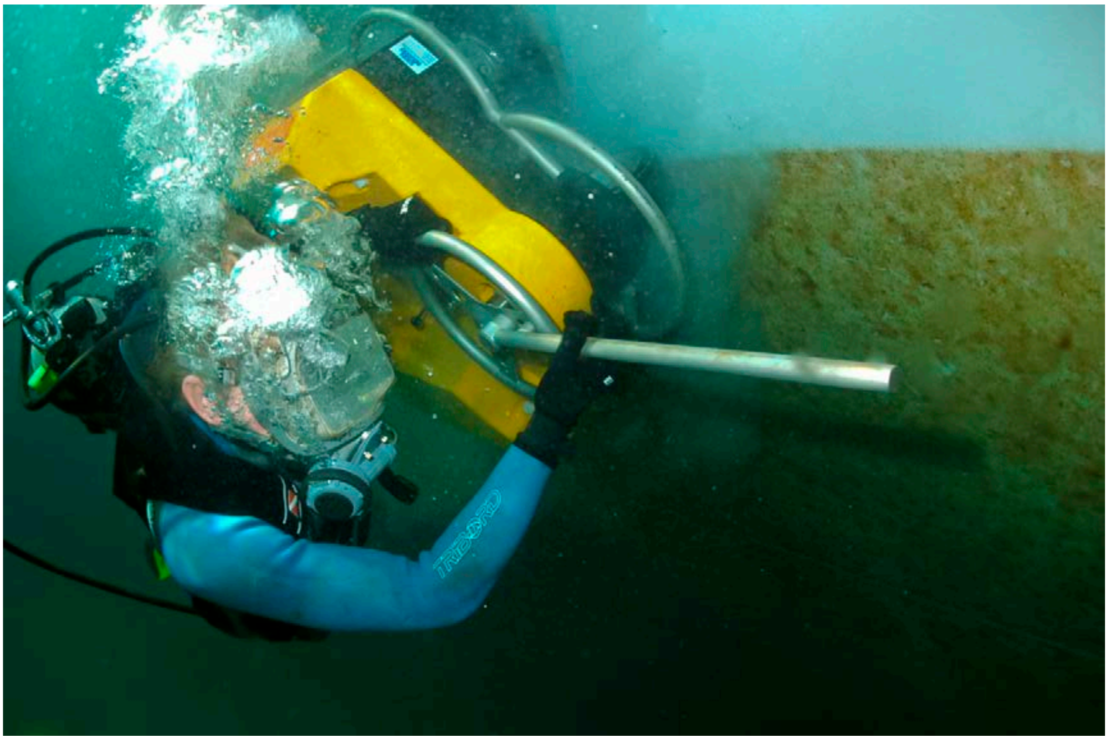
WHITE PAPER

Underwater ship hull cleaning: cost-effective, non-toxic fouling control



A practical guide to industrial underwater ship hull cleaning, its value and limitations, and how to institute a workable program for optimizing ship hull performance and saving fuel, with due concern for the environment

The Hydrex Group
www.hydrex.be

HYDREX WHITE PAPER No. 5

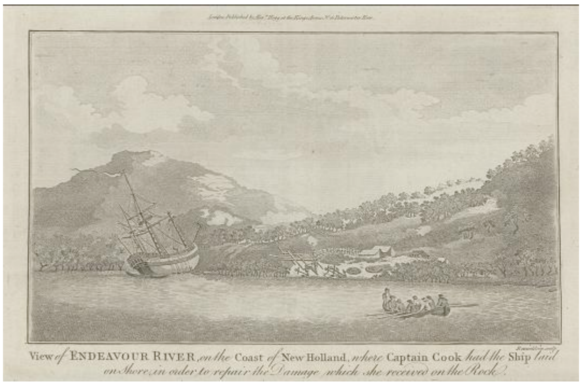
Part I. Introduction

Historical note

Cleaning ship hulls of marine fouling has been a fact of maritime life since humankind first took to the sea in boats and ships. The Greek priest and author Plutarch (45–125 AD) discusses the cleaning of ship hulls in his *Symposiacs*.

> ...for the ship continuing dry, not yet made heavy by the moisture soaking into the wood, it is probable that it lightly glides, and as long as it is clean, easily cuts the waves; but when it is thoroughly soaked, when weeds, ooze, and filth stick upon its sides, the stroke of the ship is more obtuse and weak; and the water, coming upon this clammy matter, doth not so easily part from it; and this is the reason why they usually calk their ships.[1]

The British Royal Navy was well aware of the importance of removing fouling from the hulls of their men-of-war in the 18th and 19th centuries when "Britannia ruled the waves." Captain James Cook landed his ship *Endeavour* at a small harbor he found at the mouth of what he named the Endeavour River in Australia on his way around the world so that it could be careened (laid over on its side) and the hull repaired and scraped free of barnacles.[2] Captain Cook notes elsewhere in his journal that he was looking for a suitable location to careen the ship with the sole purpose of cleaning the bottom.



Engraving of *Endeavour* beached at Endeavour River during Cook's first voyage of exploration. First published in "A new, authentic, and complete collection of voyages round the world: undertaken and performed by royal authority: containing a new, authentic, entertaining, instructive, full, and complete historical account of Captain Cook's first, second, third, and last voyages, undertaken by order of His present Majesty" page 117, edited by William Anderson, published by Alexander Hogg, 6 Paternoster Rd London (1786)

It has long been known that fouling on a ship's hull greatly increases hull friction and slows the vessel down, making it more sluggish and less maneuverable.

Technology advanced to the point where ship hulls could be cleaned with the ship still in the water by divers using a variety of hand and mechanical tools and scrapers. Cleaning the hull with the ship in the water avoided beaching and careening or the more modern equivalent, drydocking, thus saving time and expense while still getting the job done.

For a brief time towards the end of the 20th century, the introduction of the highly toxic TBT into hull paints gave the illusion that ship hull cleaning was an unnecessary thing of the past. The idea was that all the hard work required to keep a ship hull clean could be avoided, substituting chemicals for manpower. This was one of those unfortunate "if it seems too good to be true it probably is" scenarios. It was soon discovered that TBT was a two-edged sword and the damage the poisonous substance caused to the marine environment was extensive, severe and unsustainable.[3] [4] Nevertheless, during the "TBT era" the subject and practice of underwater ship hull cleaning went into decline in terms of repute, technology, skill and general availability.

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[1] Plutarch *Symposiacs* Book II Question VII

[2] Blainey, Geoffrey (2008). *Sea of Dangers: Captain Cook and his rivals* Penguin Group (Australia) 252-257.

[3] Janice Limson, "Tributyltin - the most toxic chemical ever deliberately released into the seas" *Science in Africa*

[4] EU-Life *Organotins* http://www.ukmarinesac.org.uk/activities/water-quality/wq8_26_1.htm accessed June 2011.

The TBT deception also resulted in the current attitude towards underwater cleaning held by many shipowners/operators who consider it a hassle and a logistical nightmare. The tendency is to avoid underwater hull cleaning.

Vicious circle

However, the antifouling technology which replaced TBT-laden hull paint was relatively ineffective. All ship hulls develop a biofilm or slime layer at the very least, regardless of the bottom paint used, and this, combined with rough hull coatings, carries with it a fuel penalty of as much as 20% or more. [5] [6] And there is an additional liability to the antifouling technology which replaced the TBT paints: the coatings could not be cleaned without damage to the paint and to the marine environment.

...underwater ship hull cleaning, thoroughly and efficiently done on an industrial basis and on a suitable hull coating, is the answer to reducing fuel costs, cutting GHG emissions, preventing the spread of non-indigenous species and avoiding marine chemical pollution.

Rising costs of bunker fuel mean that a 20% fuel penalty is intolerable.

The underwater hull paint industry has created a "damned if you do, damned if you don't" situation for shipowners/operators which includes frequent drydocking and paint replacement, a built-in fuel penalty, and coatings which are ineffective in preventing fouling yet are not suitable for underwater cleaning (the only practical means of avoiding the fuel penalty incurred).

Today underwater ship hull cleaning thoroughly and efficiently done on an industrial basis and on a suitable hull coating is the answer to reducing fuel costs, cutting GHG emissions, preventing the spread of non-indigenous species and avoiding marine chemical pollution.

Practical approach

Much of the literature reviewed on the subject of underwater ship hull cleaning takes a theoretical approach to the subject or is produced by people who are remote from the slime, weed, barnacles and other fouling on the typical ship hull, have not looked at fouled hulls underwater or cleaned ship hulls or talked to those who have. Often they try to compare underwater cleaning to apparently similar activities carried out on land, demonstrating an unfamiliarity with hydrodynamics and the differences between operations carried out on land and in the water. The real issues are not necessarily identified. Potentialities are missed. Restrictions are also missed. The result is that the view of underwater cleaning currently in circulation in the maritime industry and in academic writings tends to be rather impractical and divorced from reality, leaving shipowners and operators ill-informed on the subject.

This paper is a realistic survey of the subject of underwater ship hull cleaning, examining benefits as well as difficulties and limitations, with a view to providing an accurate and useful summary which can be put into use by shipowners and operators on an immediate basis using today's technology to save 20% or more on fuel costs and GHG emissions, reduce the need for drydocking, prevent the spread of non-indigenous invasive species and all without polluting the marine environment. Knowledgeable experts on and practitioners of underwater ship hull cleaning have been consulted with a view to describing real situations, issues and solutions.

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[5] "The Slime Factor" (Hydrex White Paper No. 2, section "No hull or coating immune" (2010) 6-7

[6] M. P. Schultz and G. W Swain, "The Effect of Biofilms on Turbulent Boundary Layers," Journal of Fluids Engineering, Vol. 121 / 51, (March, 1999).

Part II. Vectors of change

In the second decade of the 21st century, a number of vectors are converging, driving the shipping industry towards a more efficient and environmentally safe approach to hull coating and fouling control. The vectors involved are

1. rising cost of fuel,

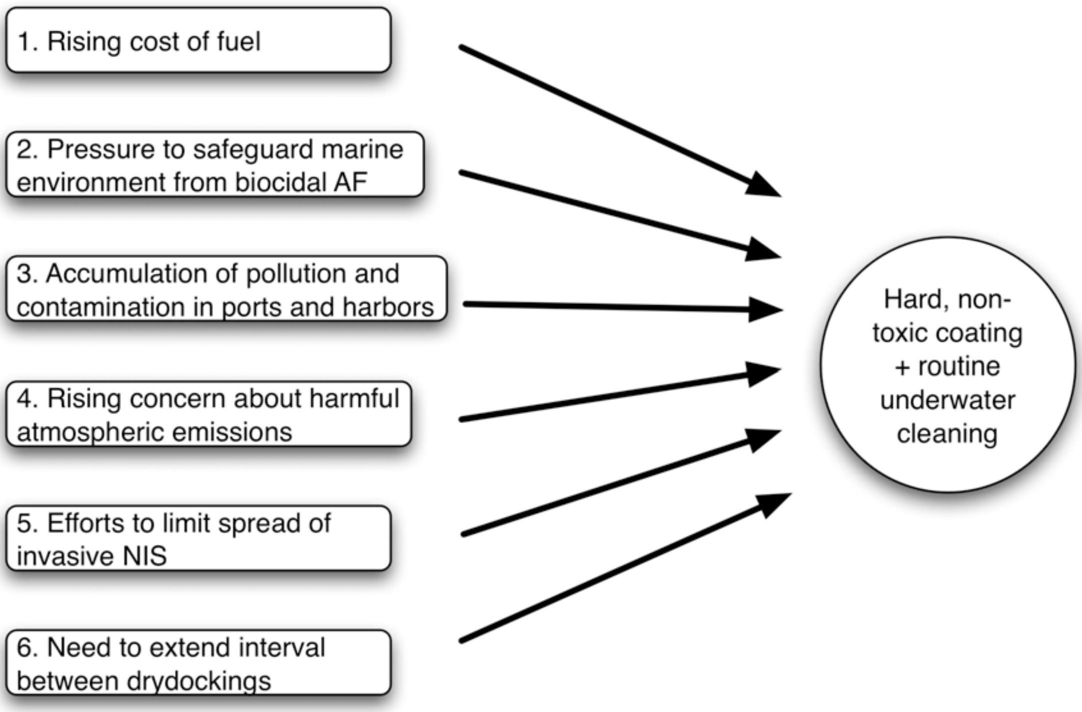
2. pressure to safeguard the marine environment from the harmful effects of chemical biocides contained in conventional antifouling paints,

3. the problem of accumulating pollution and contamination of ports and harbors and their immediate surroundings, along with the great difficulty of dredging or trying to clean up those areas,

4. rising concern about harmful atmospheric emissions such as nitrous oxides (NOx), sulfur oxides (SOx), so-called green house gases (GHG),

5. efforts to limit the spread of invasive non-indigenous species (NIS) via ship hull fouling

6. the economic need to extend the interval between drydockings.

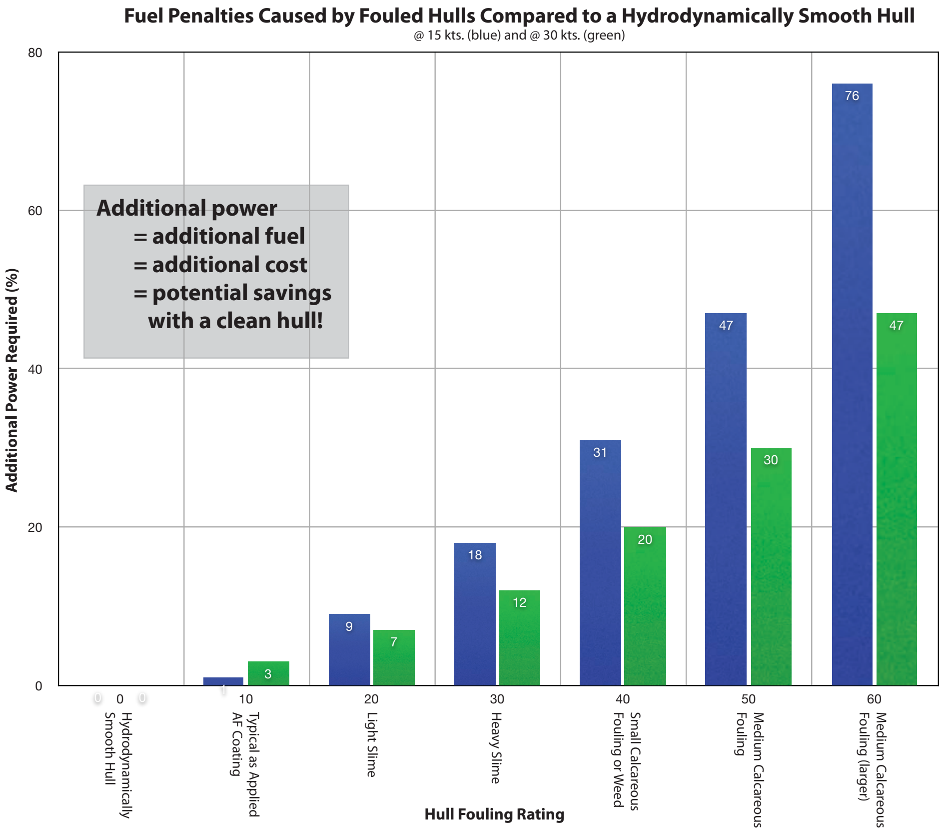


Fast, effective, widely available industrial grade underwater hull cleaning plays a key role in each of 1 - 6 above. Let's see how.

1. Rising cost of fuel

This has been well documented in a previous White Paper in this series, Hydrex White Paper No. 3, *Clean Ships Hulls and Ports–Without Compromise*. The price of bunker fuel has been rising and all indications are that it will continue to do so. This is a major concern for all shipowners/operators who are looking for ways to reduce this cost so that they can maintain a profit margin without having to raise their prices excessively.

Hull fouling increases fuel consumption dramatically, as the following chart shows:



Data taken from Schultz, Michael P., Department of Naval Architecture and Ocean Engineering, United States Naval Academy, Annapolis, Maryland, USA(2007) 'Effects of coating roughness and biofouling on ship resistance and powering', Biofouling, 23:5, 331 - 341, and Naval Ships' Technical Manual Chapter 081 Waterborne Underwater Hull Cleaning of Navy Ships.

Therefore keeping a ship's hull in smooth condition and free even of slime can add up to savings as high as 20% or more. Currently available antifouling (AF) coating systems are not particularly effective in preventing a build-up of slime. Fouling release (FR) coating systems also accumulate slime. Surface treated composite (STC) systems also build-up slime. In fact all available coatings tend to accumulate biofouling in the form of slime or biofilm quite rapidly, depending on the ship's disposition and the waters in which it sails. Thus a fuel penalty of as much as 20% or more is usual with any ship, no matter what hull coating system is in use, unless the fouling is removed.

2. Avoiding chemical pollution of the oceans and waterways

This factor has been a major concern since TBT was found to be so damaging. Even though TBT has been banned and is no longer in use as an antifouling biocide, the biocides currently in use including copper and a number of so-called booster biocides or co-biocides are under scrutiny and are being increasingly regulated against (the latest development is the Washington State ban on the use of copper in antifouling paint for recreational craft, the first US state to restrict the use of copper for this purpose). Part of the Synopsis of the bill as Enacted, C 2248 L 11, is quoted here:

> Background: Aquatic antifouling paints are used on water vessel hulls to prevent the growth of aquatic organisms such as barnacles and algae. Most of these antifouling paints use copper to reduce the growth.
>
> According to a 2007 study, the Department of Ecology (DOE) has conducted research measuring copper concentrations in marinas and found the primary source of copper to be from the antifouling paints found on boat hulls. Research has shown copper to be highly toxic to aquatic life.
>
> Summary: Recreational water vessels are defined as a vessel that is less than 65 feet in length, and used primarily for pleasure or leased, rented, or chartered to a person for the pleasure of that person. It does not include a vessel that is subject to United States Coast Guard inspection and is engaged in commercial use or carries paying passengers.

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> After January 1, 2018, new recreational water vessels with antifouling paint containing copper may not be sold in the state. Beginning January 1, 2020, the sale of copper antifouling paint intended for use on recreational water vessels is prohibited. [7]

At time of writing, a similar bill has been introduced in California, SB 623, which is in final stages of approval in the California Senate.

This is a valid concern. The trend here is towards a complete ban on biocides in hull coatings where there is any doubt about the environmental safety of these biocides. So far no biocide has been developed which is completely safe environmentally, which targets only the fouling which actually settles or attempts to settle on the hull, and which loses its toxicity within a very short time or distance from the hull so that no non-target organisms are affected, the surrounding water is not polluted and the poisons do not settle in sediment in port areas.

It is extremely difficult to predict the impact biocides and heavy metals will have on marine life in the future. The precautionary principle suggests that non-toxic strategies are the safest approach to adopt.

Until such a biocide is developed and tested, the regulation against all biocides which do not meet these specifications and which continue to pollute the oceans, ports and waterways will increase. In Chapter 25 of the 2009 book *Advances in marine antifouling coatings and technologies,* A. J. Scarding includes the following:

> 25.1.1 The need for non-toxic alternatives
>
> The control of biofouling has finally reached an important crossroad. No longer is it acceptable to use TBT or indeed any other toxins which will harm non-target marine organisms. It is extremely difficult to predict the impact biocides and heavy metals will have on marine life in the future. The precautionary principle suggests that non-toxic strategies are the safest approach to adopt.[8]

Already many ports in the world understandably ban the underwater cleaning of hulls coated with biocidal AF paint in order to protect their waters and environment.

3. Problem of accumulation of pollution and contamination in ports and harbors

This is the same general situation as covered in point number 2 above but with local consequences of grave concern to ports and harbors. It extends to inland waterways. Due to the activity in ports, the fact that ships can remain there for some time and the work carried out in drydocks and ship repair yards, the pollution and contamination of these waters and the local seabed is intensified many times compared to the effects of biocides in deep water. Port authorities are rightfully protective of their immediate environment, concerned for the health and safety of those using the port and the general cleanliness of the water and seabed. [9]

4. GHG, CO_2, NOx, SOx

Harmful emissions go hand in hand with fuel consumption. Responsible governments, environmental agencies and a number of NGOs are working hard to reduce the worldwide emission of greenhouse gases, carbon dioxide (CO_2) nitrous oxides (NOx), sulfur oxides (SOx), particulate matter (PM) and other atmospheric pollutants. International shipping is not the main culprit when it comes to these emissions but nevertheless plays a significant role. Thus part of the worldwide endeavor to reduce these emissions from all sources are the efforts by the IMO and others to reduce that component of the overall emissions which can be attributed to shipping.[10]

These emissions tend to be in direct proportion to the amount of fuel burned by ships. Propulsive fuel consumption can be reduced in a number of ways. A major factor is avoiding the extra fuel required to overcome the hull friction increase caused by fouling. This brings us back to the points covered above under "Rising cost of fuel." Reduce fuel consumption by removing slime and other biofouling in a timely manner and this will automatically reduce the emissions of atmospheric pollutants.

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[7] Final Bill Report SSB 5436 2011-12, Washington State Legislature

[8] A. J Scarding, Chapter 25, "Surface modification approaches to control marine biofouling," *Advances in marine antifouling coatings and technologies*, Edited by Claire Hellio and Diego Yebra, Woodhead Publishing Limited, 2009: 664

[9] Hydrex White Paper No 3, Clean Ship Hulls and Ports – Without Compromise

[10] Second IMO GHG Study 2009

5. Invasive, non-indigenous species (NIS)

Greater and greater pressure is being exerted to prevent or limit the spread of invasive non-indigenous species (NIS) via shipping, both from ship hull fouling and from ballast tanks.[11]

Trying to prevent this spread by applying highly toxic AF coatings is a self-defeating activity from an environmental point of view. Like robbing Peter to pay Paul, the gains that might be made in limiting the NIS spread are outweighed by the damage done by the chemicals. The AF coatings currently in general use are not very effective in preventing the spread of NIS. In fact there is evidence that they contribute to the creation of a sort of super-NIS which are resistant to biocides and better armed to take over a new marine environment than the local species they displace.[12] Neither are the FR coatings effective since some NIS are translocated even if others do not adhere or are washed off. If some NIS are transported, the damage is done. In order to really prevent the spread of NIS, ships must sail with a completely clean hull. They will not usually pick up fouling while en route and therefore if they sail with a clean hull from Port A they will arrive at Port B with a clean hull: no NIS. But this would require thorough cleaning before the ship sails, not a 20%, 40%, 75% job.

6. Fewer, shorter drydockings

As a further means of maintaining or increasing profit margins by keeping ships in service as much of the time as possible, trends are towards longer intervals between drydocking and less time spent in drydock. Many operations to the underwater hull and other parts of the ship below the water line can be accomplished more quickly and economically in the water, without pulling the vessel out of the water in drydock. This includes underwater hull cleaning and propeller polishing, both designed to reduce fuel consumption, as well as minor and major repairs which, if not done, would prevent a ship from operating at all.

Many operations to the underwater hull and other parts of the ship below the water line can be accomplished more quickly and economically in the water, without pulling the vessel out of the water in drydock.

Many of these cleaning, maintenance and repair activities can also be done in drydock just as well or in some cases better, but the expense of frequent drydocking is prohibitive in terms of the drydocking fees and labor costs themselves and the financial loss resulting from having a vessel out of service frequently and/or for extended periods of time. Others of these operations, such as hull cleaning on a surface treated composite (STC) coated hull, are better performed in the water due to the ease of access and the lubricant effect of the water when using mechanical tools. In fact an STC coated hull improves in smoothness and hydrodynamic properties when cleaned in the water, a combined effect of the tools and the water.

The pressure to drydock vessels less frequently and for shorter periods of time so as to keep costs down is increasing, as seen in the push towards a 7.5 or even 10 year drydocking interval. The main obstacles to this extended interval are hull corrosion and fouling. The main incentive, if these factors are handled, is a great reduction in costs.

The following article published by the Baltic and International Maritime Council (BIMCO) states the situation and trend very clearly:

> Drydocking a ship periodically has been regarded as important, and an adequate network of drydocks and graving docks has been regarded as essential for both efficiency and safety. At the regular docking, the fouling over the ship's submerged body can be scrubbed off, new coatings applied while the important underwater elements, such as the stern tube and its seals which prevent water getting into the ship (and any oil getting out) can be inspected. The propeller can be polished, and the various intakes such as the sea water suction, or the bow thrusters and its tunnel, can be inspected and overhauled.
>
> It is fair to suggest that shipowners regard drydocking as a necessary evil, with the ship out of service for this periodic inspection. Drydocks are expensive to hire, and with so many very large ships at sea, it is sometimes difficult to find one available, especially for an emergency. It is usually necessary to book many months, or even years, ahead of the drydocking date, while big owners of big ships often contract their dockings on a block booking system that they hope will give them preferential treatment for their vessels.
>
> Owners have tried to convince classification societies that the interval between dockings could be extended, on the grounds of more reliable and high performance hull coatings that keep growth at

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[11] MEPC 55, (Marine Environment Protection Committee 55th Session), MPEC 56

[12] Jamie Gonzalez & Leigh Taylor Johnson, "Copper-Tolerant Hull-Borne Invasive Species: Further Analysis, Sea Grant, 2008

> bay for longer, along with maintenance programmes that help to demonstrate the vessel's ongoing quality. But what is a real breakthrough is underwater maintenance and repair equipment and technology that will virtually do everything a drydock can do, but without needing that drydock.
>
> There are now underwater repair specialists that will undertake quite extensive repairs using "cofferdams" – chambers that can fit tightly to the underwater body of a ship and provide a dry refuge to the repair team. It is possible to scrub growth off the underwater shape, even to recoat with certain coatings, while propeller polishing is a job that can be done by divers as well as can be undertaken by people working in drydocks. It then becomes possible to extend the intervals between dockings, with savings in time and money, and without having to take the ship out of service.
>
> Much of this technology has emerged from the offshore industry, where maintenance regimes and specialist coatings have been developed that will enable floating platforms and storage vessels to stay on station for 20 years or more. Ships will still need drydocking , but not so often, and the huge expense of building docks capable of taking today's huge vessels might be mitigated.[13]

These six vectors of change are all driving the industry in the same direction: use of a hard, inert, non-toxic coating and routine in-water cleaning. There are many advantages to this approach.

[13] BIMCO http://editor.bimco.org/en/Corporate/Education/Seascapes/Sea_View/Doing_without_drydocks.aspx (2010) accessed June 2011.

Part III. A workable approach to underwater ship hull cleaning

To clean or not to clean

Any level of fouling, including biofilm or slime, carries with it a considerable fuel penalty. With current fuel prices, this is too much to ignore. [14]

There is currently no hull coating available which will not foul. Some coatings are more resistive to heavy fouling than others; some coatings make it harder for heavy fouling to adhere; some are easier to clean than others; some shed some of the fouling when the vessel is traveling, particularly when it travels at speed. But all currently available hull coatings will foul, even if the fouling is limited to slime and weed.

The only way to remove this fouling is by cleaning it off. This can be done in drydock using pressure washing with widely varying results depending on the type of coating and the degree of fouling. Or it can be done underwater using a variety of methods, some more effective than others, some too impractical for general use (e.g. high pressure underwater washing for soft coatings such as fouling release coatings, which is too slow and expensive to be of any real value).

Like it or not, ship hull cleaning is an essential part of operating a vessel or a fleet efficiently and economically.

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Having decided that hull cleaning is essential, it is worth looking at how to get it done in a cost-effective and environmentally safe manner.

How to clean

There are two main choices:

1. clean in drydock
2. clean underwater.

Cleaning in drydock using pressure washing is possible on all coatings unless the fouling has become too heavy to wash off. In theory, even biocidal coatings can be cleaned in drydock where adequate provision is made for collecting the debris and any waste water and disposing of the biocides safely. Fouling release coatings, providing the fouling is limited to slime, can also be cleaned in drydock by low pressure water jet.

The main problem with cleaning in drydock is that it is much too expensive to drydock a vessel with the frequency required to keep the hull free of fouling. It could mean drydocking a ship every month or two. Any shipowner or operator knows that this is much too costly and also much too disruptive to a ship's operating schedule and it simply will not happen.

While there are a number of techniques and methods of underwater cleaning under research and development, the currently available best practice for removing the fouling from below the water line on a vessel consists of the following elements:

1. Divers specially trained and experienced in underwater ship hull cleaning

2. Self-propelled mechanical underwater cleaning machines with rotating tools (or scrapers in the case of heavy fouling) which are kept in contact with the hull by suction and steered by a diver (these are used to clean the fouling off the larger areas of the hull such as the vertical sides or the flat bottom)

3. Smaller mechanical tools to clean areas where the larger machines cannot reach or clean

4. Hand scrapers and tools to clean niche areas

5. The above are best accomplished with the vessel at anchor rather than quayside, allowing easy access to all parts of the hull including the flat bottom. When the ship is against the quay, diving to clean the vertical side next to the quay is made difficult by fenders, and the flat bottom is often too close to the harbor bottom to allow the diver easy access and freedom of movement. An alternative, if the ship is to be cleaned while moored rather than at anchor, is

[14] For a full description and explanation of the problem and solution, see Hydrex White Paper No. 2 "The Slime Factor" available for download at www.shiphullperformance.org

just to clean the outer side of the hull. When the ship reaches its destination it can be moored facing the opposite direction and the side of the hull which was not cleaned before can now be accessed easily for cleaning. It is not ideal since the ship sails with half the hull fouled to some degree at least. It is preferable to clean a ship at anchor and this can be done while bunkering or other normal operations are in progress so as not to disrupt operations.

6. Cleaning is best done by well trained and equipped divers operating from dedicated workboats set up for rapid and efficient dive support, using fast, powerful hydraulic rotating tool cleaning machines. Done this way, using two or more workboats with several diver teams on each, the largest VLCCs can be cleaned 100% in 6 - 12 hours. The cost of effective, rapid cleaning is dwarfed by the savings that will be gained as an immediate result. Usually the payback will be achieved before the next crossing is complete.

7. Independent verification of the cleaning where there is any doubt about the performance of the company employed.

Any real limitation to underwater cleaning centers on the type of hull coating in use.

Any real limitation to underwater cleaning centers on the type of hull coating in use.

AF coatings cannot be cleaned underwater without hazard to the environment. It is also invariably destructive to the coating which becomes depleted more rapidly.[15] (As a note, while this accelerated depletion may appear beneficial from the point of view of repeat business for the manufacturer and those who benefit financially from repainting, it is hazardous to the environment and expensive to the shipowner/operator.) Methods of collecting the debris from cleaning and of filtering the water to remove harmful elements have been tried but the damaging substances (the heavy metals and biocides) cannot be prevented from spreading in the water. Any system which truly filtered out all the biocides released during underwater cleaning would be so expensive and time-consuming that it would be cheaper and quicker to drydock the vessel and clean the hull there where such collection and filtering, although still expensive and difficult, would be more easily accomplished. This has already been ruled out as an economic impossibility, except for occasional cleaning when the ship is already in drydock for other reasons. However, that frequency of cleaning is inadequate when it comes to achieving the benefits attainable from keeping the hull free of fouling.

FR coatings are easily damaged and must be cleaned very gently which is only useful if the fouling is no more than a biofilm. Great care must be taken to make sure that only the mildest of tools are used and the integrity of the coating is not compromised through careless or aggressive cleaning. Research and development are in progress on small, remotely controlled cleaning machines for "hull grooming," by which is meant very frequent light cleaning of the fouling-release coated hull to remove slime in its early stages, but so far no such system has emerged into commercial use.

Hard, inert coatings can be cleaned underwater without any risk of chemical pollution to the environment or of damage to the coating, and a specially-formulated glassflake vinylester resin coating can be cleaned aggressively and rapidly and will only improve in smoothness with each cleaning.

How clean is clean?

If underwater hull cleaning is going to produce all the expected results, provide maximum reduction in fuel costs and prevent the spread of NIS, then it has to be fully done. This means that all the fouling is removed from below the water line, including niche areas, sea chests, rudders, intakes and all the underwater equipment.

Considerable fuel savings can be achieved by cleaning the vertical sides and the large areas of the hull. This takes less time than a complete cleaning, but will not in itself fully deal with the threat of ships spreading NIS, since these invasive species often populate the less accessible parts of the vessel.

From a practical point of view, there are degrees of hull cleaning and fouling removal. Without taking into consideration the threat of spreading NIS, a ship's hull could be partially cleaned without great attention to small detail (i.e. about 95% clean) and this would result in a

[15] Hydrex White Paper No 4 "Ship hull coatings compared," (2011)

considerable fuel savings. It would not, however, prevent the spread of NIS in the form of stowaways in niches, sea chests and less accessible areas of the ship.

If a ship is to sail clean then the cleaning must be 100%. It takes longer and therefore costs more. However, this extra time and money is more than recovered since the ship operates with a clean hull, thus benefiting from the maximum fuel savings. If cleaned 100% before sailing, then there is no risk of spreading NIS since these species do not attach to the hull while the ship is in motion, only when it is laid up at anchor or quayside.

In most circumstances, the best and most viable approach is to clean the ship 100% and to do so regularly and always before sailing if the ship has been stationary for a long enough period to have become fouled.

In most circumstances, the best and most viable approach is to clean the ship 100% and to do so regularly and always before sailing if the ship has been stationary for a long enough period to have become fouled.

In order for this to occur, the infrastructure must be in place to facilitate industrial level, high quality, fast and affordable underwater cleaning, as described above under "How to clean." And ship hulls must be protected with a system which lends itself to fast, effective underwater cleaning without risk of damage to the coating and without posing any kind of hazard to the environment.

To facilitate 100% underwater hull cleaning, it is predicted that the design of sea chests and other niche areas of the underwater ship will be improved for ease of cleaning, so that routine in-water cleaning can be performed more rapidly and affordably as often as needed.

The benefits of routine, industrial underwater cleaning

Assuming that a ship's bottom is painted with an appropriate hard coating which can safely be cleaned routinely in the water, there are many benefits to be obtained from such cleaning:

1. Dramatically reduced fuel consumption and GHG

2. Oceans safe and free from chemical pollution

3. Clean ports, harbors and shipyards

4. Spread of NIS curtailed or prevented

5. Increased drydock interval (no need to drydock just for hull cleaning or painting)

6. Cost of repainting saved

7. Better protection for the hull

8. Prolonged service life of the ship

9. Higher secondhand values.

As can be seen, the above list shows a fairly equal mix of economic and environmental benefits achievable from underwater cleaning on a suitable coating, and there is no compromise of one for the other. While the environment benefits greatly from a combination of a hard, inert coating and routine underwater cleaning, the shipowner/operator benefits financially. The costs which can be saved are enormous when one takes into account all the factors:

A. Fuel savings of 25% or more constitute by far the largest economic benefit

B. Savings on repainting, on drydocking including the off-hire time saved, are significant

C. The reduced total ownership cost (TOC) of the ship, the increased value when it comes time to sell the vessel, the prolonged service life, all add up to major economic benefits as well.

One might well ask: Where is the downside? What is the compromise? If it can be considered a downside, there will be some extra work involved in scheduling and organizing the routine underwater hull cleaning required. The ship will have to be coated with a hard coating at newbuild or repainted in drydock (once) with a hard coating. This requires grit blasting to prepare the surface. Once grit blasted and coated, that will be the last time the ship has to be repainted. However, the result will be a considerably stronger and more corrosion resistant coating which will never need to be replaced. There is no other downside, and the benefits, both economic and environmental, far outweigh the cost and effort involved.

Infrastructure

While industrial quality underwater cleaning is available now, the infrastructure is far from mature. As the industry changes to this non-toxic economically efficient system, this infrastructure will build up so that hull monitoring and high quality underwater cleaning become more and more available around the world. When the gasoline engine automobile was first invented there was no network of gasoline stations around the world. But it did not take long for such a network to be established. Nowadays one has to work fairly hard to run out of gasoline and not have a station nearby. As the need to clean these automobiles became apparent, the car wash was invented and has now become a regular feature in gasoline pumps and service stations. As mobile phones become a part of life, so do charging stations at airports, in airplanes, trains and cars. As the internet becomes another utility, so wi-fi becomes available on airplanes, cruise ships, at airports, restaurants and coffee shops, let alone in every house and office building. One can logically expect the same phenomena to apply to underwater ship hull cleaning as more and more shipowners realize that the solution to fuel saving and environmental protection is a hard, inert, non-toxic coating coupled with routine underwater cleaning.

It is worth mentioning here that the idea of a "car wash" for ships has been considered but no workable version has been devised because of the insurmountable obstacle presented by the extreme variety of hull shapes and sizes and by the differences between conditions and physical laws which apply under the water and those which apply on land. However, research on better, faster and cheaper methods of hull cleaning will continue and the field remains open. Meanwhile there is a Best Available Technology here today as described in this White Paper. It should be put into general and broad use until a better technology is developed.

What to look for in an underwater cleaning provider

Not all underwater hull cleaning is equal.

Not all underwater hull cleaning is equal. Very far from it. It has been known for a shipowner to pay a substantial sum to have the ship bottom thoroughly cleaned and to be informed by the provider that the job was done, only to find out when the ship had to be emergency drydocked two weeks later that very little of the fouling had been removed. The problem is that one cannot see what is being done under the ship or what the result is unless one has an independent inspection carried out immediately after the cleaning is reported complete.

Following are some points which a shipowner or operator should look for when choosing a provider (or providers) of underwater hull cleaning.

1. Does the company being considered provide industrial grade, high speed underwater cleaning? (The largest vessels afloat can be cleaned to a 92-98% clean standard in 6-12 hours by a well-established, well-equipped and well-trained company and to a 100% clean standard in 12 hours with a large, competent and well-equipped team.)

2. Is the underwater cleaning company large enough to cope with underwater hull cleaning wherever and whenever it is needed?

3. Will the company provide underwater hull cleaning at short notice at any suitable location in the world? (Water current and visibility are factors here).

4. Does the company have a documented track record (with credible references) of successful underwater hull cleaning?

5. Is the company committed to cleaning only those hulls and coatings which will not be damaged by the cleaning?

6. Is the provider committed to cleaning only those coatings which will not be hazardous to the marine environment when cleaned in the water? (Beware of claims made for recovery or filter systems which may be largely ineffective in recovering and filtering the pulse discharge of contaminants and pollutants associated with underwater cleaning of biocidal antifouling paints.)

7. Does the company have and use powerful, fast equipment for cleaning large surface areas rapidly as well as smaller, versatile equipment to clean more difficult areas?

8. Are the divers well-trained and experienced in hull cleaning specifically? (It takes 6 months to a year to train a competent diver to be able to deliver fast, high quality hull cleaning, including training on the equipment and enough experience to be fast and efficient.)

9. Is the provider sufficiently well-organized and efficient to be able to mobilize fast to any location where the underwater hull cleaning is needed so that there are no delays in the ship's schedule? (Properly organized hull cleaning can be carried out with no or minimal extra delays caused to the ship, which is very important if the routine underwater hull cleaning approach is to work efficiently and economically.)

10. Does the company offer hull monitoring and inspection services to help the shipowner/operator determine the optimum interval between underwater hull cleanings in order to realize the maximum savings?

High quality, reliability and speed may cost more, but they also result in far greater savings.

11. Bear in mind that the best company is not necessarily the cheapest company. Considering the savings to be gained from a clean hull, it is worth paying a few hundred or even a few thousand dollars more to get the job done competently, fully and rapidly, thus saving tens or hundreds of thousands of dollars in fuel. High quality, reliability and speed may cost more, but they also result in far greater savings.

12. There is always a risk involved in taking on a new supplier or provider in any industry or discipline and underwater hull cleaning is no exception. Once one has had successful experience with a particular provider, trust builds up and expectancies tend to be met routinely. Once a shipowner/operator has found a company that meets all of these criteria consistently, it would be wise to stick with that company, with the occasional spot check of the work to make sure it remains at a high standard. Ideally this independent inspection should become a standard part of in-water hull cleaning.

Typical underwater cleaning jobs

Following are a few examples of how this system might work in the real world.

Scenario 1

A large VLCC is at anchor bunkering. A full underwater hull cleaning has been scheduled to be done concurrently. The underwater cleaning company sends two workboats/dive platforms out to the ship, each with two teams of divers and all the equipment needed aboard. One workboat works on each side of the ship and the divers begin cleaning, using large, powerful hydraulic underwater cleaning machines, covering the vertical sides rapidly. The entire hull is quickly but thoroughly cleaned in this way, the divers working in shifts so that four divers are working on the vertical sides and flat bottom simultaneously. As the larger areas are completed, the divers switch to using smaller machines or hand tools to clean the niche areas, sea chests, rudder, and other smaller parts of the underwater ship hull.

Within 12 hours and before the ship is scheduled to sail, the cleaning is complete, the work inspected and the workboats on their way.

The VLCC sails with a clean hull, saves tens or hundreds of thousands of dollars in fuel on the next crossing alone, is free from NIS when arriving at the next port of call and thus qualifies for discounted port fees due to reduced fuel consumption and emissions.

Scenario 2

A cruise ship schedules an underwater cleaning for the end of one cruise, before the next cruise is due to begin. As soon as the ship docks and while she is unloading and loading, a dive team is mobilized with dive gear operating from a workboat which ties up to the side of the ship away from the dock. The dive team cleans that side of the ship in four hours. At the end of her next cruise (perhaps a week later) the ship is docked facing the opposite direction so that the side of the hull not previously cleaned is accessible from the water. The exposed side, the flat bottom and the rest of the hull are cleaned.

The ship sails for a month and then the above procedure is repeated. The cruise ship saves 25% of propulsive fuel costs due to a clean hull, without ever interrupting her schedule.

Scenario 3

A naval destroyer is tied up for six months, during which time the hull is cleaned twice. Then orders come for deployment in 48 hours. The contractor responsible for keeping the hull clean is called in; the ship is taking on stores and ammunition. The cleaning is done from workboats with the ship at anchor in a total of four hours. She then sails clean, saving tens or hundreds of thousands of dollars in fuel on the operation which keeps her at sea for several months. There is no risk of spreading NIS since the hull is clean of fouling. Since the operation involves being at sea and traveling at high speeds most of the time with only a few short stops, no cleaning is needed until the ship has once again been quayside for some time. The Navy ship, with a responsibility even higher than that of commercial vessels for not contributing to marine or atmospheric pollution, behaves as a "good citizen" by not leaching poisonous substances into the oceans and by keeping fuel consumption as low as possible within operational bounds.

Case Studies

As already discussed, the technology described herein is already in use by a number of successful and respected shipping companies. Having found a competitive advantage, some of these shipping companies are understandably reluctant to broadcast their methods and their success. Nevertheless, the continued adoption of the system for more and more vessels in their fleet tells the story. Following are two case studies of fleets using the approach of a hard coating combined with in-water conditioning and cleaning.

Cruise line

A major, well-respected cruise line, known for its environmentally-sound practices as well as its quality of service and economic efficiency, switched from conventional AF paint to a hard, inert, glassflake vinylester resin combined with routine hull cleaning. The first of their cruise ships was repainted with the environmentally safe hard coating in 2006. The underwater hull was then conditioned and routinely cleaned in the water. When in drydock in 2009, only dock block application (to coat the areas of the hull which were obstructed by the blocks in drydock when the ship was originally sprayed in 2006) and very minor touch-ups of slight mechanical damage were required.

As a result of the improved performance noted in the first ship, the cruise line's second ship was switched from AF to hard coating in 2008, was also cleaned routinely, and was drydocked in 2010 with similar results. A third cruise ship was coated with the hard coating at newbuild stage in 2010 and launched in early 2011. A fourth vessel for the same cruise line is currently under construction and is also being finished with the same hard coating.

It is the practice of this cruise line to have the hulls cleaned underwater as frequently as once a month. These vessels tend to cruise in warm or tropical waters where fouling can build up fairly rapidly. The cleaning is scheduled in such a way that it does not interrupt the cruise ships' sailing schedules, a very important factor since off-hire time for a cruise ship represents a huge loss of revenue. In order to maintain the sailing schedule without interruption, the underwater cleaning varies between simply cleaning the vertical sides of the hull and full underwater hull cleaning.

The cruise line has reported a very significant improvement in fuel efficiency as a result of the hard coating and routine underwater cleaning. Proof of the success of the initial application to the first vessel is the fact that the rest of the cruise line's ships have switched to a hard coating and cleaning and the new-builds have all had the hard coating and cleaning system applied from the beginning.

Cargo fleet

A Canadian cargo vessel company has switched from traditional AF to a hard, non-toxic glass-flake vinylester resin underwater hull coating for an initial two ships, a 14,600 ton Ro/Ro and a 21,850 ton Ro/Ro, both in 2011.

The initial underwater conditioning of the new coating was carried out soon after application and the shipowners intention is to clean the hulls underwater twice a year. Since these vessels trade in colder water, this may be adequate to maintain the hull at optimum efficiency.

As these successful applications show, there is virtually no limit to how rapidly a ship can be cleaned in the water. It is simply a matter of having enough competent teams and suitable equipment. Even the largest hulls can be cleaned in a relatively short time without interrupting operations.

Part IV. An example of an underwater hull cleaning company and system

While there are a number of reputable companies offering underwater hull cleaning services, Hydrex is a good example of one that meets the criteria delineated in this White Paper. It is also one which we are particularly familiar with and can use as an example of the approach under discussion.

Facilities around the globe

With headquarters in Antwerp, Belgium, Hydrex has offices in Tampa Bay, Florida, the Bay of Algeciras, Spain, Mumbai and Vishakhapatnam, India and Port Gentil, Gabon. These offices are fully equipped, answer calls 24/7 and have the personnel and equipment of the entire Group at their disposal for extremely rapid mobilization to jobs.

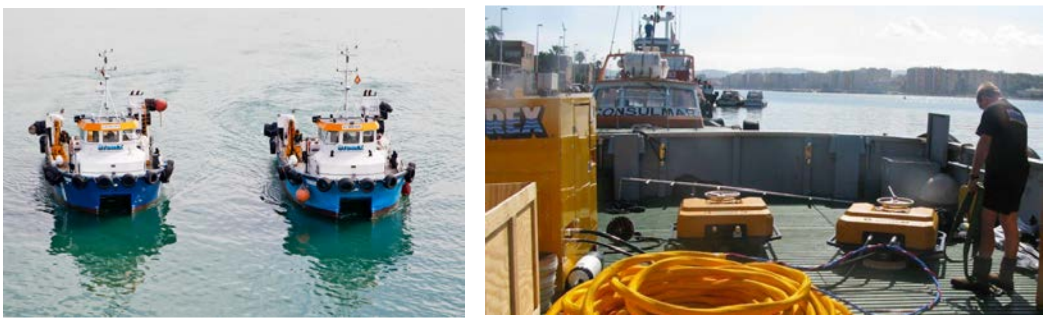
Personnel

The Hydrex Group has a large team of trained and experienced divers on staff as well as an established network of reliable, local diving companies with experienced divers trained on Hydrex underwater cleaning equipment and procedures who can be called on to deliver underwater cleaning locally.

Equipment

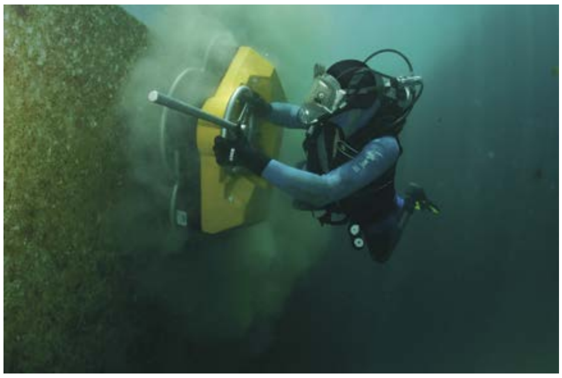
Hydrex uses its own, proprietary underwater cleaning equipment. The company founder began development of hydraulic tools for underwater hull cleaning in 1981 and there has been continual research and development ever since by Hydrex's in-house engineers, based on experience with conditions and requirements. The result is Hydrex's current line-up of hydraulic underwater cleaning machines, tools and other underwater hull cleaning equipment which is the most advanced in the industry today.

In the Bay of Algeciras, Hydrex has two workboats specially equipped as dive platforms and ready to mobilize at short notice so that ships can be inspected and serviced while at anchor. Cleaning the underwater hull while the ship is away from the quayside is preferable as this provides easier access to both vertical sides and the flat bottom and the divers can work freely around the ship, thus speeding the operation and permitting a higher quality, faster result. The workboats at Algeciras have been a successful pilot and the system will be expanded to other Hydrex stations.



The easiest and most effective way to carry out underwater cleaning is from a workboat/dive platform.

Large, powerful underwater cleaning equipment makes it possible to remove fouling rapidly and completely.

Different equipment and tools are used for different underwater cleaning jobs, different types of fouling and different parts of the hull or structure being cleaned.

Coating system

Unique to Hydrex is the Ecospeed underwater hull coating system. This includes a proprietary glassflake vinylester resin coating which is completely non-toxic, lasts the service life of the ship with no need for repainting, only requiring minor touch-ups; the coating is combined with in-water conditioning and routine cleaning which improve the hydrodynamic performance of the hull without damaging the coating in any way, no matter how frequently it is cleaned.

The advantages of this coating system are that it does not cause any chemical pollution of the marine environment when it is cleaned repeatedly (this has been subjected to rigorous independent tests), and the routine cleaning, no matter how frequent, does not damage the coating in any way – on the contrary, the hydrodynamic characteristics of the surface improve with routine cleaning.

The combination of a long-lasting, non-toxic underwater hull coating which is maintained through underwater conditioning and cleaning, and the provision of such underwater cleaning on an industrial, worldwide basis, makes Hydrex the leading provider of alternative, non-biocidal hull protection and performance and renders the need for poisoning the oceans to try to control hull fouling an obsolete approach.

Vessel or fleet operational costs assessment

Find out if your operational costs for your vessel(s) or your fleet could be drastically reduced by changing your approach to underwater hull protection and maintenance.

To obtain a free initial consultation on ship hull performance for your vessel(s) or fleet simply send an email to the following email address with "Free Consultancy" in the subject line and information about your vessel or fleet and an expert will get back to you promptly:

performance@hydrex.be

To find out more about Ecospeed and Hydrex, visit the following websites:

www.hydrex.be

www.hydrex.us

www.ecospeed.be

If you would like to be added to the mailing list for future white papers on ship hull performance and related subjects and/or copies of the quarterly journal *Ship Hull Performance* please go to the following link, register and state your preferences:

www.ShipHullPerformance.org

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