NATURE OF DISCHARGE REPORT

Hull Coating Leachate

1.0 INTRODUCTION

The National Defense Authorization Act of 1996 amended Section 312 of the Federal Water Pollution Control Act (also known as the Clean Water Act (CWA)) to require that the Secretary of Defense and the Administrator of the Environmental Protection Agency (EPA) develop uniform national discharge standards (UNDS) for vessels of the Armed Forces for "...discharges, other than sewage, incidental to normal operation of a vessel of the Armed Forces, ..." [Section 312(n)(1)]. UNDS is being developed in three phases. The first phase (which this report supports), will determine which discharges will be required to be controlled by marine pollution control devices (MPCDs)—either equipment or management practices. The second phase will develop MPCD performance standards. The final phase will determine the design, construction, installation, and use of MPCDs.

A nature of discharge (NOD) report has been prepared for each of the discharges that has been identified as a candidate for regulation under UNDS. The NOD reports were developed based on information obtained from the technical community within the Navy and other branches of the Armed Forces with vessels potentially subject to UNDS, from information available in existing technical reports and documentation, and, when required, from data obtained from discharge samples that were collected under the UNDS program.

The purpose of the NOD report is to describe the discharge in detail, including the system that produces the discharge, the equipment involved, the constituents released to the environment, and the current practice, if any, to prevent or minimize environmental effects. Where existing process information is insufficient to characterize the discharge, the NOD report provides the results of additional sampling or other data gathered on the discharge. Based on the above information, the NOD report describes how the estimated constituent concentrations and mass loading to the environment were determined. Finally, the NOD report assesses the potential for environmental effect. The NOD report contains sections on: Discharge Description, Discharge Characteristics, Nature of Discharge Analysis, Conclusions, and Data Sources and References.

2.0 DISCHARGE DESCRIPTION

This section describes the hull coating leachate discharge and includes information on the coating systems used and how they function (Section 2.1), a general description of the constituents of the discharge (Section 2.2), and the vessels that produce this discharge (Section 2.3).

2.1 System Description and Operation

Underwater hull coating systems typically include a base anticorrosive (AC) coating covered by an antifouling (AF) coating. The function of the AC coat, in conjunction with cathodic protection (described in the Cathodic Protection NOD report), is to prevent hull corrosion. The AC coat also provides bonding between the hull and the AF topcoats. Since the AC coating is not exposed directly to the seawater, unless the AF coating has been damaged, the AC coatings do not leach. The AF topcoat inhibits the development of marine growth on the hull. Marine fouling is undesirable because it increases drag and fuel consumption, while decreasing vessel speed.[1]

2.1.1 Types of AF Topcoats

Several different types of AF topcoats, qualified to MIL-PRF-24647 or MIL-P-15931, are used on the hulls of the Armed Forces vessels.[2,3] Within MIL-PRF-24647, they are categorized by:

- action;
- type of substrate;
- volatile organic compound (VOC) content of the coating; and
- service life requirement and color.

Action - The coating may work through ablative (Type I) or nonablative (Type II) action. An ablative coating thins as it erodes or dissolves. Through this action, a fresh layer of antifouling agent (e.g., copper) is exposed, maintaining the antifouling properties of the paint. Type II nonablative AF coatings do not thin during service. Some of these coatings function by leaching metals that prevent marine fouling.[1]

Type of Substrate - Most hulls of major vessels in the Armed Forces are steel. Hulls of smaller vessels and some specialty vessels (e.g., minesweepers and minehunters) are often constructed of alternate materials such as aluminum, fiberglass sheathing, glass reinforced plastic (GRP), rubber, or wood. The coating system applied will vary with the hull material. For instance, steel, fiberglass, GRP, and wood hulls are typically coated with copper-based coatings, and aluminum hulls with tributyltin (TBT) or biocide-free silicone-based coatings.[1,4] Rubber craft are left unpainted and, therefore, do not contribute to this discharge.

VOC Content - Coatings are classified into four grades based on their maximum VOC content. The upper limits for each grade are 3.4 pounds per gallon (lbs/gal), 2.8 lbs/gal, 2.3 lbs/gal, and zero lbs/gal.[2]

Service Life Requirement and Color - Coatings are also classified based on the desired service life of the coating system and their color. A vessel's coating system may have a five-, seven-, or ten-year service life. Vessels also may use either red, black, or gray coatings (and white on some smaller craft). Therefore, there are a number of different coating combinations, based on service life and color.[1]

2.2 Releases to the Environment

AF topcoats control biological growth by ablating and/or releasing antifouling agents into the surrounding water. This release is gradual and continuous. The release rate depends on the type of paint, water temperature, vessel speed, frequency of vessel movement in and out of port, and coating age. The type of material released is dependent on the type of topcoat employed. Most hulls use copper-based coatings; therefore, copper and zinc (another biocide commonly found in antifouling paints) are the most common releases. Those aluminum-hulled vessels with TBT-containing coatings will release TBT and small amounts of zinc, and may release copper, depending on the TBT coating formulation.[1]

2.3 Vessels Producing the Discharge

Most vessels of the Armed Forces use AC paints or AC/AF coating systems. Selected boats and craft may not be coated with AF paint if they spend most of their time out of the water. The Navy, Military Sealift Command (MSC) and United States Coast Guard (USCG) use paint systems qualified to MIL-PRF-24647. The Army uses paint systems with AF topcoats qualified to MIL-P-15931. Additional guidance for Navy vessels is contained in Naval Ships' Technical Manual (NSTM) Chapter 631.[5,6] It should be noted that paint types and applications vary for each vessel, depending on where the vessels are docked and the port in which they are painted, which influences paint availability.

2.3.1 Copper-Based Coatings

Most Navy, MSC, USCG, and Army ships have steel hulls with copper-based AF coatings. The Navy ships that do not have steel hulls are the mine countermeasure vessels (MCM 1 and MHC 51 Classes), consisting of 26 ships. MCM 1 Class vessels have wood hulls sheathed with fiberglass and MHC 51 Class vessels have GRP hulls.[7] However, these vessels are still protected with AC coats and copper ablative AF paints similar to those applied to steel vessels.[1]

MSC vessels use two types of Navy-approved copper-based AF paints, ablative and nonablative. Approved MSC underwater hull coatings are listed in MSC Instruction 4750.2C.[8] The USCG utilizes Navy-approved hull coating systems qualified to MIL-PRF-24647, as listed in the USCG Coatings and Color Manual.[9] The Air Force uses copper ablative paints similar to those used by the Navy.[10] AF topcoats used on Army watercraft are qualified to MIL-P-15931, as listed in Department of the Army Technical Bulletin TB 43-0144.[3]

2.3.2 TBT-Based Coatings

The predominant use of TBT-based coatings in the Armed Forces has been on aluminum-hulled vessels. Copper-based AF paints can accelerate the rate at which aluminum hulls corrode, especially if defects or damage to the AC coating are present. Currently, all Navy ships with aluminum hulls (i.e., hydrofoils) have been decommissioned.[1] However, the Navy does have approximately 280 small boats and craft with aluminum hulls. Approximately 10-20% of the aluminum-hulled small boats and craft in the Navy (28-56 vessels; e.g., special warfare patrol craft) could still have TBT-based hull coatings.[11] The USCG estimates that 50 aluminum-hulled small boats and craft are coated with AF paint containing TBT.[12] The MSC has no vessels with aluminum hulls.[13] The Air Force has six large vessels with aluminum hulls, the MR Class missile retrievers. These vessels are coated with TBT-free, copper-based coatings.[7,10] The Air Force also has approximately 50 small craft that may have TBT-containing coatings. The Army has approximately 11 small boats and craft that may have TBT coatings.[13] The numbers of vessels from the respective Armed Forces branches estimated to have TBT coatings are listed below.

- Navy - 56
- USCG - 50
- MSC - 0
- Air Force - 50
- Army - 11

3.0 DISCHARGE CHARACTERISTICS

This section contains qualitative and quantitative information that characterizes the discharge. Section 3.1 describes where the discharge occurs with respect to harbors and near-shore areas, Section 3.2 describes the rate of the discharge, Section 3.3 lists the constituents in the discharge, and Section 3.4 gives the concentrations of the constituents in the discharge.

3.1 Locality

This discharge occurs within harbors, rivers, and coastal waters from every surface vessel and submarine, as well as most boats and craft. This discharge is continuous and will occur any time a painted vessel is waterborne.

3.2 Rate

This discharge is not a flow; rather, it is the release of AF agents from hull coatings into the surrounding water. This rate of release, which is the combined effect of ablation and leaching, has been the subject of previous Navy studies.[14] In these studies, painted panels were submerged in San Diego Bay and copper and zinc release rates were calculated for two of the most frequently used ablative copper AF paint systems.

Dynamic exposure tests included intervals of simulated vessel movement (cruising) at 17 knots followed by periods of no movement, in order to simulate actual vessel operations. The calculated long-term average release rates (from both test coatings) for simulated vessel operation exposures were 17.0 micrograms per square centimeter-day (($\mu g/cm^2$)/day) for copper and 6.7 ($\mu g/cm^2$)/day for zinc. Release rates were highest at the initial stages of the exposures, when the coatings were new.[14]

Long-term average release rates for panels remaining in a static position (no simulated movement) for the entire test were 8.9 ($\mu g/cm^2$)/day for copper and 3.6 ($\mu g/cm^2$)/day for zinc.[14] It is assumed that the static tests underestimate the actual average release rate from vessels because they do not account for vessel movement and the resulting ablation effects.

A comparison of the above dynamic and static release rates shows that dynamic conditions resulted in increased release of copper and zinc. The higher release rates are presumably caused by continuous re-exposure of fresh copper and zinc. The dynamic tests may, however, overestimate actual conditions for some vessels, as the dynamic intervals used in the test may have been more aggressive than in actual practice.

In-situ release rates of TBT from vessels in Pearl Harbor were collected by the Navy in 1987 and 1988.[15] These studies reported an average steady-state TBT release rate of 0.38 ($\mu g/cm^2$)/day.

3.3 Constituents

The primary antifouling agent in most AF topcoats is copper. Because copper is toxic to marine organisms, it inhibits their accumulation and growth on the hull. Other than copper compounds, the constituents that can be released from approved, underwater hull paint systems include acrylate (in ablative coatings), vinyls (in non-ablative coatings), rosin, zinc compounds, and anticorrosive compounds.[16,17] The discharge from aluminum-hulled vessels may also contain TBT. Of the known constituents in AF coatings; copper, zinc, TBT, and ethyl benzene are priority pollutants, and there are no known bioaccumulators.

3.4 Concentrations

Most copper-based AF coatings contain 40 to 50 weight percent (wt%) cuprous oxide.[16] Some ablative AF paints also contain as much as 20 wt% zinc, which may act as a mild co-biocide.[16] Concentrations within TBT-based AF coatings range from less than 5 wt% to 25 wt% for TBT compounds and 25-50 wt% for copper. Some TBT-based coating formulations contain 1-10 wt% ethyl benzene.[18]

4.0 NATURE OF DISCHARGE ANALYSIS

Based on the discharge characteristics presented in Section 3.0, the nature of the discharge and its potential impact on the environment can be evaluated. The estimated mass loadings are presented in Section 4.1. In Section 4.2, the concentrations of discharge constituents after release to the environment are estimated and compared with the water quality criteria. In Section 4.3, the potential for the transfer of non-indigenous species is discussed.

4.1 Mass Loadings

4.1.1 Copper and Zinc Loadings

The mass loadings for copper and zinc were calculated for Navy, MSC, USCG, Army, and Air Force vessels based on the reported release rates.[14] Loading for a single vessel was calculated by the following equation:

Copper Loading = (release rate)(surface area)(time)

where: release rate = dynamic release of copper and zinc (Section 3.2)
surface area = wetted surface area of vessel
time = number of days vessel is within 12 nautical miles (n.m.)

The wetted surface area of the vessels were either taken directly from a naval manual or were estimated by the following formula presented in the same source:[19]

$$S = 1.7(L)(d) + (V/d)$$

where: S = wetted surface area (ft^2)
L = length between perpendiculars (ft)
d = molded mean draft at full displacement (ft)
V = molded volume of displacement (for seawater, 35 ft^3 per ton displacement)

Calculations were performed for each vessel class. A sample calculation of the mass loading of copper from a destroyer is provided in Calculation Sheet 1 at the end of the report. From actual vessel movement data compiled for 1991 through 1995, the sum of the average number of days in port, the average number of transits, and time of operation within 12 n.m. was determined for each vessel class.[20] The number of vessels in each class are listed in conjunction with the total calculated loadings per vessel class in Table 1. A total annual copper loading of 216,657 lbs (98,257 kilograms (kg)) and a total annual zinc loading of 85,389 lbs (38,725 kg) were calculated. The mass loadings calculated represent the worst-case conditions.

The approach used overestimates the mass loading for the following reasons:

- Calculations were based on the dynamic release rate, and vessels are not in motion while pierside.
- All vessels were assumed to be deployed at ports within the jurisdiction of the United States, while many are actually deployed overseas.
- All vessels are assumed to be fully operational; that is, no reduction was made to account for the number of vessels which may be in dry dock during the year.
- All small workboats and utility craft were assumed to be in the water at all times, when they may actually be stored on land.
- Amphibious assault craft of both the Army and Navy, which are capable of being transported or otherwise held within larger amphibious ships, were assumed to be in the open water at all times.

4.1.2 TBT Loadings

Table 2 presents mass loadings of TBT from Navy, USCG, Army, and Air Force vessels, based on the study of TBT concentration measurements from five vessels in Pearl Harbor.[15] The average release rate measured during this study was 0.38 ($\mu g/cm^2$)/day. The mass loading value was estimated to be 24 lbs/yr (11 kg/yr) based on the following assumptions:

- Small boats and craft were estimated to be within 12 n.m. at all times and to spend 10% of the year out of the water. This assumption leads to an overestimate of the mass loadings for TBT because many small boats and craft spend much more than 10% of their time out of the water.
- Twenty percent of the Navy's aluminum-hulled small boats and craft were assumed to still have TBT-based AF coatings, although the actual number may be as low as 10%.
- All of the 50 Air Force and 11 Army small craft were assumed to be painted with TBT coatings.

Use of these assumptions also overestimates the potential TBT loading since the use of TBT coatings is being phased out, and the number of TBT coated craft in the Armed Forces is continually declining.

4.2 Environmental Concentrations

The estimated quantities of constituents released to the environment are shown in Tables 1 and 2. Using the mass loadings and a tidal prism model for analyzing mixing within specific harbors, the resulting concentration of constituents in the environment were estimated in the manner described below.

4.2.1 Copper and Zinc Concentrations

Table 3 lists the Federal and most stringent state water quality criteria for the constituents of the hull coating leachate discharge. Using the annual copper and zinc loadings and annual tidal excursion volumes, the average copper and zinc concentrations caused by these vessels were calculated for each port. The approach used to estimate concentrations uses a simplified dilution model based on tidal flow in three major Armed Forces ports and hereafter referred to as the "tidal prism" approach. The tidal prism approach uses the mass of the constituent generated by vessels and mixes this mass with a volume of water. The mass is calculated by determining the number of vessels in a particular homeport, the wetted surface area of each vessel's hull, and the number of hours each vessel spends in port (both pierside and in transit). Together, these factors are used to calculate an annual loading to the harbor. The water volume used is the sum of all outgoing tides over a year times the surface area of the harbor. The sum of outgoing tides is called the "annual tidal excursion." This can be calculated by subtracting the annual mean low tide from the annual mean high tide and multiplying the difference by the number of days in the year. Annual tidal excursion data is readily available from the National Oceanographic and Atmospheric Agency (NOAA) and the 1996 data [21] was used for these calculations. The following is the equation used to estimate concentrations of copper and zinc contributed to harbors by hull coating leachate:

Concentration increase = Annual load / Annual tidal prism volume
where: annual load = (kg/yr)/(10^9 μg/kg) = (μg/yr)
annual tidal prism volume = (m^3/yr) (10^3 L/m^3) = (L/yr)
Concentration increase = μg/L

The three ports used for the tidal prism model are Mayport, FL, San Diego, CA, and Pearl Harbor, HI. These ports were selected because they have minimal river inflow, small but well-defined harbor areas, and a high number of vessels of the Armed Forces. Each of these factors will tend to provide higher concentrations of copper and zinc, either due to less volume of water or higher numbers of potential sources. Other major ports, such as Norfolk (VA) and Bremerton (WA), were considered, but not included because of large river effects and very large harbor areas. The 1996 annual tidal volumes (annual tidal excursion times the harbor surface area) for the three ports are shown below:

- San Diego, CA, 3.78×10^{10} m^3 per year;
- Mayport, FL, 6.7×10^8 m^3 per year; and
- Pearl Harbor, HI, 3.42×10^9 m^3 per year.

The tidal prism model assumes steady-state conditions, where copper and zinc are completely mixed with the harbor water and are removed solely by discharge from the port during ebb tides. The outgoing tidal volumes are assumed to be carried away by long-shore currents (i.e., those moving parallel to shore) and do not re-enter the harbor. The tidal prism model also does not assume removal or concentration by other factors such as river flow, precipitation, evaporation, or sediment exchange. By not accounting for removal or dilution due to river flow, precipitation, and sediment exchange, the results depict a higher water column concentration than expected. The effect of evaporation could be to increase concentration due to water loss, or the effect could be neutral since water loss by evaporation is replaced by (additional) water inflow from the sea. While the model assumes complete mixing, there will be areas in the harbors with higher concentrations, primarily near the source vessels, along with areas of lower concentration.

To estimate the annual load for the same three ports, the number and types of vessels in each of these locations were obtained.[22] The ratios of Navy vessels at each of these ports to the total number of vessels per respective ship class were multiplied by the copper and zinc mass loadings of Table 1 and summed. The estimated contribution of Armed Forces' AF paint to the existing copper and zinc concentrations in each port is provided in Table 4. The actual annual load attributable to hull coating leachate for each of these ports should be smaller than estimated for two reasons. First, the calculated mass loadings are based upon dynamic release rates, yet the vessels in port are primarily static. Also, the mass loadings of copper and zinc were determined using the total amount of time that the vessels are within 12 n.m., not just in port. Therefore, the actual concentrations in port will be lower than stated.

The calculated copper concentration increases are shown in Table 5 and range from 0.19 μg/L at San Diego to 3.0 μg/L at Mayport, the latter of which exceeds Federal and state water quality criteria. Copper from AF paint adds to the ambient copper concentrations from other sources. In other words, these concentrations represent the ambient copper concentration if hull coating leachate were the only source of copper in each harbor. Ambient copper concentrations in San Diego Harbor have been reported to average near 3.7 μg/L, with locally impacted areas near vessels at twice the average.[23]

As demonstrated by Table 5, the estimated copper contributions from hull coating releases are a significant contributor to total copper levels within the Navy ports analyzed. In addition, some of these ports are already near or above ambient water quality criteria levels for copper. Therefore, dilution of copper to levels below the water quality criteria cannot be expected. By contrast, the three ports analyzed were all well below the water quality criteria for zinc, and estimated zinc concentration increases were not large enough to cause the zinc levels in these ports to approach the zinc water quality criteria.[24]

4.2.2 TBT Concentrations

As discussed in Section 2.3.2, only small boats and craft of the Armed Forces still use TBT-containing coatings. A tidal prism approach can also be used to estimate TBT concentrations, assuming that the TBT loading in each harbor is proportional to the copper loading, as might be the case if the locations of small boats and craft parallel that of larger vessels. As shown in Calculation Sheet 2, TBT is estimated to range from 0.02 nanograms per liter (ng/L) to 0.30 ng/L in the harbors analyzed. TBT does not have specific Federal water quality criteria at the present; however, criteria have been proposed.[25] Table 3 lists the proposed Federal and most stringent state water quality criteria for TBT.

4.3 Potential for Introducing Non-Indigenous Species

Although it is possible for non-indigenous species to be transported on vessel hulls, AF coatings reduce the amount of marine growth on vessel hulls. The discharge itself (released components of AF coatings) does not provide the opportunity for transport of non-indigenous species.

5.0 CONCLUSIONS

Hull coating leachate has the potential to cause an adverse environmental effect because estimated mass loadings of copper from hull coatings are significant and could cause environmental copper concentrations to exceed water quality criteria in some ports.

6.0 DATA SOURCES AND REFERENCES

To characterize this discharge, information from various sources was obtained, reviewed, and analyzed. Process information and assumptions were used to estimate the rates of discharge. Table 6 shows the sources of data used to develop this NOD report.

Specific References

1. UNDS Equipment Expert Meeting Minutes - Hull Coating Leachate, 20 August 1996.

2. Military Specification, MIL-PRF-24647B, Paint System, Anticorrosive and Antifouling, Ship Hull, August 1994.

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5. Naval Ships' Technical Manual (NSTM) Chapter 631, Vol. 3, Preservation of Ships in Service, Section 8, Shipboard Paint Application, 1 November 1992.

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Product/Trade Name:	283S5772 ABC #3 - Red Ablative Antifouling Paint Product Number 406940
Manufacturer:	Ameron Protective Coatings Group
Product/Trade Name:	283S5773 ABC #3 - Black Ablative Antifouling Paint Product Number 407150
Manufacturer:	Ameron Protective Coatings Group
Product/Trade Name:	Epoxy Adhesives 2216 B/A Gray, 2216 B/A Tan NS, and 2216 B/A Translucent
Manufacturer:	3M Scotch-Weld™, March 1995
Product/Trade Name:	Epoxy Adhesives
Manufacturer:	3M Innovation, March 1996

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18. Material Safety Data Sheets for International Paint Intersmooth Hisol Plum BFA254, November 1996; and Devoe Coating Company ABC #2 Red Ablative Antifouling Coating, September 1995.

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Committee Print Number 95-30 of the Committee on Public Works and Transportation of the House of Representatives, Table 1.

The Water Quality Guidance for the Great Lakes System, Table 6A. Volume 60 Federal Register, p. 15366. March 23, 1995.

Table 1. Navy, MSC, and USCG, Army, and Air Force Mass Loadings for Ships, and Small Boats and Craft

Ship Class	Ship Class Description	Quantity of Ships per Class	Days in Port per Year	Number of Transits per year (each is a transit in and out)[T]	Days of Operation within 12 n.m.	Ship's Wetted Surface Area (sq ft)	*Copper Loading per ship class (kg/yr)	**Zinc Loading per ship class (kg/yr)
	NAVY							
AC	Area Command Cutter	2	305	0	60	539	6	2
AP	Area Point System Search Craft	6	305	0	60	343	12	5
AR	Aircraft Rescue	6	305	0	60	2,127	74	29
AT	Armored Troop Carrier	21	305	0	60	362	44	17
BH	Boom Handling	8	305	0	60	189	9	3
BT	Bomb Target	4	305	0	60	94	2	1
BW	Boston Whaler	4	305	0	60	94	2	1
CA	Catamaran	1	305	0	60	207	1	0
CC	Cabin Cruiser (Commercial)	4	305	0	60	411	9	4
CM	Landing Craft, Mechanized	151	305	0	60	4,275	3,721	1,467
CRRC	Combat Rubber Raiding Craft (USMC)	418	305	0	60	57	137	54
CT	Craft of Opportunity Coop Trainers	14	305	0	60	411	33	13
CU	Landing Craft, Utility	40	305	0	60	3,860	890	351
DB	Distribution Box	4	305	0	60	704	16	6
DT	Diving Tender	1	305	0	60	813	5	2
DW	Dive Workboat	7	305	0	60	539	22	9
HH	Hawser Handling	7	305	0	60	400	16	6
HL	Hydrographic Survey Launch	3	305	0	60	342	6	2
LA	Landing Craft, Assault	1	305	0	60	2,745	16	6
LCM(3)	Mechanized Landing Craft	2	305	0	60	not available	--	--
LCM(6)	Mechanized Landing Craft	60	305	0	60	990	342	135
LCM(8)	Mechanized Landing Craft	100	305	0	60	1,603	924	364
LCPL	Landing Craft Personnel	130	305	0	60	332	249	98
LCVP		10	305	0	60	not available	--	--
LH	Line Handling	3	305	0	60	400	7	3
MC	Mine Countermeasure Support Craft	2	305	0	60	343	4	2
ML	Motor Launch	3	305	0	60	256	4	2
MM	Marine Mammal Support Craft	5	305	0	60	331	10	4
MW	Motor Whaleboat	121	305	0	60	256	179	70
NM	Noise Measuring	1	305	0	60	800	5	2
NS	Non-Standard (commercial)	120	305	0	60	540	374	147
PE	Personnel	211	305	0	60	352	428	169
PF	Patrol Craft, Fast	3	305	0	60	539	9	4
PK	Picket Boat	1	305	0	60	366	2	1
PL	Landing Craft, Personnel Light	147	305	0	60	332	281	111
PR	Plane Personnel and Rescue	8	305	0	60	392	18	7
PT	Punt	266	305	0	60	83	127	50
SB	Sound/Sail	1	305	0	60	350	2	1
SC	Support Craft	6	305	0	60	400	14	5
SS	Swimmer Support	12	305	0	60	400	28	11
ST	Sail Training Craft	21	305	0	60	350	42	17
TC	Training Craft	19	305	0	60	580	64	25
TD	Target Drone	2	305	0	60	580	7	3
UB	Utility Boat	793	305	0	60	398	1,819	717

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N/A = Not enough information available to calculate a wetted surface area.

Table 1. Navy, MSC, and USCG, Army, and Air Force Mass Loadings for Ships, and Small Boats and Craft

Ship Class	Ship Class Description	Quantity of Ships per Class	Days in Port per Year	Number of Transits per year (each is a transit in and out)[T]	Days of Operation within 12 n.m.	Ship's Wetted Surface Area (sq ft)	*Copper Loading per ship class (kg/yr)	**Zinc Loading per ship class (kg/yr)
VP	Landing Craft, Vehicle Personnel	12	305	0	60	332	23	9
WB	Workboat	263	305	0	60	620	940	370
WH	Wherry	12	305	0	60	400	28	11
WT	Warping Tug	1	305	0	60	2,662	15	6
YFRN	Refrigerated/Covered Lighter	3	305	0	60	not available	--	--
YL	Yawl	7	305	0	60	400	16	6
YTM	Medium Harbor Tug (self-propelled)	11	305	0	60	3,170	201	79
AFDB 4	Large Auxiliary Floating Dry Dock	1	305	0	60	not available	--	--
AFDB 8	Large Auxiliary Floating Dry Dock	1	305	0	60	not available	--	--
AFDL 1	Small Auxiliary Floating Dry Docks	2	305	0	60	47,645	549	216
AFDM 14	Medium Auxiliary Floating Dry Dock	1	305	0	60	not available	--	--
AFDM 3	Medium Auxiliary Floating Dry Docks	4	305	0	60	47,645	1,099	433
AGER 2		1	305	0	60	not available	--	--
AGF 11	Raleigh Class Miscellaneous Command Ships	1	183	12	0	41,595	123	48
AGF 3	Austin Class Miscellaneous Command Ship	1	183	12	0	51,830	153	60
AGOR 21	Gyre Class Oceanographic Research Ships	1	113	11	0	8,834	16	6
AGOR 23	Thompson Class Oceanographic Research Ships	2	113	11	0	13,960	51	20
AGSS 555	Dolphin Class Submarine	1	305	0	60	9,130	53	21
AO 177	Jumboised Cimarron Class Oilers	5	188	10	0	63,185	955	376
AOE 1	Supply Class Fast Combat Support Ships	4	114	6	0	93,821	688	271
AOE 6	Sacramento Class Fast Combat Support Ship	3	183	11	0	103,520	916	361
APL	Barricks Craft (nsp)	16	305	0	60	13,775	1,270	501
ARD 2	Auxiliary Repair Dry Docks	1	305	0	60	40,750	235	93
ARDM	Medium Auxiliary Repair Dry Docks	3	305	0	60	47,645	824	325
ARS 50	Safeguard Class Savage Ships	4	208	22	0	13,299	181	71
AS 33	Emory S Land Class Submarine Tenders	1	293	6	0	59,630	278	109
AS 39	Simon Lake Class Submarine Tenders	3	229	6	0	59,630	653	257
ASDV		2	305	0	60	not available	--	--
CG 47	Ticonderoga Class Guided Missile Cruisers	27	166	12	0	37,840	2,743	1,081
CGN 36	California Class Guided Missile Cruiser	2	143	11	0	40,260	187	74
CGN 38	Virginia Class Guided Missile Cruiser	1	161	11	0	42,390	110	43
CV 59	Forrestal Class Aircraft Carrier	1	143	6	0	141,470	324	128
CV 63	Kitty Hawk Class Aircraft Carrier	3	137	7	0	141,470	934	368
CVN 65	Enterprise Class Aircraft Carrier	1	76	6	0	156,990	193	76
CVN 68	Nimitz Class Aircraft Carrier	7	147	7	0	159,500	2,633	1,038
DD 963	Spruance Class Destroyers	31	178	12	0	35,745	3,185	1,255
DDG 51	Arleigh Burke Class Guided Missile Destroyers	18	101	11	0	31,769	945	373
DDG 993	Kidd Class Guided Missile Destroyers	4	101	11	0	31,769	210	83
DSRV-1	Deep Submergence Rescue Vehicles	2	305	0	60	not available	--	--
DSV 1	Deep Submergence Vehicles	3	305	0	60	not available	--	--
FFG 7	Oliver Hazard Perry Guided Missile Frigates	43	167	13	0	19,850	2,310	910
IX 308	Unclassified Miscellaneous	2	305	0	60	5,180	60	24
IX 501	Unclassified Miscellaneous	1	305	0	60	8,365	48	19
IX 35	Barrick Ships	2	305	0	60	not available	--	--
EX YFU	Harbor Utility Craft	1	305	0	60	4,160	24	9

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Table 1. Navy, MSC, and USCG, Army, and Air Force Mass Loadings for Ships, and Small Boats and Craft

Ship Class	Ship Class Description	Quantity of Ships per Class	Days in Port per Year	Number of Transits per year (each is a transit in and out)[T]	Days of Operation within 12 n.m.	Ship's Wetted Surface Area (sq ft)	*Copper Loading per ship class (kg/yr)	**Zinc Loading per ship class (kg/yr)
SES 200	High Performance Test Platform (ex- USCG Dorado)	1	305	0	60	not available	--	--
LCC 19	Blue Ridge Class Amphibious Command Ships	2	179	8	0	51,250	294	116
LCU 1610	1600 Class Landing Craft Utility	40	200	6	0	3,915	500	197
LHA 1	Tarawa Class Amphibious Assault Ships	5	173	9	0	94,325	1,311	517
LHD 1	Wasp Class Amphibious Transport Docks	4	185	13	0	88,965	1,064	419
LPD 14	Amphibious Transport Docks	2	178	11	0	51,830	297	117
LPD 4	Austin Class Amphibious Transport Docks	3	178	11	0	51,830	446	176
LPD 7	Amphibious Transport Docks	3	178	11	0	51,830	446	176
LPH 2	Iwo Jima Class Amphibious Assault Ships	2	186	11	0	49,945	299	118
LSD 36	Anchorage Class Dock Landing Ships	5	215	13	0	45,405	786	310
LSD 41	Whidbey Island Class Dock Landing Ships	8	170	13	0	51,020	1,124	443
LSD 49	Harpers Ferry Dock Landing Ships	3	215	13	0	41,595	432	170
LST 1179	Tank Landing Ships	3	178	11	0	34,650	298	118
MCM 1	Avenger Class Mine Countermeasures Vessels	14	232	28	0	8,410	449	177
MHC 51	Osprey Class Coastal Minehunters	12	232	28	0	6,418	294	116
PC	Cyclone Class Coastal Defense Ships	13	105	18	0	3,704	84	33
SLWT	Side Loadable Warping Tugs	24	305	0	0	not available	--	--
SSBN 726	Ohio Class Ballistic Missile Submarine	17	183	6	0	74,575	3,704	1,460
SSN 640	Sturgeon Class Attack Submarine	13	183	6	0	27,075	1,028	405
SSN 688	Los Angeles Class Attack Submarine	56	183	6	0	34,765	5,688	2,242
SSN 671	Narwhal Class Submarines	1	183	6	0	29,135	85	34
SSN 637	Benjamin Franklin Class Submarines	2	183	6	0	44,061	257	101
YC	Open Lighters (nsp)	254	305	0	60	6,475	9,480	3,736
YCF	Car Float (nsp)	1	305	0	60	not available	--	--
YCV	Aircraft Transportation Lighters (nsp)	9	305	0	60	not available	--	--
YD	Floating Cranes (nsp)	63	305	0	60	12,875	4,676	1,843
YDT	Diving Tenders	3	305	0	60	8,885	154	61
YFB	Ferryboat or Launch (nsp)	2	305	0	60	3,895	45	18
YFN	Covered Lighters (nsp)	157	305	0	60	6,680	6,046	2,383
YFNB	Large Covered Lighters (nsp)	11	305	0	60	15,955	1,012	399
YFND	Dry Dock Companion Craft (nsp)	2	305	0	60	not available	--	--
YFNX	Lighter - Special Purpose (nsp)	8	305	0	60	4,760	220	87
YFP	Floating Power Barges (nsp)	2	305	0	60	15,590	180	71
YFRT	Covered Lighters - Range Tender (self propelled)	2	305	0	60	5,490	63	25
YFU 83	Harbor Utility Craft (self propelled)	1	305	0	60	3,915	23	9
YFU 91	Harbor Utility Craft (self propelled)	1	305	0	60	3,915	23	9
YGN 80	Garbage Lighters (nsp)	3	305	0	60	not available	--	--
YLC	Salvage Lift Crane (nsp)	1	305	0	60	not available	--	--
YM	Dredges (self propelled)	2	305	0	60	not available	--	--
YMN	Dredge (nsp)	1	305	0	60	not available	--	--
YNG	Gate Craft (nsp)	2	305	0	60	4,760	55	22
YO 65	Fuel Oil Barges (self propelled)	3	305	0	60	10,205	176	70
YOG 5	Gasoline Barges (self propelled)	2	305	0	60	10,205	118	46
YOGN	Gasoline Barges (nsp)	12	305	0	60	8,512	589	232
YON	Fuel Oil Barges (nsp)	48	305	0	60	8,512	2,355	928

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Table 1. Navy, MSC, and USCG, Army, and Air Force Mass Loadings for Ships, and Small Boats and Craft

Ship Class	Ship Class Description	Quantity of Ships per Class	Days in Port per Year	Number of Transits per year (each is a transit in and out)[T]	Days of Operation within 12 n.m.	Ship's Wetted Surface Area (sq ft)	*Copper Loading per ship class (kg/yr)	**Zinc Loading per ship class (kg/yr)
YOS	Oil Storage Barges (nsp)	14	305	0	60	8,512	687	271
YPD	Floating Pile Drivers (nsp)	4	305	0	60	not available	--	--
YR	Floating Workshops (nsp)	25	305	0	60	7,350	1,059	417
YRB	Repair and Berthing Barges (nsp)	4	305	0	60	4,320	100	39
YRBM	Repair, Berthing and Messing Barges (nsp)	39	305	0	60	10,180	2,289	902
YRDH	Floating Dry Dock Workshop (Hull) (nsp)	1	305	0	60	not available	--	--
YRR	Radiological Repair Barges (nsp)	9	305	0	60	6,405	332	131
YRST	Salvage Craft Tenders (nsp)	3	305	0	60	10,965	190	75
YSD 11	Seaplane Wrecking Derrick (self propelled)	1	305	0	60	3,845	22	9
YSR	Sludge Removal Barges (nsp)	14	305	0	60	not available	--	--
YTB 752	Large Harbor Tug (self propelled)	1	305	0	60	3,170	18	7
YTB 756	Large Harbor Tugs (self propelled)	3	305	0	60	3,265	56	22
YTB 760	Large Harbor Tugs (self propelled)	68	305	0	60	3,265	1,280	504
YTL 422	Small Harbor Tug (self propelled)	1	305	0	60	1,015	6	2
YTT 9	Torpedo Trails Craft (self propelled)	3	305	0	60	not available	--	--
YWN	Water Barges (nsp)	6	305	0	60	not available	--	--
	MILITARY SEALIFT COMMAND							
T-AE	Kilauea Class Ammunition Ships	8	26	4	0	54,240	187	74
T-AFS	Mars Class Combat Stores Ships	8	148	7	0	46,930	891	351
T-AG	Mission Class Navigation Research Ship	2	151	10	0	59,126	288	114
T-AGM	Compass Island Class Missile Instrumentation Ship	1	133	4	0	47,791	101	40
T-AGOS	Stalwart Class Ocean Surveillance Ship	5	70	4	0	10,987	62	24
T-AGOS	Victorious Class Ocean Surveillance Ship	4	107	5	0	14,679	101	40
T-AGS	Silas Bent Class Surveying Ships	2	44	6	0	13,913	20	8
T-AGS	Waters Class Surveying Ships	1	7	1	0	36,590	4	2
T-AGS	John McDonnell Class Surveying Ships	2	96	6	0	10,085	31	12
T-AGS	Pathfinder Class Surveying Ships	4	96	6	0	19,383	120	47
T-AH	Mercy Class Hospital Ships	2	184	2	0	123,862	722	285
T-AKR	Algol Class Vehicle Cargo Ships	8	109	3	0	111,650	1,552	612
T-AKR	Maersk Class Fast Sealift Ships	3	59	9	0	107,028	314	124
T-AO	Henry J Kaiser Class Oilers	13	78	6	0	44,511	731	288
T-ARC	Zeus Class Cable Repairing Ship	1	8	2	0	41,176	6	2
T-ATF	Powhatan Class Fleet Ocean Tugs	7	127	16	0	11,398	167	66
	COAST GUARD							
WAGB	Polar Class Icebreakers	2	148	4	100	36,132	285	112
WAGB	Mackinaw Class Icebreakers	1	215	4	150	19,167	111	44
WHEC	Hamilton and Hero Class High Endurance Cutters	12	151	13	0	17,339	510	201
WIX	Eagle Class Sail Training Cutter	1	188	7	150	12,264	66	26
WLB	Juniper Class Seagoing Buoy Tenders	16	190	18	100	10,357	775	305
WLB	Balsam Class Buoy Tender WLB 180A	8	190	18	100	6,751	252	100
WLB	Balsam Class Buoy Tender WLB 180B	2	120	5	100	6,751	47	19
WLB	Balsam Class Buoy Tender WLB 180C	13	123	16	100	6,751	316	125
WLI	Inland Buoy Tender WLI 100A	1	160	0	205	2,432	14	6

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Table 1. Navy, MSC, and USCG, Army, and Air Force Mass Loadings for Ships, and Small Boats and Craft

Ship Class	Ship Class Description	Quantity of Ships per Class	Days in Port per Year	Number of Transits per year (each is a transit in and out)[T]	Days of Operation within 12 n.m.	Ship's Wetted Surface Area (sq ft)	*Copper Loading per ship class (kg/yr)	**Zinc Loading per ship class (kg/yr)
WLI	Inland Buoy Tender WLI 100C	1	160	0	205	2,068	12	5
WLI	Inland Buoy Tender WLI 65303	2	160	0	205	1,037	12	5
WLI	Inland Buoy Tender WLI 65400	2	160	0	205	1,142	13	5
WLIC	Inland Construction Tender 115	1	160	0	205	2,796	16	6
WLIC 100	Cosmos Class Inland Construction Tenders	3	160	0	205	2,432	42	17
WLIC 75A	Anvil Class Construction Tenders	2	160	0	205	1,753	20	8
WLIC 75B	Inland Construction Tenders	3	160	0	205	1,753	30	12
WLIC 75D	Clamp Class Inland Construction Tenders	2	160	0	205	1,753	20	8
WLIC 115	Inland Construction Tenders	1	160	0	205	2,796	16	6
WLIC 160	Pamlico Class Inland Construction Tenders	4	160	0	205	5,113	118	46
WLM	White Sumac Class Coastal Buoy Tenders	9	123	16	200	4,648	217	85
WLM	Keeper Class Coastal Buoy Tenders	14	123	16	200	6,408	465	183
WMEC	Diver Class Medium Endurance Cutters	1	98	9	0	8,954	14	6
WMEC	Storis Class Medium Endurance Cutters	1	167	11	0	9,498	26	10
WMEC	Reliance Class Medium Endurance Cutters	5	235	13	0	10,976	207	82
WMEC	Reliance Class Medium Endurance Cutters	11	149	9	0	10,976	290	114
WMEC	Famous Class Medium Endurance Cutters	4	137	6	0	10,976	96	38
WMEC	Famous Class Medium Endurance Cutters	9	164	7	0	10,976	259	102
WPB	Island Class Patrol Craft A	16	135	6	200	2,171	185	73
WPB	Island Class Patrol Craft B	21	135	6	200	2,171	243	96
WPB	Island Class Patrol Craft C	12	135	6	200	2,171	139	55
WPB	Point Class Patrol Craft B	1	135	6	200	1,243	7	3
WPB	Point Class Patrol Craft C	28	135	6	200	1,243	185	73
WPB	Point Class Patrol Craft D	8	135	6	200	1,243	53	21
WTGB	Bay Class Icebreaking Tugs	9	215	1	150	4,869	253	100
WYTL	65 ft. Class Harbor Tugs A	3	50	6	300	1,083	18	7
WYTL	65 ft. Class Harbor Tugs B	3	50	6	300	1,083	18	7
WYTL	65 ft. Class Harbor Tugs C	3	50	6	300	1,083	18	7
WYTL	65 ft. Class Harbor Tugs D	2	50	6	300	1,083	12	5
	ARMY							
BCDK	Barge, conversion deck enclosure kit	3	305	0	60	3,376	58	23
BD	89 Ton Derrick Barge (nsp)	12	335	0	30	10,442	722	285
BK	Cargo Barge (nsp)	2	335	0	30	1,947	22	9
BPL	Barge, pier, self-elevating	1	305	0	60	N/A	--	--
FB		3	305	0	60	N/A	--	--
FMS	Floating Machine Shop	3	305	0	60	3,775	65	26
J-BOAT	Workboat, Picket Boat	6	305	0	60	771	27	11
LARC-LX	Lighter, Amphibious, Resupply, Cargo	23	305	0	60	1,209	160	63
LCM-8	Landing Craft, Mechanized	104	305	0	60	1,603	961	379
LCU-1600	1600 Class Landing Craft Utility	13	305	0	60	3,557	267	105
LCU-2000	2000 Class Landing Craft Utility	35	275	3	60	6,646	1,234	486
LSV	Landing Ship, Vehicle	6	150	20	30	17,470	309	122
LT	Large Tug (100'-128')	16	305	0	60	3,026	279	110
Q-BOAT	Workboat (over 50')	1	305	0	60		--	--

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Table 1. Navy, MSC, and USCG, Army, and Air Force Mass Loadings for Ships, and Small Boats and Craft

Ship Class	Ship Class Description	Quantity of Ships per Class	Days in Port per Year	Number of Transits per year (each is a transit in and out)[T]	Days of Operation within 12 n.m.	Ship's Wetted Surface Area (sq ft)	*Copper Loading per ship class (kg/yr)	**Zinc Loading per ship class (kg/yr)
ST-65	65 ft Small Tug	11	305	0	60	1,381	88	35
	AIR FORCE							
B	*Barge*	4	305	0	60	N/A	--	--
DT		2	305	0	60	N/A	--	--
MR	Missile Retrievers	6	305	0	60	1,954	68	27
TG	Small Tug	2	305	0	60	721	8	3
TR	*Torpedo Retriever*	3	305	0	60	2,127	37	14
						Total Loading	**98,257**	**38,725**

* = Based on a dynamic copper leaching rate of 17 ug/cm^2/day.

** = Based on a dynamic zinc leaching rate of 6.7 ug/cm^2/day.

NOTES:

1) A transit includes inbound and outbound legs of 4 hours between the 12 n.m. limit and port.
2) Small boats and craft of the Navy were assumed to spend 365 days per year within 12 n.m. and 60 of those days underway within 12 n.m.
3) Number of workboats estimated
4) Tank Landing Ships (LST) assumed to have similar operations to other amphibious assault ships
5) All vessels of the Army and Air Force assumed to have movement characteristics similar to coastal vessels of the Navy
6) Italicized ship class descriptions are assumed, since only the ship class (letter) designation and quantity were provided.

[T]Zero entered for number of transits per year when no further information was available.
nsp = not self-propelled
N/A = Not enough information available to calculate a wetted surface area.

Table 2. Estimated TBT Mass Loadings within 12 n.m. from Small Boats and Craft

Class	Description	Quantity	Vessel Wetted Surface Area (sq ft)[a]	Total Wetted Surface Area per Class (sq ft)
	Navy Small Boats and Craft			
PB	Mark III Patrol Boats	11	1,835	20,185
PB	Mark IV Patrol Boat	3	2,368	7,104
PBR	Stinger Class River Patrol Boat	25	410	10,250
ATC	Mini Armored Troop Carrier[b]	20	810	16,197
TR	Torpedo Retrievers	22	2,127	46,794
HS	Harbor Security Boat	70	189	13,230
LARC-LX	Lighter Amphibious Resupply Cargo	23	1,214	27,922
WB	Boom Handling Workboat	25	340	8,499
WB	35ft Workboat[b.c]	50	620	30,990
YP 654	Patrol Craft, Training	1	1,302	1,302
YP 676	Patrol Craft, Training	27	2,302	62,154
	Total Number of Small Boats and Craft	277	Net Surface Area	244,627
	Small Boats and Craft w/TBT Coatings	55	TBT Coated Area	48,572
	Coast Guard Small Boats and Craft			
	Motor Lifeboats	6	535	3,213
	Small Boats	44	513	22,576
			TBT Coated Area	25,789
	Army Small Boats and Craft			
PB-HS	Patrol Boat, High Speed	10	189	1,890
T-BOAT	Small Freight (under 100')	1	not available	
			TBT Coated Area	1,890

Table 2. Estimated TBT Mass Loadings within 12 n.m. from Small Boats and Craft

Class	Description	Quantity	Vessel Wetted Surface Area (sq ft)[a]	Total Wetted Surface Area per Class (sq ft)
	Air Force Small Boats and Craft			
U[h]	*Utility Craft*[j]	47	398	18,706
P[i]	*Patrol Boat*[j]	3	1,235	3,704
			TBT Coated Area	22,410
	Total Surface Area of all Vessels with TBT Coatings (sq. ft)			98,661
	Total Surface Area of all Vessels with TBT Coatings (sq. cm)			91,656,090
	Loading (kg/yr) with 20% of Navy small boats and craft having TBT paint =			12.7
	Final total (kg/yr) after adjusting for time spent out of water			**11.4**

Sample Calculation for TBT Loading per Vessel Class (kg/yr):

Quantity of Vessels x Vessel Wetted Surface Area (ft^2) x TBT Leaching Rate ($\mu g/cm^2$)/day...

...x (0.90 x 365 days/yr) x (6.452 cm^2/in^2) x (144 in^2/ft^2) x (10^{-9} kg/mg)

Notes:

a) Where available, beam measurements are at the waterline.

b) This craft or boat is rectangular.

c) No information was available regarding quantities of workboats by class. The quantities listed are not reliable.

d) TBT Loadings based on all operations per ship occurring within 12 n.m. and applying a 10% factor to subtract the time that some small boats and craft spend completely out of water.

e) The steady state TBT leaching rate was taken from a Naval Command, Control & Ocean Surveillance Center RDT&E Division Hull Coatings Discharge Evaluation on Butyltin Concentrations Measurements in Pearl Harbor, Hawaii from April 1986 to January 1988.

f) Steady-state TBT release rate assumed to be (0.38 $\mu g/cm^2$)/day.

g) 20% of all Navy small boats and craft are assumed to have TBT coated hulls.

h) Air Force "P" designators are assumed to have similar size as the Coast Guard Point Class Patrol Craft.

i) Air Force "U" designator is assumed to have a similar size to the Navy utility boat.

j) Italicized ship class descriptions are assumed, since only the ship class (letter) designation and quantity were provided.

Table 3. A Comparison of Estimated Concentrations Versus Water Quality Criteria

Constituent	Estimated Environmental Concentration (μg/L)[a]	Federal Chronic Water Quality Criteria (μg/L)	Most Stringent State Chronic Water Quality Criteria (μg/L)
Copper (dissolved)	0.19-3.0	2.4	2.4 (CT, MS)
Zinc (dissolved)	5.0-12.8	81	76.6 (WA)
TBT	0.00002 - 0.0003	0.01[b]	0.001 (VA)

Notes:
Refer to federal criteria promulgated by EPA in its National Toxics Rule, 40 CFR 131.36 (57 FR 60848; Dec. 22, 1992 and 60 FR 22230; May 4, 1995)

CT - Connecticut
MS - Mississippi
VA= Virginia
WA- Washington
[a] Range is for three high use Navy ports: San Diego, CA; Mayport, FL; and Pearl Harbor, HI.
[b] Proposed water quality criteria, August 7, 1997

Table 4. Copper and Zinc Loading into San Diego, Pearl Harbor, and Mayport for Use in Concentration Estimate

Ship Class	Ship Class Description	Quantity of Ships per Class	*Copper Loading per year (kg/yr)	*Zinc Loading per year (kg/yr)
	SAN DIEGO HARBOR			
CG 47	Ticonderoga Class Guided Missile Cruisers	8	813	320
CV 63	Kitty Hawk Class Aircraft Carrier	2	623	245
DD 963	Spruance Class Destroyers	6	616	243
DDG 51	Arleigh Burke Class Guided Missile Destroyers	5	263	104
LHA 1	Tarawa Class Amphibious Assault Ships	2	524	207
LHD 1	Wasp Class Amphibious Transport Docks	2	532	210
LPD 4	Austin Class Amphibious Transport Docks	5	743	293
LSD 41	Whidbey Island Class Dock Landing Ships	2	281	111
LSD 49	Harpers Ferry Dock Landing Ships	1	144	57
PC	Cyclone Class Coastal Defense Ships	4	26	10
FFG 7	Oliver Hazard Perry Guided Missile Frigates	11	590	233
SSN	Los Angeles Class Attack Submarines	9	914	360
SSN	Sturgeon Class Attack Submarine	1	79	31
LSD	Anchorage Class Dock Landing Ships	3	472	186
AGF	Raleigh Class Miscellaneous Flagship	1	123	48
AS	Emory S Land Class Submarine Tender	1	278	109
LPH	Iwo Jima Class Assault Ship	1	150	59
		Total Loading =	**7,171**	**2,826**
	PEARL HARBOR			
AO 177	Jumboised Cimarron Class Oilers	2	382	150
ARS 50	Safeguard Class Savage Ships	2	91	36
CG 47	Ticonderoga Class Guided Missile Cruisers	3	305	120
DD 963	Spruance Class Destroyers	4	411	162
DDG 51	Arleigh Burke Class Guided Missile Destroyers	3	158	63
FFG	Oliver Hazard Perry Guided Missile Frigates	2	107	42
SSN	Los Angeles Class Attack Submarine	15	1,524	601
SSN	Sturgeon Class Attack Submarine	4	316	125
SSN	Benjamin Franklin Class Submarines	1	129	51
		Total Loading =	**3,423**	**1,350**
	MAYPORT HARBOR			
CG 47	Ticonderoga Class Guided Missile Cruisers	5	508	200
CV 63	Kitty Hawk Class Aircraft Carrier	1	311	123
DD 963	Spruance Class Destroyers	5	514	202
DDG 51	Arleigh Burke Class Guided Missile Destroyers	2	105	41
FFG	Oliver Hazard Perry Guided Missile Frigates	10	537	212
		Total Loading =	**1,975**	**778**

Table 5. Estimated Copper and Zinc Contributions to Some Ports of the Armed Forces

Port	Ambient Cu Concentration (μg/L)	Cu from Hull Coating Leachate (μg/L)	Ambient Zn Concentration (μg/L)[a]	Zn from Hull Coating Leachate (μg/L)
San Diego	3.7[b]	0.19	11.3	0.074
Mayport	Unknown[c]	3.0	5.0	1.16
Pearl Harbor	1.76[a]	1.0	12.8	0.39

[a] Information from STORET database.
[b] For San Diego Bay, information from prior Navy Studies.
[c] Available STORET information was insufficient to make estimate.

Table 6. Data Sources

	Data Source			
NOD Section	**Reported**	**Sampling**	**Estimated**	**Equipment Expert**
2.1 Equipment Description and Operation				X
2.2 Releases to the Environment	X			X
2.3 Vessels Producing the Discharge	UNDS Database			X
3.1 Locality				X
3.2 Rate	X			
3.3 Constituents	MSDS			X
3.4 Concentrations	X			
4.1 Mass Loadings			X	
4.2 Environmental Concentrations			X	
4.3 Potential for Introducing Non-Indigenous Species				X

Copper Loading = (release rate)(surface area)(Number of ships)(time), where:

release rate = daily dynamic release rate of copper kg/cm^2
surface area = wetted surface area of a DD 963 Class ship (cm^2)
Number of ships = total number of ships in DD 963 Class
time = {$\sum$ (time in port + time in transit + time in operation within 12 n.m.)}(number of DD 963 Class ships)(number of days within 12 n.m. each year per ship)

1) Daily dynamic release rate of copper (From NRaD study)
= 17 ($\mu g/cm^2$)/day = (17 ($\mu g/cm^2$)/day) (1 kg / 1,000,000,000 μg) = 17 x 10^{-9} (kg/cm^2)/day

2) Wetted surface area of a DD 963 Class ship in cm^2 (From NSTM Chapter 633)
= (35,745 ft^2) (929 cm^2/ft^2) = 33,207,105 cm^2/ship

3) Number of DD 963 Class ships = 31 ships (From ship inventory database)

4) Number of days within 12 n.m. each year per ship (From ship movement database)
= days in port/year + [(transits/year) (2 legs/transit) (4 hrs/leg) (1 day/24 hours)] + days operation within 12 n.m./yr
= 178 days/yr + [(12 transits/yr) (2 legs/transit) (4 hrs/leg) (1 day/24 hrs)] + 0 days/yr = 182 days/yr

Thus:
Copper Loading = (17 x 10^{-9} (kg/cm^2)/day)(33,207,105 cm^2/ship)(31 ships)(182 days/yr)
= 3,185 kg/yr = **7,007 lbs/yr**

Calculation Sheet 1. Mass Loading of Copper from DD 963 Class Vessels

Copper loading in San Diego = 7,171 kg/yr (See Table 4)
Copper loading in Pearl Harbor = 3,423 kg/yr (See Table 4)
Copper loading in Mayport = 1,975 kg (See Table 4)

Total copper loading = 98,257 kg/yr (See Table 1)

Proportion of copper loading in each harbor to the total copper loading:
San Diego = (7,171 kg/yr) / (98,257 kg/yr) = 0.073 (or 7.3%)
Pearl Harbor = 0.035 (or 3.5%)
Mayport = 0.020 (or 2%)

Total estimated TBT loading = 11.4 kg/yr (See Table 2)

Estimated TBT loading in each harbor = (copper proportion) (total TBT loading):
San Diego = (0.073) (11.4 kg/yr) = 0.8 kg/yr
Pearl Harbor = (0.035) (11.4 kg/yr) = 0.4 kg/yr
Mayport = (0.020) (11.4 kg/yr) = 0.2 kg/yr

Proportion of copper concentration in each harbor (Table 5) to annual copper loading in the respective harbor:
San Diego = $(0.19 \times 10^{-6}$ g/L Cu) / $(7{,}171 \times 10^{3}$ g Cu) = 2.7×10^{-14}
Pearl Harbor = $(1 \times 10^{-6}$ g/L Cu) / $(3{,}423 \times 10^{3}$ g Cu) = 2.9×10^{-13}
Mayport = $(3 \times 10^{-6}$ g/L Cu) / $(1{,}975 \times 10^{3}$ g Cu) = 1.5×10^{-12}

Estimated TBT concentration in each harbor is proportional to copper ratio:
San Diego: (0.19 μg/L Cu) / (7,171 kg Cu) = (X μg/L TBT) / (0.8 kg TBT)
X = (2.7×10^{-14}) $(0.8 \times 10^{3}$ g TBT) = **2.2×10^{-5} μg/L TBT**
Pearl Harbor: X = (2.9×10^{-13}) $(0.4 \times 10^{3}$ g TBT) = **1.2×10^{-4} μg/L TBT**
Mayport: X = (1.5×10^{-12}) $(0.2 \times 10^{3}$ g TBT) = **3.0×10^{-4} μg/L TBT**

Calculation Sheet 2. Estimates of Contributed TBT Concentrations by Harbor