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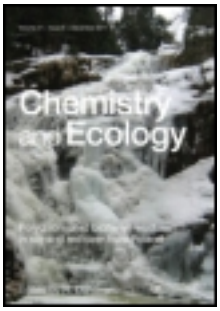

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COMPOSITION OF FLOATING DEBRIS IN HARBOURS OF THE UNITED STATES

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As part of a programme to characterize floating anthropogenic debris in the aquatic environment, the US Environmental Protection Agency (EPA) conducted 18 field surveys in the harbours of major metropolitan cities of the east, west, and Gulf coasts of the United States and the Mid-Atlantic Bight. The surveys were designed to provide information on the types, relative amounts, and distributions of aquatic debris in different geographic regions of the United States. Neuston nets (0.33 mm mesh) were used to collect surface debris during outgoing tides on two or three consecutive days in selected areas of each city. After each net tow, the debris, which ranged in size from small resin pellets to large plastic sheeting pieces, was identified, categorized, and counted. The data are being used to qualitatively characterize aquatic debris in coastal metropolitan areas, to examine potential regional variations, and to tentatively identify potential sources.

KEYWORDS: Plastic debris, US harbours, potential sources

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INTRODUCTION

In response to domestic and international concerns about aquatic plastic debris, the United States Congress passed the Marine Plastic Pollution Research and Control Act of 1987. Under Title II of this Act, the US Environmental Protection Agency (EPA) was directed to issue a Report to the Congress on methods for reducing plastic pollution. One section of the comprehensive Report to the Congress (EPA, 1990a) discusses the types and sources of marine plastic debris, the transport and fate of this debris, and its effects on the marine environment and on human health and safety. It also lists what EPA believes to be items of particular concern in the marine debris. These items of EPA concern are pellets, condoms, tampons, syringes/medical items, nets/traps, line/rope, six-pack yokes (or similar beverage yokes), and plastic bags and sheeting.

The paucity of data available prior to the preparation of the Report to the Congress prompted EPA to conduct field studies to characterize plastic debris and its sources along the coastal United States. Initiated in 1988, EPA's Harbor Studies Program (Redford, 1990) focuses on examining plastic and other floating debirs in major habours along the US Atlantic, Gulf, and Pacific coasts. The objective of this ongoing field programme is to characterize the types, relative amounts, and distributions of marine debris in representative harbours.

To date, EPA has conducted 17 surveys in the harbours of 11 metropolitan areas of the coastal United States: New York, New York; Boston, Massachusetts; Philadelphia, Pennsylvania; Baltimore, Maryland; Norfolk, Virginia; Miami, Florida; Houston, Texas; Tacoma and Seattle, Washington; and Oakland and

San Francisco, California. Additionally, the offshore portion of the Mid-Atlantic Bight between Cape May, New Jersey, and Cape Henry, Virginia, were surveyed. This paper presents a summary of the results of the surveys thus far conducted under the Harbor Studies Program.

METHODS

Sample Collection

Sampling at each harbour was conducted on two or three consecutive days, between November 1988 and September 1990. Sampling dates and the total number of samples collected at each location are presented in Table 1. Two to four areas within each harbour were designated for study. The selection of these areas was based on several criteria, such as (1) proximity of combined sewer overflows (CSO) and stormwater outfalls (close proximity was preferred), (2) volume of ship traffic or boating activity (large volumes were preferred), (3) industrialization (highly industrialized areas were preferred), and (4) representatives of overall debris conditions in each harbour.

Table 1 EPA Harbor Studies Program surveys of floating debris

City	*Survey dates*	*Number of samples*
New York, NY	November 11–13, 1988	43
	July 7–9, 1989	27
Boston, MA	December 2–4, 1988	49
	April 10–12, 1990	32
Philadelphia, PA	January 26–27, 1989	29
Baltimore, MD	January 29–30, 1989	29
	June 21–23, 1989	12
	June 3–5, 1990	17
Norfolk, VA	June 6–8, 1990	29
Mid-Atlantic Bight	August 29–30, 1989	5
Miami, FL	February 3–5, 1989	31
	February 13–15, 1990	20
Houston, TX	February 6–8, 1990	15
	September 26–27, 1990	8
Tacoma, WA	February 15–17, 1989	11
Seattle, WA	February 15–17, 1989	6
San Francisco, CA	February 21–23, 1989	15
Oakland, CA	February 21–23, 1989	12
Total samples		390

Floating debris often is observed concentrated in dense windrows, commonly referred to as debris slicks (EPA, 1988), that are influenced by surface currents and winds. Because the location, size, shape, and integrity of slicks were highly variable within each harbour, sampling was not conducted along predetermined, randomly selected transects, but was conducted in slicks that were dense with floating debris. Sampling was directed toward the areas containing dense masses of debris within the slicks.

Accumulated debris within a given harbour is most likely to be transported out of

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the harbour with an outgoing tide. As a result, all sampling activities were initiated 1 to 2 h before ebb tide at each location where tides are an influencing factor. Selected areas within a harbour were sampled concurrently by deploying two or more small vessels.

Samples were collected by using a 0.33 mm-mesh neuston net with dimensions of either 1 × 2 × 4, 0.5 × 1 × 4, or 0.5 × 1 × 2 m. To minimize disturbance from the wake of the vessel, the net was towed from a boom positioned abeam of the vessel. Each net tow made through a slick was considered a single sample, regardless of the tow length. Tows were conducted at a speed of 2 kn for approximately 20 min, or until a sample volume of approximately 60 l was collected; in several cases, 60 l samples were collected within 1 min of net deployment. If more than one tow was made within a slick, each tow sample was considered to be a replicate. Following each tow, the captured debris was placed into labelled containers until it was processed in the laboratory.

For each collection, a sample log form was completed. Date, time, meteorological conditions, and the dimensions and location of each sampled slick were recorded on the form. To ensure consistency, the same two scientists assessed the slick dimensions and debris concentrations during all surveys. Visual fixes of charted landmarks were used to plot tow locations on navigational charts.

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Sample Processing and Analysis

All samples were processed and analyzed immediately after returning from the field. Sample processing involved several steps and included:

1. rinsing all items (anthropogenic and natural) with tap water and passing the rinse water through a 0.33 mm mesh sieve to collect smaller man-made items
2. separating all anthropogenic materials from natural materials
3. sorting and identifying debris into specific descriptive categories
4. enumerating debris and recording the counts on an inventory sheet.

An adaptation of the national beach survey data card developed by the Center for Marine Conservation (CMC) (EPA, 1990b) was used during the first two surveys of the programme. However, many new categories were added to accommodate the differences in the composition between floating debris collected during the Harbor Studies Programme and beached debris reported by CMC. To date, the Harbor Studies Programme inventory sheet contains over 230 different items (Figure 1).

Upon return from the field, the data were entered into a database and the percent composition was calculated for each item or combination of items. Percentages are calculated based on numbers of items found, not on weight or volume of the items. Samples were photo-documented immediately upon return to the laboratory.

Calculations

As much as possible, all man-made items in the samples were classified and enumerated. Percent composition of each item from each sampled city was determined by dividing the item enumeration by the total number of items from the city. However, special consideration was given to some items due to extenuating circumstances.

Some items were found in numbers so large that enumerating the items would

FLOATABLES SURVEY DATA INVENTORY SHEET--Sheet 1

ATTACH SAMPLE LABEL HERE

PLASTICS
- Absorbant Material ____ ____
- Bags and Ties
  - Bags ≤ 1-gal capacity ____ ____
  - Condiment bag ____ ____
  - Garbage bag tie ____ ____
  - Bags > 1-gal capacity ____ ____
  - Misc. bags ____ ____
  - Misc. pieces ____ ____
  - Vegetable sack ____ ____
- Banding Material
  - Electrical wire tie ____ ____
  - Strapping band ____ ____
- Bottles
  - Bottles ≤ 1-gal capacity ____ ____
  - Bottles > 1-gal capacity ____ ____
  - Beverage bottles ____ ____
  - Misc. bottles ____ ____
  - Misc. pieces ____ ____
- Caps and lids
  - Caps/lids ____ ____
  - Cap/lid liners ____ ____
  - Cap/lid pieces ____ ____
  - Pull tab from plastic lid ____ ____
- Cigarette/Cigar Items
  - Wrappers and packs ____ ____
  - Cigar tips ____ ____
  - Cigarette butts & filters ____ ____
  - Disposable lighters ____ ____
- Containers
  - Lemon juice dispensers ____ ____
  - Misc. containers ____ ____
- Dishware
  - Cups, spoons, forks, straws ____ ____
  - Dishes/plates ____ ____
  - Misc. pieces ____ ____
- Drug Paraphernalia
  - Crack vial caps ____ ____
  - Crack vials w/caps ____ ____
  - Crack vials w/o caps ____ ____
- Fishing/Boating Items
  - Floats & lures ____ ____
  - Fishing line-monofilament ____ ____
  - Netting ____ ____
- Food Wrappers--Misc. ____ ____
- Hair Care & Cosmetic Items--Misc. ____ ____
- Housewares & Tools--Misc. ____ ____
- Labels--Misc. ____ ____
- Line/Rope
  - Filament ____ ____
  - Rope length ≤ 2 ft ____ ____
  - Rope length > 2 ft ____ ____
- Medical
  - Adhesive bandages ____ ____
  - Adhesive bandage wrappers ____ ____
  - Cough syrup bottles ____ ____
  - Cylindrical tubes ____ ____
  - Cylindrical tube pieces ____ ____
  - Lip balm & containers ____ ____
  - Misc. ____ ____
  - Needle covers ____ ____
  - Pill vials & caps ____ ____
  - Syringes (whole) ____ ____
  - Syringes (pieces) ____ ____
  - Syringes with blood ____ ____
  - Tube ends only ____ ____
  - Vials ____ ____
  - Vial caps ____ ____
- Miscellaneous
  - Foil wrappers (plastic-coated) ____ ____
  - Hardhat band ____ ____
  - Misc. Items ____ ____
  - Pieces ____ ____
  - Wrappers ____ ____
  - Polyvinylchloride (PVC) ____ ____
  - Toys ____ ____
  - Tubing ____ ____
  - Vials ____ ____
- Pellets & Spherules ____ ____
- Personal Hygiene
  - Condoms (whole) ____ ____
  - Condoms (pieces) ____ ____
  - Diapers ____ ____
  - Panty liners ____ ____
  - Cotton swabs (whole) ____ ____
  - Cotton swabs (tube only) ____ ____
  - Sanitary items ____ ____
  - Sanitary napkins ____ ____
  - Tampon applicators ____ ____
  - Tampon wrappers ____ ____
- Photographic Items
  - Film containers ____ ____
  - Photos ____ ____
- Sheeting
  - ≤ 2 ft ____ ____
  - > 2 ft ____ ____
- Six-Pack Yokes (or similar)
  - Whole ____ ____
  - Pieces ____ ____
- Writing Utensils--Misc. ____ ____
- Containers--Bucket ____ ____
- Housewares & Tools--Hardhat ____ ____
- Housewares & Tools--Tape ____ ____
- Miscellaneous--Bakery Pallet ____ ____
- Miscellaneous--Plastic Plants ____ ____
- Fishing/Boating Items--Misc. ____ ____
- Miscellaneous--Packing Material ____ ____
- Dishware--Coffee Stirrers ____ ____
- Personal Hygiene--Tampons ____ ____

GLASS
- Bottles
  - Alcohol bottles ____ ____
  - Food bottles ____ ____
- Light bulbs ____ ____
- Misc. Pieces ____ ____
- Marbles ____ ____
- Bottles--Medical ____ ____

Figure 1 Data inventory sheet (sheet 1 page 1 only) for EPA Harbor Studies Programme

require an excessive amount of time or, in the case of grease balls, would be very difficult to enumerate accurately owing to their very small size (1–2 mm in diameter) and delicate structure (easily broken when handled). The presence of these "too numerous to count" (TNTC) items was noted on the respective data inventory sheets, and these records are noted in the Harbor Studies Programme reports (EPA, 1990b, 1991). No numerical estimates of these TNTC items were included in

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the calculated percentages reported herein; however, TNTC reports were labelled in the database. Items with one or more TNTC records in each city are listed in Table 2.

Table 2 Items too numerous to count in one or more Habor Studies Programme samples

City	*Item*
Boston	Grease balls Toilet paper pieces Tar balls Polystyrene spheres Slag pieces Food items Polystyrene pieces smaller than a baseball
New York City	Grease balls Polystyrene spheres Faecal material Food items Miscellaneous living organisms Foil pieces
Philadelphia	Grease balls
Baltimore	Polystyrene spheres Grease balls
Norfolk	Slag pieces Grease balls Plastic sheeting < 0.6 m Miscellaneous living organisms Plastic filaments
Mid-Atlantic Bight	None
Miami	Cork pieces Polystyrene spheres Grease balls Burned wood pieces
Houston	None
Tacoma	Wood chips Polystyrene spheres
Seattle	None
San Francisco	None
Oakland	None

Plastic pellets were found in extremely high numbers in several samples; these pellets were never reported as TNTC and were always enumerated owing to their significance as a hazard to wildlife. These very high numbers of pellets masked the relationships between the other debris items in the individual cities and in the total programme. Therefore, the enumerations for plastic pellets are not included in the percentage calculations presented in this report unless otherwise indicated. A complete discussion of plastic pellets is included in a separate section.

During this study, items were enumerated but they were not weighed or measured in any other manner. All cited percentages are based on numbers of items found. For those cities surveyed more than once, the percentages are based on the sums of each

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item from all surveys of the city and are not based on averaged values. For example, the percentages cited for Baltimore are calculated on the basis of the sum of the enumerations for the three separate surveys.

RESULTS AND DISCUSSION

Plastic and Polystyrene

To date, 99% of all debris collected for the Harbor Studies Programme, including plastic pellets, was composed of plastic and foamed polystyrene (all foamed polymers are included under this category). Although foamed polymers are plastics, they are treated separately in this discussion on the basis of their physical properties and uses. Excluding plastic pellets, plastic (55%) and foamed polystyrene (28%) composed approximately 83% of all debris collected during the programme (Figure 2).

Miscellaneous debris [primarily grease balls, tar, and slag (a waste product of steel welding)] comprised approximately 10% of all debris. The remaining major categories (wood, paper, metal, rubber, glass, and textile) comprised approximately 7% of all debris. A summary of debris in each major category for the entire programme is shown in Figure 2.

For all cities combined, plastic debris comprised the greatest percentage of debris. Houston had the highest percentage of plastic debris (62%, or 98% including plastic pellets) (Table 3 and Figure 3). Baltimore, Miami, and New York had the second, third, and fourth highest percentages of plastic debris with 59%, 58%, and 57%, respectively. The debris collected from each remaining city had less than 50% plastic. Tacoma had the lowest percentage of plastic (28%); however, if plastic pellets are included in the totals for all cities, Tacoma has the second highest percentage of plastic at 84%.

Foamed polystyrene comprised the second highest percentage of items (Figure 2). The highest percentages of foamed polystyrene were found in West Coast cities (Figure 3). Of all cities sampled, Tacoma had the greatest percentage of foamed polystyrene (56%), and San Francisco, Seattle, and Oakland had the second, third, and fourth highest percentages of foamed polystyrene (52%, 45%, and 42%, respectively). New York contained the lowest percentage (13%) of foamed polystyrene in a metropolitan area, and the Mid-Atlantic Bight contained the lowest percentage overall (5%).

Plastic Pellets

Plastic pellets are the raw materials from which moulded plastic products are manufactured, and are among the least obvious debris discharged into the aquatic environment. This is evidenced by their exclusion from beach cleanup reports produced by the CMC. However, these small items, innocuous to most observers, are mistaken for food by a variety of aquatic animals, particularly fishes and birds. It is suspected that the pellets ingested by fishes and birds are often neither digested nor passed through the digestive system. When enough pellets have accumulated in the digestive tract of the animals, hunger may subside, resulting in possible starvation and ultimately death. Plastic pellets may also block the digestive systems of these animals. Although death of birds or fishes has not been positively linked to pellet ingestion, the overall health of these organisms is most probably affected. As a

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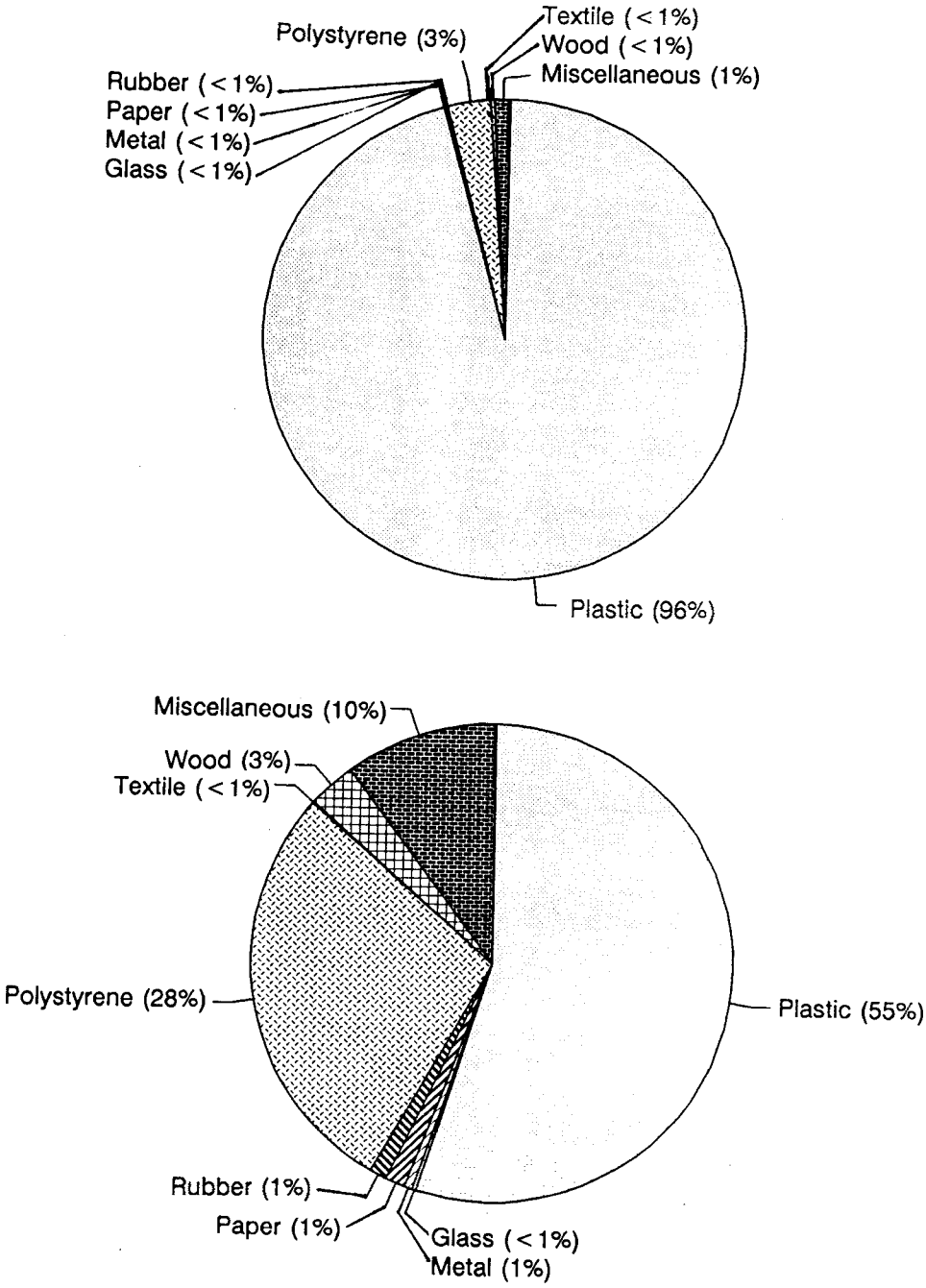

Figure 2 Percent composition of debris categories including plastic pellets (top) and excluding plastic pellets (bottom)

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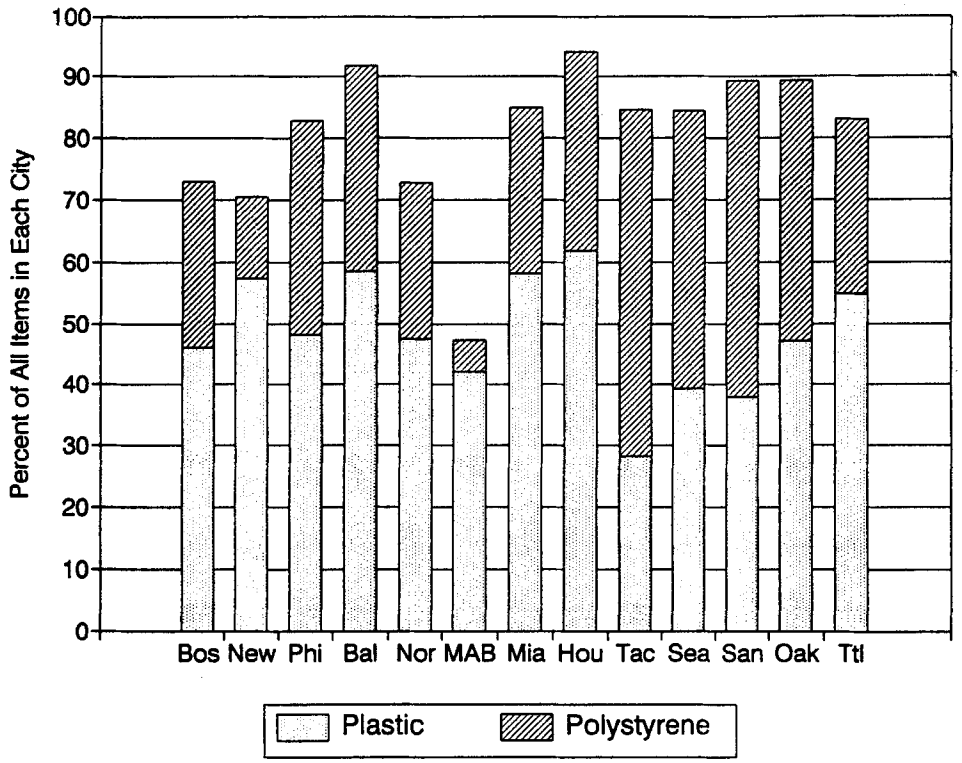
				% Composition of all items (excluding plastic pellets)				
	Total items excluding pellets	*Plastic pellets/ spherules*	*Plastic*	*Polystyrene*	*Other items of EPA concern*	*Sewage*[a,b]	*Medical*[a,c]	*Drug*[d]
Boston, MA	9,204	3,201	46.10	27.03	6.69	0.41	0.16	0.32
New York, NY	17,305	11,266	57.33	13.31	15.62	0.92	0.25	1.52
Philadelphia, PA	1,956	877	48.11	34.71	21.01	2.30	0.10	1.07
Baltimore, MD	17,873	6,606	58.56	33.44	13.65	0.62	0.49	0.29
Norfolk, VA	5,610	135	47.47	25.40	24.74	0.37	0.05	–
Mid-Atlantic Bight	19	1	42.11	5.26	10.53	–	–	5.26
Miami, FL	5,850	356	58.26	26.77	36.34	0.09	0.05	0.02
Houston, TX	15,490	700,344	61.97	32.37	12.22	0.08	0.11	0.01
Tacoma, WA	1,100	3,834	28.18	56.45	43.45	–	0.09	–
Seattle, WA	685	24	39.27	45.11	25.84	–	0.29	–
San Francisco, CA	3,008	297	37.87	51.50	15.36	0.10	0.07	–
Oakland, CA	1,240	279	47.18	42.42	25.81	0.08	0.08	–
Total programme	79,340	727,220	54.89	28.31	16.41	0.50	0.22	0.46

a Also includes some items of EPA concern.
b Sewage-related items: Condoms (whole and pieces), diapers, panty liners, sanitary items, sanitary napkins, tampons, tampon applicators, tampon wrappers, and faecal material.
c Medical-related items: Cylindrical tubes (whole and pieces), tube ends, needle covers, syringes (whole and pieces), syringes with blood, needle covers, miscellaneous medical items, pill vials and caps, vials and vial caps, tongue depressors, and pills.
d Drug-related items: Crack vials with and without caps, crack vial caps, cocaine wrappers, and illegal substances.



Key to Abbreviations

Bal:	Baltimore, MD	New:	New York, NY	San:	San Francisco, CA
Bos:	Boston, MA	Nor:	Norfolk, VA	Sea:	Seattle, WA
Hou:	Houston, TX	Oak:	Oakland, CA	Tac:	Tacoma, WA
MAB:	Mid-Atlantic Bight	Phi:	Philadelphia, PA	Ttl:	Program Total
Mia:	Miami, FL				

Figure 3 Percent composition of plastic and polystyrene debris (excluding plastic pellets) in each city sampled during the EPA Harbor Studies Program

result, a discussion of the distribution and percentages of plastic pellets is essential to understanding the potential impact of floating debris.

Overall, plastic pellets were the most common item found during the Harbor Studies Program. Pellets of every size, shape, and colour were collected; most of the pellets either were colourless or were white or off-white, but several other colours (black, green, yellow, amber, orange, blue, purple, etc.) were also observed. All pellets were less than 5 mm in diameter. These characteristics were consistent with EPA's description of polyethylene or polypropylene pellets (EPA, 1990a). Visual assessments by a polymer chemist revealed that a variety of pure and additive-containing plastic pellets were found in all of the samples examined.

Plastic pellets were ubiquitous. They were found in each of the 11 cities and in the Mid-Atlantic Bight (Table 3 and Figure 4). A total of 29 different areas (two to four in each harbour) were surveyed during the programme, and pellets were found in 27 of the 29 areas. Hampton Roads in Norfolk and the Weymouth/Neponset Rivers in Boston were the only areas where pellets were not found; however, plastic pellets

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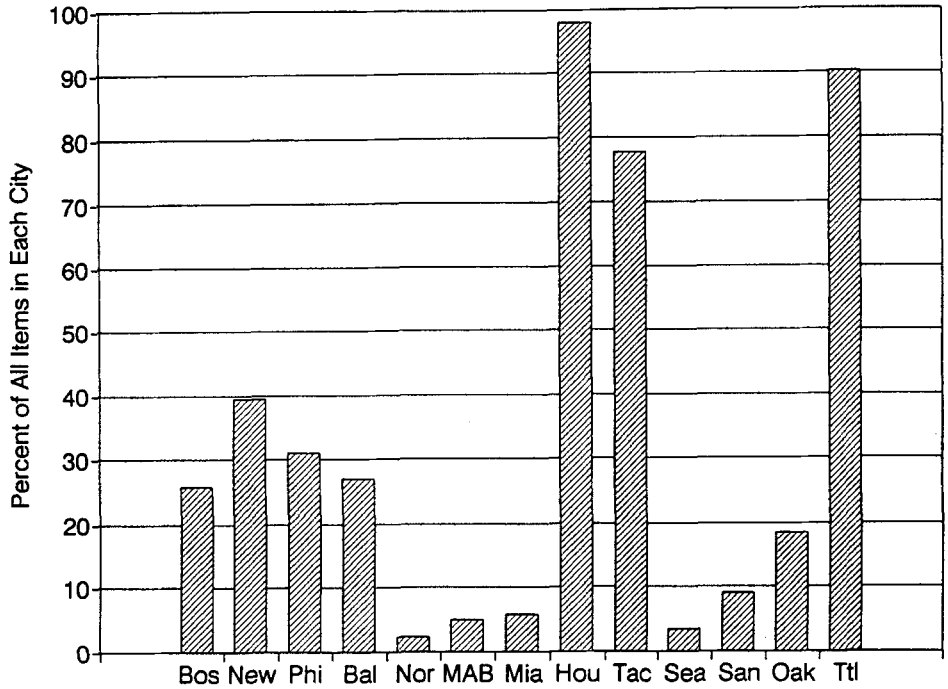

Key to Abbreviations

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MAB:	Mid-Atlantic Bight	Phi:	Philadelphia, PA	Ttl:	Program Total
Mia:	Miami, FL				

Figure 4 Percentage of plastic pellets in each city sampled during the EPA Harbor Studies Program

were found in the Elizabeth River in Norfolk and in the remaining four areas sampled in Boston.

Except in Norfolk, plastic pellets were among the most common items found in each of the 11 cities surveyed. Pellets were the most abundant item in seven of the cities: Baltimore, Boston, Houston, New York, Oakland, Philadelphia, and Tacoma. Of all debris collected in San Francisco, Miami, and Seattle, pellets ranked third, fifth, and seventh, respectively. In the Mid-Atlantic Bight, pellets ranked sixth, and in Norfolk, they ranked 14th (i.e. not among the most common items).

Of all cities surveyed, the greatest number, variety, and percentage of pellets were collected in the Houston Ship Channel at Houston (Figure 4). It is interesting to note that Houston has one of the greatest concentrations of plastics industries in the United States, and that several pellet extruding and processing plants are located along or near the channel. Over 700,000 pellets comprised approximately 98% of all the debris collected during the two Houston surveys. Many Houston samples contained thousands to tens of thousands of pellets; more than 225,000 pellets were

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counted in a single sample. Pellets of every colour and shape were observed, although most of the pellets either were colourless or were white or off-white. Some of the Houston pellets were rubberized; these pellets were ovoid.

In Tacoma, 78% of all debris was composed of plastic pellets. Unlike the pellets from the Houston Ship Channel, those from Tacoma were the same size, shape, and colour, indicating that the pellets probably originated from a single source. The fact that most of the pellets from Tacoma (2732 out of 3834) came from a single sample supports this theory.

New York City had the second highest number (11,266 plastic pellets) and the third highest percentage of plastic pellets (39%), based on the total debris collected during the two New York surveys. These pellets equalled only slightly less than 2% of the total number of plastic pellets (700,344) collected in Houston. In samples collected from the Hudson and East Rivers, the pellets varied considerably in colour and shape, possibly indicating several sources of entry into the marine environment. In some cases, these pellets were found embedded in grease, tar, or other organic matter (including faecal matter), indicating that CSOs are a possible source of discharge. In samples collected from the Kills (the water body separating Staten Island from New Jersey), pellets were generally uniform in size, shape, and colour, indicating a probable single-source discharge. In the remaining cities in which pellets were among the most abundant items (Baltimore, Boston, Oakland, and Philadelphia), composition of pellets ranged from 31% in Philadelphia to 18% in Oakland.

Two items of interest, one associated with plastics production and the other associated with pellet transportation, were noted durng the Harbor Studies Program and associated EPA projects. During the two surveys in the Houston Ship Channel, plastic powder, another form of raw material used to make moulded products, was observed floating at the water surface and was collected in considerable volume along with other debris. Initially, this powder was thought to be grain dust from nearby grain elevators, and was discarded as non man-made debris. However, later discussions with plastics industry personnel indicated that the grain dust was probably plastic powder. To verify this possibility, some of the material was removed from the Houston samples and was heated. The grains melted and subsequently solidified into an amorphous mass after it was allowed to cool. The mass appeared to be plastic, although this was not confirmed by chemical analysis. Survey scientists do not recall collecting this powder in other cities, but this could simply mean that the powder was not recognized.

In addition, a number of flattened plastic discs approximately 1 cm in diameter were found in samples collected from several different harbors. These discs were categorized and counted as miscellaneous plastic pieces because they were irregular in shape and could not be identified. However, several discs identical to the ones collected during the surveys were found during a visit to a plastic pellet extruder conducted under a separate EPA project. The plastic discs, as well as plastic pellets, were scattered along train tracks and underneath hopper cars in the loading and cleaning areas of the extruder facility. Plastics industry personnel identified the discs as plastic pellets that were flattened by the railroad hopper cars.

Items of Concern

EPA has identified eight items of concern because of the risks that the items pose to human health and safety, aquatic life, and the aesthetic and economic quality of the

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environment. These items are pellets; condoms; tampons; syringes and other medical debris; nets and traps; line and rope; beverage yokes (i.e., six-pack yokes); and plastic bags and sheets. Thirty two items identified and enumerated during the Harbor Studies Program are included in these items of EPA concern (EPA, 1990b) (Table 4). Six of these 32 items were found in all surveys: plastic bags > 3.8 l, plastic bags < 3.8 l, plastic filaments, plastic pellets, polystyrene spheres, and plastic sheeting < 0.6 m.

Table 4 Items of EPA concern

Items of EPA concern	*Items included*
Pellets	Plastic pellets Polystyrene spheres Polystyrene spheres (1-cm)
Condoms	Condoms (whole) Condoms (pieces)
Tampons	Tampons Tampon applicators Tampon wrappers
Syringes/Medical	Syringes (whole) Syringes (pieces) Syringes with blood Vials Vial caps Insulin bottles Needle covers
Nets/Traps	Netting Floats and lures
Line/Rope	Rope (textile) Plastic rope > 0.6 m Plastic rope < 0.6 m Plastic filaments Plastic strapping band Fishing line – monofilament
Beverage Yokes	Six-pack yokes or similar (whole) Six-pack yokes or similar (pieces)
Plastic Bags/Sheeting	Bags > 3.8 l Bags < 3.8 l Condiment bag Miscellaneous bags (whole) Miscellaneous bags (pieces) Sheeting > 0.6 m Sheeting < 0.6 m

Including plastic pellets, items of EPA concern comprised over 91% of all debris in all cities (98% of the Houston debris was plastic pellets). Excluding plastic pellets, Tacoma and Miami contained the highest percentages of the 32 items of EPA concern (43% and 36% of all debris in each city, respectively), and Boston, Mid-Atlantic Bight, and Houston contained the lowest percentages (7%, 11%, and 12%, respectively) (Table 3). The six ubiquitous items (excluding plastic pellets) (Table 5) comprised over 13% of all debris in all cities combined. Excluding plastic pellets, the most common item of EPA concern in all cities was plastic bags and sheeting (8%). The least common item was nets and traps (0.02%).

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Table 5 Ubiquitous items[a] found during the EPA Harbor Studies Program

Category	*Item*
Plastic	Bags < 3.8 l[b]
	Bags > 3.8 l[b]
	Bottles < 3.8 l
	Caps and lids (whole and pieces)
	Cigar and cigarette wrappers and packs
	Cigar tips
	Cigarette butts and filters
	Cups, spoons, forks, straws
	Coffee stirrers
	Miscellaneous pieces
	Filaments[b]
	Pellets[b]
	Sheeting < 0.6 m[b]
Polystyrene	Spheres[b]
	Cups and bowls (pieces)
	Pieces smaller than a baseball
	Packing peanuts
	Miscellaneous packing material
Paper	Miscellaneous paper pieces
Miscellaneous	Grease balls

a Excluding Mid-Atlantic Bight.
b Item of EPA concern.

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Commonly Found Items

As previously discussed plastic pellets were the most common item found during the Harbor Studies Program, and was the most common item in seven of the cities studied. Excluding plastic pellets, the ten most common items comprised over 65% of all debris collected during the Harbor Studies Program. Eight of the ten most common items were either plastic or polystyrene (Table 6). The most common item was miscellaneous plastic pieces, which comprised approximately one-fifth of all items collected. This item was consistently among the most common items in all cities, and it comprised between 3% (Norfolk) and 42% (Houston) of the items collected.

Table 6 Most common items (excluding plastic pellets)[a]

Item	%
Miscellaneous plastic pieces	19.51
Polystyrene pieces smaller than a baseball	11.24
Plastic sheeting < 0.6 m[b]	6.57
Cigarette butts and filters	5.43
Grease balls	4.31
Polystyrene cups and bowls (pieces)	4.07
Polystyrene spheres[b]	4.03
Miscellaneous plastic food wrappers	3.94
Polystyrene beverage labels	3.47
Slag	2.96

a Plastic pellets were the most common item.
b Item of EPA concern.

Polystyrene pieces smaller than a baseball, plastic sheeting less than 0.6 m, and cigarette butts and filters were also common. Two common items, plastic sheeting less than 0.6 m and polystyrene spheres, are items of EPA concern.

Nineteen items were found in all cities (Table 5): six of these were items of EPA concern and 17 items are made of plastic or polystyrene. Several of these 19 ubiquitous items are associated with the use of tobacco or the consumption of food products, and are typically present in street litter (although no evidence exists to prove that the items collected in the study actually originated in street litter).

Items associated with tobacco use, such as cigarette butts and filters, cigar tips, and cigar and cigarette wrappers and packs, comprised over 8% of all debris in all cities combined (excluding plastic pellets) (Figure 5). Baltimore contained the greatest percentage (over 14%) of these three items combined. In Seattle, cigarette butts and filters comprised nearly 11% of the debris, and the three items combined were over 12% of the debris (excluding plastic pellets). A possible explanation for the significant presence of the tobacco use-related products in aquatic debris is that the consumer fails to recognize the fact that, although the tobacco itself may decompose quickly, the filters and packaging contain plastic and will persist long after the tobacco is gone.

Other ubiquitous items, such as cups, spoons, forks, and straws, coffee stirrers, and pieces of polystyrene cups and bowls, are associated with food and beverage consumption. These items comprised nearly 7% of all debris (excluding plastic pellets) (Figure 5). An additional 7% of the debris was comprised of food-related items that were not ubiquitous, including plastic, paper, and polystyrene cups, bowls, plates, and trays; fast-food containers and wrappers; plastic, glass, and metal beverage and food containers and wrappers; food (e.g., candy and chewing gum) wrappers; lollipop and ice cream sticks; condiment bags; beverage can insulators; and beverage container yokes (e.g., six-pack rings). Nearly one-quarter of the debris collected in Baltimore (three surveys combined) can be classified as food-related. This percentage may be attributable to recreational development in the Inner Harbor and the location of a large carryout restaurant mall adjacent to the waterway.

Caps and lids (whole and pieces) were also conspicuous in the debris of all cities (Figure 5). A wide variety of sizes, shapes, and colours of caps and lids were collected, but the origin of these items could not be determined. Over 4% of all debris collected was caps and lids (including cap/lid liners), and the items comprised between < 1% (Tacoma) and nearly 9% (Baltimore) of the debris in the individual cities. No caps or lids were found in the Mid-Atlantic Bight.

Sewage-Related Debris

Several sewage-related items were collected during the Harbor Studies Program. Northeastern cities contained the greatest numbers and percentages of sewage-related debris (Figure 6). Over 2% of the debris collected in Philadelphia was sewage-related (Table 3); the most common item of this type in the city was condoms, which comprised approximately 1% of all debris. New York City also contained a high percentage (nearly 1%) of this type of debris. In contrast, Miami, Houston, and the west coast cities contained very low percentages of sewage-related items; the percentages ranged from 0% (no sewage-related debris) in Seattle, Tacoma, and the Mid-Atlantic Bight to 0.1% in San Francisco.

The differences between the cities in regard to the presence of sewage-related debris may be attributable to the condition of the municipal sanitary systems. The

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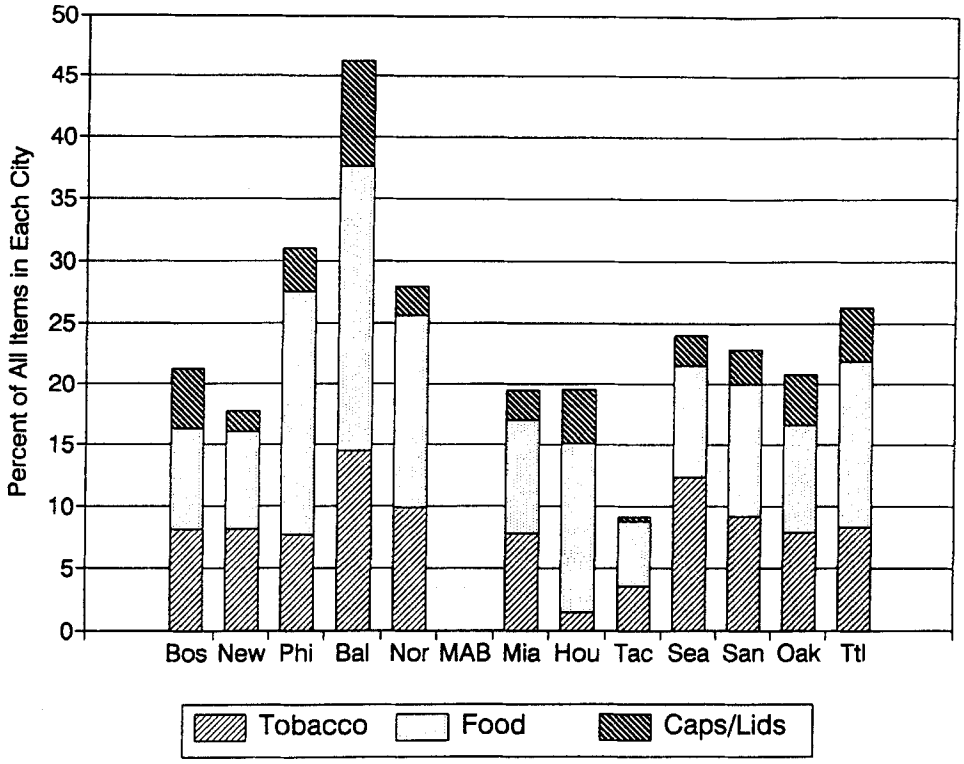

Key to Abbreviations

Bal:	Baltimore, MD	New:	New York, NY	San:	San Francisco, CA
Bos:	Boston, MA	Nor:	Norfolk, VA	Sea:	Seattle, WA
Hou:	Houston, TX	Oak:	Oakland, CA	Tac:	Tacoma, WA
MAB:	Mid-Atlantic Bight	Phi:	Philadelphia, PA	Ttl:	Program Total
Mia:	Miami, FL				

Figure 5 Percent composition of three common debris types (excluding plastic pellets) in each city sampled during the EPA Harbor Studies Program.

cities that contained higher percentages of sewage-related debris also generally contained greater percentages of medical- and drug-related debris. Because Boston, New York, Philadelphia, and Baltimore have not yet completed the upgrading of their municipal sewage systems, a possible explanation for the presence of these three debris types could be periodic CSO and storm sewer discharges from antiquated municipal sewage systems. In the remaining cities, which contain lower percentages of sewage-related debris, CSO systems are not prevalent because of initial development or modernization of the city sewers.

Medical-Related Debris

In the late 1980s, public attention was focused on the presence of medical-related debris in the marine environment. This public awareness was heightened at that time due to numerous beach wash-ups of this debris along the northeastern United States.

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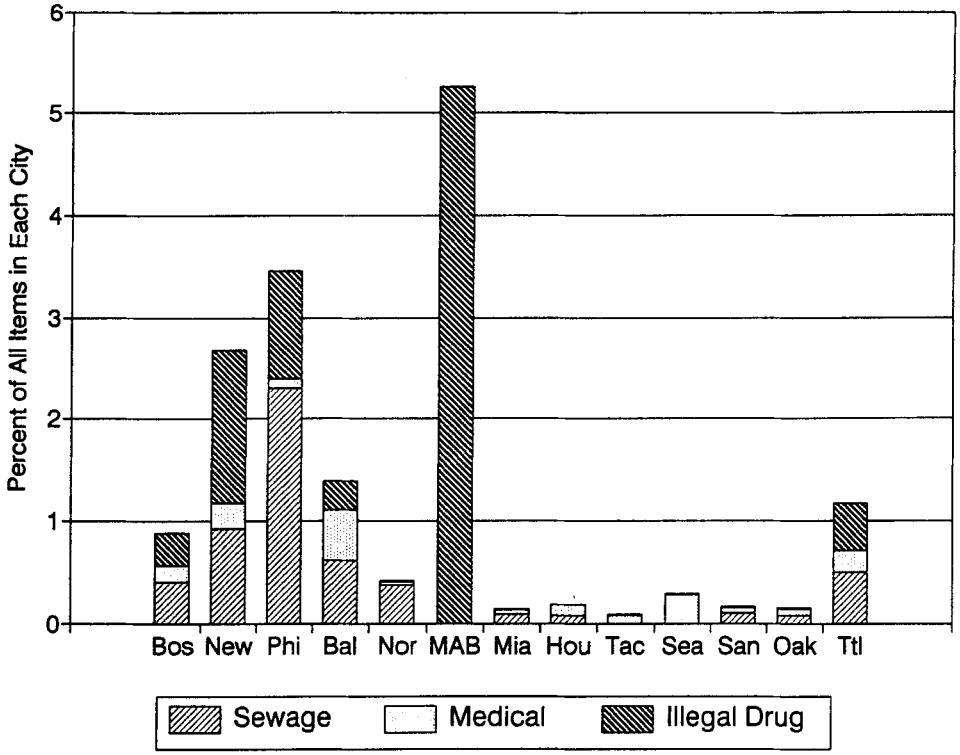

Key to Abbreviations

Bal:	Baltimore, MD	New:	New York, NY	San:	San Francisco, CA
Bos:	Boston, MA	Nor:	Norfolk, VA	Sea:	Seattle, WA
Hou:	Houston, TX	Oak:	Oakland, CA	Tac:	Tacoma, WA
MAB:	Mid-Atlantic Bight	Phi:	Philadelphia, PA	Ttl:	Program Total
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Figure 6 Percent composition of sewage-, medical, and illegal drug-related debris (excluding plastic pellets) from each city sampled during the EPA Harbor Studies Program.

The designation "medical- related debris" does not necessarily connote illegally or improperly disposed hospital waste, although these wastes have been documented in beach wash ups. Instead, for the present study, medical wastes refer to those items normally associated with the treatment of non-routine human health conditions. For example, 1 ml syringes used by diabetics to administer insulin are considered medical waste, but adhesive bandages are not considered to be medical waste. In addition to these types of syringes, medical waste also includes needle covers, prescription medication vials and containers, test tubes, etc. Items not considered medical-related include adhesive bandages, cotton swabs, non-prescription cough syrup bottles, etc.

Medical-related items were found in every harbour surveyed (Table 3). The most common medical-related items were needle covers and syringes or syringe pieces, all of which were the 1 ml insulin-dispensing type. However, the sources of these were not determined. Two of the syringes collected in Baltimore contained visible

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amounts of blood, which could be expected in syringes used by illegal drug users. Many of the syringes collected during the programme were capped at both ends, which indicated that the users had attempted proper syringe disposal. This type of behaviour would be typical of insulin users. Carelessly discarded syringes, such as those used by illegal drug users, would not be expected to be properly discarded.

Five syringes collected during the programme were analyzed for traces of insulin and several other substances, including cocaine. Two of the five syringes contained traces of cocaine: one of the syringes also contained traces of lidocaine and the other contained traces of insulin. A third syringe contained only traces of insulin. The last two syringes contain no traces of any analyte.

Baltimore contained the greatest numbers of syringes (49 syringes and pieces) and the greatest percentage (nearly 0.5%) of medical-related debris (Figure 6). Seattle contained the next highest percentage of medical-related debris, although only a total of approximately 700 items (excluding plastic pellets) were collected in the city.

Overall, northeastern cities (cities north of Norfolk) contained the greatest percentages of medical-related debris compared to the cities on the west coast. A syringe piece found in Tacoma and a needle cover found in San Francisco represented the only syringe-associated debris found in west coast cities. Norfolk, Miami, Philadelphia, and Houston also contained relatively low percentages of medical-related debris.

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Illegal Drug-Related Debris

Items associated with illegal drug use were found in all eastern cities except Norfolk. These items included capped and uncapped crack vials, crack vial caps, cocaine wrappers, and illegal substances (i.e., marijuana cigarettes). New York City contained the greatest percentages (over 1.5%) of illegal drug-related debris. No drug-related debris was found in the four west coast cities. All syringes were assumed to be medical-related and, therefore, were discussed in the previous section.

Offshore Studies

Floating debris in offshore areas has been reported by several authors. Although sampling efforts comparable to those conducted in US harbours were not performed in offshore areas, debris sitings were recorded during two EPA surveys.

During a survey of the 106-Mile Deepwater Municipal Sludge Dump Site (106-Mile Site), which is located 112 nm (nautical miles) east of Atlantic City, New Jersey, EPA observed free-floating debris and debris slicks in and around the site. These slicks contained condoms, tampon applicators, crack vials and caps, balloon pieces, grease and tar balls, pieces of wood, and other miscellaneous plastic pieces. However, the source of the slicks could not be positively identified.

In August 1989, EPA conducted a marine debris survey along transits of Wilmington, Baltimore, Washington, and Norfolk Canyons in the Mid-Atlantic Bight. A total of five samples were collected, and only 20 items were found. These items included a capped crack vial; short lengths of monofilament line; several unidentified pieces of plastic, glass, rubber, and polystyrene; an unidentified paper item; a food item; a plastic pellet; paint chips; and grease balls. High winds and building seas interfered with sampling equipment deployment, thereby preventing the collection of more samples.

In addition to the samples collected during the Mid-Atlantic Bight survey in

August 1989, visual sitings of surface debris were recorded. In several areas, at least one debris item was reported every few minutes. Styrofoam cups were the most frequently reported items. Cut lumber and plastic sheeting were also frequently reported.

SUMMARY

Plastic and polystyrene debris were numerically the largest component of marine debris in surface slicks from every city sampled. The most commonly found debris items were either plastic or polystyrene, and the several of these items may be associated with street litter.

Plastic pellets were a significant portion of the plastic debris and were collected in every harbour. Plastic pellets comprised nearly 98% of the debris collected in Houston. Plastic powder and flattened plastic pellets were also found in some samples, but they were not enumerated.

Several sewage-, illegal drug-, and medical-related items were found during the study but these items were not major components of the debris. The syringes were typically capped at one or both ends, which indicated that the user had attempted proper syringe disposal.

These surveys were the first in a continuing series of surveys sponsored under EPA's Harbor Studies Program. The programme is providing the first semiquantitative evaluation of marine debris in US harbours. Future surveys are being planned to study additional cities, and many of the cities discussed in this study will be resampled.

Acknowledgements

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