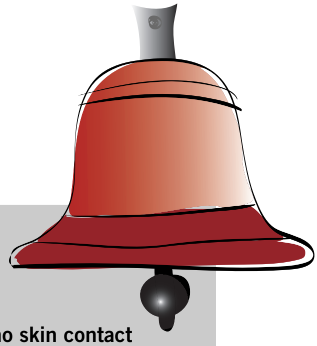
Summary and conclusions



THE ”CLEAN SHIP” – a possible option

On the clean ship...

1. the handling of carcinogenic bunker fuel on board is done so that no skin contact occurs.
2. the handling of bunker fuel at bunkring is done in such a way that no spill occurs (see Grön Bunkring).
3. hazardous waste does not occur in the bunker fuel. A number of waste markers are included in the bunker analysis and if background levels are exceeded, the ship will take measures against the fuel supplier.
4. only bunker fuel containing less than 1 % sulphur is used on voyage in the North Sea or the Baltic Sea.
5. in harbour areas only so called ”harbour diesel” is used, i.e. marine distillate fuels with low content of sulphur (less than 0.2 %) and polycyclic aromatics.
6. there is a well-functioning oil separation of bilge water on board. The oil content does not exceed 5 ppm in outgoing water, emission data (volumes, oil content) is documented during operation, measuring instruments are calibrated towards real conditions and yearly, there is an unbiased control during operation.
7. only environmentally adapted oil is used in the stern tube. The base oil is rapidly degraded in the environment, the additives do not have a high toxicity and they are not persistant nor have they shown to be bioaccumulating. The additives do not constitute a serious health risk and the oil is compatible with the seals that are used.
8. only environmentally adapted hydraulic fluid and lubricant grease is used externally or where there is a risk of leakage into the sea. The environmental criteria are formulated in the Swedish standards for hydraulic fluids and lubricant grease respectively.
9. cleaning agents which are classified as toxic, carcinogenic, mutagenic or toxic to reproduction are not used. Nor are substances leading to the classification as dangerous to the environment in use. Organic solvents are only accepted under certain circumstances. The cleaning agents do not disturb the bilge water separation.
10. antifouling paints containing organotin compounds (TBT) are not found. The choice of antifouling paints is towards those with the least burden on the environment as the SPC in combination with silicon coatings or hard epoxy coatings.
11. water-borne or high solid anti-corrosion paints are used. Pigments with serious health effects such as lead and chromate are not accepted. Paints containing isocyanates are avoided.
12. boiler and cooling system treatment agents used are not classified as dangerous to the environment, carcinogenic, mutagenic or toxic to reproduction. An exception can be made for the environmentally toxic substance nitrite as it is not bioaccumulating or persistent. Additionally, the boiler treatment agents used are neither sensitizing nor toxic.

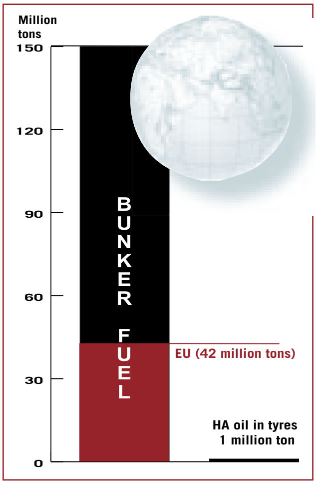
Shipping has an irreplaceable function as conveyer of people and goods over the whole world. Shipping is also basically an environmentally sound and sustainable means of transport. It has comparatively low demands on infrastructure and can transport large quantities of goods at a low consumption of energy.

Transport at sea is increasing and good opportunities exist for a further growth. The international character of shipping has, however, led to an exemption from a large portion of the environmental demands put on the land-based means of transport and enterprises. Shipping today is encumbered with a number of health and environmental problems which are important to solve.

An object of this report is to scrutinize the use of *chemical products* within the merchant fleet and to try to form an opinion of what are the greatest risks of health and environment. The object is also to find possible and reasonable ways to a rather immediate improvement of the health and environment situation on *existing ships* and, to some extent, also in *harbours*.

Hopefully this report can contribute to the picture of what a ”*clean ship*” can look like. A thought is also that shipowners investing in ”*clean ships*” shall get market benefits by receiving more transport commissions.

Bunker fuel



Bunker fuel is the collective term for fuel to ships. The world merchant fleet handles and consumes 150 million tons of bunker fuel each year. Totally dominating is the heavy fuel oil or the marine residual fuel. This oil is classified as *carcinogenic* (toxic symbol) and *dangerous to the environment* due to a high content of polyaromatic aromatics (PCA). Marine residual fuels with varying content of PCA can be found on the market but none that is exempted from classification as carcinogenic.

Studies have shown that engine room personnel on ships run an increased risk of getting cancer. Exposure to marine residual fuel on the skin shows a relatively immediate absorption in the body of carcinogenic polycyclic aromatics and that these also react with the genetic material.
The handling on board of marine residual fuels must radically improve. *Everyone* must get a clear understanding that these products are very dangerous to health. No oil should get in contact with skin and correct safety equipment should be chosen. All personnel that in any way get in contact

with marine residual fuel must receive accurate handling instructions. In the long run it is urgent to develop *non-carcinogenic fuels* for ships.

To bunker means to refuel a ship. Bunkering operations are often carried out at sea where large volumes of marine residual fuel are handled from heavily loaded so called bunker ships. Bunkering can take place all round the clock and sometimes the weather is far from suitable. Outside Göteborg which is the biggest bunker harbour in Scandinavia with a yearly shipment of 2 million tons of bunker fuel, accidents have happened with considerable oil spill as a consequence.

The project *Grön Bunkring* started in 1998 to try to minimize the risks at bunkering operations. In this project a number of actors took an active part: the fuel suppliers, the bunker ships, the Coast Guard, Göteborg Harbour and the County Administation of Västra Götaland. A number of demands were put on equipment, education, control etc. of the bunker ships. A ship that fulfills all demands gets a ”green bunker card”.

The bunker suppliers in Göteborg contract only ships having received this green card. Today it includes all the 25 bunker ships in the harbour of Göteborg. No serious incidents have occurred since the project was carried through and Grön Bunkring has received international attention as an interesting measure against oil spills. A *”clean ship”* naturally chooses to bunker its fuel from harbours where the handling is done in the safest way possible.

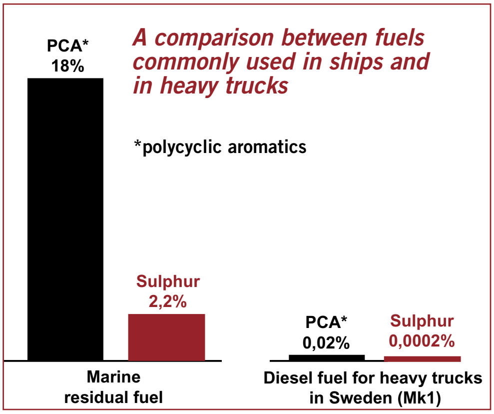
The technical specification for marine residual fuel gives a rather wide framework of what the fuel can contain. Today the society is putting up stricter demands and rules of the handling of *hazardous waste* at the same time as the costs of destruction is rising. An evident risk is that certain types of waste go into the marine residual fuel. There are no indications that this is the case in Sweden but certainly in other major bunker harbours in the world.

At regular intervals, waste oil, heavy metals, paint residuals, solvents, different chemical wasteproducts in the marine residual fuel have been found. The problem is what is never disclosed, though. The *standardised control* of hazardous substances in the fuel should for example be enlarged with waste markers like zinc, calcium, phosphorous and polycyclic aromatics. Not least so a ship/shipowner can take measures against a supplier if the fuel contains waste.

From a general point of view it is also urgent with a type of random sampling or ”doping control” of marine residual fuel, screening for a large number of hazardous substances or substance groups. It would be of great interest to study, for example, total organic chlor, PCB, certain biocides, strong solvents etc. It is highly in the interest of shipping and shipowners to get a better control of what they buy and then combust in harbours and at sea.

Combustion and emissions

The combustion of bunker fuel in shipping results in vast emissions of, for example, sulphur dioxide, nitrogen oxides and polycyclic aromatics (PCA). This significantly contributes to the total pollution load on the environment.



Sulphur and nitrogen oxides

The emissions of sulphur dioxide and nitrogen oxides have an influence on the health of a large number of people in Europe. The environment is affected by acidification on vegetation and materials. Concurrently with the sea transport increase and the lowering of the emissions from land-based sources, the emissions from shipping are increasing both in the total share and in total figures.

A comparison between sea transport and heavy road transport according to *emitted grams per ton kilometers* reveals that the sulphur dioxide emissions and to some extent the particle emissions are considerably higher for ships. The nitrogen oxides and the volatile organic compounds are for the moment of the same emission magnitude as heavy trucks while the carbon dioxide emissions are clearly of advantage to the ships.

The easiest way to reduce the sulphur emissions is to use bunker fuel with low sulphur content. A mean value of the sulphur content in marine residual fuel is around 3 % on a world basis. Today there is a market for marine residual fuel with less than 1 % sulphur. In the north of Europe there is a possible supply of about 1.2 million tons/year. The extra cost for marine residual fuel with a low sulphur content is around 20 US dollars/ton. To cover the total demand from shipping there is a need of desulphurising the residual fuels though, a process not run by the refineries in the world today. The alternative is desulphurising of the emission gases on board.

When it comes to reducing the emissions of nitrogen oxides it is not so much a question of how the fuel is composed but rather a question of combustion and reduction technique. Initially there is a higher investment cost than just choosing a cleaner and more expensive fuel. There are technically well-tried methods of lowering the emissions of nitrogen oxides.

The ”*clean ship*” naturally chooses fuel of low sulphur content. The marine residual fuel should contain less than 1 % sulphur. In a second step reduction technique for nitrogen oxides are installed which leads to an emission lower than 12 grams NOx/kWh at 75 % motor load. This is the limit of differentiated fairway charges in Sweden.

Polycyclic aromatics

Marine residual fuel is classified as cancerogenic due to a high content of polycyclic aromatics (PCA). Very few studies are made on the emissions of PCA from combustion of marine residual fuel. Within the scope of this report the emissions of polycyclic aromatic hydrocarbons (PAH)* were studied from Pure Car/Truck Carrier ship. The ship was using marine residual fuel for the main engine and marine distillate fuel (gas oil) for auxiliary engines.

** Polycyclic aromatic hydrocarbons (PAH) refers only to the pure hydrocarbons. Polycyclic aromatics (PCA) is a wider definition where also substances like nitrogen, oxygen and sulphur can be bound to the hydrocarbon structures.*

The PAH emissions were about 10 times higher per energy unit from the combustion of marine residual fuel than from the gas oil. The difference in the emissions correlated well to the difference in PCA content between the fuels. The fact that the content of PCA in the fuel plays a crucial part for the magnitude of the emission is known from earlier studies on diesel engines.

If you compare the PAH emission per energy unit with a heavy diesel truck, which has the most outstanding emission factors for PAH with regard to road traffic, the emissions from marine residual fuel are about 30 times higher. The engine effect of the ship is about 40 times higher. The PAH emission from a large ship entering a harbour on marine residual fuel may correspond to the PAH emission from about *1200 heavy diesel trucks.*

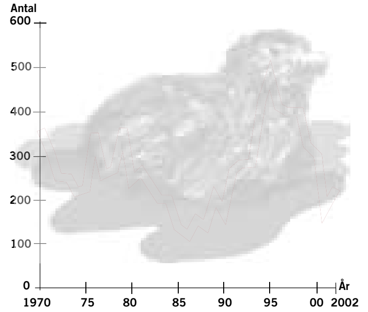
Due to health risks in densely populated areas in Europe many efforts have been made over the years trying to reduce emissions from road traffic. There are for example demands on cleaner diesel engines as well as cleaner diesel fuel. The so-called Miljöklass 1 diesel (Mk 1) dominates the Swedish diesel market for heavy vehicles. *Ordinary marine residual fuel has a PCA content which is about 1000 times higher than the Mk 1 diesel and a sulphur content which is about 10 000 times higher.*

Many ships use marine residual fuel in harbour areas. With improved engines, for instance, more ships can use marine residual fuels in the auxiliary engines to produce electricity in berth. The emission of sulphur dioxide and polycyclic aromatic hydrocarbons in big harbours will probably in many cases significantly contribute to worsened air quality in surrounding areas.

A simple and quick way of solving this problem is to use only so-called ”*harbour diesel*” in harbour areas. Many different refinery streams can be included in a marine diesel oil or gas oil. Some streams like the cracked gas oil contain very high amounts of PCA. The ”harbour diesel” should therefore have demands *both on sulphur (< 0.2 %) and on PCA content*. The ”*clean ship*” heading for Göteborg does naturally switch over to ”harbour diesel” when approaching the harbour area.

Oil discharge and bilge water

The number of oil discharges detected by the Swedish Coast Guard



Large oil spills at sea have got most attention when it comes to environmental problems with shipping. Beside the big tanker accidents there are other problems though of at least equally serious matter. Still after more than 20 years of conventions and prohibitions there are more or less deliberately continuous discharges of tank cleaning waste, sludge and oil containing bilge water in the Skagerrak, the Kattegat and the Baltic Sea.

The discharges are devastating for the sea-birds. For example almost the whole population of long-tailed ducks stay in the south of the Baltic Sea during wintertime. They are primarily feeding on sea mussels. The big fairways pass close to the mussel banks though. The long-tailed ducks misjudge easily an oil discharge as being calm water – with disastrous consequences. Every year over 100 000 long-tailed ducks die on Hoburgs bank because of oil discharges.

Despite increased resources for the Swedish Coast Guard it has been difficult to convict anyone even for obvious discharges of oil into the sea. The United Nations Convention on the Law of the Sea, UNCLOS, regulates the right to the sea and to the innocent passage. According to this convention a ship discharging oil in the high seas can only be taken measures against by the flag State i.e. the country whose flag the vessel is flying. A ship discharging oil within the economic zone of 200 nautical miles can only be convicted if a ”major damage” to the environment can be proved. A discharge within the territorial zone of 12 nautical miles must still be proved to be ”wilful and serious” to result in a conviction.

An important technical reason for the continuous oil discharges is that most of the large ships of today lack a well-functioning oil separation of the bilge water. The usual equipment on board is simple gravimetric bilge water separators which are not capable to break the stable emulsions formed when waste water is mixed with engine oils, gear oils, emulgating stern tube oils, degreasing agents, lubricant grease, cleaning agents etc.

The tests for approval of the gravimetric bilge water separators are based upon ideal conditions when pure oil is mixed with water. This is never the real situation. A control made by Göteborg Harbour showed that 90 % of the ships calling at Göteborg did not have a well-functioning oil separation. The options for these ships are either to ”adjust” the alarm level on the bilge water separator and discharge the emulsion at sea *or* to close the taps and hand over all oil contaminated waste water for treatment ashore.

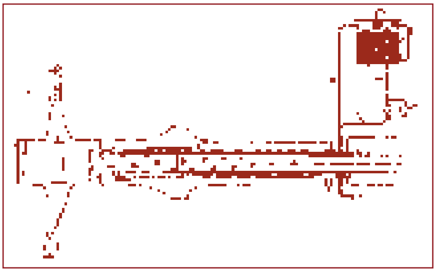
As a matter of fact, there are no driving forces to improve the oil separation equipment on board and many ships have chosen to hand over large volumes of oil contaminated waste water to the harbours. As a consequence the harbours have got heavily increased costs of waste water treatment - in Göteborg the expenses have doubled in a five-year-period. Many Swedish harbours have made up their *own regulations* if or how much oil contaminated waste water that they accept. These regulations are in conflict with the Swedish legislation that harbours shall accept ship generated waste without extra charges.

Furthermore the treatment of sludge and oil contaminated water is often insufficient ashore. The usually toxic waste is drained out in many harbours with emission levels many hundred times higher than what a modern purification technique can accomplish. A number of Swedish harbours have been examined for environmental permits. In turn this has led to the fact that large volumes of bilge water/sludge are transported by *trucks* over long distances to facilities that have an acceptable treatment function.

Primarily the ship should treat the oil contaminated bilge water itself in an environmentally accceptable way. The *”clean ship”* should have an equipment that can break emulsions. The oil content should not exceed *5 ppm* in outgoing bilge water, emission data (volumes, oil content) should be documented during operation, measuring instruments should be calibrated towards real conditions and yearly, there should be an unbiased control during operation.

Additionally there should be reception facilities in all major Swedish ports – preferably with a standard approval – which can also treat the oil waste. In small harbours it may be sufficient with reception tanks from which the waste can be transported to treatment plants. To reduce the investment burden the harbours should cooperate to a great extent. The national government has a responsibility to allocate economic means so that the whole country has an acceptable system to take care of oil waste from shipping – all in line with the Baltic Strategy that Sweden has taken an active role to create and that Sweden has also signed.

Lubricants



A ship cannot function without lubricants. There is a need for engine oils, cylinder oils, gear oils, hydraulic fluids, lubricant grease, stern tube oils etc. Some of these products are so-called loss lubricants. They they are never really exchanged but are consumed during use and will finally end up in the environment. These types of products are especially important to design as being more ”environmentally adapted”.

The propeller shaft of a ship is carried through the hull by a stern tube stuffing box. Within the stern tube there are bearings and lubricants to support and lubricate the propeller shaft. To prevent water leaking in through the stern tube there are seals but the lubricant is also held at a certain overpressure. A propeller shaft becomes a little warped over the time. Wires and nets can also be dragged into the propeller and damage seals in the stern tube. The elasticity of the seals can also be altered by for example additives in the lubricants. Considerable amounts of lubricant oil can gradually leak out into the sea.

A rule of thumb sometimes used is that up to 1 % of the thickness in millimeters of the seal is an acceptable leakage level counted as litres per 24 hours. A 600 mm seal can consequently leak about 6 litres of oil/24 hours without measures being taken. That could result in about 2 m^3 of oil/year and propeller. Loss volumes of that magnitude have also been reported from for example Swedish passenger ferries. The total emissions of stern tube oils from the world merchant fleet have by some actors been estimated at around 60 000 m^3/year.

Engine oil or gear oil is often used for the stern tube lubrication. These oils contain a large number of additives where many are redundant in a stern tube. The additives are often toxic to aquatic organisms, persistent in the environment and have a potential to bioaccumulate. The base oil itself is usually of petroleum origin and does not biodegrade quickly.

Stern tube oils are loss lubricants and are therefore urgent to design as more ”environmentally adapted”. They are emitted directly into a sensitive compartment, sometimes during low-temperature conditions when biodegradation is very slow. The stern tube oils should only contain fast biodegradable, non-toxic base oils and additives whose occurrence and environmental risk is reduced as much as possible – without jeopardizing the function.

Criteria for health and environmental adapted stern tube oils are defined in detail in this report. Discussions are being held, for the moment, with a number of oil companies about products fulfilling these criteria.

Other loss lubricants are used on board. Hydraulic fluids for external hydraulics and lubricant greases for wires, windlass and as propeller lubricants in smaller ships, are some examples. On the market there are ”environmentally adapted” products which have passed an unbiased control. It is always important however to consult the producer on the technical suitability. The producers will always have the full responsibility for their products.

The *”clean ship”* naturally uses environmentally adapted and technically well suitable lubricants in all applications where there is a risk of oil leakage into the sea.

Cleaning agents

On a ship there are many types of cleaning products used. This report is mainly focused on the rough cleaning on board. When cleaning, large volumes are consumed, strong agents are utilized and the final destination is often the bilge water, the sludge or the sea. Some of the strong chemicals used can also affect the occupational environment on board. The rough cleaning can be divided into three main areas:

1. **General cleaning on deck, passages and likewise where the problem is mainly soot and dirt.**
2. **Cleaning on oil-polluted surfaces, in cargo spaces and in the engine room.**
3. **Cleaning of heavily polluted surfaces or metal components with carbonized material or thick oil layers. The cleaning is often done in special vessels**

From a health point of view it is mainly the handling of strong organic solvents which constitutes a risk. A survey of products from a number of major suppliers of marine chemicals shows that there are many types of solvents with a serious health risk in use. They are among others *cancerogenic diesel oil, sensitizing d-limonen, toxic cresol and harmful high-aromatic hydrocarbons.* These solvents are often used in close spaces, sparsely ventilated.

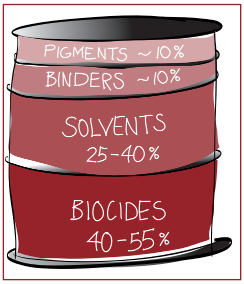
From an environmental standpoint there are, besides the solvents, a number of surfactants that should be avoided. It is primarily some non-ionic surfactants like *nonyl phenol ethoxylates* and cationic surfactants like the *quartenary ammonium compounds.* They only slowly biodegrade and they are toxic to marine organisms. Some cleaning agents may directly end up in the sea but surfactants can also be carried out by the bilge water.

If many different types of cleaning products are mixed with sludge, for example, a stable emulsion will usually be the result. This may happen in the bilge water tank and without an active demulsification and separation process it will be difficult to get clean bilge water. It is important to choose cleaning products with surfactants that contribute to an easy separation of oil and water. Nor should they hinder the function of an active separation equipment.

In this report a proposal for *health and environmental criteria for cleaning agents on ships* is defined. To be able to make a judgement over products according to these criteria, it is necessary to get full information on all components included. There is a possibility today to put aside the high-aromatic hydrocarbons and diesel tubs, to avoid carbon removers with mixtures of chlorobenzene and cresol and to choose modern water-borne cleaning systems instead.

Alkaline products with suger-based surfactants, oil dissolvers with non-toxic surfactants and low-volatile solvents along with powerful cleaning products based on micro-emulsions, are examples that can be used on a ”*clean ship*”.

Anti-fouling paints



Fouling on the hull of a vessel leads to an increase of friction when running through water and with that an increased consumption of energy . An increased roughness of 0.025 mm on the hull´s surface can lower the speed by 1 %. To prevent this fouling, vessels and pleasure boats around the world are treated with 80 000 tons of anti-fouling paint each year.

In Sweden anti-fouling paints are regarded as pesticides and must have an approval to be used. In paints applied on vessels over 12 metres only *cupper compounds, ”triazine”(Irgarol), ”isothiazoline”* and *zinc pyrithione* are accepted as active ingredients. The total biocide content in the most widely used products in Sweden is between 40–55 % by weight.

A weakness in the Swedish legislation is that other substances dangerous to the environment certainly can be added to these paints just as long as they are not called active ingredients.

A rough estimation reveals that 10 large tankers (> 200 000 dwt) use as much active substance, counted as the amount of cupper consumed per year, as the whole Swedish pleasure boat fleet does (1996). One must remember though that the pleasure crafts often stay in very sensitive areas and mostly during a period where disturbances can have serious consequences for the marine environment.

Organotin compounds (TBT) have played a dominating role in anti-fouling paints for vessels since the 1970´s. Tributyl tin oxide (TBTO) which is the active form, is extremely toxic for a wide spectrum of marine species and is highly bioaccumulating. Damage is demonstrated on certain marine organisms exposed to very low concentrations (shellfish for example). High concentrations of TBTO have been found both in water and in sediments.

The International Maritime Organization (IMO) have decided on a global ban on organotin compounds in paints applied on vessels from January 1st, 2003. However it is not ratified by sufficiently many member states and has therefore not come into force yet (May 2003). In Sweden this ban is in force since January 2003 and within EU the same ban will probably be in force before the end of 2003. The major producers of anti-fouling paints have ceased to use TBT as an active ingredient, though.

The most commonly used alternatives to self-polishing coatings (SPC) containing TBT are the so-called controlled depletion polymer (CDP) coatings. These are paints with a traditional matrix consisting of soluble resin and polymers governing the biocide leakage. Cupric oxide is dominating as biocide in these concepts. The cupper content is high but the effect is decaying over time and the intervals of repainting are less than three years.

Relatively new on the market are the SPC paints where other biocide components than TBT are bound to the matrix. Cupper is used but the content is somewhat lower than in the CDP-paints. Above all, the biocide leakage is lower per unit of time, it is easier to control and the intervals of repainting are around five years.

Cupper is a toxic substance to many marine organisms. It is accumulated in sediments but there is a risk of release into the water if conditions change. There are alternatives to anti-fouling paints on the market without chemical or toxic action.

Coatings consisting of polysiloxane binders – silicone paints – with a high internal mobility in the structure make it hard for the fouling organisms to settle on the hull´s surface. A condition for these coatings to be effective though, is that the vessel has a speed of at least 15 knots through water and that it is not lying still more than 5 days in a row. An estimate is that these criteria are fulfilled by around 20 % of the world merchant fleet. The silicone paints are stated to have intervals of repainting around 5 years or more but they are sensitive to quay or ice wear.

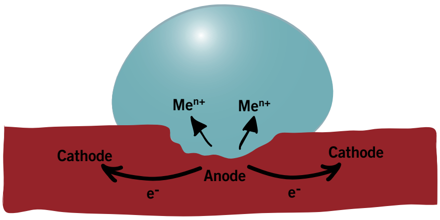
Hard coatings built up by epoxy binders without chemical or physical foul release are sometimes used on the hulls of ice breakers, certain passenger ferries and on naval ships.

A condition for good function though is mechanical cleaning by divers at regular intervals.

Interesting research is done, among other places, at Chalmers University of Technology in Göteborg and also at the University of Göteborg. It concerns the use of of anti-fouling substances which are based on non-toxic mechanisms. Derivates of imidazoline (catemines) in low concentrations are demonstrated to give very effective ”signals” hindering the barnacle to colonize an area – without harm to the organism. A judgement is though that it will take some years before this research leads to commercial products.

Concerning environmentally adapted coatings for the hulls there is not today a really good option. There are alternatives or combination of alternatives though which are to be preferred for the ”*clean ship*”. The choice must be governed by what type of vessel that is going to be painted. In some cases new SPC paints without TBT in combination with for example silicon paints on surfaces not exposed to wear, could be a solution. Another alternative is hard epoxy coatings bearing in mind that this requires mechanical cleaning by divers at regular intervals.

Anti-corrosion paints



Normally anti-corrosion paints are applied above the upper loadline of a ship. Large volumes are used on the sides of the ship, on deck and deckhouses and in cargo spaces. Totally the world merchant fleet consumes around 120 000 tons of anti-corrosion paint. Of this amount 1600 tons are delivered by Swedish suppliers.

These paints are basically solvent-borne to a content around 50 % by weight. From the fact that all solvents evaporate it can be concluded that the total solvent emissions are of the magnitude 60 000 tons. Solvents commonly used are white spirit, methyl isobutyl ketone, different aromatic hydrocarbons like xylene and toluene. Also alcohols and esters are common like for instance butanol and butyl acetate.

The problem with the commonly used organic solvents is not only the health risk like effects on the central nervous system, dizziness and tiredness. They can also contribute to the formation of photochemical oxidants which among other things cause large forest and crop damages.

The pigments have an important task in the anti-corrosion paints. The content is usually around 30 % by weight and the function is to stop the underlying iron to be oxidized. In Sweden zinc phosphate is dominant as anticorrosion pigment but in other countries around the world pigments like the carcinogenic and sensitzing chromates and the reproduction-toxic lead are still in use.

The binders are predominantly epoxy resins, alkydes and polyurethane resins but isocyanates and acrylates do also occur. Certain binder components constitute a considerable health risk when applying the paint. Examples are the sensitizing low-molecular amines in epoxy resins and the sensitizing, and in certain cases, carcinogenic isocyanate monomers. The carcinogenic coal tar and creosote are also used as binders in many anti-corrosion paints.

On the ”*clean ship*” water-borne paints or high-solid paints with adequate function are used. Pigments with serious health risks are not accepted as well as coal tar or creosote as binders. Paints containing isocyanates are avoided.

Boiler water and cooling water treatment

Boiler water and cooling water treatment agents are different types of substances added to protect boilers and cooling water systems from corrosion and deposits. Corroding agents like dissolved oxygen and different acids found in boiler or cooling water have to be inactivated. Otherwise the steel material in the systems will erode from the inside with devastating consequences.

To the boiler system the reactive and carcinogenic substance hydrazine is traditionally added. Other substances like volatile amines with negative health effects are also common. The boiler water treatment agents are continously handled by personnel on board. Boiler water or steam condensate can leak into the bilge water. It can also go directly into the sea when top blowing or bottom blowing the boiler.

The cooling water system is somewhat easier to protect because the primary system by the engine is closed. Traditionally, the corrosion inhibitors used are sodium nitrite with alkali, borate, chromate salts and aromatic azoles. Sodium nitrite is toxic if swallowed and very toxic to aquatic organisms. It can also in contact with secondary amines form carcinogenic nitrosoamines. Secondary amines like morpholine are commonly used in boiler water and even if the cooling water system is closed, it is possible with leakage and mixture with boiler water.

It is important that the outer seawater cooling system does not get choked with macrofouling like algae and mussels. Otherwise the cooling of the engine can be jeopardized. Sometimes powerful biocides are added in the sea-water suction like disodium methylene-bis-dithiocarbamate. Alternatively electrodes dosing small amounts of cupper ions can be used.

For the ”*clean ship*” some rules of thumb can be applied when it comes to boiler water and cooling water treatment. No substances classified as dangerous to the environment, carcinogenic, mutagenic or toxic to reproduction should be used. An exception can be made for the toxic nitrite as it is not bioaccumulating nor persistent. Additionally, as far as the boiler water treatment is concerned, neither sensitizing nor toxic substances should be used.

As an interesting ”environmentally adapted” alternative for both boiler and cooling water treatment it is worth mentioning the use of a magnesium electrode as a sacrificial anode to reduce dissolved oxygen. It does not emit any hazardous substances or by-products and has been installed with good results on a number of ships today.