ORGANOTIN ANTIFOULING HULL PAINTS AND THE U.S. NAVY
A HISTORICAL PERSPECTIVE

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ABSTRACT
An interim finding of no significant impact for the U.S. Navy's fleetwide implementation of tributyltin (TBT) containing organotin antifouling hull paints appeared in the U.S. Federal Register of 21 June 1985. This finding was based on an environmental assessment and committed the Navy to (1) slow implementation of the painting program, extending over a 10-year period; (2) use of paints with release rates not greater than 0.1 TBT/cm²/day; (3) environmental monitoring at major Navy harbors, ensuring a target average concentration of 50 ng TBT/L or less; and (4) a commitment to update the environmental assessment in 1988. The paints intended for use by the Navy were registered by the U.S. Environmental Protection Agency and were used widely by recreational and commercial vessels. The public announcement by the Navy of its intended action resulted in a nearly unanimous negative response from Federal, state, and private agencies.

This paper describes the U.S. Navy's research effort, which demonstrated the unique operational and economic benefits provided by these paints for its combat ships; the consequences of preparing the environmental assessment for Fleetwide implementation; the importance and complexity of TBT paint release rates; the response of the environmental community to potential risks of TBT use; concerns and action taken by the U.S. Congress and the U.S. Environmental Protection Agency; the role of water column monitoring and laboratory bioassays; the enactment of regulatory legislation by states on both coasts; and the Navy's leadership in establishing a strategy for the environmental management of TBT.

INTRODUCTION
The U.S. Navy's military specification copper-based antifouling paints (Formulas 121 and 129) were developed when our ships were on a 2-year cycle of drydocking and repainting. However, the typical operating cycles have been lengthened to 5 years for some ships and 7 years for others. Even longer cycles may be imposed in the future. Longer operating cycles increase availability and therefore provide for more ship per capital investment. The currently used copper-based antifouling paints lose their effectiveness after 14 months in most waters and after as few as 7 months in tropical waters as shown in Figure 1, which is based on data from 43 Navy ships. As a result, Navy ships do not have effective antifouling protection throughout the 5- to 7-year cycles between overhauls and repainting. Figure 1 also shows why recreational craft using copper paints require repainting every year and perhaps more often in warmer waters.

Antifouling hull paints play a critical role in Fleet operational readiness. The drag and secondary effects on ship propulsion equipment caused by serious infestations of fouling organisms, such as barnacles and tube worms, on ship hulls and cooling water intakes seriously degrade performance by:
- Reducing maximum attainable speed by as much as 10 knots
- Increasing total underway fuel consumption up to 16%
- Increasing underway refueling frequency

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Retaining these benefits from improved hull design have permitted Navy ships to minimize hydrodynamic growths cause large increases in hydrodynamic drag. The rise in the cost of fossil fuels over the last 15 years and the uncertainty of continued availability have raised this issue to a new level of importance. Most U.S. Navy ships now spend at least 60% of their time in port and only 40% actively steaming. Since fouling organisms attach themselves to hull surfaces mostly while ships are in port, this has increased exposure to biological accretion. Many U.S. Navy ships operate in tropical waters, where the increased vigor of and longer growing season for marine fouling organisms make even greater demands on antifouling hull paints.

Consequently, the U.S. Navy has been engaged in the formulation and research of antifouling paints, including organotin paints, for many years. We have been formulating organotin paints since 1970, and we have been conducting research into the effects of tributyltin paints since 1976. From the beginning, the Navy has been concerned with the effect these paints may have on the environment, and has taken steps to minimize such effects.

Extensive ship trials have demonstrated that TBT antifouling paints provide fouling-free hull protection for the full 5 to 7 years. Power trials on one ship showed almost no power increase with time. This means that the ship's hull is in almost the same smooth conditions as when freshly painted. Only TBT antifouling hull paints achieve that kind of performance. The U.S. Navy needs the extended service life that TBT paints provide.

In addition to significant operational benefits, the economic fuel savings from the Navy's use of TBT paints would be substantial. The fuel savings resulting from 100% implementation would be approximately 1.8 million barrels per year (at 1984 fuel consumption rates). At the Navy's 1984 delivered fuel price of $60.42 per barrel, this fuel saving equates to a cost avoidance of $110 million per year.

Based on these demonstrated potential benefits, the U.S. Navy made the policy decision to begin fleetwide implementation. Before this could begin, however, we prepared an Environmental Assessment of the proposed action in compliance with the National Environmental Policy Act (NEPA) of 1969.

For the preparation of the Environmental Assessment, we developed numerical models of several harbors to dynamically simulate the distribution and fate of TBT released from Navy hulls. A key parameter required for the exercise of such numerical models is the release rate of TBT from the antifouling paint surface. The U.S. Navy can determine precisely the wetted hull area of its ships. Therefore, the release rate times the wetted hull area per ship provides an exact TBT environmental loading rate at a specific berthing location. In anticipation of the importance of TBT release rates, the Navy had developed two measurement methods. A method for conducting measurements in the laboratory was developed at the David Taylor Naval Ship Research and Development Center; the other, for conducting such measurements directly on the hull of a ship in the water, was developed at the Naval Ocean Systems Center. Both procedures represent flat plates in gently moving water, attempting to simulate ships at rest in a harbor. Both procedures show reasonable agreement. Measurements made on a number of commercially available, registered paints showed results that ranged over two orders of magnitude; that is, acceptable antifouling performance was seen in paints releasing TBT from 0.1 µg/cm²/day to greater than 10 µg/cm²/day. The implication of this result is profound, because it means that paints which release 100 times more TBT to the environment than is necessary are in wide use. Furthermore, there is no evidence to show that release rates less than 0.1 µg/cm²/day do not provide adequate antifouling performance.

In fact, release rates measured on the hull of a Navy ship, free of hard fouling after 4 1/2 years, showed an average rate significantly less than 0.1 µg/cm²/day. This ship continues to be free of hard fouling after 6 years of exposure.

The exercise of the numerical models caused us to recognize that a release rate of 0.1 µg/cm²/day was necessary in order to prevent environmental harm in some harbors where Navy ships would be berthed. Most, but not all, commercially available TBT paints had substantially higher release rates, as previously stated.

Based on our preparation of the Environmental Assessment and over 10 years of research in the laboratory and field, we were convinced that our proposed action of gradual fleetwide implementation with Navy-specified TBT paints would not result in significant environmental harm. Accordingly, on 21 June 1985, the Navy issued an Interim Finding of No Significant Impact for the proposed fleetwide implementation.
The measures the Navy took to ensure that the use of TBT paints would not cause significant environmental harm were:

- Using only those commercially available TBT paints that have the lowest release rate of TBT.
- Implementing TBT paints slowly, by painting no more than 10% of the Fleet annually nationwide until full implementation is achieved, requiring 10 years.
- Monitoring drydock TBT discharges and environmental conditions and effects at major homeports.
- Refining capabilities to predict environmental consequences of full Fleet implementation.
- Updating the Environmental Assessment in 1988 when the results of additional research studies, environmental monitoring, and initial implementation are available.
- Modifying or terminating TBT paint use, if experience shows that to be necessary to avoid significant adverse effects.

The Navy's decision to use only the lowest release rate TBT paints, which arose as a result of the NEPA process in preparing the Environmental Assessment, profoundly influenced the TBT paint industry. Several companies have and are continuing to make substantial efforts to lower the TBT release rates of their paints. In addition, the fact that commercial paints with acceptable performance have TBT release rates ranging over two orders of magnitude demonstrated that as much as 90% of the TBT currently released into the environment from these paints is unnecessary.

RESPONSE

In spite of the U.S. Navy's environmentally conservative approach, the release of the Environmental Assessment and the Interim Finding of No Significant Impact resulted in a nearly unanimous negative response from Federal, state, and private agencies concerned with environmental protection. Only the state of Hawaii found no fault with the Navy's plans. The response of the rest appeared to assume that the Navy's action would introduce a new, highly toxic and persistent substance representing an unknown, unquantified threat to estuaries in general and to economically significant marine organisms in particular. While the responses were made in good faith to a specific action proposed by the Navy, they seemed to ignore the following facts.

- TBT paints are widely used in the private sector on fishing fleets, commercial, and cruise ships; in addition, their use on recreational craft is extensive and growing.
- Restrictions to the use of TBT paints instituted in France and England were limited to small craft and did not apply to ocean-going vessels.
- Restrictions in France and England were primarily the result of TBT-painted recreational craft moored in close proximity to beds of the Pacific oyster, which is especially sensitive to TBT.

It is interesting to note that a study of vessel-related contamination of southern California harbors by copper and other metals including tin was published in 1979. This study included data from harbor mussels collected in 1974 which contained up to 10 times natural levels of copper. In addition, the vessel-related materials, cadmium, chromium, lead, tin, zinc, and PCB were measured at levels 2 to 20 times above background in tissue specimens collected from areas of high vessel activity. While the tin levels in mussel tissue were not measured as TBT at that time, it is likely that it was TBT. More importantly, this study showed that vessel-related contamination of harbors was a problem 10 years before the Navy considered fleet-wide use of TBT paints.

REACTION

A number of events ensued in reaction to the U.S. Navy's implementation plan:

- Water column TBT monitoring was begun by California, Virginia, Maryland, and the U.S. EPA.
- Marine scientists on both coasts made public statements expressing alarm.
- Media reaction to these public statements caused more media reaction, reflecting and magnifying public statements of alarm by marine scientists.
- The U.S. Congress, heeding the alarm expressed by marine scientists, included a statement in the 1986 Department of Defense Appropriations Act which prevented the Navy from painting any of its vessels with TBT paint. Unfortunately, as a result, the Navy could not even paint its aluminum-hulled craft with TBT, a necessary and routine procedure for 20 years. Furthermore, all ocean-going vessels, including foreign navies and recreational craft in the U.S.A. continued to use these high performance hull coatings, while the U.S. Navy could not.
The U.S. EPA initiated a Special Review of all pesticide products containing TBT as antifoulants, under authority of FIFRA. This action was based on a Tributyltin Support Document, which included large amounts of Navy-generated data.

The U.S. EPA then issued a Data Call-In Notice to all registrants of TBT antifouling paints, requiring them to provide extensive data on their products. This notice included a requirement to provide TBT release rate information on all registered paints.

With the entrance of the EPA, the concern about TBT paints raised by the Navy's intention to use them properly shifted to the widespread and growing use of these materials in the private sector. Of greatest initial interest was the determination of TBT release rates from the paint film.

**TBT Release Rates**

In anticipation of the EPA's Data Call-In Notice requiring the measurement of TBT release rates, the industry, with over 300 registered products to be measured, found the Navy's procedures too costly. Accordingly, the American Society for Testing and Materials (ASTM) was asked to develop a less expensive procedure. ASTM Subcommittee D01.45, Marine Coatings, formed a special task group that consisted of representatives from industry, the U.S. Navy, the Canadian Navy, the U.S. EPA, and the National Bureau of Standards. After a number of meetings and extensive discussions, a proposed method was devised. It consists of a polycarbonate cylinder painted with the candidate paint. The cylinder rotates at 60 rpm in a baffled, cylindrical container of synthetic seawater. Samples of the seawater are analyzed periodically for tin content by solvent extraction and graphite furnace atomic absorption spectroscopy. This method is designed to provide a laboratory procedure to measure solvent-extractable TBT release rates which occur during a period of immersion under specified conditions of constant temperature, pH, and salinity. This method serves as a comparative guide for organotin release rates in service. Results obtained may not necessarily reflect actual TBT release rates which will occur in service, but they provide comparisons of the release rate characteristics of different antifouling formulations. After several revisions, the Chairman of ASTM Subcommittee D01.45 approved the use of Draft #6 of the proposed method by the EPA with the understanding that this draft is subject to revision prior to issuance of an official ASTM standard. This draft, with some amendments by the EPA, became part of the Data Call-In Notice to TBT paint registrants.

Consternation arose among registrants, users, and regulators as preliminary results from the EPA release rate method became available, because there was a substantial difference in the results of paints measured by the EPA and Navy procedures. For example, two registered, commercially available, field-proven TBT paints for steel-hulled Navy ships gave Navy-measured release rates of 0.1 and 0.2 μg/cm²/day; the same paints measured by the EPA method gave release rates of 1.9 and 4.0 μg/cm²/day, respectively. Both coatings are ablative paints, providing for a self-smoothing of the hull surface as the ship moves through the water. It appears that these paints, designed to ablate when a ship is underway, released significantly more TBT on the surface of a 7-cm-diameter cylinder rotating at 60 rpm, than in the Navy's flat plate technique. For a nonablative paint such as one approved for use on Navy aluminum hull craft, the difference was not as large, being 1.5 by the Navy method and 1.8 μg/cm²/day for the EPA method. What added to the consternation was that pending state and Federal legislation designed to regulate the use of TBT paints was being based on Navy release rate information, while the largest data base, on the basis of which TBT paints would be regulated, was being accumulated by the EPA.

The U.S. Navy's approach to measuring TBT release rates was to apply such measurements to predicting the environmental fate of TBT, using numerical models. This raises the question of which procedure comes closest to measuring the release rate under actual environmental conditions. The EPA procedure contains a statement disclaiming that results reflect release rates occurring in service. Of the Navy procedures, the measurement made directly on the hull in water, though time-consuming and expensive, comes closest to reproducing conditions of paint age; water salinity, pH, and temperature; and the presence on the paint of a microbial biofilm or slime layer.

**Release Rates and the Biofilm**

Surfaces exposed to natural waters, even if they are releasing biocides to prevent macrofouling, become coated with a biofilm or slime layer. This layer consists of a complex community of bacteria, protozoa, dinoflagellates, and other microalgae together with their cellular exudates. This slime layer can increase the resistance to motion by up to 10X. Ablative TBT paints, which do not accumulate biofilms under dynamic conditions, become coated with slime under static conditions. The role of the biofilm in modifying the release of TBT from painted surfaces was investigated at the Navy Biosciences Laboratory several years ago. This study showed that microbial biofilms formed on painted panels releasing TBT accumulated high concentrations of the biocide. These slime layers were removed from the panels and centrifuged to separate solids from the liquid portion. The TBT content of the centrifugate was measured to be greater than 20 μg/L, which is considered to be above the solubility limit of TBT in seawater, while the biofilm interstitial water contained 1 μg/L, considered to be near the solubility limit. These concentrations of TBT, if biologically active, are four or more orders of magnitude above biocidal levels. In a recent investigation at the David Taylor Naval Ship Research and Development Center, biofilms were formed in the laboratory with either TBT-resistant bacteria or
algal growth rates. In both cases, significant short-term changes in the steady-state TBT release rate were observed. These investigations focus attention on the biofilm as a factor in understanding the mechanism of antifouling by TBT, and its influence on the release and biodegradation rate of TBT.

As a result of the TBT biofilm investigations conducted so far, the following hypothesis is proposed. The slime layer and its exudates accumulate TBT from controlled release paints. This layer behaves as a biological capacitor, concentrating TBT to several orders of magnitude above concentrations lethal to settling organisms and thereby either preventing their attachment or killing them shortly after attachment. The high concentration of TBT in the interstitial water may also decrease the rate of diffusion of TBT from the paint matrix by decreasing the concentration gradient in accordance with Fisk's First Law of Diffusion. If the foregoing hypothesis is valid, it has two practical consequences.

1. The wide range of TBT release rates as measured by laboratory procedures may not be as significant for environmental impact as previously considered, because the biofilm has the capacity to modify the diffusion of TBT through the paint matrix.

2. Paints having much lower release rates may be as effective as the currently available, field-proven low release rate paints with nominal rates of 0.1 \( \mu g/cm^2/day \) because the biofilm will accumulate biocidal concentrations of TBT.

A test of this hypothesis is underway at the National Bureau of Standards under Navy sponsorship. The NBS research will:

- Develop techniques to measure TBT concentrations in biofilms using epifluorescence microscopy with appropriate fluorogenic ligands and Fourier transform infrared spectroscopy.
- Measure the rate of TBT accumulation in biofilms.
- Determine the bioavailability of TBT in the biofilm.
- Determine a method to evaluate the potential effectiveness of very low TBT release rate paints.

The foregoing illustrates the complexity of determining the release of TBT from painted surfaces in natural waters; nevertheless, preliminary monitoring data from Navy harbors where TBT test ships are located indicate that observed TBT concentrations are lower than or approximately equal to the concentrations predicted by the numerical models, based on Navy measured release rates. This demonstrates that while release rates can be used to make predictions, it is environmental monitoring of the water column that provides key information concerning potential environmental consequences.

**Environmental Monitoring**

Ultratrace analytical procedures to measure TBT and its degradation products in natural waters were not available until recently. A recent Interagency Workshop on Aquatic Sampling and Analysis for Organotin Compounds was held at the U.S. Naval Academy, Annapolis, MD, 3-5 June 1986. It was clear from this workshop that a number of accurate analytical procedures to determine TBT and other organotin compounds in water had been developed. However, the number of samples that could be analyzed during an average 8-hour day ranged from 3 to 50. Therefore, the proper selection of a procedure for harbor and bioassay samples will affect laboratory costs significantly.

Two analytical procedures for ultratrace speciation of butyltin compounds in natural waters were developed under Navy sponsorship; one at the National Bureau of Standards and the other at the Naval Ocean Systems Center. An interlaboratory comparison of both methods showed good agreement. Under Navy sponsorship, the National Bureau of Standards has initiated a world-wide interlaboratory comparison of analytical methods for speciation of butyltin compounds in aqueous solution. Progress of this undertaking is being reported at the Oceans 87 Conference.

In preparation for fleetwide implementation of TBT paint, the Navy conducted baseline measurements in 15 U.S. harbors and estuaries. This was the most extensive sampling and analysis effort conducted anywhere in the world. Results showed that the highest concentrations of TBT in water were consistently found in recreational craft marinas, small boat harbors, and adjacent to vessel repair facilities. Sites in open or well-flushed harbor areas often exhibited TBT concentrations less than 5 ng/L (parts per trillion) in water. Of 455 water samples analyzed for TBT content during the course of this baseline survey, 75% measured less than 5 ng/L. The presence of high concentrations of TBT in and near recreational craft marinas has been confirmed by other investigations.

A more recent monitoring effort was conducted in northern Chesapeake Bay. This effort found high TBT and dibutyltin concentrations in recreational craft marinas early in June when freshly painted boats were placed in the water. A sharp decline in TBT concentrations occurred during summer and early fall. In addition, TBT values declined to three orders of magnitude when measured away from marina areas. This monitoring effort demonstrated the following:

- The presence of dibutyltin, the first degradation product of TBT;
The sharp decline in TBT concentrations away from marina areas; and

The overall decline of TBT values after the beginning of the boating season.

All of these factors indicate that regulation of the primary source of this biocide in marinas will probably result in its rapid disappearance from the water column of estuaries. Water column monitoring in estuaries previously measured is the best means to determine the effectiveness of regulatory implementation.

Measurement of TBT in the water does not provide information about TBT bioavailability; therefore, the measurement of high concentrations of TBT by itself does not constitute direct evidence of environmental harm. When combined with laboratory toxicity studies, however, high concentrations of TBT in marinas constitute persuasive circumstantial evidence for potential harm and therefore regulatory action.

BIOLICAL EFFECTS

Laboratory measurements of the toxic biological effects of TBT are being reported in an increasing number of scientific papers. Most papers have reported acute effects at TBT concentrations orders of magnitude above what is actually measured in the environment, with the exception of the very highest transient values found in some recreational craft marinas. This was partially due to an inability by most laboratories until very recently to measure TBT and distinguish it from its biodegraded products at concentrations less than 1000 ng/L; and the ability to obtain rapid, unquestionable results in terms of mortality and dramatic morphological effects. Toxicity papers presented at the Oceans 86 Conference reflected such unrealistically high values, but also presented results of effects at much lower concentrations. The lower concentrations used were 20 to 45 ng/L31-34 and the higher ones were 300,000 ng/L and higher for effects on human erythrocytes.29 Of increasing value and interest are chronic studies, which are more difficult to perform than acute studies, requiring substantially more investment of laboratory skills and time. A model example of such a study was performed by the Naval Ocean Systems Center using mussels.33

As the TBT bioassay data base grows in size, the question of its interpretation concerning ecological significance grows in importance. This issue was addressed by M.K. Salazar at the Oceans 86 Conference.36 He cited a review by White and Champ37 which drew the following conclusions about bioassays.

They are not comparable among laboratories.

They do not accurately simulate the natural environment.

They are not good predictors of ecological consequences.

Their use by regulators as a predictive tool is questionable.

For these reasons, Salazar pointed out, the interpretation of laboratory bioassay results and extrapolation from the laboratory to the field is subjective, even for well characterized contaminants. He concluded that the interpretation and environmental significance of organotin bioassays depends upon a complete understanding of bioavailability, and environmental impact cannot be predicted with the data available from organotin bioassays and environmental monitoring. Taking such conclusions seriously creates a problem, because almost the entire data base on TBT consists of monitoring and bioassay data. One step to resolve this problem is conduct more site specific flow-through bioassays, such as the first one of its kind reported by R.S. Henderson at the Oceans 86 Conference.34 Results of this study showed that no significant deleterious effects were evident on either the settlement or survival of fouling organisms, or the condition index of American oysters (Crassostrea virginica) in long-term exposures at 40 ng/L.

WATER QUALITY CRITERIA FOR TBT

What the rapidly growing TBT community has been awaiting is a TBT water quality criterion developed by the U.S. EPA under Section 304(a) of the Clean Water Act. In recent testimony before a U.S. Senate committee, it was announced that the EPA will issue a water quality advisory instead of a criterion while awaiting a significant amount of new data which may result from the TBT Special Review.38 While the advisory is based on less data and therefore more uncertainty, it is intended to be used in the same manner as water quality criteria for the establishment of water quality standards. The testimony announced that criteria for saltwater are on the order of 240 ng/L for the Criterion Maximum Concentration (acute) and 30 ng/L for the Criterion Continuous Concentration (chronic).38 It was also pointed out that additional chronic data will not be available for another 2 to 4 years.

LEGISLATION

Although the EPA is conducting a Special Review of TBT paints, it is clear that under the statutory requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), implementation of regulatory action might not be forthcoming for several years.38 Prior to regulatory action, FIFRA requires a careful risk and benefit analysis based on an extensive data base which still needs to be established. State legislatures, and the U.S. Congress, are not under such constraints. Accordingly, with the states of Maryland and Virginia providing leadership, state legislatures and both houses of Congress began preparing legislation to regulate the use of TBT paints. Nearly identical bills have been enacted in Maryland, Virginia, and Oregon; a similar bill is nearing enactment in California. More stringent bills have been enacted in Washington and Alaska. Essentially, these bills ban the sale and use of TBT paints by vessels under
The first ship painted as part of this plan was a model of a mathematical model of Pearl Harbor, application of the paint, monitoring the concentration of butyltins in harbor waters following undocking of the shipyard activities involved in the environmental impact will be eliminated or severely curtailed. Whether the legislative action by the states of Maryland and Virginia will manifest itself in significantly lower TBT water column concentration in the Chesapeake Bay during the 1988 boating season remains to be determined.

**ORGANOTIN ANTIFOULING HULL PAINTS FOR THE U.S. NAVY**

Let us return to the Navy's use now that the momentum of environmental concern over TBT, initiated and focused by the Navy's intention to use these high performance antifouling coatings, has resulted in the EPA's Special Review as well as passage of regulating legislation. None of the TBT legislation enacted prevents the Navy from using TBT paints. For 1987, the U.S. Congress authorized the Navy to conduct a two-harbor case study on the application of TBT paints to its ships. Accordingly, an Implementation Plan was prepared jointly by the David Taylor Naval Ship Research and Development Center and the Naval Ocean Systems Center. Implementation of the case study involved development of a mathematical model of Pearl Harbor, documenting the shipyard activities involved in the application of the paint, monitoring the concentration of butyltins in harbor waters following undocking of the ship, and studying the environmental fate and toxicity of TBT in Pearl Harbor waters. The first ship painted as part of this plan was a frigate at the Pearl Harbor Naval Shipyard.

The state of Hawaii, however, filed a preliminary injunction in the U.S. District Court to prevent this frigate from being undocked, causing any form of TBT to be placed in the waters of Pearl Harbor, or painting any other ships with TBT. Hawaii based its motion on the grounds that the Navy had violated the following:

1. The Coastal Zone Management Act
2. The National Environmental Policy Act
3. The Federal Water Pollution Control Act.

After extensive testimony was taken, the Court concluded that Hawaii's arguments were without merit and ordered the motion for preliminary injunction be denied in all respects. The Court concluded that the Navy had not violated any of the Federal acts as charged by Hawaii. The frigate was undocked and the study proceeded. The Federal Court in its ruling also stated the following:

"The Navy is by far and away the most responsible user of TBT in Hawaiian waters. It uses paint with low release levels, has instituted procedures to minimize discharge from drydocks, has contributed immensely to the available base of scientific data, and is proceeding in a very cautious manner. If some damage is indicated after the program is commenced, the program can be discontinued. If damage occurs, it will not be irreparable and can be eliminated. Given the widespread unregulated use of TBT by others, the harm posed by the Navy is nonexistent."

This citation from the Court's ruling is of particular interest since it restates the Navy's position in its Interim Finding of No Significant Impact.

Another state in which U.S. Navy ships have a significant presence is Virginia. This state has enacted legislation regulating TBT paint use which does not prohibit the Navy from implementing its program. A public hearing on organotin antifouling paints was conducted by the Virginia Department of Agriculture and Consumer Affairs. Testimony presented at that hearing put the Navy's potential contribution of TBT to Virginia waters into perspective. The following vessel statistics and assumptions were used:

- Commercial ship traffic in Virginia waters in 1985 was 3246, according to the Virginia Port Authority. Of these ships, 22% were assumed to use organotin, and the average underwater hull area was assumed to be 20,000 ft². (Use of organotin paints on commercial vessels may be much higher than 22%). A TBT release rate of 1 pg/cm²/day by the Navy was assumed.
- The Chesapeake Bay fishing fleet numbers 2840 according to the National Marine Fisheries Service; half of that was assumed to operate in Virginia waters, with an average underwater hull area of 300 ft², and an estimated 90% use of TBT paint, releasing 1 pg/cm²/day.
- Based on U.S. Coast Guard data, 158,000 recreational craft operate in Virginia waters; these craft have an average length of 20 feet and an average underwater hull area of 150 ft². Only 10% of these use any antifouling paint and of these 30% use organotin paints with an estimated release rate of 5 pg/cm²/day by the Navy procedure.

Table I presents estimated releases of TBT to Virginia waters based on these assumptions and residence times. Estimates for the commercial fleet are very conservative and could easily be four times higher. Based on recently enacted legislation, the contribution from recreational craft, at least those smaller than 25 meters, should be eliminated.
if not entirely during the next boating season, at least during the one thereafter. While this would increase the percent of the potential Navy contribution, Table 1 serves to place it in proper perspective.

Table 1. Estimates of TBT Released to Virginia Waters from Vessels

<table>
<thead>
<tr>
<th>Vessel Type</th>
<th>Painted Hull Area (ft²)</th>
<th>Release Rate (µg/cm²/day)</th>
<th>Vessel Residence Time (%)</th>
<th>Total Release (lb/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Ships</td>
<td>14,360,000</td>
<td>1.0</td>
<td>10</td>
<td>1089</td>
</tr>
<tr>
<td>Fishing Fleet</td>
<td>340,000</td>
<td>1.0</td>
<td>50</td>
<td>127</td>
</tr>
<tr>
<td>Recreational Craft</td>
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<td>5.0</td>
<td>100</td>
<td>2661</td>
</tr>
<tr>
<td>U.S. Navy*</td>
<td>4,700,000</td>
<td>0.1</td>
<td>50</td>
<td>176</td>
</tr>
</tbody>
</table>

*Hypothetical 100% implementation in 10 years.

While Table 1 is limited to Virginia, it illustrates for other states where the U.S. Navy has a significant presence. On a nationwide basis, if the entire Navy were painted with TBT after 10 years, its contribution would represent 2% of the current contribution to the environment.43

**SUMMARY**

The U.S. Navy, in its continuing efforts to maintain operational readiness in fulfilling its military mission as well as minimizing cost, has identified low release rate TBT-based antifouling paints as the best means to keep its water-wetted hulls smooth and efficient worldwide. Although the Navy's contribution of the TBT biocide to the environment is small when compared to private sector use, its announced intention through publication of an Environmental Assessment, stimulated the environmental community into action. While this clearly was not the intent, it was clearly the result. The Navy's research was instrumental in providing the U.S. EPA with data to support its Special Review; in identifying TBT release rate as an intrinsic property of these paints and as a means for their regulation; in developing analytical methods for environmental monitoring; in encouraging the industry to lower the release rate; and in establishing a regulatory strategy by identifying recreational craft marinas as the primary source of TBT entering the environment and therefore as the place where regulation should focus.

The original determination of need for these high performance state-of-the-art antifouling hull paints remains the same. It is anticipated that the U.S. Navy will now be able to proceed with its implementation program to use these paints, as they are being used by most other navies in the world.

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