendency of increased corrosion risk and energy consumption could be higher (Plesman, M. 1997).

2.8.2 Prickly coatings

Prickly coatings are basically coatings with very tiny prickles. The length and distribution of the prickles are the main determining factors of its effectiveness and hulls painted with such coatings are known to avert the attachment of unicellular organisms such as algae and barnacles without any detrimental effect to the environment. The use of this system on the surfaces of stationary objects such as buoys and even cooling water inlets seems to be a promising and realistic option in the near future; however, it is not seen as being the most effective solution for the hull of vessels as the prickles could escalate the resistance of vessels (Plesman, M. 1997).

2.8.3 Ultrasonic system

The ultrasonic system uses a transducer and digital electronics technology. It functions by generating simultaneously, bursts of ultrasonic energy in numerous range of frequencies. A sporadic pattern forms minute bubbles and shrinks them during periods of positive and negative pressures respectively by a process called cavitation. This phenomenon creates a micro-jet action, that is able to clean the underwater part of the hull surface and also reverberates and kills unicellular organisms such as algae. The elimination of the preliminary link in the food chain by this process constrains the growth of barnacles and other marine fauna or flora that feed on the algae (NRG Marine 2010). This system is however only effective for smaller vessels such as pleasure yachts and small boats but not suitable for larger merchant vessels.

2.9 Ecospeed®

Ecospeed is basically a system which is made of a glass platelet, vinylester resin based coating and which allows for a regular in-water cleaning to keep any ship hull operating at maximum performance. It is classified as a Surface Treated Composite (STC) and is available from Hydrex®, an international company that specializes in underwater ship protection, maintenance and repair (Hydrex, 2011).

When a ship hull requires painting either at the new build stage or in drydock, the coating is applied once and lasts for the whole lifetime of the ship. Very minor touch-ups however may be required during routine drydocking and this less than 1% of the total surface area (Hydrex, 2011). It is guaranteed for 10 years and its service life is much longer. Cost of initial application is similar to any other underwater hull paint but it is easier than others to apply, in that it requires only two coats on bare metal with a two to three hour drying time in between coats and extended maximum overspray time.

Regular in-water cleaning and hull inspection greatly helps to prevent the build-up of slime and heavier fouling and this helps in keeping the vessel at optimum performance all the time. The coating improves with regular cleaning with the skin friction reducing with each cleaning. Cleaning of the largest vessels can be accomplished in 6-12 hours and can usually be carried out without adversely interrupting the ship’s normal operations (Hydrex, 2011).

The European authorities have tested and certified Ecospeed as not being harmful to the environment and as being completely non-toxic. Ships that use Ecospeed on their hulls sail with the security of knowing that they are not spreading any pollution through their hull coating.
and because they are easily maintained at optimum performance, they save very significant fuel costs, while reducing carbon dioxide emissions (Hydrex, 2011).

2.10 The Economical and Environmental benefits of Ecospeed as demonstrated by the EU Life Project

In an attempt to evaluate the economical and environmental advantages of Ecospeed as a chemical free durable hull protection system, a project termed the EU Life demonstration project (ECOTEC-STC) was undertaken from 31st March, 2010 over a 3.5 year period under the auspices of Hydrex. The aforementioned project was subdivided into a number of project tasks which were undertaken under the supervision and administration of Hydrex (Hydrex, 2011).

2.10.1 Project Tasks

The first task was geared towards testing and modification of the tools for maintaining the optimization of the underwater treatment of STCs and acquiring new prototypes. Several shipowners including Interscan, Peter Döhle, Exmar-CMB and Codralux were incorporated as partners when the demonstration of its ease of application was carried out. The durability of the coating was proven when consequent inspections showed its toughness and robustness making it indestructible. The port of Antwerp appraised the underwater treatment and its impact on the environment with the help of

Fig. 2.0 Conditioning of Ecospeed test plate during experiments for the project. Source: (Hydrex, 2011).

Fig. 2.1 Extensive tests with underwater cleaning equipment were carried out during the project conditioning of Ecospeed test plate during experiments for the project. Source: (Hydrex, 2011).
Rijkswaterstaat Zeeland and European Reference Materials (ERM). There was also the conduct of risk assessment to determine the probabilities of transferring alien species when underwater cleaning is carried out. At the end of the project, the results of the findings were tested on a 1000-TEU container vessel belonging to the partner shipowner Peter Döhle in the port of Rotterdam. In two years the consumption of fuel from sister vessels of the same partners, Peter Döhle and Exmar-CMB was observed. The evaluation of the input that was provided was conducted with VITO (Flemish Institute for Technological Research) and Hogere Zeevaart school (Antwerp Maritime Academy). Lastly, a comparative analysis of the roughness and robustness characteristics and the drag of Ecospeed was compared with other coatings in collaboration with VITO (Hydrex, 2011).

The results from the project were collated together and a comparative breakdown was made between Ecospeed and copper based SPCs and FR systems with respect to their economical and environmental impact.

### 2.10.2 Economical Impact

The application costs as well as increased fuel costs were among the different aspects that were measured along with the total economic impact. This was then assessed for a 1000-TEU container that was coated with Ecospeed and which had its coating consistently cleaned (Hydrex, 2011).

### 2.10.3 Total Application Costs

There may be a higher initial cost to use and apply Ecospeed. When taken over a period of 10 years which is the warranty period for Ecospeed, the final cost will be much lower as Ecospeed will only require minor touch-ups whereas a Self-Polishing Copolymer (SPC) or a Foul Release (FR) will require a full reapplication at regular intervals (Hydrex, 2011).

### 2.17.3 Transferability of ECOTEC-STC

To prove that the surface quality gets better with each underwater treatment which comprises both cleaning and conditioning, fuel consumption data is being gathered continually to substantiate that the vessel performance becomes better throughout the lifespan, unlike other coatings.

The results of the project were promulgated to all the environmental regulatory bodies and agencies and port authorities worldwide in order to permit the underwater treatment of Ecospeed. Because of the fear of introduction of biocides or the dangers of transporting NIS, a number of ports and countries have prohibited underwater cleaning. The results of the experiment and the derived benchmark for environmentally safe underwater cleaning have already persuaded quite a
number of economically significant ports to reverse the ban. Source: (Hydrex, 2011).

The commercially important ports of Rotterdam, Antwerp, Copenhagen, Oslo and Barcelona, which uphold a prohibition on underwater cleaning, agreed between 2009 and 2010 to permit the underwater cleaning of hulls coated with Ecospeed, and more recently the West coast of U.S.A. and Canada, Seattle, Long Beach and Vancouver are also allowing underwater cleaning (Hydrex, 2011). It is projected that the list will increase in the foreseeable future. All these ports acknowledge the adverse influence of biocidal paints and seek to encourage environmentally benign solutions.

2.18 Summary

Modern approaches to achieving a broad based antifouling system that is environmentally acceptable have been reviewed. The success of an antifouling option is linked to its mode of application, its effectiveness as well as its environmental acceptability. IMO’s legislation is the main driving force in the designing and implementation of antifouling coatings but increased legislation from local and regional pesticide control authorities also play a major role. Because of the differing operational profiles of the various types of vessels that exist, it is somewhat tasking to devise a single universal coating to be used by all vessels.

Although the introduction of booster biocides into some of the SPC coating systems showed some cost benefits, they have been proven to be environmentally unacceptable due to concerns over their toxicity. Foul Release Coatings (FRCs) are ineffective in resisting biofouling whilst the vessel is moored to a dock or at anchorage. The alternative fouling control systems currently in wide use are not as effective as their TBT predecessor and this means that the search for a better design and implementation of antifouling coating technology must be encouraged and continued. In the short term, the only alternative with a potential that seems to be able to reach a sufficient degree of development to replace biocide-based antifouling coatings is Ecospeed. Improved products derived from the current ones and new binder systems and booster biocides will, very likely, be banned in the foreseeable future as there is evidence of recent legislation in the Baltic, certain parts of EU, California and Washington in the U.S.A. and certain parts of U.K. which will ultimately lead to the prohibition of these systems. There are already some options that deserve special attention due to their promising characteristics as effective systems and Ecospeed is one such system as it involves a more economical and environmentally friendly mode of action.

....

[Editor’s note: Chapter 3 of the thesis describes the methods used for conducting an industry survey regarding underwater ship hull coatings. For reasons of space this chapter has been omitted. Following are excerpts from the results of the survey along with conclusions.]
Chapter 4
Findings and results

4.1 Data Presentation and Analysis

The purpose of this chapter is to present the findings, analyse them and find results in order to identify the present day thinking of the stakeholders (ship-owners and operators), fulfilling objective 3 of this project. For this purpose each question is taken individually and analysed, and the results are summarised at the end of the chapter.

The statistics of the responses received from the questionnaire are presented in the table 1.2 below.

<table>
<thead>
<tr>
<th>Country</th>
<th>Questionnaire sent</th>
<th>Response received</th>
<th>Percentage of response</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYPRUS</td>
<td>16</td>
<td>8</td>
<td>50.0%</td>
</tr>
<tr>
<td>GERMANY</td>
<td>9</td>
<td>4</td>
<td>44.4%</td>
</tr>
<tr>
<td>GREECE</td>
<td>16</td>
<td>8</td>
<td>50.0%</td>
</tr>
<tr>
<td>HONG KONG</td>
<td>12</td>
<td>9</td>
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</tr>
<tr>
<td>INDIA</td>
<td>10</td>
<td>7</td>
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<tr>
<td>NORWAY</td>
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<td>5</td>
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</tr>
<tr>
<td>SINGAPORE</td>
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<td>9</td>
<td>50.0%</td>
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<tr>
<td>U.K.</td>
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<td>8</td>
<td>28.5%</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>12</td>
<td>8</td>
<td>66.6%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>129</strong></td>
<td><strong>66</strong></td>
<td><strong>Total % age = 51%</strong></td>
</tr>
</tbody>
</table>

*Table 1.2* The response statistics to the questionnaire.

<table>
<thead>
<tr>
<th>Country</th>
<th>Respondents</th>
<th>Entity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYPRUS</td>
<td>8</td>
<td>5 Technical Superintendents, 2 Technical managers and 1 Port Captain</td>
</tr>
<tr>
<td>GERMANY</td>
<td>4</td>
<td>4 Technical Superintendents</td>
</tr>
<tr>
<td>GREECE</td>
<td>8</td>
<td>6 Technical Superintendents and 3 Technical Managers</td>
</tr>
<tr>
<td>HONG KONG</td>
<td>9</td>
<td>5 Technical Superintendents, 3 Technical managers and 1 Designated Personnel</td>
</tr>
<tr>
<td>INDIA</td>
<td>7</td>
<td>4 Technical Superintendents, 2 Port Captains and 1 Designated Personnel</td>
</tr>
<tr>
<td>NORWAY</td>
<td>5</td>
<td>5 Technical Superintendents</td>
</tr>
<tr>
<td>SINGAPORE</td>
<td>9</td>
<td>5 Technical Superintendents, 2 Technical managers, 1 Port Captain and 1 Designated Personnel</td>
</tr>
<tr>
<td>U.K.</td>
<td>8</td>
<td>6 Technical Superintendents, 2 Technical managers</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>8</td>
<td>4 Technical Superintendents, Technical managers and 2 Port Captains</td>
</tr>
</tbody>
</table>

*Table 1.3* The various entities of the respondents who answered the Questionnaire.
4.4 Response to Question 3

Q3. How effective is the system that your company uses?

Number of respondents versus Country

Fig. 3.3 The response to Question 3.

4.4.1 Analysis of the Response to Question 3

Question 3 was asked to check from the ship-owners and operators, how effective they thought the system they are using was. A greater percentage of the respondents (48%) replied that it was somewhat effective, 33% replied it was very effective, 12% said it was extremely effective and 7% replied it was slightly effective. This results shows that the greater percentage (48%), who answered somewhat effective and the those who answered slightly effective (7%), will be willing to try a better system if it is proven to be much more effective than what they use.

4.5 Response to Question 4

Q4. Did your company use a different antifouling system prior to the current system which you now have on your vessels?
This question was asked to determine whether the shipowners and operators used a different type of antifouling system prior to the current one they are using. A massive number of the respondents (92%), answered no, and just a few (8%) answered yes. This suggests that a greater number of the respondents (92%) have been using the system they have now for a considerable period of time and that is mainly the paint system (either SPC or FR). Only a few (8%) did use a different system prior to the current one.

4.7 Response to Question 6

Q6. How effective was the other system?

Number of respondents versus Country
This question was asked to find out from those shipowners and operators who used a different system prior to the current one they use, how effective the previous system was. Approximately 67% of the respondents said the system was somewhat effective and almost 33% said it was slightly effective. This shows that the number of respondents who changed the system they previously used, wanted a better system which will be more effective in helping to protect their ship hulls and to save some operational costs.

4.8 Response to Question 7

Q7. Why did your company change this system?

4.10 Response to Question 9

Q9. Do you agree with the fact that, when choosing an antifouling system, its impact on the marine environment should be taken into consideration?
4.10.1 Analysis of the Response to Question 9

This question was asked to verify whether the ship-owners and operators have the environmental considerations at heart when choosing an antifouling option. 21% said they extremely agree that the environment should be considered when choosing a system for their ships. 47% of the respondents agreed, 26% somewhat agreed, 6% slightly agreed and nobody disagreed to the fact that the environment was a key factor to be considered when choosing an antifouling option. These results show that a vast majority of the ship-owners and operators are environmentally conscious or are becoming conscious of the negative impact that results from polluted seas and will opt for a more environmentally friendly option if they have to make a choice for an antifouling system.

4.11 Response to Question 10

Q10. Which of the following factors or attributes in a new antifouling system do you think will make your company consider changing from the present system to the new one?

4.11.1 Analysis of the Response to Question 10

The purpose of this question was to find out from the ship-owners and operators, the factor or factors that will encourage or motivate them to switch from the current system they are using to a new option. Cost appeared to be of a major concern as 42% opted for cost. 33% said the lifespan of the system will be a main factor. 17% said its environmental acceptability will be the main
attribute that will make them consider changing and 8% said, its ease of application will be the determining factor. Cost therefore seems to be a major player for the ship-owners and operators as this was reflected in the response to question 8 as well.

4.12 Response to Question 11

Q11. In light of the current state of technology, is it likely that your company will be willing to take on a new antifouling option if it is proven to be more effective and eco-friendly than the present system you are using?

Although having some resemblance to the previous question, this question was asked to find out whether the ship-owners and operators will actually change from the current system they are using to a new option if the new system is proven to be more effective in all respects, i.e. being cost effective and eco-friendly. 8% of the respondents answered by saying it is extremely likely they will change, a reasonable 39% said it is very likely, 45% said it is somewhat likely, 8% answered it is slightly likely and the same percentage said it is not at all likely. This response portrays that a greater percentage of the respondents show some degree of willingness to swap to a new system provided this system meets all the attributes mentioned.

4.13 Response to Question 12

Q12. Has your company heard about the Ecospeed antifouling system?

Although having some resemblance to the previous question, this question was asked to find out whether the ship-owners and operators will actually change from the current system they are using to a new option if the new system is proven to be more effective in all respects, i.e. being cost effective and eco-friendly. 8% of the respondents answered by saying it is extremely likely they will change, a reasonable 39% said it is very likely, 45% said it is somewhat likely, 8% answered it is slightly likely and the same percentage said it is not at all likely. This response portrays that a greater percentage of the respondents show some degree of willingness to swap to a new system provided this system meets all the attributes mentioned.
4.13.1 Analysis of the Response to Question 12

This was a very simple question that was asked to verify from the respondents whether they have heard about the Ecospeed antifouling system. A greater percentage (85%) responded No, and 15% responded Yes. This clearly suggests that not many ship-owners and operators know about this option despite its profound benefits.

4.14 Response to Question 13

Q13. Do you think your company will be willing to change to the Ecospeed antifouling system which comes with a guaranteed lifetime of 10 yrs and an expected lifetime of 25 yrs?

Number of respondents versus Country

4.14.1 Analysis of the Response to Question 13

This question was asked to find out whether the ship-owners and operators will be willing to change to the Ecospeed antifouling option (revisiting objective 3) which comes with a guaranteed lifetime of 10 yrs and an expected lifetime of 25 yrs. Even though only 15% of the respondents were aware of this option as per the response from question 12, quite a good number of respondents were optimistic about changing. 5% said it is extremely likely, 27% said it is very likely they will change, 53% answered it is somewhat likely and 15% said it is slightly likely. No one chose, it is not at all likely, and this shows that a system which is effective and will last for longer period of time is very much welcome as this will save every ship-owner and operator a lot of operational costs such as docking for repainting the underwater part of the hull.

4.15 Response to Question 14

Q14. With the safety of the environment being a concern for every ship owner and operator, is it likely
that your company will agree to change to the Ecospeed antifouling system which is 100% free of biocides and therefore environmentally safe?

4.15.1 Analysis of the Response to Question 14

The purpose of this question was to determine whether the ship-owners and operators are willing to change to the Ecospeed option which is 100% free of biocides and environmentally safe (revisiting objective 3 again). A question regarding environmental concerns has already been asked earlier on, and the response showed a keen optimism for environmentally safe options from the respondents and so the response to this question was not much of a surprise. A good 51% said it is somewhat likely, 26% said it is very likely, 17% said it is slightly likely and 6% answered it is extremely likely. This suggests that, the Ecospeed, if given the right publicity, through the appropriate medium will be very much patronized by ship-owners and operators.

4.16 Response to Question 15

Q15. The regular underwater treatment of Ecospeed antifouling system is put forward as a Best Available Technology to minimize the risk of transferring Non-indigenous Marine Species (NIS). Do you agree that this is a way forward in eliminating the problem of ships being used as a vector for transporting these alien species?
4.16.1 Analysis of the Response to Question 15

The transfer of Non Indigenous Species (NIS) by fouled ship hulls has come under scrutiny in recent years by the IMO, and yet they seem unable to provide a workable solution until now. The main reason for this question was to find the opinion of the ship-owners and operators whether they agree to the fact that Ecospeed’s regular underwater cleaning and treatment is a solution to eradicating or minimising drastically the risk of transferring NIS by ships’ hulls, as it is the best available technology for tackling this menace. 36% of the respondents said they agree, 15% said they extremely agree, 35% said they somewhat agree and 14% responded they slightly agree. With a greater proportion of the respondents agreeing or somewhat agreeing shows that they are optimistic of Ecospeed being a possible way forward in eliminating or significantly reducing the spread of NIS via ships’ hulls.

4.17 Response to Question 16

Q16. Ecospeed antifouling system’s decreased resistance is higher than other coatings as regular underwater treatment is used preventatively to keep added drag caused by marine fouling under control and increased fuel costs are minimized to significantly lower levels than would be the case for SPC’s or FR’s. Do you agree that this is a system which your company should consider using on their vessels?

4.17.1 Analysis of the Response to Question 16

This question was asked to find out from the ship-owners and operators whether they consider Ecospeed as an option they should use on their ships, given its
cost effectiveness and eco-friendliness when compared to the other systems (revisiting objective 3 again). 12% of the respondents said they extremely agree, 38% said they agree, 36% said they somewhat agree, 14% responded they slightly agree but no one disagreed. An overwhelming number of the respondents extremely agreeing or agreeing or even somewhat agreeing depicts that most ship-owners are very keen on reducing operational costs through minimising fuel costs. The recent hike in fuel prices is a bane they desperately want to avoid. This response suggests a strong will from the ship-owners and operators to switch over from their current system to Ecospeed as they see it to be an economically efficient antifouling option.

4.18 Response to Question 17

Q17. At its 42nd session, in November 2008, the MEPC of IMO banned the use of antifouling systems containing the organotin compound Tributyltin (TBT), without providing a standard option to be followed by all vessels. In your opinion, do you agree that IMO should come up with some effective, standard antifouling option that all vessels must comply with?

Number of respondents versus Country

Figure 6.1 The response to Question 17

4.18.1 Analysis of the Response to Question 17

When it comes to legislation and laying down of rules and regulations with respect to the antifouling systems, the IMO have done considerable work, but they have still not been able to come up with an effective standard system that all merchant ships should comply with. At its diplomatic conference in October 2001, IMO, as part of its measures to control potential adverse impacts associated with the use of tributyltin compounds, only recommended that governments should adopt and promote effective measures within their jurisdiction to encourage development of alternatives to antifouling paints containing tributyltin compounds, giving due regard to any potential environmental hazards which might be posed by such alternative formulations, and to engage in monitoring to evaluate the effectiveness of control measures adopted and provide for sharing such data with other interested parties. In November 2008, the use of antifouling systems containing the organotin tributyltin (TBT) was completely banned without any standard system being set in place. This question was therefore asked to find out from the
ship-owners and operators whether they agree to the fact that IMO should come up with some effective and standard option which all merchant ships must comply with. 21% of the respondents answered they extremely agree, 46% answered they agree, 30% said they somewhat agree, 3% said they slightly agreed and none of the respondents disagreed with this statement. The response showed that ship-owners and operators realized that some form of an effective and standard option should be implemented by IMO and it is quite evident from the response that an effective and standard antifouling option provided by IMO will be very much welcomed by the majority of the ship-owners and operators if not all.

4.19 Conclusion From Findings and Results

The purpose of this chapter was to identify industry thinking (mainly ship-owners and operators) with regards to antifouling systems, the related eco-effectiveness criteria and to ascertain their willingness to change to the Ecospeed antifouling system given its profound benefits. The ‘mix and match’ research strategy that was used to gain insight into the minds of the ship-owners and operators from different entities resulted in a reasonably large amount of highly valuable data for analysis. However, due to the limitation of the researcher to use computer software for analysis, the data was manually analysed.

This developed a possibility of results being subjective, particularly in case of qualitative analysis. However, utmost care was taken to maintain objectivity, and original comments were introduced at every possible opportunity.

From the results above, it could be concluded that majority of the ship-owners and operators showed some interest in addressing the marine fouling issue and are willing to take on a solution which is cost-effective, which will result in huge savings compared to the technology and approaches currently in widespread use, and which is entirely non-toxic and safe for the environment.

Chapter 5 Discussion and evaluation

5.1 Purpose

The purpose of this chapter is to evaluate the findings and results of this project with a closer and more detailed look at the various high level factors which must be taken into consideration when evaluating which antifouling system to use on a ship, either at new-build stage or when it comes time to repaint, as well as discussing the elements of the literature review to see how all these factors and elements of the objectives correlate with each other.

5.2 Discussion and Evaluation

The essence of applying protective coatings to the hull of a ship is primarily to protect it from corrosion and in the case of antifouling coatings from biofouling. This means that any coating that is applied is supposed to protect the hull without any adverse effects. It is also worth mentioning that a particular coating which works for vessels which solely work in warmer climates may not be suitable for the ones that ply the ice regions such as ice breakers and ice trading cargo vessels. Other vessels that are subjected to regular mechanical rough treatment will need a more durable system than one that is most often tied to the quayside. Thus the working environment and the choice of coating system should be compatible.

When one becomes successful in choosing the right system for the hull, there will still be the need to consider how long the system will last. If a particular antifouling system will last for about 3-5 years and another could last the lifetime of the ship, then the best option is to go for the one that will greatly help in reducing reapplication
costs. When the overall costs for reapplication of the existing systems are compared to the cost involved in the regular underwater treatment of Ecospeed, there is still a huge difference which makes Ecospeed the most appropriate viable option.

A system which continues to improve upon its smoothness after cleaning without damage to the coating is seen to be much better than a system which requires reapplication, with chances of increasing skin friction which in a nutshell will add up to huge costs in extra fuel and the resulting GHG emissions. The costs involved in the surface preparation of either an SPC or FR coated hull can be very high with lots of time loss. Some of the coatings could take a week and others as much as 2-3 weeks to apply, whereas Ecospeed requires just two coats with approximately 3 hours curing time in between. This makes it easy to repair or touch-up and that means a significant time gain when in drydock if repairs are to be effected.

It is very important to know whether the coating system is toxic or non-toxic to the oceans, marinas, bays, rivers and waterways. It is very evident that the current main antifouling systems in use are not entirely free of poisonous chemicals. This has been elaborated already in the literature and for SPC’s, they are known to leach biocides into the oceans. Foul Release coatings which are presented as non-toxic are found to alter the enzymes in barnacle glue, making their non-stick function not only mechanical but also biochemical. Silicone oils in silicone-based FR coatings are also found to have harmful effects on marine life (Hydrex, 2011).

Ecospeed is not toxic at all because it is simply a protective coating and not an active paint. It also releases the least VOC’s compared to the other existing systems. The regular cleaning of the underwater part of the hull also helps greatly to curb the dangers of translocating hull-borne, non-indigenous, invasive marine species which can distort the local ecosystem, with commercial consequences. SPC coatings may prevent the invasive species from attaching to the hull for a while, however some species are able to withstand and resist the copper and other biocides making it probable for NIS to be translocated with the resulting consequences. A system such as Ecospeed which permits in-water cleaning without damage to the coating can be effectively cleaned before a fouled vessel sails with the surety of arriving at the next port with a clean hull and eliminate the threat of translocating NIS.

The most important feature needed to be looked at is how much can be saved, whilst keeping the environment free from poisonous chemicals and invasive species, and not just what will be spent. The findings from the survey show that an overwhelming majority of the respondents are very keen to save fuel costs and are also thoughtful about the environmental consequences of increased fuel consumption due to an excessively fouled hull. They expressed optimism in changing to a different antifouling option if significant savings in cost can be achieved and Ecospeed has the potential of doing exactly that.

The majority of the respondents also agreed that an excessively fouled hull contributes to the translocation of NIS. The fuel penalty renders a very huge cost and reapplication which incorporates labour, materials, dry-docking and even off-hire times also contributed significantly to the cost factor. The application of the right coating system at the new-build stage will be the best option. However, application of the right coating during a ship’s first reapplication or other subsequent reapplications will help save costs in the long term. The choice of the right antifouling option that best suits a ship’s operational and other specific needs can go a long way in helping shipowners and operators to saving huge sums, contribute in reducing the global carbon footprint and save local ecosystems from invasive species thereby protecting biodiversity.

5.3 Conclusion

Based on all of these factors, a good estimate can be obtained of how much any hull coating system, maintenance, repair, cleaning and replacement if needed is going to cost for the lifetime of the ship. It might appear that quite a number of different factors have to be taken into consideration, but the exercise is well worth
the effort, particularly when considering a new hull coating system for a fleet. The right choice can make a difference of millions, even billions of dollars when projected out for the full lifetime of all the vessels of the fleet.

## Chapter 6
### Conclusion

The research design using various research methods was taken to successfully achieve the stated research objectives. This was done to identify the factors that need consideration in order to produce recommendation(s) for a possible future best practice(s) in relation to antifouling systems and the related economic and environmental criteria. The purpose of this chapter is to ascertain if the research objectives are met and to draw implications from the results achieved under each objective.

As mentioned earlier, an IMO report using data from Lloyd’s Register’s Fairplay, put the world fleet at 100,243 vessels in 2007 and it is obvious that this figure has grown appreciably by now. World fleet fuel consumption (excluding military) is estimated at 333 million tonnes. Taking the price of bunker fuel at approximately $470 per tonne (at time of writing) showed a total expenditure of $156.51 billion per year on bunker fuel for the non-military world fleet. CO2 (carbon dioxide) emissions are estimated at 1,050 million tonnes per year, NOx (nitrous oxides) emissions are estimated at 25 million tonnes per year and SOx (sulfur oxides) emissions estimated at 15 million tonnes per year. (CO2, NOx, SOx are among the key greenhouse gases which international organizations are working hard to reduce).

The report also showed that significant amounts of the energy generated by the fuel supplied to the engines are lost in the form of heat or exhaust and greater part of the remaining energy is spent in overcoming hull friction. It is therefore clear that an enormous amount of the energy generated is used in overcoming hull friction.

It has already been highlighted that keeping a hull clean can save about 20% of fuel consumption. This means that great savings in fuel in a year can be achieved worldwide based on the IMO figures given above. GHG emissions would also be drastically cut down.

Marine biofouling is a big predicament for vessels as it has a direct link to the economics of shipping and if not tackled properly can result in an adverse impact on the environment. It has always been a problem for shipowners and operators since time immemorial and the attachment of marine organisms ranging from slime to hard barnacles increases the weight and drag on the ship which causes increase in the fuel consumption which can be a significantly high cost based on the present escalating fuel prices.

### 6.1 Objective 1 revisited

To identify the range and effectiveness of antifouling options currently available for merchant shipping

The conclusions related to this objective are drawn from the literature review. It was discovered that traditional antifouling technology uses coatings that chemically release biocides to kill or retard the growth of fouling. TBT-based coatings, which were introduced in the mid-1960s, have for years been the most effective antifoulings due to their acute toxicity to target fouling organisms. However, severe environmental problems due to the extreme toxicity of TBT have led to a global ban that entered into force in 2008.

The toxicity of TBT remains a problem for the foreseeable future since high concentrations of TBT are still being detected in the vicinity of ports and shipyards, particularly in sediments in which TBT has accumulated (IMO, 2002). SPC coatings containing copper and other biocides have now become the most widely applied type of antifoulings. They are designed to chemically
release copper and other biocides into surface waters to slow down the growth of fouling organisms. In areas where ships and boats are stationary for a long time such as ports, marinas and anchorages, copper and other biocides accumulate in the water column and sediments may reach toxic levels. FR coatings on the other hand which previously were thought to be non-toxic have been found to leach oils which change the enzymes in barnacle glue making it not only mechanical but biochemical as well.

6.1.1 Implications of objective 1

Since the greater proportion of antifouling systems currently in wide use are biocidal, their negative impact on the environment will continue for quite a considerable period of time unless very drastic measures are taken, such as introduction of a suitable alternative coatings to replace the existing options. Studies show that dissolved copper at concentrations found in areas such as San Diego affects growth, development, and reproduction of marine life such as mussels, oysters, scallops, sea urchins, and crustaceans.

These species showed reduced or abnormal growth at embryo, larval and adult stage and deficiencies in adult digestive, reproductive and muscle tissues. In addition, most copper-based antifoulings contain ‘booster’ biocides to widen the antifouling spectrum. The use of some of these booster biocides has already been banned in certain countries and most of them have come under increased environmental scrutiny. Marine life in port and marina waters will continue to experience the cumulative effects of these poisonous chemicals except in the case of the few countries that have already put in place legislation to reduce or to ban completely the use of these coatings containing biocides. Every reduction of pollution release will therefore help the environment and reducing dissolved copper or other biocide levels will promote a healthier and more abundant food chain for fish, other marine life and birds. Regulations worldwide to reduce the released amounts of copper and other biocides are under review in some countries and many more countries will soon emulate this move, as biocide-free antifouling strategies are considered an effective way to reduce pollution.

6.2 Objective 2 revisited

To make a comparative analysis of the Ecospeed antifouling system to the main options mentioned above.

This objective was also covered under the literature review. A comparative analysis of Ecospeed with the existing main antifouling systems, i.e. the Self-Polishing Copolymers (SPCs) and Foul Release (FR), using various criteria was carried out and it was deduced that Ecospeed had an economic and environmental advantage over the other systems. A traditional ice-going epoxy hard coating demonstrated skin friction marginally greater than that of a modern SPC (both unfouled). In contrast, a conditioned glass flake vinylester hard coating (Ecospeed) showed considerably less skin friction than the same SPC and only slightly more than a third generation FR coating (Hydrex, 2011). Ecospeed, which is produced by a reputable company that offers underwater hull maintenance and repair, conducted a project on selected ships and gathered very reliable and important data.

Ecospeed when combined with routine in-water cleaning helps the ship to sail with no more than light slime and can deliver savings of up to 20% of fuel costs compared to SPC or FR system coated ships which will both build up a slime layer. Ecospeed is very durable and because of its added ingredients for hardness and adhesion, it is able to be used for all conditions including ice. (Hydrex, 2011). Ecospeed, which is produced by a reputable company that offers underwater hull maintenance and repair, conducted a project on selected ships and gathered very reliable and important data.

The ship’s hull smoothness improves with each repeated cleaning, becoming hydrodynamically smoother. Ecospeed is a very tough coating that remains firmly on the hull regardless of excessive flexing and which lasts the lifetime of the ship without requiring
replacement. Only very minimal touch-ups if required need to be done when in the docks for routine checks required by classification rules. Ecospeed has a greater corrosion and abrasion resistance and tends to last. Tests done on glass flake vinyl ester STC (Ecospeed) showed it to be entirely non-toxic to the marine environment when in use, or when conditioned or cleaned in the water. VOC content of Ecospeed is very much less than the existing systems. It also offers huge fuel savings and therefore lowest fuel consumption and GHG emission. The study also shows that significantly smaller amounts of Volatile Organic Compounds (VOCs) are released into the atmosphere with each application of Ecospeed in comparison to the other antifoulings (Hydrex, 2011).

### 6.2.1 Implications of objective 2

The comparative analysis showed that Ecospeed as a Surface Treated Coating is a valuable alternative technology to the biocidal copper-based antifoulings and silicone-based FR systems that are currently on the market. From the enormous economic and environmental benefits generated by this option, and from the response received from shipowners and operators during the survey, it can be speculated that most shipowners and operators will soon gear towards replacing their coating system with one that will come with profound benefits, such as great savings in fuel costs, at the earliest opportunity. Apart from the huge savings in operational costs, the fact that this option will assist to alleviate the problem of pollution of the oceans, harbours, bays, marinas and anchorages from the biocide-based antifouling systems, will urge the shipowners and operators to opt for this system. This is in conformance with the survey conducted as it showed that a greater percentage of the shipowners and operators expressed their concern for the need to consider the environmental consequences when choosing an antifouling option for their hull.

### 6.3 Objective 3 revisited

To conduct a survey on ship owners and operators to determine their willingness to use the Ecospeed antifouling system.

The survey using a questionnaire to ascertain from the shipowners and operators their willingness to use the Ecospeed antifouling system showed a large scale optimism for this option. A greater number of the shipowners and operators surveyed were willing to change from the current system they are using to the Ecospeed as they saw the huge economic benefits to be gained such as a guaranteed lifetime of 10 yrs and an expected lifetime of 25 yrs.

There is also a strong optimism for this system due to the regular underwater treatment which is used preventatively to keep added drag caused by marine fouling under control and thus to minimize greatly the risk of transferring non-indigenous marine species, causing increased fuel costs to be minimized to significantly lower levels. There is also the benefits of not having to paint, in combination with the available underwater technologies for maintenance and repair, which may well extend the drydocking interval and thus save a great deal of expense and loss of business/off-hire for the shipowner or operator.

### 6.3.1 Implications of the response to objective 3

The response from the survey conducted showed that most ship-owners and operators are willing to seek a coating which in itself is long-lasting so that frequent repairs or replacements do not keep the ship out of service and add great expense. This implies they will narrow down their choice of hull coating system and find the one which most benefits their vessel, fleet and circumstance.

There is the realization that their ships need to be kept out of drydock as much as possible so that they can be in service, whether cargo or passenger ships.
Paint application should never be a prime reason to drydock a vessel and all of this must be economically or commercially viable for the shipowner or operator so that the cost of protecting and maintaining a ship’s hull and keeping it at optimum performance without environmental damage is not overly expensive. The enormous savings in fuel costs when using Ecospeed will influence ship operators to select this option as the current trend of skyrocketing fuel prices is every shipowner and ship operator’s bane.

Chapter 7 Recommendations

The purpose of this chapter is to fulfill the last objective of the dissertation by synthesising findings into recommendation(s) for future best practice(s). These recommendation(s) are for the people and organizations who are in some way involved in the process of finding the right ship hull coating system, from an economic and environmental perspective with a uniform balance, which is viable and hence acceptable to the industry as a whole.

Recommendation 1

There is the urgent need to avoid polluting the oceans, ports and inland waterways with toxic chemicals from ship hulls. Regulatory bodies such as the IMO, environmentalists and others interested in reducing or eliminating ocean pollution should only permit coatings on hulls which are proven to be completely non-toxic, non-polluting, not leaching and not harmful in any way to the marine environment. IMO should not permit ship hulls to be coated with any kind of toxic chemical which leaches into the water. This is very straightforward. There is no need to compromise and permit substances to be used which are somewhat less toxic, or whose poisons are not that strong but which are still detrimental to a port. TBT was known to be highly toxic and to be having very destructive effects on the marine environment years before regulations from the IMO finally banned its use.

Recommendation 2

Ships should be inspected before they sail and cleaned if the hull is fouled. This serves a dual purpose of preventing the spread of NIS and reducing fuel consumption. If a ship arrives in port in a heavily fouled state, it should be cleaned as soon as possible, and not allowed to remain in port since the NIS may spawn and the invasive species can spread. Special arrangements can be made to clean such ships so that the debris is collected. This will be expensive and will deter shipowners from sailing with heavy fouling. In the end shipowners will save vast amounts of money by sailing with clean hulls.

Recommendation 3

Some developed ports already segregate hulls coated with toxic coatings, where in-water cleaning can be detrimental to the port environment, and those coated with non-toxic, non-polluting coatings where cleaning presents no threat. All ports should consider this distinction and should do well to permit and encourage in-water cleaning of hulls coated with non-toxic coatings before ships sail. Ports should also permit and encourage in-water cleaning of inbound ships, as long as these are coated with non-toxic coatings and the fouling falls within the slime/weed stage.

Recommendation 4

Special provision should be made by ports for the cleaning of ships coated with non-toxic coatings that arrive heavily fouled. They must be cleaned at the earliest opportunity to prevent spawning of the NIS they might be carrying. They must be cleaned, preferably at an anchorage, and the debris collected. This will be expensive but may encourage shipowners to clean before sailing to a foreign port.

Recommendation 5

Ports should impose levies on ships arriving with a toxic coated and/or badly fouled hull by increasing port fees,
and reward ships sailing with a non-toxic, clean hull by reducing their port fees.

Recommendation 6
Cleaning of slime or light weed should be carried out on all hulls for the meantime as this is better than not cleaning at all, until all ships become coated with hard non-toxic coatings. However the risks involved need to be critically assessed by each port.

Recommendation 7
A hard glass flake reinforced vinyl ester resin STC (Ecospeed), using a high proportion of relatively large glass flakes with added ingredients for hardness and adhesion should be applied to all ships, which lasts the lifetime of the ship and can be cleaned underwater without any detrimental effect to the environment.

Recommendation 8
If a ship currently has a Self-Polishing Copolymer (SPC) or a Foul Release (FR) coating, this should be replaced at the first opportunity with a hard STC coating which is entirely non-toxic and which can be cleaned repeatedly in the water without suffering any damage and, in fact, with improvement after each cleaning.

Recommendation 9
If a ship has been laid idle for some time at a port so that the hull has fouled to any degree, the hull should be cleaned in the water before the vessel sails. The hull would be inspected after the cleaning, ideally by a classification society, and given a clean bill of health. The ship thus sails at optimum performance, resulting in minimal fuel consumption and therefore minimal GHG emissions.

Recommendation 10
Whenever arriving at a foreign port, all ships must present a certificate from a classification society or some other qualified body showing that the hull coating is non-toxic, non-polluting and was 100% clean on sailing and therefore on arrival since ships generally do not experience fouling when sailing. The port of arrival should reward such a ship with reduced port fees. The opposite also applies. If a ship arrives coated with a biocidal antifouling system and in a heavily fouled state, the Port Authority should impose a penalty and require that it be cleaned immediately, with precautions taken to reduce pollution and prevent the spread of NIS.

If the ship remains for a significant length of time in the port of arrival so that fouling builds up, it is again cleaned in the water in port (preferably at anchorage, not quayside) and a certificate is again issued before she sails. When applied consistently by all ports, this approach will eventually bring about a very desirable result. The ports will remain clean, ships will sail with unfouled hulls, fuel consumption will drop, GHG will be reduced, and NIS will not be spread.

7.2 A Possible way forward
There is general consensus among the key bodies who share the common cause for reducing or eliminating ocean pollution that whenever possible, biocides should not be used in any form of hull coatings. There seems not to be a solution for this problem and IMO as well as other regulatory bodies would very much wish that a suitable alternative system could be developed to tackle this burden. The fact remains that the current systems available are still toxic. The idea that not using biocides will cause greater fuel consumption which consequently will mean more pollution to the atmosphere and emission of GHG does not justify their use by any standard.

It is known that the copper and other biocides used in manufacturing antifouling paints are toxic to the marine environment and that the full range of their effects is not even fully known. It is a good thing that biocide based antifouling paints are continuously under scrutiny from environmentalists and other regulatory bodies as
this will help accelerate the development of suitable alternative non-biocidal antifouling systems in the near future.

However, today there is at least one class of coating available which does not leach any chemicals, biocides or harmful oils into the water. It is purely inert and does not produce any chemical reaction when immersed in sea water or fresh water. This is the class of Surface Treated Composites STCs (Ecospeed). It is definitely not the only inert coating in existence but it is one which provides a workable and viable answer to all the different factors outlined in this thesis. Fuel prices are rising and changes in IMO regulations for sulphur content promise to cause even higher increases in fuel costs over the coming years. Ship-owners and operators are running on tighter budgets and margins and cost of hull protection and maintenance must be carefully balanced against savings in fuel consumption. Keeping hulls clean of fouling, even light slime, through regular in-water cleaning can result in massive savings, dwarfing the cost of paint application and in-water hull maintenance. Some of the key factors that will contribute to keeping the fuel penalty low are:

- Designing a hydrodynamically efficient ship
- Coatings to be applied should not add resistance to the hull but rather improve its smoothness and remain smooth
- The hull should as much as possible be kept free of fouling, and ships should avoid sailing even with medium slime. This can be achieved when the right type of coating, used with routine in-water cleaning and with monitoring applied.

A couple of hours delay as a result of cleaning can easily be compensated for during transit as a clean hull will sail faster with significantly lower fuel consumption. IMO’s subcommittee on Bulk, Liquids and Gases, at its 15th session provided detailed recommendations for in-water inspection, cleaning and maintenance which, if followed using trained and experienced personnel to carry out the work, will lead to significantly reduced fuel consumption as well as greatly reducing the NIS risk.
In October 2001, the IMO International Conference on the Control of Harmful Anti-Fouling Systems for Ships, in Agenda item 8, included the following points:

THE PARTIES TO THIS CONVENTION, NOTING that scientific studies and investigations by Governments and competent international organizations have shown that certain anti-fouling systems used on ships pose a substantial risk of toxicity and other chronic impacts to ecologically and economically important marine organisms and also that human health may be harmed as a result of the consumption of affected seafood,

NOTING IN PARTICULAR the serious concern regarding anti-fouling systems that use organotin compounds as biocides and being convinced that the introduction of such organotins into the environment must be phased-out,

RECALLING that Chapter 17 of Agenda 21 adopted by the United Nations Conference on Environment and Development, 1992, calls upon States to take measures to reduce pollution caused by organotin compounds used in anti-fouling systems,

RECALLING ALSO that resolution A.895(21), adopted by the Assembly of the International Maritime Organization on 25 November 1999, urges the Organization’s Marine Environment Protection Committee (MEPC) to work towards the expeditious development of a global legally binding instrument to address the harmful effects of anti-fouling systems as a matter of urgency,

MINDFUL OF the precautionary approach set out in Principle 15 of the Rio Declaration on Environment and Development and referred to in resolution MEPC.67(37) adopted by MEPC on 15 September 1995,

RECOGNIZING the importance of protecting the marine environment and human health from adverse effects of anti-fouling systems,

RECOGNIZING ALSO that the use of anti-fouling systems to prevent the build-up of organisms on the surface of ships is of critical importance to efficient commerce, shipping and impeding the spread of harmful aquatic organisms and pathogens,

RECOGNIZING FURTHER the need to continue to develop anti-fouling systems which are effective and environmentally safe and to promote the substitution of harmful systems by less harmful systems or preferably harmless systems,

HAVE AGREED as follows:

ARTICLE 1
General Obligations

(1) Each Party to this Convention undertakes to give full and complete effect to its provisions in order to reduce or eliminate adverse effects on the marine environment and human health caused by anti-fouling systems.

(2) The Annexes form an integral part of this Convention. Unless expressly provided otherwise, a reference to this Convention constitutes at the same time a reference to its Annexes.

(3) No provision of this Convention shall be interpreted as preventing a State from taking, individually or jointly, more stringent measures with respect to the reduction or elimination of adverse effects of anti-fouling systems on the environment, consistent with international law.

(4) Parties shall endeavour to co-operate for the purpose of effective implementation, compliance and enforcement of this Convention.

(5) The Parties undertake to encourage the continued development of anti-fouling systems that are effective and environmentally safe.
Coming soon

A new book

Surface Treated Composites
WHITE BOOK

A proven, non-toxic, cost-effective alternative technology for underwater ship hull protection and biofouling control

Boud Van Rompay

The new Surface Treated Composites WHITE BOOK by Boud Van Rompay is in final stages of preparation and should be available in printed form before the end of the year.

The Ship Hull Performance White Book contains the material covered in the popular Hydrex White Papers 1 - 11 and the Journal of Ship Hull Performance condensed into a single book. The material has been reorganized and entirely updated and revised. It is a fully documented description of an environmentally friendly, cost-effective fully tested and proven alternative to current prevailing practices for the protection of ships’ hulls and the control of biofouling. The alternative method described has the main benefits of being much longer lasting than the conventional systems in use, entirely non-toxic and environmentally benign and of offering cost savings of 10 - 40% compared to these conventional systems.

Fully indexed and with a comprehensive glossary, bibliography and reference section, this book will be invaluable to anyone seeking a full grasp of the issues surrounding ship hull performance, hull protection, fouling control and current antifouling systems and anyone seeking to reduce the adverse environmental effects of ships and shipping. It opens the door to an alternative approach which does not require widespread ocean pollution and sediment contamination, one which will greatly reduce the costs of transport by sea and save a great deal of fuel and therefore GHG emissions.

We are publishing the introduction to the book in full here as it summarizes the content and purpose of the book.

Introduction

The current system for hull protection and antifouling in general use consists of epoxy anticorrosion paint coated with layers of copper oxide and other chemicals in a soluble matrix so that these chemicals can gradually leach into the water with a view to killing fouling organisms when they settle or try to settle on the hull.

This system is designed for frequent reapplication of the chemical layers and for frequent patching and full reapplication of the entire system on bare steel which it requires every ten to fifteen years. It is modeled on the idea of repeated reapplication which means repeat business for the suppliers of the chemicals, the paint and for the shipyards.
The antifouling coatings in current use have the highly undesirable effect of distributing very large quantities of copper oxide and a number of other biocides such as the extremely toxic herbicides Irgarol 1051 and Diuron into the sea, especially around ports, marinas and anchorages. The damage does not end with water pollution; the heavy metals and other chemicals used persist in the sediment, which they contaminate.

**The biggest maritime disaster of all time**

When an average ship of 50-100,000 tons has a new antifouling coating applied, which is every two or three years usually, 15 tons of biocides are sprayed onto the hull. Of those 15 tons the large component of harmful VOCs is lost instantly into the air, which is itself highly undesirable. During the application, some of the toxic substances are lost to the air and to the water in the form of overspray and waste. The next step is to refloat the ship. This results in an instant, large scale distribution of biocides into the water which pollutes the shipyard and surrounding water and contaminates the sediment locally. The ship then usually sails for two or three years before it goes back to drydock, leaching biocides wherever it goes. It is often cleaned in the water which creates a sudden pulse discharge of biocides into the water where it is cleaned. This cleaning can take off 30-50% of the remaining biocide coating. Eventually the ship returns to drydock so that the depleted or exhausted biocidal coating can be renewed. The 15 tons of biocide originally applied have all been dispersed, polluting the water and contaminating the sediment wherever the ship has sailed or been laid up.

When one multiplies this across the world fleet one sees that it adds up to some 100,000 tons of highly toxic chemicals dispersed into the water every year, with the highest concentrations in ports and harbors, especially around shipyards.

It has been proven that these chemicals persist and that earlier claims about short half lives were largely exaggerations or fabrications. The chemicals accumulate in sediments and these accumulations continue to build up over the years. Evidently the 100,000 tons that were spread in the year 2000, 2001, 2002 and so on are still there, so the accumulation is amounting to millions of tons. This distribution of millions of tons of highly toxic chemicals into the water by ships in the form of antifouling paint constitutes the biggest maritime disaster of all time.

Being gradual and continual rather than sudden and temporary, this disaster is not perceived as such and up to now the use of these biocides has not been banned. The full effects of continuing this highly undesirable approach to hull protection and biofouling control will be even more severe than the damage already done.

This environmental damage is a huge price to pay for a system that is not even very workable. Using the current antifouling systems, some $70 billion worth of fuel is being wasted every year due to increased hull roughness and biofouling associated with biocidal antifouling coatings.

The soft, leaching type of coating which has to be replaced frequently may serve the purposes of the suppliers in terms of repeat business, but it does not serve the purpose of the end user, the shipping industry or the planet.

**A wrong approach**

It is a highly destructive approach and cannot be sustained for the following reasons:

1. It results in the distribution of tens or hundreds of thousands of tons of heavy metals and highly toxic biocides straight into the water as described above.
2. The chemicals used are not able to keep a slime layer from building up and they are not able to effectively deter macrofouling for the entire period between routine drydocking. Thus in-water cleaning is often employed. This results in the sudden depletion of 30-50% of the remaining antifouling coating. This is discharged into the water where the ship is being cleaned, causing a massive emission.
3. Due to the nature of the coatings used, the complex build-up of different layers of different substances on a substrate which naturally interacts electrolytically with the metals in the biocide coatings, the spot blasting, patching and coating repair used to try to extend the life of the coating in drydock, there is a very significant
degradation of the coating. It becomes rougher and rougher over its life. Long before the hull is reblasted and a full new coating system applied, the fuel penalty caused by the added roughness, without considering hull fouling, has been shown to reach 25-40%. This means that a great deal more fuel is being burned than necessary to maintain speed. This is accompanied by a proportionate unnecessary emission of CO₂, NOx, SOx and particulate matter. This fact of hull coating degradation is generally ignored or unknown. It is seldom mentioned, despite being a major cause of fuel inefficiency.

All of the above are the simple, direct consequences of using a coating system for the underwater hulls of ships which is inappropriate, undesirable and unsustainable. The surface preparation, paint and chemical coatings used in these systems are simply substandard and not fit for the purpose of protecting a ship’s hull throughout its service life and keeping the biofouling to a minimum level where the fuel penalty is acceptable.

There was a point in the development of hull protection systems and biofouling control where a severely wrong turn was taken. Early biofouling control consisted of beaching and careening a ship and scraping the hull. Then the idea of attaching copper sheets to the wooden hull was tried and found to be effective. This system could not be used with steel hulls due to the galvanic action and consequent very rapid corrosion. The idea of using a soft coating with chemicals that leached into the water was tried. It was an attempt to replace elbow grease with poisonous chemicals. The ultimate toxic substance was TBT. The harm to the environment was so great that this was eventually banned after great damage was done which is still being felt today. However the fundamentally flawed idea of leaching heavy metals and poisonous substances continued and copper oxides and a number of herbicides and other chemicals were used instead.

Note that nailing copper sheets to the wooden hull of a sailing ship is very, very different from coating the steel hulls of thousands of ships with many tons of chemicals designed to leach into the water. These cannot even be compared. The only connection between the two is that the sheets were of copper and the most common biocide used is copper oxide. But the comparison ends right there.

**The basic proposition**

The proposition is quite a simple one. Transport by sea is economical, efficient and very useful. It has been so for thousands of years. The sea, however, is a much tougher, harsher, more aggressive environment for manmade objects, including ships, than anything experienced on dry land. Water, especially saltwater, is highly corrosive. There is galvanic, electrolytic corrosion of the mild steel which is the most common material for ships’ hulls. There are the forces of cavitation which accompany fluid flows and can be very damaging to steel and other substrates. There are particles in the water such as ice, sand, gravel or lava which are all aggressive to the underwater hull. Impact of objects is another source of attack. Last but definitely not least there is the attack of marine growth, plants and animals which attach themselves to the hull with, in some cases such as barnacles, amazing tenacity. All these factors pose a challenge to shipping. The hull must be maintained in good shape, smooth and free of fouling in order for the ship to travel rapidly through the water with an efficient consumption of fuel.

The whole idea is to continue transport by sea, keeping ships’ hulls protected and smooth, while creating a minimal and sustainable effect on the environment. The environment here refers to water quality, sediment contamination and the air or atmosphere. Shipping can have an adverse effect on all of these. The idea is to keep this effect to a minimum. The approach taken to accomplish this has been completely wrongheaded. The use of a soft, toxic coating which does not protect the hull well, which becomes rougher and rougher over time, does not prevent slime and algae from attaching to the ships’ hull nor invasive species from colonizing niche areas, which distributes hundreds of thousands of tons of heavy metals and highly toxic chemicals into the water every year and which needs frequent replacement, is not suitable and does not serve the purposes of transport by sea, no matter how profitable this approach may to suppliers be in terms of repeat business.
A fully workable, tested, successful, economically viable alternative

Over the last 15 years we have researched, formulated and put into effect an entirely different approach, much closer to the original concepts of maintaining smooth and clean hulls using elbow grease rather than biocides, but also brought into line with modern technology appropriate to the 21st century.

Research led in a 180° opposite direction from the soft, biocide leaching coating. This alternative approach consists of a hard, tough, resilient coating which thoroughly protects the hull, whether steel, aluminum or glass reinforced plastic (GRP), for the service life of the ship. It is the exact opposite of the repeated recoatings model. It is the exact opposite of the soft, leaching type of coating, being hard and inert with no active ingredient emitted into the water. Consisting mainly of glass flakes in a vinylester resin, it is an electrical insulator. It has been shown to entirely prevent cavitation damage on 100% of rudders coated with it, and rudders are notorious for succumbing to the forces of cavitation.

The coating protects the hull and underwater parts of the ship because it is hard, tenacious, tough, resistive and resilient. Instead of degrading over time, this coating becomes smoother and more efficient hydrodynamically.

The coating is kept clean of fouling by cleaning it! Nothing could be more simple or obvious. If you want something to be clean, you clean it. And "killing is not cleaning," to quote Professor Hans-Curt Flemming of the university of Duisburg Essen. The cleaning is done with the vessel afloat and is accomplished without harm to the coating or to the environment. It can be repeated as often as needed, depending on a ship’s sailing pattern, climate and other factors, in such a way that the hull never becomes fouled beyond a light slime. But even heavy calcareous fouling can be removed without the coating suffering any damage.

This system has the significant added benefits of reducing fuel consumption and thereby GHG, and eliminating the spread of invasive aquatic species. Compared to other coatings it has very low VOC emissions. Because it is applied only once, it eliminates the environmental and economic liabilities associated with repeatedly removing and reapplying the bottom paint and chemical layers.

As demand increases and this alternative approach gains acceptance, the facilities and infrastructure required for rapid, high quality industrial level hull cleaning will be established universally. The idea of a ship wash will prevail. It will not be along the lines of a car wash because the different hull shapes and sizes and the differences between activities on land and activities in the water preclude this. It could be compared to a hand car wash. Nevertheless, the cleaning can be performed thoroughly, completely, rapidly and efficiently with minimal interference to a ship’s operating schedule. The cost of such cleaning is still much less than the money currently wasted on fuel through hull roughness and fouling and on the repeated reapplication of the coating systems currently in general use.

This then is a coating system which is fit for purpose, is economically viable and environmentally sustainable.

The only loss associated with this system is the loss of repeat business to bottom paint and chemicals suppliers who rely on frequent coating replacement as their business model. This system is what shipping, shippers and the planet need.

Accountability

There is a point which is often misinterpreted, ignored or missed. When a shipowner decides to coat his ship, whether new or in service for some time, with toxic antifouling paint, he is taking a clearcut decision to continue to pollute the sea by just that amount of biocides. If he orders a ship to be coated with 15 tons of biocides, he knows that those 15 tons are going to add to an accumulation of marine pollution. Whether or not this is technically legal is not the issue. TBT was technically legal for decades before it was finally banned, but this did not reduce the harmful effects of its use. Nor did this exonerate those who continued to use it despite the fact that its harmful effects were well known and publicized broadly. It is those individuals who decided to use or continue to use TBT on their ships who are accountable for the consequences. They too hid behind the fact of legality to continue to wreak environmental havoc.

The same applies to the current crop of biocides. There
are innumerable papers pointing out the dangers to the environment of copper oxides and all the various biocides currently in use. These are known facts available to all who choose coatings for ships and boats.

Therefore those who continue to use such systems in the full knowledge that they are contributing to a maritime disaster of this magnitude are fully accountable for that contribution and that disaster.

The fact that there is a fully tested, successful and better system for protecting ships’ hulls and dealing with fouling, adds to that accountability.

That the alternative happens to be cheaper in the long run and will save shipowners and operators much expense in terms of fuel wasted, additional drydocking fees and the cost of reapplication, renders it inexcusable to continue to use the toxic solution.

This book examines all the factors involved with ample references to back up the statements made and conclusions reached.

Boud Van Rompay
Antwerp, August 2012
This year SMM celebrates its 25th anniversary.

SMM is the leading international forum of the maritime industry. Every two years, the representatives of the shipbuilding and marine equipment industries from all parts of the world meet in Hamburg, present innovations and forward-looking technologies, and set the course for future success of the industry.

There are opportunities for synergies for visitors this year – with the association between the MS&D conference and the Maritime Security and Defence section at SMM.

SMM is also the trail blazer for green technologies in shipbuilding and the marine equipment industry. gmec (global maritime environmental congress) will be held on the occasion of SMM, providing another attractive component.

Hydrex will be there at booth number B5 FG015. Hydrex Founder and CEO, Boud Van Rompay, will give a presentation at the Marine Coatings Conference 2012 at SMM.

For more information, visit visit www.smm-hamburg.de/en/
Green Ship Technology Asia Conference
26-27 September 2012
Singapore

GST Asia 2012 - The largest Asia Green Shipping and Green Ship Technology event for the maritime industry.

GST Asia 2012 will feature many green shipping initiatives including:
- The chance to hear from 50+ expert speakers including senior shipowners and operators
- Two operational and technical streams exploring the possibilities for life-cycle sustainable shipping
- Shipowner panels discuss ballast water management implementation to meet D2 standard, performance monitoring, and use of abatement technology to meet emission controls
- A shipowner only breakfast briefing - focus on evaluating best technical solutions for your fleet
- New EEDI/SEEMP Seminar - understanding implementation of these two important pieces of IMO regulations
- Stakeholder problem-solving panel discussions.

For more information, visit www.informamaritimeevents.com/event/gst-asia
An interactive forum for ship owners, operators and charterers; offering real business value through critical analysis of eco-efficient operations, held in association with BIMCO and organized by the team behind ctech, the online knowledge hub for maritime eco-efficiency technologies.

This event will give attendees the opportunity to engage with high level industry specialists offering expert insight in to the challenges and solutions for efficient operations. Fast-paced technology sessions provide the opportunity to examine first-hand key technologies that can offer real fuel saving advantages.

This year’s Ship Efficiency event will be chaired by Andreas Chryostomou, Chairman of the IMO’s MPEC.

Confirmed speakers include: Andreas Chryostomou, Chair, IMO MEPC; Lars Robert Pedersen, Deputy Secretary General, BIMCO; Damien Meadows, Head International Carbon Markets, EU; Yvo De Boer, Special Global Advisor, KPMG Climate Change and Sustainability; Dr Carsten Wiebers, Global Head of Shipping, KiW IPEX Bank; David Hardie, Head Vessel Operations Group, BMT ARGOSS; Jonathon Stoneley, Environment and Compliance, Ocean Transportation, Cargill; Tom Strang, VP Policy & Regulation Carnival Corporation; Niels Bjorn Mortensen, Head of Regulatory Affairs, A.P. Moller Maersk; Tom Kirk, Vice President of Engineering, ABS; Jukka Ignatius, Advisory Systems, ABB; Bob Billet, European Sales Manager, Applied Weather Technology; Mike Simpson, MD, Houlder Limited; Walther Bauer, Director Sales & Projects, Becker Marine Systems; René Fich Jespersen, General Manager, Alfa Laval Aalborg; Robert Dane, CEO, Solar Sailor; Ted Shergalis, CEO, Magnuss; Niels B. Clausen, Senior Manager Engine & System Application, MAN Diesel; Melvin Matthews, Nautical Consultant, Eniram; Ralf Jurgens, R&D Manager, Couple Systems; Boud Van Rompay, Founder and CEO, Hydrex nv.

Hydrex CEO, Boud Van Rompay, has been invited to give a presentation about Ecospeed on October 25th 2012, Technology Day.

The agenda is available on line along with full information about the event at: www.fathomshipping.com

North America’s leading Arctic Shipping event tackling strategic challenges and commercial opportunities in Arctic operations. The key industry event for all Arctic shipping stakeholders in North America

- Hear from leading shipping industry speakers on their strategies for operating in ice-covered waters with a focus on charts
- Evaluate what you need for developing new resource exports in the Arctic successfully
- Analyse the impact on shipping and commercial developments of environmental and local community imperatives
- Discuss the offshore operators’ perspectives on meeting logistical and regulatory challenges
- Learn from the latest ship design options and technology for ice-going shipping and offshore operations
- Benefit from an in-depth discussion on winterisation and assess criteria for efficient anti-icing solutions
- Find out the latest status of the Polar Code
- Hear from the experts on dynamic positioning in ice

For more information, visit www.informamaritimeevents.com/event/arcticshippingnorthamerica
Sensible, comprehensive, simple but vital information on:

- saving fuel costs by optimizing ship
- state-of-the-art, environmentally-safe fouling control
- reducing GHG emission from shipping
- containing invasive species
- reducing drydocking

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