CONTROL OF PLASTIC WASTES ABOARD NAVAL SHIPS AT SEA

Craig S. Alig
David Taylor Research Center Code 2834
Department of the Navy
Annapolis, Maryland 21402, U.S.A.

Larry Koss
Office of Chief of Naval Operations
Department of the Navy
Washington, D.C. 20350, U.S.A.

Tom Scarano
Naval Sea Systems Command
Department of the Navy
Washington, D.C. 20362, U.S.A.

and

Fred Chitty
Supply Operations and Policy
Commander in Chief, Atlantic Fleet
Department of the Navy
Norfolk, Virginia 23511, U.S.A.

ABSTRACT

The U.S. Navy is taking a proactive approach to comply with the prohibition on the at-sea discharge of plastics mandated by the Marine Plastic Pollution Research and Control Act of 1987. For U.S. naval ships, space and weight constraints, high crew densities, and mission requirements create unique solid waste management problems.

In pursuit of a zero discharge goal without significant adverse impact, processes, activities, operations, and systems to reduce plastics discharges are being identified, evaluated, and documented. Operational, supply, and technology-oriented solutions are now being demonstrated. Seven ships have been nominated by Commander in Chief U.S. Atlantic and Commander in Chief U.S. Pacific Fleets to participate in a plastics waste reduction demonstration project. Each ship was asked to develop its own instructions and procedures to eliminate the discharge of plastic wastes and to implement those instructions in a manner consistent with the operational requirements and mission of the ship.

Thus far, a submarine tender, a frigate, a destroyer, and two submarines have participated. Scientists and engineers from the David Taylor Research Center have collected waste generation rate and characterization data and have monitored and documented lessons learned. Naval Supply Systems Command has provided support for the demonstrations by recommending substitutes for plastic products, and new waste processing systems being developed by the Naval Sea Systems Command have been evaluated. Procedures for both the source separation of plastic and nonplastic wastes and the separation of food-contaminated plastic waste from non-food-contaminated plastic waste have been very successful aboard each of the demonstration ships. Plastic wastes have been stored and returned to port. A new Navy-developed vertical trash compactor has been successfully used to process plastic and nonplastic waste separately, and a pulper has been successfully used to process large volumes of degradable, nonplastic waste for ocean discharge.

SOLID WASTE: THE NAVY SHIPBOARD PROBLEM

For as long as ships have sailed the oceans, waste has been thrown overboard at sea. This practice continued unchallenged for centuries. The ocean's vast size and powerful assimilative capacity easily absorbed ship-generated waste with no apparent adverse impact. For many years, the waste consisted of simple degradable materials; later, the waste included metal, which sank. However, the relatively recent development of synthetic materials such as plastic, which float and persist in the marine environment when thrown into the sea, has changed the perception that there is no harm in discharging ship-generated trash at sea.

The visible evidence of ships' discharges now points an accusing finger at the maritime industry and the military for polluting the oceans, even though a great proportion of trash on the beach originates from sources ashore. Initially, the concern over marine debris, whether floating at sea or washed onto the beach, was because it offended our sense of aesthetics. However, as plastic became more pervasive in its application, other problems developed. Plastic line began to foul ships' propellers, and drifting plastic sheeting clogged ships' seawater intakes.

Floating marine debris also presented a unique problem for warships—it compromised security. Buoyant bags of trash establish a trail of floating waste which can betray a ship's location. Floating waste can be recovered more easily, enabling adversaries to gain information from the items contained therein.

Regulations of the U.S. Navy prohibit the discharge of any trash within 25 nmi of any shore, and require that all trash be weighted before disposal at sea to ensure that it sinks. However, it is difficult for shipboard personnel to consistently package or process waste for negative buoyancy without the use of special equipment.
In 1970, when the nation finally confronted the environmental crisis and sweeping clean air and water legislation was established, the Commanders in Chief of the Atlantic and Pacific Fleets recognized the need to develop strategies and technologies to deal with the solid waste problem. A comprehensive Naval Shipboard Refuse Study (NSRS) revealed that each person afloat generated about 1.4 kg (3.05 lb) of solid waste per day (Table 1). (Note that less than five thousandths of a kilogram per person per day was plastic waste.)

However, warships at sea had no holding capacity to store waste on board. Waste storage also created health and sanitation hazards and fire control problems. Overboard disposal by Navy ships continued to be the practice. Recognizing that an alternative to overboard disposal was necessary, the Naval Sea Systems Command set out to find suitable solid waste processing systems. Initially, their goal was to process the degradable waste so it would not float when discharged and to compact the intrinsically heavy, inert material so it would sink to the bottom. This would eliminate the problems caused by floating debris. At the time, plastic waste was not viewed as a serious problem because of the small amounts generated aboard ship.

What seemed a simple concept in the early 1970's proved to be extremely difficult to execute. Commercially available equipment could not meet the rigorous requirements imposed by the Navy (Table 2). Dozens of candidates were evaluated at the Navy's David Taylor Research Center, but none could satisfy the demands of a warship. The first real equipment successes began when industry teamed with the increasing experience of the Navy, and a family of Navy-model food waste disposers was developed.

During the late 1970's, the Navy's engineering communities at the Naval Sea Systems Command and David Taylor Research Center initiated a long-term shipboard solid waste control research and development program.

RISING TIDE OF MARINE PLASTICS AND U.S. REACTION

Public concern over marine debris magnified enormously in the 1980's because of the terrible impact that synthetic material, particularly plastic, was having on marine life. The amount of floating marine debris continued to increase, creating more beach litter and overwhelming waterfront communities struggling to maintain a high-quality beach environment.

The increase in floating marine debris corresponded to the increased use of plastic products in the home, industry, and marketplace. Plastic and synthetic products found their way aboard maritime ships—and then overboard. Comparing studies conducted in 1971 and 1987, Table 1 shows an approximate twentyfold increase in Navy shipboard plastic waste. No prohibitions existed in the early 1980's against the discharge of shipboard-generated waste once a ship was beyond 3 nmi of the shoreline.
Table 1.--Generation of naval shipboard solid waste (kg (lb) per person per day).

<table>
<thead>
<tr>
<th>Item</th>
<th>Naval shipboard refuse study - 1971</th>
<th>Naval shipboard refuse study - 1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>0.004 (0.01)</td>
<td>0.095 (0.21)</td>
</tr>
<tr>
<td>Food waste</td>
<td>0.603 (1.33)</td>
<td>0.580 (1.28)</td>
</tr>
<tr>
<td>Glass</td>
<td>0.008 (0.02)</td>
<td>0.059 (0.13)</td>
</tr>
<tr>
<td>Metal</td>
<td>0.299 (0.66)</td>
<td>0.186 (0.41)</td>
</tr>
<tr>
<td>Rubber</td>
<td>0.004 (0.01)</td>
<td>0.004 (0.01)</td>
</tr>
<tr>
<td>Paper, other</td>
<td>0.463 (1.02)</td>
<td>0.503 (1.11)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1.38 (3.05)</td>
<td>1.43 (3.15)</td>
</tr>
</tbody>
</table>

Table 2.--Criteria for naval shipboard waste processing equipment.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>High</td>
</tr>
<tr>
<td>Manpower</td>
<td>Low</td>
</tr>
<tr>
<td>Safety</td>
<td>Extremely safe</td>
</tr>
<tr>
<td>Space needed and weight</td>
<td>Low</td>
</tr>
<tr>
<td>Simplicity</td>
<td>Extremely simple</td>
</tr>
<tr>
<td>Ability to withstand shock and vibration</td>
<td>Rugged beyond belief</td>
</tr>
</tbody>
</table>

During the past few years, the deadly impact that synthetic plastic materials have on marine sea life has been graphically documented and widely publicized by environmental organizations. Countless photographs document the deadly consequences of ingestion of plastic by birds, turtles, and marine mammals, and their entanglement in synthetic fishing line and nets and in plastic sheeting.

Clearly, the Navy is not a contributor to the deadliest form of marine plastic--the synthetic rope of fishing nets. The low number of Navy ships at sea compared to the commercial fishing and merchant fleets makes the Navy a minor contributor (ca. 2.5%) to the total plastics waste problem. However, the high population density aboard naval vessels and the plastic waste discharged daily from each ship at sea adds up over time. As a role model, the Navy must demonstrate leadership with an intensive effort to eliminate the discharge of floating marine debris.

The International Convention for the Prevention of Pollution from Ships (commonly known as MARPOL) was the first comprehensive agreement to
control marine pollution worldwide. The MARPOL was drafted in 1973 (MARPOL 73) and updated in 1978 (MARPOL 73/78). The MARPOL 73/78 included Annex V as an option which would prohibit ships from discharging plastic wastes at sea. The convention was ratified in 1980 with its protocol of Annexes 1 and 2 to eliminate the discharge of oil at sea; yet, it was 1987 before the international outcry against plastic waste forced leaders around the world to take action on Annex V.

In the fall of 1987, the U.S. Senate gave its unanimous consent to the ratification of Annex V to MARPOL 73/78. The 29 signatory nations represented over 50% of the world's merchant fleet tonnage. Annex V dictates that no vessel from a signatory nation may dispose of any plastics into the sea or dump floating solid waste within 25 nm of any shoreline. Annex V also prohibits the discharge of any solid waste (except ground food waste) into special areas such as the Baltic or Mediterranean Seas.

Congress passed enabling legislation immediately after ratification of Annex V—the Marine Plastic Pollution Research and Control Act of 1987 (Public Law 100-220), which took effect 1 January 1989 for all maritime vessels, and takes effect 1 January 1994 for Navy ships. Congress recognized that full compliance in 5 years would be extremely difficult for the Navy because of the time required to complete development of and to procure and install the appropriate equipment on about 500 ships. Therefore, Congress required that the Navy report in 3 years on progress made toward full compliance, with the expectation that the compliance deadline could be extended if warranted.

In October 1987, the Assistant Secretary of the Navy for Shipbuilding and Logistics created an ad hoc advisory committee on plastics. For 7 months, the committee met and traveled to Navy research centers and supply depots, and visited several naval ships of various types. In June 1988 it delivered its final report to the Assistant Secretary. The report contained 42 specific recommendations for the Navy to meet its solid waste management goals by 1994. The recommendations were divided into four categories: technology, operations, supply, and education.

CRITICAL NAVY ISSUES

In formulating a plan to achieve full compliance with P.L. 100-220, a number of critical issues had to be addressed.

- How do we separate the plastic waste, which comprises 7% by weight of all the solid waste generated, without creating labor-intensive efforts, which could negatively affect crew morale?

- Where do we install solid waste processing equipment aboard a military vessel so that it is centrally located, efficiently arranged, and minimizes the crew's labor burden? (While the food waste (0.58 kg (1.28 lb) per person per day) can be discharged directly overboard at sea when processed through galley or scullery garbage grinders, the remaining solid
waste (0.85 kg (1.87 lb) per person per day) must be transported and processed for disposal or storage. For example, 900 kg (close to 1 ton) of waste per day is generated at dozens of different rates and locations aboard a 1,000-man ship. It must be carried by hand to processing centers and then carried elsewhere for disposal or long-term storage.)

- Where do we find space to store solid waste? (There is very little designated trash storage space aboard a warship, and there are no unused spaces that can readily be made available. However, since plastic waste cannot be discharged overboard, space must be found without creating fire, health, or sanitation hazards, and without reducing the quality of life aboard ship. Full regulatory compliance demands that equipment be developed specifically to process plastic waste for volume reduction and sanitation.)

- How do we reduce the quantity of plastic waste generated aboard ship? (Alternatives are available for products such as polyethylene trash bags and polystyrene coffee cups. However, plastic is widely used for packaging, and often is the most cost-effective material for that application, especially food products. It has taken years to develop and implement plastics that are efficient and economical (e.g., shrink wrap). Material and product substitutions that perform as well and are as economical may require a long-term search.) Realistically, plastic waste may best be managed by accepting its continued use and developing a plastic waste processor which, together with recycling, will allow us to control the plastic waste storage problem aboard ship.

**NAVY PLAN FOR FULL COMPLIANCE**

The Navy's approach to full compliance with MARPOL Annex V and P.L. 100-220 contains four parts. They are technology initiatives, operational changes, substitutes for plastic products, and education. We may think of "people" as the fifth part of our approach. Unfortunately, the human side is sometimes the most difficult to specify, predict, and control.

**Technology Initiatives**

In the context of naval ships, technology refers to the equipment that will be installed to provide each ship with part of the capability required for onboard management of solid and plastic wastes. It is important to understand the rationale behind solid waste technology initiatives before the details can be presented.

First, our shipboard technology initiatives reflect the need to comply with all of the requirements of Annex V, which includes managing the total solid waste stream and prohibiting the discharge of plastics. The complexities associated with shipboard equipment installation force us to consider
the total solution to the problem rather than small areas at a time. This approach seems necessary also if we are to achieve our goal and implement timely solutions at a reasonable cost. Therefore, the Navy's technology program places the same emphasis on solid waste management as on plastics discharge prohibition.

Second, a "generic" solution for a "typical" ship would be reassuring; however, many unique solutions are needed to satisfy the multiplicity of ship designs and operating scenarios. The Navy may install solid waste management equipment on approximately 500 ships that fall into about 60 different ship classes! Additionally, surface ships may carry as few as 200 people or as many as 6,000, and submarines have requirements that are entirely unique.

Third, naval ships differ significantly from commercial vessels and will find it more difficult to comply with Annex V because their population density usually is much higher. A 305-m (1,000-ft) naval ship may have a crew of 6,000, while the same size oil tanker may have a crew of 40. Obviously, the contributing population determines the quantity of plastic and other solid waste produced. While the maritime fleet has similar problems with large population densities on cruise ships, they differ significantly from Navy ships in their mission, purpose, and time at sea. Furthermore, Navy ships have no occupational specialty to manage solid waste.

The Navy is developing three shipboard systems that will be major factors in our compliance with Annex V: a vertical trash compactor, a solid waste pulper, and a plastic waste processor. Each system will be of a single size with a fixed capacity, making it easier to train operators and obtain parts necessary for repair and maintenance. Larger ships may require multiple units.

Presently, onboard incineration of solid and plastic wastes does not play a major role in the Navy's plan to comply with Annex V, because this type of burning emits potentially toxic and corrosive waste products in its exhaust gases and ash. Additionally, our experience with conventional marine solid waste incinerators has shown that suitable, high-capacity incinerators that meet the requirements of Table 2 are unavailable. However, we are investigating advanced thermal destruction technologies for limited use on ships operating under unique conditions; in some cases, this may be the best alternative to achieve ultimate, at-sea volume reduction of solid waste.

Shipboard Vertical Trash Compactor

The Navy's research and development program of trash compactors began in 1979. Our objective was to develop a machine that was reliable, easy to operate, sanitary, safe, and would allow ships to meet environmental regulations for the discharge of solid waste. We found it difficult to achieve negative buoyancy in trash that was compacted into a degradable container. Finally, we were able to ensure that the container would sink by spraying seawater into the compaction chamber, then using high compaction pressure.
to force the water into the pores of the trash to displace the air. A preproduction prototype, such as the one shown in Figure 1, is undergoing technical evaluation aboard a Navy destroyer and has met with outstanding success in the past year.

The Navy shipboard vertical trash compactor was designed to meet Navy standards for maintainability, reliability, safety, shock, vibration, structure-borne and airborne noise, electromagnetic compatibility, and habitability. It can process solid waste composed of glass bottles, metal cans, paper products, and other nonindustrial and nonhazardous waste into 20.4-kg (45-lb) trash slugs. The slugs are contained in cloth bags that can be hand carried. The compactor provides extended-time trash storage, trash slugs that sink without added metal weights, continuous safety checks, and fully automated operation controlled by a programmable logic controller. The most critical parts of the compactor are made from materials that are corrosion resistant; the compactor can be disassembled for movement and installation aboard ship. Its vertical configuration results in a footprint only $0.6 \times 1.8$ m ($2 \times 6$ ft). Volume reductions greater than 5:1 were achieved when processing plastic waste for storage aboard ship. The first of these units should be delivered to the fleet within 2 years.

Shipboard Solid Waste Pulper

Pulping solid waste is not new to the Navy. One class of ship has been successful in using commercial pulpers to process mixed solid waste. Galley and scullery food waste disposers are actually small pulpers. Used as a shipboard solid waste processing method, pulping mixes waste with water, reduces the size of the solids, and creates a wet pulp or slurry, which can be pumped directly overboard. Pulped waste is more readily biodegradable than unpulped waste, tends to be negatively or neutrally buoyant, and disperses rapidly when discharged.

Typically, pulpers operate as follows. Waste enters a large tank through a feed chute and is mixed with water. The water softens and saturates the waste material so that it can be reduced in size more easily. The mixture forms a vortex caused by the rotation of a cutting mechanism located in the bottom of the tank. The pumping action of the cutting mechanism draws trash down the vortex to the bottom of the tank where it is cut and pressed through a perforated sizing ring before being discharged as a slurry. The Navy shipboard pulper is being designed to process paper, food waste, and fiberboard. A conceptual design of the pulper appears as Figure 2. Metal, glass, plastic, and cloth are considered nonpulpable, although the design of the pulper makes it highly resistant to damage from accidental insertion of these items. It will process about 75% of the total solid waste generated aboard a ship at a rate of 262 kg (600 lb) of mixed solid waste per hour. Our experience demonstrates that these pulpers are extremely reliable and simple to operate. The first units could be delivered to the fleet within 4 years.
Figure 2.—Shipboard solid waste pulper.
Plastic Waste Processor

Plastic waste comprises about 7% by weight of the total solid waste generated on board a Navy ship. Of that quantity, 50% is contaminated with food waste. Storage of food-contaminated waste aboard ship requires significant volume reductions along with sterilization or similar treatment to control noxious odors.

The Navy's shipboard plastic waste processor is in the early stage of development. While the exact design and configuration are uncertain, Figure 3 depicts our developmental objective. The densified, sanitized block of waste plastic will be suitable for long-term shipboard storage until it can be off-loaded ashore. We anticipate a 30:1 volume reduction and an end product that is recyclable. Our goal is to have the first units delivered to the fleet within 6 years.

Shipboard Equipment Configurations

To plan the installation of our solid waste management equipment, naval ships are grouped into four categories—small, medium, and large surface ships, and submarines. The conceptual plan calls for compactors only to be installed on small surface ships; compactors and plastic waste processors on the mid-sized ships; and compactors, plastic waste processors, and pulpers on larger ships. Some larger ships may require more than one of each system to ensure maximum efficiency. This plan assumes that personnel on board each ship will separate plastic manually at its source and will use their food waste disposers.

On smaller surface ships, all solid waste (except food) will be processed through the compactor. Negatively buoyant, nonplastic slugs will be stored on board for shore disposal or for overboard discharge where permissible. The compactor can process an all-plastic slug which provides at least a 5:1 volume reduction.

Medium-sized surface ships can accommodate a compactor and a plastic waste processor. The compactor will process all of the solid waste except separated plastics and food waste. Nonplastic slugs will be stored on board for disposal ashore or for overboard discharge. The plastic waste processor will process all plastics including food-contaminated waste, and the densified (30:1) and sanitized plastic will be stored on board for disposal ashore.

All three systems will be installed on larger surface ships in single or multiple units, depending on the need and the space available. Each system will be targeted to a specific segment of the solid waste stream to ensure maximum utilization and efficiency. Separated plastic waste will be processed for storage and shore disposal. The remainder of the solid waste stream will be separated at its source into pulpables (e.g., paper, fiberboard, and light wood) and nonpulpables (e.g., glass and metal cans). The compactor will process nonpulpables into negatively buoyant slugs for overboard discharge when the ship is 25 nmi from the shoreline. Pulpables will be processed by the pulper when the ship is at least 12 nmi from shore.
Figure 3.--Shipboard plastic waste processor.
and pumped overboard. Larger ships are most able to maximize the use of waste management technology and minimize the amount of waste retained on board for shore disposal.

Because of limited space and other constraints, the current Navy plan does not include the development and installation of new solid and plastic waste equipment for submarines. However, submarines will comply with Annex V to the maximum extent possible by using material substitutions to minimize the generation of plastic waste; by source separation and onboard storage of plastic waste that is not food-contaminated; and by continuing the current practice of compaction, weighting for negative buoyancy, and overboard discharge of the remaining solid waste.

Operational Constraints

The Navy’s response to the need for operational changes met with four major constraints.

1. Manpower.--An 81-h work week is standard for sailors operating at sea, and expectations of what a crew member is to accomplish during a shift leaves no time for special handling of plastic waste. The establishment of additional jobs to fulfill this need is not probable because no funding is available for such a position, and there is no berthing space on the ships for additional crew members.

2. Space.--Space is at a premium aboard even the largest naval ships. The typical seagoing merchant ship is considerably larger than the average naval surface combatant, yet its crew numbers 30 compared to 300 sailors aboard a Navy ship. While aircraft carriers are the largest ships in the fleet, their crew exceeds 6,000, thus making their population density similar to that of our smaller surface ships. The cramped quarters aboard our ships leave little space for the installation of new equipment.

3. Quality of life.--It is critical that the Navy maintain the quality of life at sea as a top priority to enable us to continue to attract high quality personnel. Routine operations involve 7 to 25 continuous days at sea, with 45 days not unusual. Long deployments may require 80 to 150 continuous days at sea. Thus, it is imperative that each sailor have a clean, healthy, and safe place in which to live. Controlling plastic waste cannot be allowed to negatively affect quality of life aboard ship.

4. Financial constraints.--Congress has not allocated additional funds for the increased operating costs that will be incurred during implementation of the procedures to prevent plastic pollution. In fact, budgets are being cut and daily operating funds are scarce. In forecasting the operational changes ahead, funding concerns force us to note that the
cost of paper coffee cups is double that of polystyrene cups, and paper trash can liners are quadruple the price of those made of plastic.

Hence, the Navy must reduce plastic pollution in the marine environment while operating within these realities. We must change the way we process solid waste, yet minimize the increase in manpower and financial resources required and maintain the high quality of life aboard ship.

Substitutes for Plastic Products

Many items contribute to the problems of plastic waste aboard ship, most of which cannot be controlled. A destroyer with a crew of approximately 300 was used as one of our plastic waste reduction demonstration study ships. During one 16-day period, the David Taylor Research Center study team inventoried 6,179 individual pieces of plastic waste. "Miscellaneous" sources, those not attributable to berthing, work center, or food service areas, accounted for 25% of the waste. The two most numerous items were six-pack rings and trash bags; however, frozen meat packaging, food wrap, and food containers accounted for 14 of the remaining top 23 categories of plastic waste collected. Acceptable, nonplastic substitutes for these items will not be available for many years, if ever.

However, nonplastic substitutes are available for some of the plastic items. Ships have found nonplastic substitutes for coffee cups and stirrers, tableware, and trash can liners. While plastic bags are still used to collect and hold plastic waste for disposal ashore, paper bags are now specified for collection and at-sea disposal of nonplastic solid waste.

New procedures will eliminate some disposable plastic products. For example, food waste can be disposed in food pulpers or garbage grinders, which eliminates serious storage problems caused by the collection of food waste in plastic bags. This practice also requires less manpower; the daily garbage does not have to be carried from the galley to the fantail and dumped overboard for disposal.

Education

All shipboard personnel must be educated on the hazard that waste plastic poses to marine life and on the procedures necessary for effective shipboard solid waste management. Navy personnel have become increasingly aware of the potential adverse impact that shipboard operations have on the environment. Shipboard solid waste separation management must become a task that each crew member accepts as part of the ship's routine operation.

IMMEDIATE REDUCTIONS IN PLASTICS DISPOSAL AT SEA: SHIPBOARD PLASTIC WASTE REDUCTION DEMONSTRATIONS

The 5-year implementation period does not afford us the time to conduct paper studies. While the research and development required for technical solutions have been accelerated and are moving forward as quickly
as possible, we must implement changes in waste management and disposal practices now, not because Congress expects it of us, but because it is environmentally expedient.

Changing shipboard operational procedures was the single viable alternative to effect the expeditious reduction of plastic wastes discharged at sea. Our focus was on the segregation of plastic wastes from other solid wastes, and its short-term storage aboard ship. Many of the recommendations in the report of the ad hoc advisory committee on plastics were directed toward achieving this objective. Shipboard plastic waste reduction demonstration studies were conducted aboard five surface ships and two submarines to test and evaluate each recommendation. Studies on two additional surface ships are planned. Thus far, the demonstration studies have illustrated several major points:

- Navy shipboard plastic waste represents about 7% by weight of the total solid waste stream; 50% of that waste originates in food service areas.

- Plastic waste generation is nearly constant across ship classes, ranging between 45 and 90 g (0.1 and 0.2 lb) per person per day.

- Separation of the plastic from other waste at its source was most effective and required the least effort. Trash cans or bags labeled "Plastic Waste Only" were essential. In most living and work spaces they would hold a 1- to 2-week accumulation of plastic waste.

- Onboard storage of plastic contaminated with food waste was limited to approximately 3 days before the noxious odor began to affect the quality of life and it posed a threat to health and sanitation conditions.

- Uncontaminated plastic waste can be stored on board up to 3 weeks; the originating work center seems to be the most appropriate choice for storage on most ships. The plastic waste was collected and placed in pier-side dumpsters when a ship returned to port.

**POLICY GUIDANCE**

The commanders of the Atlantic and Pacific fleets have issued policy guidance to the commanding officers of the ships. Each ship must separate and store plastic that is not contaminated with food waste for at least the first 20 days of any underway period, and longer if space allows. Plastic that is contaminated with food waste must be held on board for the last 3 days of any underway period. Plastic waste stored on board will be off-loaded in port. If retention compromises the health, safety, or combat readiness of the ship and those aboard, properly packaged and negatively buoyant plastic waste may be discharged overboard when the ship is beyond 50 nmi from any shoreline. Such disposal must be approved by the
commanding officer and a log entry made indicating the time and position of overboard discharge. Noncompliance with the dumping policy must be reported in writing. This policy became effective 15 January 1989 for ships in the Atlantic fleet, and 1 March 1989 for Pacific fleet ships. The effective dates were chosen to coincide with the issuance of education packages for each ship. Each package includes the "Ship's Guide for the Management of Plastic Waste at Sea."

Fleet implementation of the new procedures will produce an immediate reduction in the total plastic waste discharged overboard by an astounding 70%! The aggressive action exhibited by our operational forces affords our engineering community time to develop and install solid waste management equipment aboard ships that will promote still further reductions. Also, the Navy's supply community will use this opportunity to research alternative products to reduce the amount of plastic used on board ship. The U.S. Navy stands firmly committed to achieving full compliance with all environmental regulations.