Increasing influences to the marine environment caused by anti-fouling paints for ship bottom and the trials to improve it
by Chugo Yokochi, Hideaki Nogami and Yoshiteru Tomura

Abstract
The energy efficiency is very good for the automobile with comparison 8.3 times for the transportation by the ship as a mass transportation means of natural resources, foodstuffs and industrial product variously.1) And transportation by the ship will keep occupying the position which will be important in future too, because the load on environment is less than other transportation means.

In the meantime, as the increase in ship operating quality by the globalization of economy activity, the adverse effect which the painting of ship bottom gives on the marine environment is also increasing in recent years.

The one is the sea water pollution caused by organo-tin based anti-fouling paints which greatly influences fuel consumption of the ship.

That is to say, the development of safer and long-lasting tin free anti-fouling paints has been looked for about two decades to replace organo-tin type anti-fouling paints.

In this paper, the bad influence caused by anti-fouling paints on marine environment and countermeasures promoted until now with it in Japan are described.

In the first paragraph, the features of marine organisms and the fragility of its system are described. And the history of the effects of anti-fouling paints on marine environment is also reported.

In the second paragraph, the history of regulations of tin-type anti-fouling paints and the development of tin-free anti-fouling paints in Japan is described.

In the 3rd paragraph, the development situation of the safer anti-fouling technology by concept which completely differs from until now under development is reported. And, this technology has the possibility of reducing the quantity of biocides discharged to the ocean.

1. Features of marine organisms and the scar which the struggle between marine creatures and mankind left in the marine environment
Ocean is about 70% of the surface of the earth, and the volume of sea water is 1,370 million kilo square meters. The average depth of the sea is 3,795 meter.2) There live various kinds of creatures in the sea from micro-organisms less than 1 micron up to blue whales of 120 tons or more. And creatures, such as riftia and
Calyptogena nagrifica live around chimneys which use hydro-sulfide as their energy and they do not need oxygen and the sun shine as their energy.

The organisms which is very much rich like this in a diversity inhabit the ocean. The amount of species is estimated with that 1 million kinds are exceeded in the sea.

Based on the surprising liveliness of organisms in the sea, various kind of creatures easily stick to ship bottom, and their attachment has been annoying mankind since the age of Phoenicians and Carthaginians. It was reported in ancient literatures that they had used pitch and cupper in order to prevent marine creatures from sticking on ship bottom. It is called as fouling that those creatures stick to ship bottom, various structures and facilities in the sea. 1,993 kinds of fouling creatures which stick to these structures are reported in the sea near Japan.

As shown in Figure-1, organic polymer film sticks at initial stage, and next, it shifts to bacteria. Then, it moves to slime (various kind of diatom), protozoan and large flora and fauna in order. This transition is not the meaning which goes even in the sea in where at the identical speed. A. Redfield of Woods Hole Oceanographic Institution in U.S.A. discovered that carbon, nitrogen and phosphorus were taken at fixed ratio, when the phytoplankton did photosynthesis.

It is proven that the growth rate of micro creatures in the sea is influenced from this fact at feed rate of these main nutriment elements.

In addition, J. Martine discovered that even if these main nutriment elements were supplied at the Red Fields ratio, 1/200 iron was necessary for the phosphorus so that the phytoplankton can proliferate smoothly in 1988.

Iron which dissolves in the surface layer of the sea is easily removed away by oxidation reaction into insoluble ferric hydroxide in the short time. Therefore, ferrous iron in the surface layer must be supplied from somewhere in order to maintain good productivity of the surface layer in the sea.

There is a good example which shows this law in Japan.

A large swarm of herring had surged for the spawning to the open sea in many river mouths in Hokkaido the Japan Sea side where the seaweed flourished very much before World War Second. However, swarm of herring disappeared from some coast-offs where sea weeds forest in the river mouth sea withered.

Based on the research done by Katsuhiko Matsunaga of former Hokkaido University, this regrettable process progressed as below.

The catch of herring had been in good condition until about 1950. So, large amount of woods in the river hinterland was completely cut in order to get firewood to dry herring and also to reclaim farmlands. As the results, ferrous organic complex
(furbonic acid) which was made in the forest and supplied to bays and coast-off via rivers stopped to be fed into the sea. Then, seaweed forest in coast-off disappeared at that time.

Recently, the activity in which the fisherman afforests deciduous trees the mountains in the river hinterlands have begun in order to recover fishing resources such as seaweed and fish in Japan.

In other example, the development side was opposed to protection side which consisted of downstream fishermen, etc. on the development of the virgin forest in Shirakami Mountains in the Japan north-eastern area where very valuable virgin beech and other trees forest and special species have been maintained until now.

In the initial stage in which the deforestation began, the river became muddy. So, animals, fishes in the down streams and river mouth sea area of the basin were decreasing sharply. Finally, the protection side which was consisted of people live in the mountains, lovers of Shirakami Mountains and the association of fishermen in the down stream drove end and the development program into the stop after long strife. The virgin forest of Shirakami Mountains was chosen in World Natural Heritage in 1993.

It has been proven that the ecosystem of the ocean which seemed to be the infinity has been balanced on a delicate situation, as these examples show.

The sea does not absorb refuse and pollutants which the mankind discharge infinity. And reckless deforestation of forest in the river basins is connected with the depletion of fishing resources of coastal sea and bays.

The introduction was lengthened, it describes the negative effect which ship bottom paints have given to marine environment, next.

As shown in the table-2, mercury oxide, organic arsenic compounds and pesticides of chlorinated compounds etc. which have strong toxicity had been used as biocides for anti-fouling paints until 1960s, because of the poor knowledge and experiences of negative effects of them on living things in the sea.

As sizes and total tonnage of vessels became bigger and bigger in 1960s, the consumption of harmful anti-fouling paints sharply increased. The problems on safety for human health and the marine environment had become tangible in Japan.

Then, the researching committee of Number 141 Researching Committee had been projected by Japanese Shipbuilder Research Institute in order to develop safe biocides for anti-fouling paints. Then, safe anti-fouling paints composed with approved safe biocides were registered to Japanese Shipbuilders Association(JSBA) since 1973.
The safe anti-fouling paints had been supplied with safety mark of circled (S) and others without the safety mark were excluded for about two decades since 1973.

Organic tin biocides were approved as safe and excellent ones by JSBA in 1978. The large amount of organic-tin biocides had been used until the middle of 1980s. However, since the use of organic-tin biocides were concentrated in most of all anti-fouling paints, high concentration of organic-tins in bodied of fishes was detected by the survey results done by former Japanese Environment Agency etc.

Simultaneously, the deformation in which the back borne of fish fostered in culture cage which were applied by organic-tins type anti-fouling paints occurred which were applied, and it developed in which the fish price of cultured fishes plummeted.

As we had confronted with big social problems such as organic-mercury disaster: Minamata disaster in 1953 and Agano river disaster in 1964, cadmium disaster: J intsu river disaster and PCB oil disaster in 1968 in Japan, in the background resistant sense of caution of our nation towards heavy metals and chemical substances, we banned tri-phenyl tin biocides in 1989 in Japan. And the regulation to reduce of the consumption of tri-butyl tin anti-fouling paints started in 1990.

Finally, we abandoned perfectly organic tin anti-fouling paints in Japan in 1997. In case of European countries and USA, France banned organic-tins to the use for small boats less than 25 meter long in 1985. However, the regulation for deep sea going vessels has not proceeded at the same step.

Afterwards, many reports announced that the concentration of organic tin in living things in the sea became bigger step by step, and the deformation of “impo-sex” that penis was formed in female body of some kinds of shells was reported in the sea over all in the world.

It was reported in 1999 that the catch of abalone declined to one tenth and female abalone of 20 % became to male in the sea of western Japan where the concentration of organic tin was very high.

On the point of view of the environmental preservation, it might be late that Japan started to regulate organic tin anti-fouling paints in preceding in the world since 1989.

2. Trend of the regulation for organic tin antifouling paints and the future to be had

The 42nd Marine Environmental Protection Committee(MEPC) adopted the bill in 1998 to ban the application of any organic tin anti-fouling paints since 2003 and to prohibit the existence of them on the surface of ship bottom and marine
structures since 2008. The bill is taken a vote in the committee of International Maritime Organization held in October, 2001.

Anti-fouling paints based on organic tin acrylic polymers were all-around with long lasting anti-fouling performance and less selectivity of the performance to organisms. In addition, the self-polishing function of organic tin acrylic polymer reduces the friction resistance of ship bottom. This benefited ship owners to reduce the fuel cost in wide range which had drastically raised up to 2.5 times before 2nd oil crisis happened in December, 1978.

So, the technology of organic tin anti-fouling paints based on acrylic polymer were highly evaluated. However, this technology closed the life span of about two decades in Japan.

We employ cuprous oxide, which is estimated not to accumulate in living things in the sea and safer co-biocides than organic tin in Japan. However, in the point of view of history that regulation for biocides has raised to safer ones every decade, even if some biocide and anti-fouling paint used at present as safe ones, it might become unsafe later 2 or 3 decades, if the use of biocide is concentrated to a specific biocide. It is inevitable to observe carefully the concentration of biocides in the environment in future, too.

Anti-fouling methods for ship bottom employed at present are listed in table-3. The application of anti-fouling paints occupies most in the whole countermeasures for expelling organism-sticking to ship bottom etc. This method prevents organisms-sticking by leaching constantly biocides which kill or revel organisms-sticking to the the surface of ship bottom and other marine structures.

In general, there might be contradiction between that safer anti-fouling paints exhaust in a short interval and that long-lasting ones might not be always harmless to the environment.

Now, many tin-free anti-fouling paints have been developed, such as tri-alkyl silyl -acrylate type, acryl polymer of metal ester type etc., and some of them show excellent performance. However, in the point of view of the balance of cost-performance, they will need a time a little to replace perfectly tin type anti-fouling paints.

Marine creatures secrete some substances, which are easily resolved to harmless substances with low energy and reproducible way in the sea, in order to repel other kind of sticking-creatures from outside. It is surprised in “the art” of marine creatures which is given by God. When will the mankind be able to reach the same level of the art given by the god to marine creatures!
3. New anti-fouling technology

1) Concept of Development

The earth, the third planet in the solar system, is the most beautiful planet in the system. Why are there the ocean, the atmosphere and continents only on the earth? Lives on the earth have been developed harmoniously for such an incredibly long time as 4 billion years since its birth. We have improved the environment and developed our current standard of living under the slogan "Bigger, More and Faster" for the last 100 years to increase an industrial efficiency. However, it is true that this splendid harmony started to collapse gradually and destruction has been accelerated nowadays. Particularly, some anomalies in the reproduction system of marine products, which are our daily food stuff, have been reported lately. Mr. Horiguchi's research group at National Environmental Laboratory (in Tukuba City, Ibaragi Prefecture) published their research work in August, 1999 that anomalies were found in the reproduction system due to the organic tin as described at the first paragraph, and the report caused a great sensation. The 21st century is indeed the age of coexistence, mutual prosperity and symbiosis with the nature. Therefore, we realized that we badly need a pollution-free and long-lasting anti-fouling method for ship bottom.

2) Measures and Progress of Anti-fouling by Negative Ion Effect

The negative ion effect has already been announced in the research on sterilization in the medical field and put to practical use.10) When Hideaki Nogami, the inventor of this product, was engaged in his research on food sterilization at Kurume Research Park in Fukuoka Prefecture (Public Laboratory Facilities) in 1992, he noticed that cultured shells moved slightly everyday when he placed pellets of tourmaline and the mixture of ores including rare earth element in a water tank.11) He was interested in the phenomenon and repeated this experiment, and found what is called Marine Creature Repellent Phenomenon. This was the beginning of his large-scale development. Experiments for practical use have been carried out in cooperation with small squid fishing boats at Tsushima, Nagasaki Prefecture since 1998. He succeeded in finding the most effective mixing ratio of ores as a marine paint additive with no bad influence on the navigation of a ship and processing fine powder in an average particle diameter of $5 \text{ m}$ which can well-match with paint.
3). Negative Ion Effect in the sea

It is reported that there are 600 kinds of adhesives and as many as 1,300 kinds of creatures that are the cause of fouling on the ship bottom. First bacteria start sticking and grow up to hundreds of microns for several days. This is generally called "slime."

It is well known that this will induce the adhesion of other creatures, resulting in a large-scale fouling. In other words, it will lead to the attachment of barnacles, sea squirts, shells and algae, etc. It is also well known that those creatures stick and grow mainly while a ship is at anchor. They do not stick so much while the ship is sailing at the speed of more than 5 knots. We are convinced from this fact that it becomes a strong anti-fouling method to make use of negative ion effects on an initial stage of fouling.

Since the cellular surface of bacteria has a negative-ionized carboxyl and is negatively electrified, it repels when the object to stick is covered with weak negative ions. This repelling action causes marine-creature-repellent phenomenon and brings about an anti-fouling effect without using hazardous substances. Moreover, it has been verified that if this additive is mixed with tin-free marine paints currently on the market, the anti-fouling effect can last about 2 times longer synergistically than that of a tin type. (Reference 1).

This is because the release of anti-fouling ingredients in the paint is controlled and also a new anti-fouling function is likely working. It is considered to be different from the conventional anti-fouling mechanism that prevents fouling by dissolving lots of anti-fouling agent. The purpose of developing this additive is to mix a permanently-electrified special ores that emit negative ions, ceramics (non-organic) with other substances, and the mixing mechanism brings about a synergistic effect scientifically. By controlling the release rate of biocides and components in paint film, we will be able to obtain a new anti-fouling function that guarantees a fairy long-lasting anti-fouling effect. (Refer to attached photos)

(Reference 1) Experimental example

23 months after the paint with this additive was applied on a small leisure boat.
It was painted with a brush one time and the paint film was about 50 µm thick.
(Normally the conventional paint for these leisure boats exhausts in 6 - 10 months)

4). Outline of Manufacturing Ceramic Additive

50 % each of total weight of negative-ion-emitting natural ore substances (phosphate salt with rare earth elements) and tourmaline, etc. were put into fine
ceramic processing under strict control of burning temperature at a ceramics factory in Arita City, Nagasaki Prefecture which is famous for its traditional ceramics technology, and then each substance was pulverized to a particle diameter of 3 to 5 μm and well mixed. In case the particle diameter of powder is bigger, it will cause problems such as slowing down of ship's speed, poor binding strength to the paint, difficulty in painting. Meanwhile, if it is too small, there will be a big loss in the pulverizing process, resulting in higher cost. The reason why negative-ion-emitting compound powder and tourmaline powder are mixed is that the use of a single powder of a negative-ion-emitting compound can not adequately prevent bodies such as shells, algae from adhering to the full, while the use of a mixture containing two powders acts synergistically to increase the negative ion effect. Since the upper limit of burning temperature of mixed ores differs delicately depending on the ores, we needed a technical cooperation of a ceramics factory where there are many combustion furnaces available to control different temperatures. This is an essential manufacturing process of making fine powder in an average particle diameter of 3 to 5 μm.

5). Effective Usage

This product is an additive. Basically it can not be used alone. Add this ceramic additive to the anti-fouling paint to a ratio of 1 to 10 and stir them well. The mixture can be applied the same way as we do the conventional paint. It has been verified that the mixing ratio of 1 to 10 is the best to have the intended effect of the invention.

We have good results on all kinds of paints - hydrolysis type, self-polishing type and various other kinds of anti-fouling paints. Needless to say, this product is not applied to the hazardous compounds such as organic tin since it has been developed to protect marine environment.

6). Effect of Ceramic Additive

As mentioned at the second paragraph, various tin-free types of anti-fouling paints have been generally used in Japan since 1990, and a lot of technical developments have been tried to extend the period of re-painting that needs to be done due to the attachment of marine creatures. There was an experiment to install a device that generates weak negative ions electrically on the ship bottom, but it was not put to practical use.

The effects of negative ion barrier that this ceramic additive creates are as follows.
(1). By adding it to tin-free type paint, we will be able to substantially delay the starting of marine creatures sticking. (approximately 2 times longer than tin-type anti-fouling paints.)

(2). The anti-fouling effect is expected to work in the sea (salt water), lake and rivers (fresh water).

(3). It benefits for the marine preservation since it controls the release of anti-fouling agents by extending the life of current anti-fouling paints.

(4). Not only extending the repair interval to minimize the maintenance cost of a ship, but also it requires less fuel by reducing the loads on the engine and lessens the damage to the ship structure during navigation. The expected benefits seem to be enormous.

The above mentioned effects were verified mainly on small fishing boats and lots of leisure boats in Nagasaki, Kyushu. More verifications are now being carried out in cooperation with middle-size passenger boats and a weather observation ship in the Pacific Ocean that belongs to Meteorological Agency.

7). Prospects for the Future

There is no border for marine environment and neither is for marine creatures. The gift from the 20th century to the 21st century would be a well-balanced marine environment. Since ancient times we have led our lives supported by marine products. One example is Japanese traditional "Sushi." This is the very Japanese food culture obtained from the sea. We hope that this invention will serve as one of the ways to maintain rich food culture as we have enjoyed so far. We greatly appreciate the support and consideration of all the concerned organizations to give us the opportunity of introducing our ceramic additive at this UJ NR which is the first international meeting after IMO 2001/45th MEPC, Marine Environment Protection Committee. We would also like to express our gratitude to the U.S. government who granted a patent for the invention as "Additive to Anti-fouling Paint."

Literatures

2 The mechanism of the ocean: page 90, 1997: Ocean Research Laboratory of Tokyo University
3 Manuals of countermeasures to prevent fouling creatures, page 112 1991
   Committee Associated with Electricity and Chemistry to prevent marine fouling
4 ditto: page 31.
5 Nobuhiro Fushitani: Project to search the mechanism of attachment of marine organisms,
   page 37 1995
6 The mechanism of the ocean: page 131 to 132, 1997:
   Ocean Research Laboratory of Tokyo University
7 Katsuhiko Matsunaga: "Disappearance of forest resulted in killing the sea", page 132 1994
8 Number of 27th in November of Nikkei Construction, page 58:
   "Combination among forests, rivers and sea"
9 Inserted recent events by author to next literature:
   "Tokizo Miyajima,: Number of July in 1988 of Marine, page 8 & 88" 1988
10 Treatise on Food Sterilization Research by Energy/Environment Research Group at
   Mitsubishi Electric Central Laboratory, "Negative ions control the propagation of
   germs and mold without spoiling food."
11 Application of Tourmaline written by Tetsujiro Kubo, "Application of Individual
   Organism"
12 Marine Creatures & Fouling of Ship Bottom issued by Ship Technology Association
   "Marine Paint & its Application"
Table 1. "Redfield's Ratio" of element composition in plankton's body

<table>
<thead>
<tr>
<th>Species of plankton</th>
<th>carbon (C)</th>
<th>nitrogen (N)</th>
<th>phosphorus (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>animal</td>
<td>103</td>
<td>16.5</td>
<td>1</td>
</tr>
<tr>
<td>botanical</td>
<td>108</td>
<td>15.5</td>
<td>1</td>
</tr>
<tr>
<td>average ratio</td>
<td>106</td>
<td>16</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 1. Order of biofouling
### Table-2. Transition of anti-fouling paints

<table>
<thead>
<tr>
<th>Chronology</th>
<th>Major antifouling technology and relevant events</th>
<th>Environmental issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC, 6 to 5 century</td>
<td>Pitches, copper, wax, tar and asphalt were used by Phoenicians and Carthaginians.</td>
<td></td>
</tr>
<tr>
<td>Since BC 3 century</td>
<td>Tar, wax and metal plating of copper and lead were used by Roman.</td>
<td></td>
</tr>
<tr>
<td>BC in 412</td>
<td>Compounds with arsenic and sulphur were used.</td>
<td></td>
</tr>
<tr>
<td>in 1625</td>
<td>Compound with iron oxide, cement and copper was used.</td>
<td></td>
</tr>
<tr>
<td>Since 1777</td>
<td>Royal Navy employed copper plating.</td>
<td></td>
</tr>
<tr>
<td>in the middle of 19th century</td>
<td>Copper, arsenic and mercury oxide were recomposed with linseed oil, shellac and tar.</td>
<td></td>
</tr>
<tr>
<td>in 1884</td>
<td>Anti-fouling paint made by ginger, tannin of Japanese persimmon, lacquer: 1st patent in Japan.</td>
<td></td>
</tr>
<tr>
<td>Before 1950</td>
<td>Cuprous oxide and mercury oxide were composed with modified resin of wood rosin and linseed oil.</td>
<td></td>
</tr>
<tr>
<td>In 1950s</td>
<td>Chlorinated vinyl resin enforced the physical property of paint film and high percentage of cuprous oxide was composed and resulted in improving the antifouling performance.</td>
<td></td>
</tr>
<tr>
<td>in 1952</td>
<td>Standardization of mercury free paint by JIS</td>
<td></td>
</tr>
<tr>
<td>in 1960s</td>
<td>As larger size vessels were built, various kinds of strong organic biocides were developed in order to prolong dock interval.</td>
<td>Strong biocides injured paint workers.</td>
</tr>
<tr>
<td>in 1973</td>
<td>SR 141 committee entrusted by JSBA researched safe and acceptable biocides. Then JSBA authorized safe anti-fouling paints.</td>
<td>Establishment of regulation for examination of chemical substances,</td>
</tr>
<tr>
<td>in September, 1978</td>
<td>Organic tin compounds and organic tin acrylate were registered to JSBA. Then, huge amount of organic tin based anti-fouling paints were consumed.</td>
<td></td>
</tr>
<tr>
<td>in December, 1978</td>
<td>The price of crude oil drastically raised up to 2.5 time by 2nd oil crisis.</td>
<td></td>
</tr>
<tr>
<td>in 1985 to 1986</td>
<td>France banned to use organic tin biocides for small boats less than 25 meter, then UK and USA followed.</td>
<td>In August, 1986: Former environmental agency announced the report of the polluted condition by organic tins</td>
</tr>
<tr>
<td>in May, 1989</td>
<td>Triphenyltin were banned in Japan.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
<td>Implication</td>
</tr>
<tr>
<td>------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>in July, 1990</td>
<td>Former Ministry of Transpotation started to regulate the use of tributyl tin anti-fouling paints, and followed by relevant industrial association.</td>
<td></td>
</tr>
<tr>
<td>Since in the middle of 1985 to about 1995</td>
<td>Many intensive development and researches for safer biocides had been done by official institutes and private companies.</td>
<td>Trialkyltin compounds were pointed out to influence badly the function of sexual hormone.</td>
</tr>
<tr>
<td>in 1997</td>
<td>All of organic tin based anti-fouling paints were banned completely in Japan</td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>Function</td>
<td>Tasks/Problem</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>---------------</td>
</tr>
<tr>
<td>1. Application of antifouling paints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-1 Soluble matrix type</td>
<td>Wood rosin is composed of soluble matrix, which promotes biocides to leach out into sea water.</td>
<td>As the passage of time, layer of skeleton at upper surface of paint film becomes thicker and depress biocides to leach out, and the life is shortingeneral.</td>
</tr>
<tr>
<td>1-2 Self-polishing type</td>
<td>Polymer is resolved by hydration and solves into sea with biocides</td>
<td>Depending on a condition of seawater and activity of ship, unstable polishing performance results in unstable performance. The average performance of this type has come closer recently to the one of tin type in Japan. However, cost-performance should be improved more.</td>
</tr>
<tr>
<td>2. Electric conductive method</td>
<td>Apply electric conductive coating to ship bottom, and charge electricity to electrolysis seawater and the barrier of ClO ion evade organisms.</td>
<td>Life of electric conductive coating is too short in spite that the cost is too expensive at present.</td>
</tr>
<tr>
<td>3. Repelling water type</td>
<td>By the function of repelling water of silicon rubber and teflon resin, organisms are repelled. Much safer method.</td>
<td>Price of paints is too high. So, life-cost performance in not acceptable to common marchant vessels at present.</td>
</tr>
<tr>
<td>4. Plating of metal of copper or its alloys</td>
<td>By leaching copper ion, evade or kill organisms.</td>
<td>Difficult to get strong adhesive power with copper or its alloy and glues.</td>
</tr>
</tbody>
</table>
Antifouling test on the ship bottom paint with ceramic additive

This is a fundamental test to verify how it will affect the antifouling mechanism as well as the matching with paint when the ceramic additive is mixed with paint. This method enables us to compare various test date at the same time and check effectively how marine creatures stick on the hull when a ship is at anchor.

Method of test : Raft suspension test (3 kinds of soaking test in the sea)
Date of starting test : May 20. 2000
The place of test : The Mie bay of Pacific Ocean
Paint used for test : Hydrolysis Type 6 Months specification (for FRP)
No.1  05-S1 The additive is mixed 5% by weight into the ship bottom paint
No.2  05-S2 The additive is mixed 10% by weight into the ship bottom paint
    (the most recommendable mixing ratio)
No.3 05-S3 Only paint (without the additive)

Date of Photo Taken
    File A   January 26.2001. (8 months after the test started)
    (antifouling function of 05-S3 is gone)
    File B   May 17.2001. (12 months after the test started)
    File C   August 9.2001. (15 months after the test started)

Evaluation of the result - It is taken for granted that the conventional ship bottom paint loses an antifouling function in 8 months, but we could verify that if the ceramic powder is added to the paint, the antifouling effect will still remain fully even 15 months later.
January 26, 2001. (8 months after the test started)

(antifouling function of 05-53 is gone)
File B  May 17.2001. (12 months after the test started)
File C  August 9, 2001. (15 months after the test started)
(the most recommendable mixing ratio)