CHARACTERIZATION OF URBAN-SOURCE FLOATABLES

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ABSTRACT

This paper is intended as a reference document to present the physical characteristics of floatables and other materials in beach wash-ups, in discharges from storm- and combined-sewer systems, and on urban streets and sidewalks. The information presented in the paper may be useful to develop an understanding of the transport of material from urban streets through the sewer system and ultimately into receiving waters and onto shorelines and beaches. Furthermore, regulatory requirements regarding control of floatables can be ambiguous, and floatables-control alternatives can depend upon the characteristics of the targeted and incidental material.

KEYWORDS

Floatables, CSO, combined sewers, storm sewers, litter, water pollution control, beach wash-ups

INTRODUCTION

The United States Environmental Protection Agency (EPA) has long identified combined-sewer overflows (CSOs) as potential stressors of receiving-water quality in and near urban areas (EPA, 1989; 1994). At the same time, EPA has recognized that the complexity and scale of CSO abatement issues present potentially significant economic burdens in affected communities. To support its CSO Control Policy (EPA 1994), EPA issued guidance (EPA 1995a, 1995b) mandating floatables control as one of the Nine Minimum Controls and as part of the Long Term Control Plan for CSO abatement. Regulatory agencies at the state, watershed, and local levels have also begun to focus on the control of floatables discharges from CSOs and from storm sewers.

Alternatives for floatables control typically include screening, netting, installation of in-line baffles, and vortex technology. Each of these alternatives takes advantage of some characteristic of the floatable items — usually size, buoyancy, and/or rise velocity — to remove the items. However, only limited information has been published that describes typical characteristics of floatables, either in bulk or individually. A knowledge of floatables characteristics would be particularly useful to evaluate and/or design an appropriate removal system. As municipalities face the issues of floatables control, they are typically uninformed about the characteristics of CSO or storm-sewer floatables and hence may not be well prepared to develop appropriate control measures. In an effort to provide a comprehensive database of information that can be used for the design of floatables-control measures, this paper presents the results of a variety of investigations into the characteristics of floatable litter in a number of urban areas.

The Floatables Problem

Floatables discharged to receiving waters create a variety of problems. Visible, floating material degrades the aesthetics of waterways and their shorelines, which in turn can contribute to loss of use (e.g. beach closings) and can have an adverse economic impact on recreation and business in the area. Debris slicks can represent a potential hazard to commercial and recreational boating. Cases are continually documented reporting death and injury to wildlife, from birds to endangered whales, that ingest or become entangled in floatable debris. When the floatable material contains items of an unsanitary or sensitive nature, such as syringes, condoms or feminine napkins, the impacts on public health and aesthetics are intensified.

The Floatables Process Train

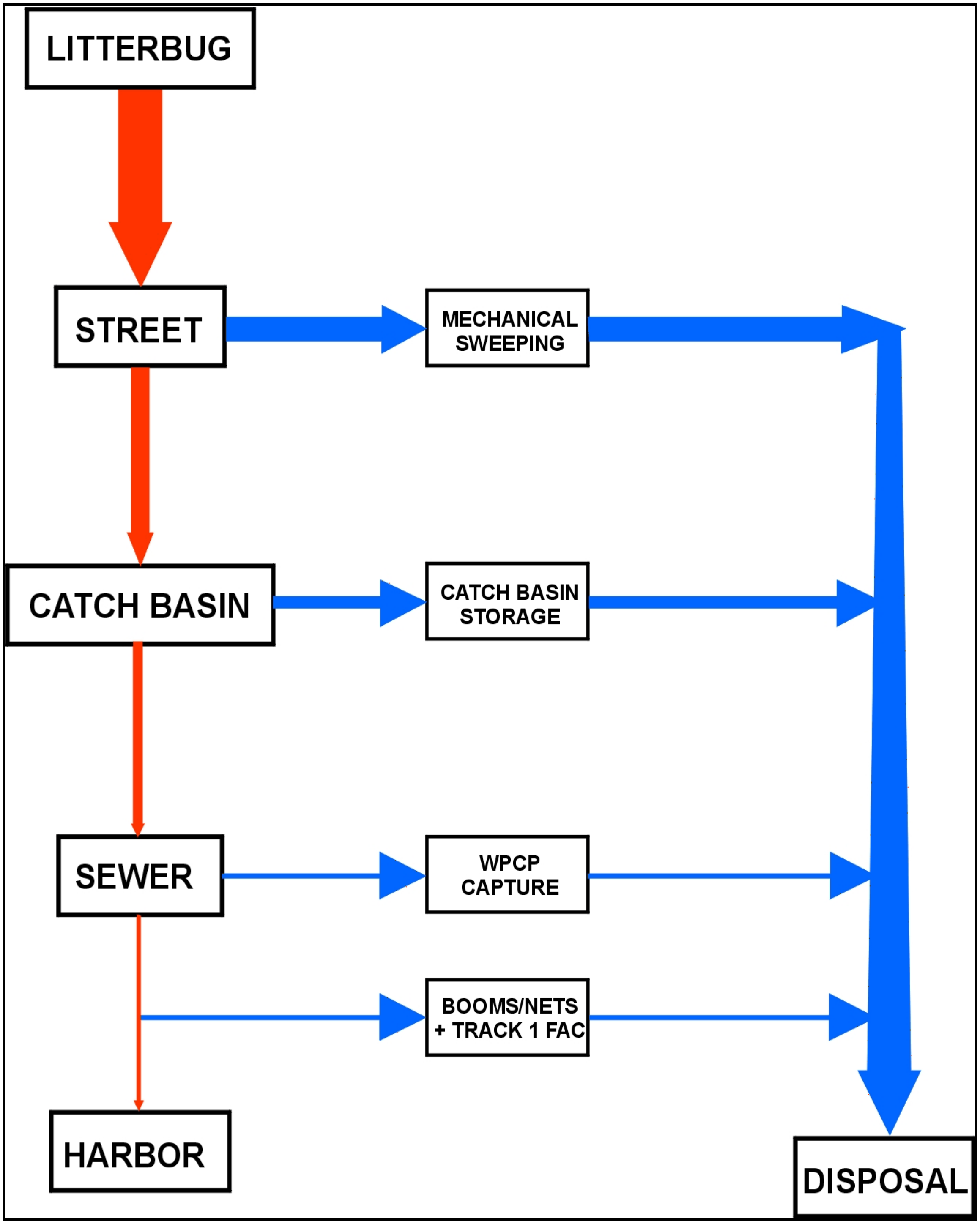
By the time floatables wash up along the shorelines, they have typically traveled a considerable distance. Studies performed in the City of New York (HydroQual, 1992) determined that about 95 percent of floatable litter items discharged from CSOs originated as street litter; the remaining 5 percent originates from sanitary sewage and includes personal hygiene items flushed down toilets. A floatable item deposited on a street or sidewalk and not removed by street sweeping will be washed into a catch basin during a rainfall event. If the item is not retained in the catch basin and removed when the catch basin is cleaned, the item will be washed into the sewer system. If the item is not conveyed to the water pollution control plant (WPCP), it will be discharged with CSO. Unless an end-of-pipe facility, such as a floatables-containment boom, captures the item before it reaches the open water, prevailing currents or winds can transport it downstream or onshore.

Because different floatable materials have different characteristics, some are captured at various points along this “process train” more readily than others, some degrade along the way, and others are more likely to reach the beach. Floatables-control devices may be selected to take advantage of the characteristics of the floatables at a particular point in this process train.

The Regulatory Perspective

Whereas regulatory criteria for chemical constituents are typically well defined and expressed with numeric concentrations, the narrative criteria typically employed for floatables can be more ambiguous. In the Nine Minimum Controls of its CSO Control Policy, EPA calls for control of “visible solid and floatable materials” in CSOs. Ostensibly, EPA’s intent was to address the aesthetics of the receiving water and, to a certain degree, the public health impacts of the targeted materials. The intent was not to eliminate harmless material, such as leaves and twigs. In point of fact, beach-cleanup efforts conducted by private environmental groups, such as the Center for Marine Conservation, do not include these “natural” items when they collect and characterize wash-up materials. Similarly, fecal matter is not typically observed in beach wash-ups (HydroQual, 1993).

Floatables Process Train (New York City)



Other regulatory agencies sometimes use different language or make additional distinctions to better define targeted pollutants. For example, New York State's Code of Rules and Regulations (NYCRR) presents narrative standards that distinguish between "suspended colloidal and settleable solids," "oil and floating substances," and "garbage and other refuse." New Jersey general permit language stipulates that "the discharge of solids/floatables which pass through a screen having openings of 1.3 cm (1/2 inch) is prohibited."

Although permits, as actually written, determine the regulatory requirements for individual discharges, guidance documents typically provide interpretation of the intent. Selection of a control alternative to meet applicable regulations may well depend upon which classes of pollutants are targeted for control. For example, screening devices may effectively control garbage, but will not control oils or settleable solids.

Defining the Nature of Floatables

This paper addresses the characteristics of floatables. However, the term "floatables" is ambiguous and can refer to a host of pollutants with vastly different characteristics that are discharged from CSOs and storm sewers. This section presents an overview of some of the different material classifications used to describe CSO pollutants, and then presents a working definition of floatables. Wherever possible, this paper applies consistent definitions for the various types of materials and classifications.

CSO discharges contain a wide array of pollutants in various forms that can be classified in a number of ways. Material can be classified as positively, neutrally, or negatively buoyant; liquid, colloidal, or solid; natural or anthroprogenic; organic or inorganic; rigid or deformable, visible or invisible, etc. Of course, there is considerable overlap between these classes, and more sub-classifications within each (such as size classification of solid materials).

The term "floatable materials" would appear to refer to any positively buoyant substance. However, in most contexts, "floatables" refers to positively and near-neutrally buoyant items. Indeed, whether an item actually floats has as much to do with the flow condition and physical shape of the item as the actual buoyancy of the item. In turbulent-flow environments, quite negatively buoyant items can be well mixed within the flow. In addition, some materials, such as porous paper, lose buoyancy over time as they absorb water. Where possible in this investigation, a distinction is made between items having a persistent buoyancy and those which are either immediately "sinkers" or become sinkers or degrade within a period of time on the order of hours to days in the water.

Furthermore, "floatables" typically refers to solid items rather than liquids or colloids. Separate regulatory criteria are typically applicable to floatable liquids or semi-solids, such as oil and grease. Fecal matter, which can range from nearly solid to nearly liquid, is highly deformable and not typically considered to be solid. The fact that fecal matter is rarely observed among beach wash-up materials supports this contention. Therefore, fecal matter is not considered "floatable pollution" in this investigation.

"Floatables" are also generally considered to be larger solids, rather than the smaller, suspended or settleable solids typically associated with the buildup of sediment mounds in receiving waters. Although discharge of these materials and the buildup of sediment mounds near CSO outfalls can be a water-quality problem, these smaller solids would be measured as part of "total suspended solids" or "settleable solids" tests and are hence regulated under those criteria. These smaller, settleable solids also typically require a different set of considerations for control than floatable materials. Moreover, floatables represent a visual pollution, and hence have a "detection limit" related to their size. EPA's guidance targets "visible" solids and floatable materials, but does not specify the distance from which the items must be visible. Other regulatory agencies associate an actual, minimum size. For example, New Jersey DEP targets solids larger than 0.5 inch for removal. Other regulators have specified minimum sizes as small as 0.2 inches (Allison).

Although material discharged from CSOs includes a significant amount of "natural" materials, such as leaves, twigs and other vegetation, these materials are not typically considered floatable pollution because they are not objectionable when found on beaches. In fact, beach-cleanup projects typically do not include these natural materials when they collect and characterize wash-up materials. Although large quantities of such material can accumulate and cause a nuisance in smaller, enclosed receiving waters, studies have shown that this material typically does not contribute significantly to the total stormwater nutrient load with respect to nitrogen and phosphorus (Allison). Because these natural materials are harmless and non-polluting, they are not considered to be floatable pollution. However, the amount of natural materials discharged can be significant, and collection and handling of this material must be considered when certain control alternatives are selected.

BEACH WASH-UPS

The accumulation of trash on beaches and along shorelines of impacted waterways is the most obvious impact of floatable pollution, and perhaps the primary reason that regulatory agencies have targeted floatable pollution for control. Understanding the nature of floatable pollution in beach wash-ups is instrumental in understanding what item types need to be controlled and how to best control the discharge of these items to the receiving waters.

Available Data

As part of this investigation, beach wash-up data have been compiled from a number of different sources. The largest historical database regarding beach wash-ups is maintained by the Center for Marine Conservation (CMC), which has coordinated beach cleanup projects in the United States and abroad each year since 1988. Additional studies of shoreline wash-ups have been conducted under the National Park Marine Debris Monitoring Program (National Park Service, 1991), the New Jersey Floatables Study (SAIC, 1987), and the New York City Floatables Study (HydroQual, 1993). Various other studies specifically related to wash-ups of medical waste and sanitary items (such as condoms and tampon applicators) have also been completed, but these do not document other types of trash/litter and hence are not considered herein.

The remainder of this section presents a summary of the characteristics of floatables as documented in studies of beach wash-ups. Considered parameters include overall shoreline concentration of wash-up floatables, wash-up material composition, size distribution of wash-up material, and most common items. Subsequent sections of this report will address similar parameters for different points in the "process train" to illustrate how the material composition changes.

Shoreline Concentration of Floatable Pollution

CMC reported 1998 data indicating that, for the United States as a whole, concentrations of floatables averaged about 89 lbs per 1,000 ft of shoreline, or about 154 items per 1,000 ft of shoreline. These statistics have varied year to year and from site to site. For example, CMC data reported for 1990 indicate that the US averaged about 137 lbs/1,000 ft or 219 items/1,000 ft. The National Park Marine Debris Monitoring Program reported a range of 140 items/1,000 ft to 330 items/1,000 ft, with an overall average of about 227 items/1,000 ft for shorelines along seven national parks during fall 1989 and summer 1990. Floatable concentrations averaging as high as 1,500 items per 1,000 ft have been reported in northern New Jersey. As part of New York City's Floatables Study, intensive weekly shoreline surveys, conducted during the summer of 1990 at 25 beaches of New York and New Jersey, found floatables concentrations ranging from 1 item/1,000 ft to 2,420 items/1,000 ft, and an overall average of about 152 items/1,000 ft.

Material Composition of Wash-Ups (Trash/Litter)

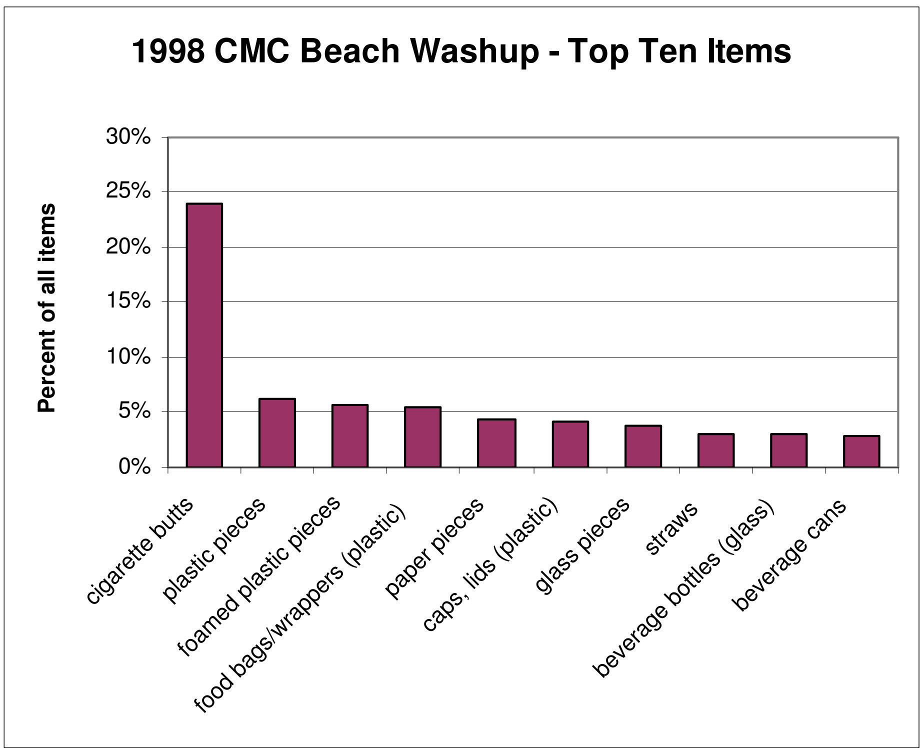
According to the CMC results reported for 1990, plastics represent the largest portion (64 percent on an item-count basis) of the trash/litter wash-up debris collected nationally. Items composed of foamed plastic, such as Styrofoam, represented about 13 percent of the total; cigarette butts (considered plastic in the study) represented 13 percent of the total; and items composed of other plastics (39 percent), metal (10 percent), glass (10 percent), paper (10 percent), lumber (3 percent), rubber (2 percent), and cloth (1 percent) rounded out the remainder.

Similar statistics are available from the shoreline surveys conducted in the summer of 1990 as part of New York City's Floatables Study, which also found plastic to represent the largest portion (78 percent on an item-count basis, including foamed plastic and cigarette butts in addition to other plastic pieces) of the trash/litter wash-ups. The material breakdown in this study was as follows (again on an item-count basis): foamed plastic (25 percent), other plastic pieces (42 percent), cigarette butts--considered paper in the study--(about 11 percent), other paper (8 percent), metal (6 percent), processed wood (5 percent), rubber (1 percent), glass (0.6 percent), cloth (0.6 percent), and miscellaneous (0.8 percent).

The results of the National Park Marine Debris Monitoring Program indicated that 90 percent of the wash-up trash was plastic (including foamed plastic); and the remainder was glass (4 percent), metal (2 percent), processed wood (2 percent), and miscellaneous (2 percent).

Most Common Wash-Up Items

The CMC results for 1998 show that the ten most-frequently occurring items comprised 62 percent of all items found on beaches. These items were cigarette butts (24 percent), plastic pieces (6.1 percent), foamed-plastic pieces (5.6 percent), plastic food bags/wrappers (5.4 percent), paper pieces (4.3 percent), plastic caps and lids (4.2 percent), glass pieces (3.9 percent), plastic straws (3.0 percent), glass beverage bottles (2.9 percent), metal beverage cans (2.8 percent), plastic beverage bottles (2.7 percent), and metal bottle caps (2.0 percent). The CMC results for 1990 were slightly different, with the top ten items comprising only 54 percent of all items found. These items were cigarette butts (12.6 percent), plastic pieces (6.8 percent), foamed plastic pieces (5.9 percent), paper pieces (4.7 percent), glass pieces (4.6 percent), plastic food bags/wrappers (4.23 percent), glass beverage bottles (4.0 percent), metal beverage cans (4.0 percent), and plastic caps and lids (3.9 percent).



The National Park Marine Debris Monitoring Program reported the ten most common items during 1988 and 1989 were foamed-plastic pieces (26.0 percent), hard plastic pieces (10.0 percent), plastic caps and lids (6.0 percent), rope (5.7 percent), plastic bags (5.2 percent), bottles of unspecified material (4.5 percent), plastic straws (4.0 percent), plastic sheeting (3.2 percent), rubber balloons (3.0 percent), and plastic food containers/utensils (1.2 percent).

Results of the New York City Floatables Study indicated that the top ten items, which comprised 75.6 percent of the total number of wash-up items in the summer of 1990, were foamed-plastic pieces (20.6 percent), cigarette butts (11.0 percent), plastic pieces (10.2 percent), plastic straws

(7.1 percent), paper pieces (6.7 percent), plastic candy wrappers (5.9 percent), processed-wood pieces (5.1 percent), plastic bag fragments (3.4 percent), metal foil wrappers/pieces (2.9 percent), and foamed-plastic cups (2.7 percent). This investigation also determined that glass fragments, which made up a high proportion (21 percent) of trash items found on some beaches, were not from wash-ups but rather from direct deposition to the beach. This determination was based on site-specific evidence, which indicated a significant difference in the preponderance of glass and glass fragments between beaches where there was direct pedestrian access versus other nearby beaches without such direct access. Other materials, such as tissue paper and newspaper, were also most likely deposited directly to the beaches and were not "wash-up" material, based upon the speed with which such materials would absorb water and sink and/or degrade.

Size Distribution of Wash-Up Materials

As part of the New York City Floatables Study, collected beach wash-up materials were passed through screens with successively smaller square openings of 4, 2, 1, and 0.5 inches on a side. Counts of items retained on each screen and the material composition of the retained items were then recorded. Note that items smaller than 0.5 inch were not collected from the beaches. Results of the analysis indicated that 94, 71, 43 and 0 percent of items passed through the 4, 2, 1, and 0.5 inch screens, respectively. These percentages would shift if items smaller than 0.5 inch had been collected.

With regard to material composition, the smaller items (those passing the 1 inch screen) were typically paper, while the larger items were typically plastic. Foamed plastic was most prevalently captured on the 1.0 inch rack. Plastic, foamed plastic, and paper accounted for about 30, 16 and 36 percent of items passing the 1 inch screen; 51, 20 and 6 percent of items passing the 2 inch screen; 53, 11 and 8 percent of items passing the 4 inch screen; and 58, 8 and 20 percent of items captured on the 4 inch screen.

Conclusions Regarding Wash-Up Materials

This section presented the characteristics of floatables that are observed to wash up on beaches and along shorelines of impacted water bodies. The types of materials found during beach cleanup projects are typically plastics and other "persistently floatable" items that do not sink or degrade when exposed to water for long periods of time. Natural materials (such as leaves and branches) and even anthroprogenic organic wastes (such as fecal matter and food items) are not typically observed in beach wash-ups and hence are not considered aspects of the floatable-pollution problem.

The specific types of items found in beach wash-ups varies somewhat around the country, and the CMC attempts to trace the source of these materials based on the general character and specific item types found. For example, Gulf states tend to exhibit floatables generated by the oil industry, southestern states show evidence of recreational fishing and boating wastes, and the northeast shows exhibits evidence of sewage-related sources. The New York City Floatables Study determined that, prior to the incorporation of the Nine Minimum Controls and other floatables-abatement measures, the majority of items washing up on area beaches originated from urban street litter washed into storm- and combined-sewer systems during rain events. The remaining sections of this report present the characteristics of floatables at the source (urban streets) and at the point of discharge (CSO and storm-sewer outfalls).

DISCHARGES FROM STORM SEWERS AND COMBINED-SEWER OVERFLOWS

According to the findings of the New York City Floatables Study, street litter represents the largest single source of trash in beach wash-ups in the New York / New Jersey area. Furthermore, of the items discharged from CSOs that contribute to beach wash-ups, roughly 95 percent originated as street litter. Therefore, it is probable that storm sewers in otherwise similar but separately sewered areas will discharge items similar to those discharged from CSOs, minus the sanitary items associated with sanitary sewage. Street litter also contains other material, notably porous paper items such as napkins and newspapers, that are not observed in significant quantities in shoreline wash-ups. This material, plus natural material such as leaves and twigs, and fecal matter (in the case of CSO discharges), will comprise the total bulk of the discharge. This other material, although not necessarily pertinent with respect to beach wash-ups, must be considered when specifying end-of-pipe control alternatives such as screening.

As the “end-of-pipe” point in the floatables process train from the street to the waterway, CSO/storm-sewer outfalls are of particular importance when characterizing floatables for purposes of control. Controls instituted at CSO/storm-sewer outfalls will encounter targeted floatables as well as other material. Knowledge of the characteristics of this bulk material and of the targeted floatables is useful when selecting either end-of-pipe or in-sewer control alternatives and will likely be important with respect to required materials handling and maintenance needs. Monitoring data obtained downstream of a floatables-control device might reflect significantly different characteristics; however, none of the studies cited herein featured such in-sewer controls.

Available Data

Several studies have been conducted to characterize the materials found in stormwater and CSO discharges. This section presents an overview of the characteristics of this material from a number of different urban areas. Studies cited in this investigation were performed in New York City and surrounding areas (HydroQual, 1992, 1993; SAIC, 1987, 1988); Newark, New Jersey (Parsons, 1995); Hartford, Connecticut (CDM, 1996); Montreal, Canada (Paradis, 1996 and Cigana, 1999); and Melbourne, Australia (Allison, 1998).

Loading of Materials in Stormwater and CSO Discharges

Storm- and combined-sewer systems drain rainfall runoff from urban areas that contribute both litter and natural materials (leaves and branches) to the discharge. In combined-sewer areas, sanitary sewage also contributes fecal matter and sanitary items, such as condoms and tampon applicators, that are flushed down toilets. The total amount of material discharged can vary significantly depending upon the degree to which the watershed is littered, how forested the watershed is and whether leaves and twigs are falling from trees, whether the area is combined, and whether the intensity of the rainfall is great enough to convey the material with the flow. Thus, factors such as season, antecedent dry-weather days, and upstream source controls can significantly affect the amount of material discharged.

On a weight basis, the total amount of solid material discharged from CSOs has been reported as 0.02 lbs per watershed acre per inch of rainfall (New York/New Jersey, SAIC 1988), 0.10 lb/ac/in (Jamaica Bay, New York; HydroQual, 1988), 0.21 lb/ac/in (Fresh Creek FBM, 1988-1990, HQI Task 6), 0.76 lbs/acre/in (Hartford), and 1.7 lb/ac/in (Newark).

On a volume basis, the total amount of solid material discharged from CSOs in New York City (based on yields from an ongoing program to retain floatables using a system of floating booms or mesh nets for 23 discharges draining approximately 57,000 acres) indicates that approximately 0.10 cubic feet of material is discharged per acre per inch of rainfall. Results of intensive sampling at one of these locations (the Fresh Creek FBM facility) between November 1988 and August 1990 indicate that collected material has a bulk density of about 23 lbs/cf (wet), so that the overall weight yield is approximately 2.3 lbs/ac/in. The same study determined that dried bulk density of the same samples as approximately 4.7 lbs per cubic ft, and that the number of items per cubic foot averaged 117 for the wet samples.

Preliminary information regarding wet bulk density of CSO material in the CS3, lower deck portion of the Bowery Bay WPCP indicates a value of about 20 lb/cf (wet), which tends to confirm the earlier bulk-density measurement of 23 lb/cf (wet). The Melbourne study, which looked at yields from storm sewers only, reported an overall density of the discharged mixture of natural and trash/litter materials was approximately 16 lb/cf (dry-weight basis). This density is considerably higher than the earlier 4.7 lb/cf (dry) value, and may therefore reflect a drained rather than dried basis.

Composition of Material Discharged from CSOs

As indicated above, CSOs contribute fecal matter and other organic wastes, natural materials, non-floatable trash/litter, and floatable trash/litter. This section addresses the relative predominance of these materials in various urban areas.

Predominance of Fecal Matter

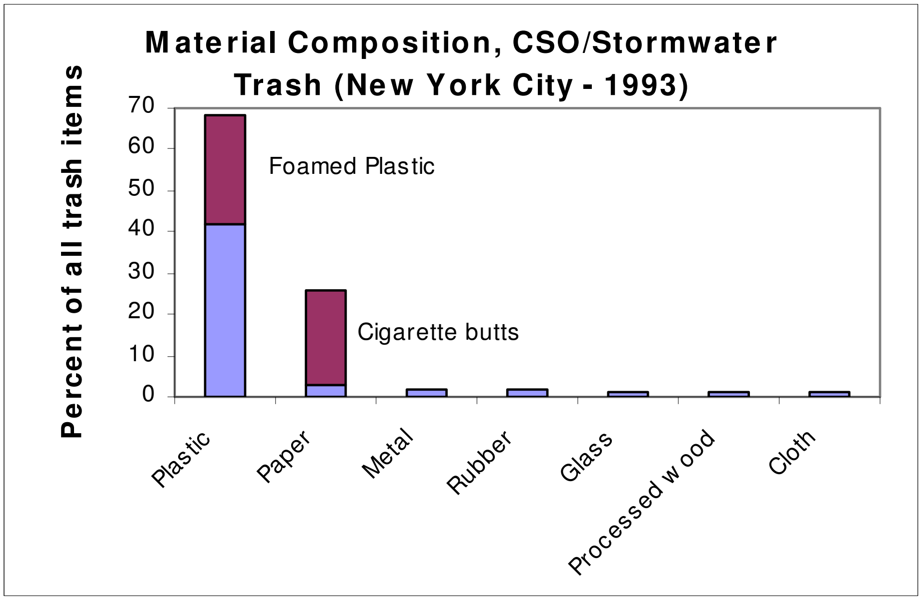
The principal difference in the material discharged from storm sewers versus CSOs is the presence of fecal matter and sanitary items. As demonstrated below, sanitary items comprise a small percentage of the materials. However, fecal matter can represent a significant portion. The SAIC study reported that approximately 69 percent (weight basis) of the discharged material was fecal in origin. The Montreal study qualitatively evaluated the surface area occupied by the discharged material as it had accumulated behind a floating boom used for sampling, and reported that approximately 30 percent of the area was occupied by fecal matter (8 percent) and sewer fat and grease (22 percent). Most other studies did not quantify the fecal matter, but based characterizations on the remainder.

Predominance of Natural Materials (Leaves, Branches and Twigs)
The available data show a wide range for the natural, vegetative portion of the non-fecal material discharged from CSOs. An SAIC study (1988) reported that about 78 percent of the material discharged from CSOs consisted primarily of natural, vegetative matter (i.e. leaves and twigs). The Newark study found that, of the non-fecal matter, approximately 73 percent (weight basis) or about 45 percent (volume basis) was natural, vegetative matter. The Hartford study reported that 95 percent (weight basis) was natural matter. Another study (HydroQual, 1989) of a single CSO outfall (Bergen Basin, New York City) showed that natural matter comprised less than 22 percent (item-count basis) of the non-fecal matter. The Montreal study showed that vegetative matter (including both natural material and food scraps) comprised about 36 percent (item-count basis) or about 50 percent (surface-area basis, as observed behind the sampling boom) of the non-fecal material. The Melbourne study, which monitored stormwater areas, reported that approximately 70 percent of the material (dry-weight basis) was natural vegetation.

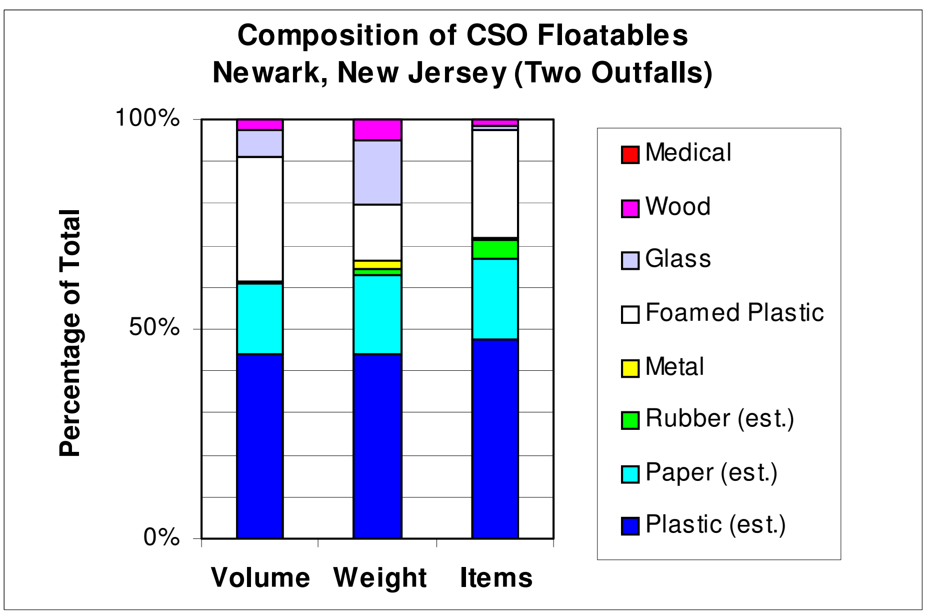
Rigidity of Discharged Items
The Montreal study reported additional characteristics for the material discharged from CSOs (not including fecal matter or grease). In an effort to determine required bar-screen spacing, the study characterized 44 percent (item-count basis) of the collected items as being rigid, and the remainder as being deformable. This characterization reflects the presence of natural items such as leaves and branches, and hence is applicable to the bulk of material discharged. The other studies did not characterize items according to rigidity, although this information can be inferred for the litter/trash portion, based on characterizations of item types, as discussed below.

Composition of CSO Trash/Litter
Most studies report the composition of the trash portion of the discharged material. This is in part because fecal and grease-related materials are not typically found on beaches, and natural, vegetative materials are not considered. As shown below, plastics consistently dominate the composition of the trash portion of the discharged material.

Several studies have reported on the composition of trash/litter discharged from New York City area CSOs. The SAIC study (1988) reported that plastics comprised approximately 64 percent (weight basis) of the discharged trash, with paper and rubber each accounting for about half of the remainder. A subsequent study (HydroQual, 1989) found that plastic (including foamed plastic) comprised at least 82 percent (item-count basis, including foamed-plastic at 16 percent) with paper comprising another 12 percent of the trash items. Results of sampling performed from 19 CSO/storm-sewer sampling sites as part of the New York City Floatables Study found that the discharged trash was comprised of plastics (68 percent, item-count basis, including 26 percent from foamed-plastic only), paper (26 percent, including about 23 percent from cigarette butts), metal (2 percent), rubber (2 percent), glass (1 percent), and processed wood and cloth (each less than 1 percent).



The Newark study characterized the trash collected from two CSOs on a volume basis, weight basis, and item-count basis for plastics (73, 58 and 72 percent, including foamed plastics at 30, 14 and 31 percent), paper (17, 19 and 19 percent), glass (6, 15 and 1 percent), processed wood (3, 5 and 2 percent), rubber (0, 2 and 5 percent), and medical (0, 0 and 1 percent). Note that these proportions are relatively consistent regardless of basis, except for foamed plastic (which was much lower on a weight basis) and glass (which was much higher on a weight basis).



The Hartford study characterized trash collected from three CSO sites on a weight basis, item-count basis, and surface-area basis for plastics (49, 52 and 67 percent, including foamed plastics at 6, 12 and 7 percent), paper (14, 23 and 11 percent, including cigarette butts at 5, 13 and 1percent), metal (7, 11 and 12 percent), rubber (1, 1 and 1 percent), glass (7, 0 and 0 percent), processed wood (2, 0 and 0 percent), "sensitive" items (7, 3 and 4 percent, including syringes, bandages, condoms, tampon applicators, feminine napkins, diaphragms, crack vials, and drug bags), and miscellaneous items (14, 11 and 4 percent, including shoes, orange peels, etc.).

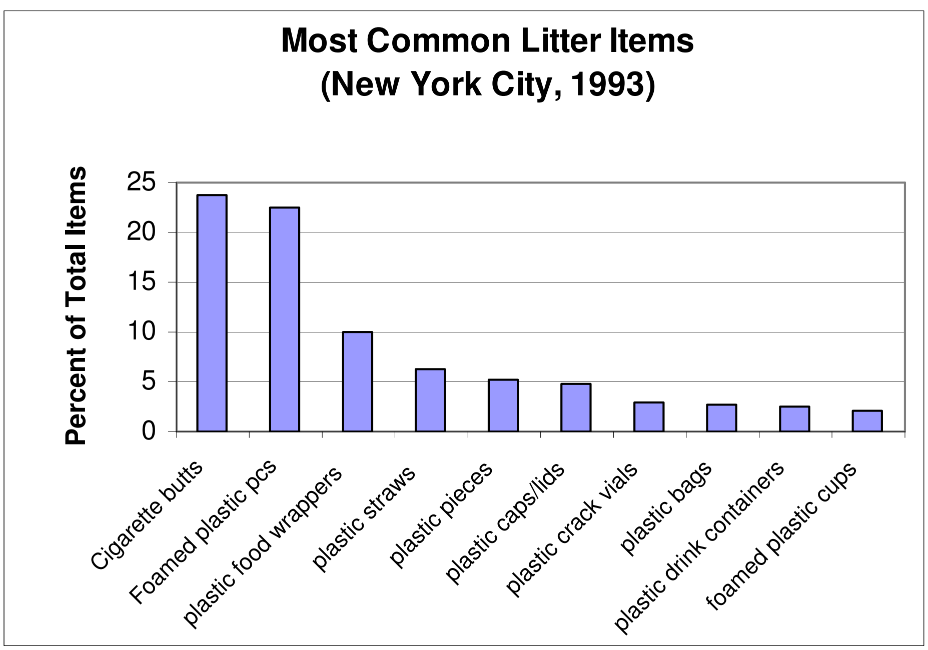
The Montreal study reported CSO trash composition on an item-count basis and an in-situ surface-area basis for plastics (22 and 29 percent), paper (50 and 18 percent, nearly all cigarette butts), wood/cardboard (8 and 8 percent), sensitive items (14 and 24 percent, including cotton swabs, bandages, condoms, tampon applicators, feminine napkins, etc.), metal (<6 and 10 percent), and other (<6 and 10 percent, including polystyrene, miscellaneous material, and for the item count basis only, metal).

The Melbourne study reports stormwater trash composition on an item-count basis for plastics (29 percent, including 3 percent foamed plastic), paper (57 percent, including 23 percent for cigarette butts), metal (12 percent), glass (less than 1 percent), and other (1 percent). It is notable that much of the litter was related to cigarettes and associated products, and also that the incidence of porous paper items, such as newpaper and flyers, was not seen in the other studies.

Most Common Item Types (CSO Trash/Litter)

The most common types of trash/litter items discharged from CSOs vary somewhat from location to location. However, cigarette butts are consistently among the most prevalent items, accounting for up to half of the items in one area.

The New York City Floatables Study enumerated specific item types, and reported the ten most common items, which comprised 84 percent of all items found, were cigarette butts (24 percent), foamed-plastic pieces (23 percent), plastic candy/food wrappers (10 percent), plastic straws (6 percent), plastic pieces (5 percent), plastic caps/lids (5 percent), crack vials (3 percent), plastic bags (3 percent), plastic drink containers (2 percent), and polystyrene cups (2 percent).



Data collected as part of the Newark study found the most frequently occurring items were plastic and paper bags (38 percent), foamed-plastic pieces (25 percent), plastic straws (11 percent), plastic bottles (11 percent), other plastic and rubber (9 percent), glass bottles (1 percent), medical items (1 percent), and cans (less than 1 percent).

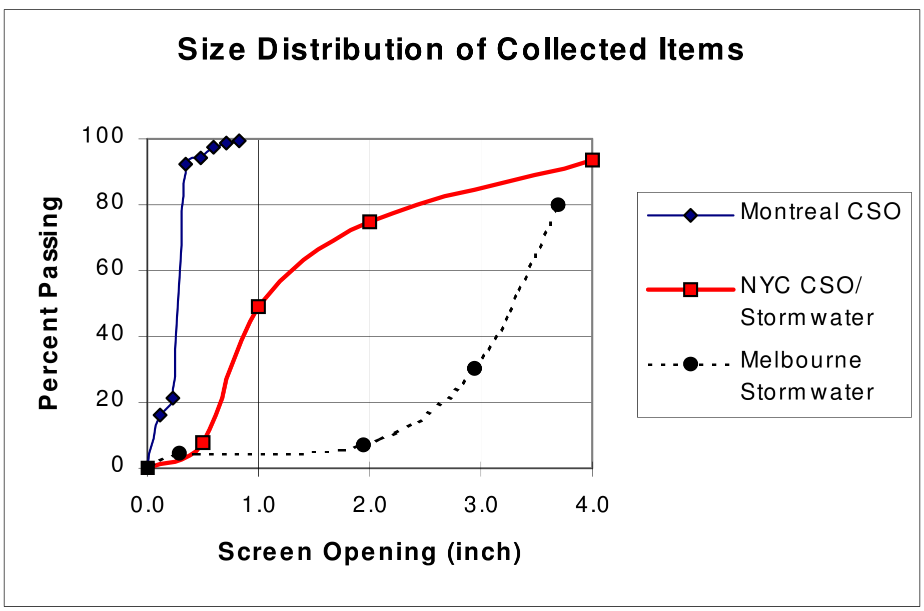
Specific item types were not available from either the Hartford or the Montreal studies. However, both studies showed cigarette butts as a separate class of material that was highly prevalent (13 percent of all items in Hartford and over half of items in Montreal). On a surface-area basis, cigarette butts were somewhat less important (1 percent of total in Hartford, 18 percent of total in Montreal). Cigarette butts were approximately 5 percent of the total trash/litter weight in Hartford.

The Melbourne study listed a total of 20 litter-item types, of which the most common were cigarette butts (23 percent), paper pieces (19 percent), plastic food wrappers (10 percent), paper food wrappers (9 percent), plastic cigarette wrappers (8 percent), metal foil (8 percent), plastic pieces (6 percent), metal cans (4 percent), foamed-plastic pieces (2 percent), and paper mailing items (2 percent).

Size Distribution of Discharged Items (Trash/Litter Only)

A few studies further characterized discharged trash items according to size. However, results of these studies vary and indicate that size distribution may vary by location.

The New York City Floatables Study performed size characterizations on material collected from 6 CSO/storm-sewer sites in 1990. Approximately 7, 49, 75, and 94 percent of the discharged trash items passed screens with square openings of 0.5, 1, 2, and 4 inches on a side. Paper was the prevalent among smaller items, accounting for over half of the material passing the 0.5 inch and 1.0 inch screens. The remainder of the smaller items were split evenly between plastic and foamed-plastic pieces. Of the larger items (those retained on 1, 2 and 4 inch screens), plastic pieces accounted for about 50 percent, polystyrene pieces accounted for about 35 percent, and other materials made up the remaining 15 percent.



The Montreal study also characterized the size distribution of rigid elements discharged by two

CSOs. Approximately 16, 21, 92, 94, 97.5, 98.5, and 99.5 percent of items had critical dimensions less than 0.12, 0.24, 0.35, 0.47, 0.59, 0.71, and 0.83 inches, respectively (and hence would pass through screens with these spacings). However, it is not clear whether these statistics include leaves and twigs, which would skew the results of an analysis of trash only. The Montreal items appear to be smaller as a whole than the New York items.

The Melbourne study reported size distributions for litter from its stormwater outfalls as follows: approximately 4, 7, 30, and 80 percent of items passed screens with spacings of 0.47, 0.79, 2.68, and 4.80 inches, respectively. These items appear to be larger than those collected in New York.

Floatability of Discharged Items (Trash/Litter Only)

As mentioned previously, whether an item floats has as much to do with the flow conditions and shape of the item as it does the buoyancy of the item. Items that sink in still-water conditions may behave like floatables in flowing conditions. Buoyant items may have shapes that slow their rise velocities and make them behave like neutrally buoyant items. Furthermore, some items such as porous paper tend to absorb water and lose buoyancy or degrade over time. For this reason, most studies did not characterize collected items as floatable or non-floatable. However, most plastics (particularly foamed plastic) and non-porous paper (such as that used for milk cartons) are persistently floatable. Based on material descriptions provided in other studies, it is possible to estimate the “persistently floatable” fraction of the trash material.

The New York City Floatabes Study described all of the trash/litter material discharged in CSO/stormwater as being floatable, with the exception of toilet paper and other porous paper that was found in an already highly degraded condition. In contrast, the Melbourne study characterized about 20 percent of the litter collected from sampled storm sewers as being floatable. This corresponds to about two-thirds of the plastic portion of the litter. The difference between the fractions of material considered floatable in these two studies is probably due more to the interpretation of the term than the difference in the material itself.

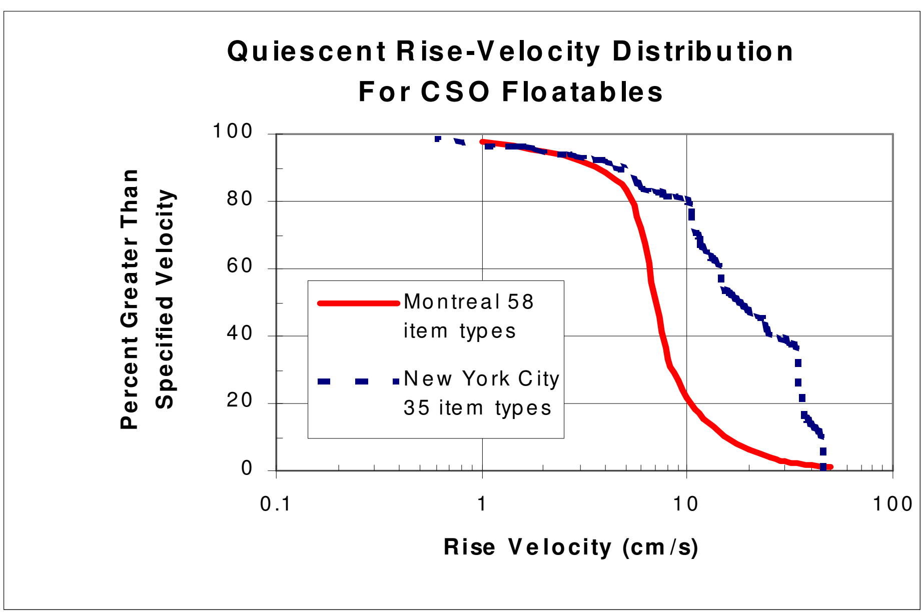
Rise Velocity of Discharged Items (Trash/Litter Only)

To further define the floatability characteristics of trash/litter discharged from CSOs and stormwater, two studies measured rise velocities of items. Results of these rise-velocity tests could be instrumental in analysis of potential floatable-removal efficiencies of such devices as stilling chambers, baffles, and vortex units, among others. Results of these tests are described below.

As part of unpublished work completed as part of the New York City Floatables Study, rise velocities of about 40 common items were measured in a quiescent “settling column” measuring 8 ft high and 0.67 ft in diameter. Items were released from the bottom of the column and timed as they rose a given distance through the column. Using the rise-velocity measurements for each item and weighting by the relative prevalence of the item in CSO/stormwater discharges, a probability distribution was developed for rise velocities of CSO/stormwater floatables (trash/litter material only). According to this distribution, approximately 97, 89, 83, 80, 47, 39,12 and 0 percent of items have rise velocities of at least 1, 5, 7, 10, 20, 30, 40 and 50 cm/s, respectively.

The Montreal study also measured rise velocities of floatable trash/litter items from CSOs. This study also employed a column for testing, but this column was about 5 ft high, with a 0.5 ft square section. Rather than releasing items from the bottom, the entire column was pivoted upside-down for the tests, which were performed on 51items selected to represent those found in the CSO discharge. Results of these tests were used to develop a rise-velocity distribution representative of the floatable CSO materials. According to this distribution, approximately 98, 84, 51, 22, 6, 3, 2, and 0 percent of items have rise velocities of at least 1, 5, 7, 10, 20, 30, 40 and 50 cm/s, respectively. To verify the accuracy of the column tests, additional tests were performed in a deep basin, where wall effects and other interfering factors were minimized. Rise-velocity results did not significantly differ between the two methods for most items.

The results of the rise-velocity tests conducted in New York City and in Montreal are significantly different. This is explained, in part, by the different composition of material used in the tests, which reflect the different composition of material discharged from the CSOs. The New York data reflect a higher prevalence of foamed plastic (e.g. Styrofoam) and other buoyant materials than the Montreal data, which reflect a predominance of cigarette butts, which have a low rise velocity when wet.



Conclusions Regarding Materials Discharged from CSOs/Storm Sewers

Although many of the persistently floatable trash/litter items responsible for much of the beach wash-up problem are discharged from CSOs and storm sewers, these items do not typically represent the bulk of material discharged from these sources. Fecal matter and natural vegetative materials can account for well over half of the material. As a result, floatables-control alternatives such as screening will require consideration of this material with respect to capacity and maintenance. Floatables-control alternatives that can take advantage of the characteristics unique to the targeted materials may therefore offer advantages. For example, alternatives that effectively capture items with higher rise velocities (such as in-line baffles or vortex concentrators) may help to remove targeted materials while allowing other materials to pass.

LITTER AND FLOATABLES ON STREETS AND SIDEWALKS

An early phase of the New York City Floatables Study (HydroQual, 1992) determined that street litter was shown to be the primary source of floatable trash/litter in beach wash-ups and in CSO discharges. Subsequent phases focused on street litter characteristics and methods to reduce the amount of litter finding its way into the sewer system (HydroQual, 1995). The effectiveness of some control methods are directly dependent upon characteristics of the litter. For example, reduction of spacing on catch basin grate openings can preclude larger-sized items, such as cans and bottles, from entering the sewer system. In addition, an understanding of how best to control the floatables problem may derive from an analysis of the material at its source.

Available Data

Studies conducted in the City of New York comprise the bulk of the information cited herein. Street litter surveys conducted by the New York City Department of Sanitation (Weiner, 1985 and Miller, 1986) first reported the composition of litter on New York City streets. The New York City Floatables Study subsequently conducted intensive surveys on approximately 100 blockfaces throughout the city. Results of these surveys provided a significant database of information to describe litter loading rates, typical litter concentrations along streets and sidewalks, litter composition, and other information (HydroQual, 1995). Anecdotal information is also available from the studies conducted in Newark (Parsons, 1995).

Concentration of Litter on Streets and Sidewalks

Analyses performed as part of the New York City Floatables Study found that street litter is concentrated within a zone along the curb extending 18 inches into the street. Very little litter was found on the streets beyond this zone. The overall average concentration of litter along New York City streets was, per 100 ft of curb, 54.5 items occupying a total surface area of 1.78 square feet and weighing 0.46 pounds. Removing non-floatable items, including porous paper items such as newspaper and napkins as well as items such as broken glass, "floatable litter" accounted for about 29 percent of the total items, 42 percent of the total surface area, and 37 percent of the total weight.

The overall concentration of litter along New York City sidewalks (from the curbline to the building line) was generally about twice as high as on the streets. Per 100 ft of sidewalk, the study found an average of 108 items occupying a total surface area of 3.61 square feet and weighing 0.99 pounds. The floatable-litter portion was roughly the same as on streets, at 29 percent of the items, 40 percent of the surface area, and 44 percent of the weight.

The study also analyzed the effect of land-use category on litter concentration. The findings of the analysis were that land-use class alone was not a valid indicator of litter concentrations. However, it was noted that commercial areas with privatized street-cleaning operations were consistently cleaner than other areas.

Material Composition of Street Litter

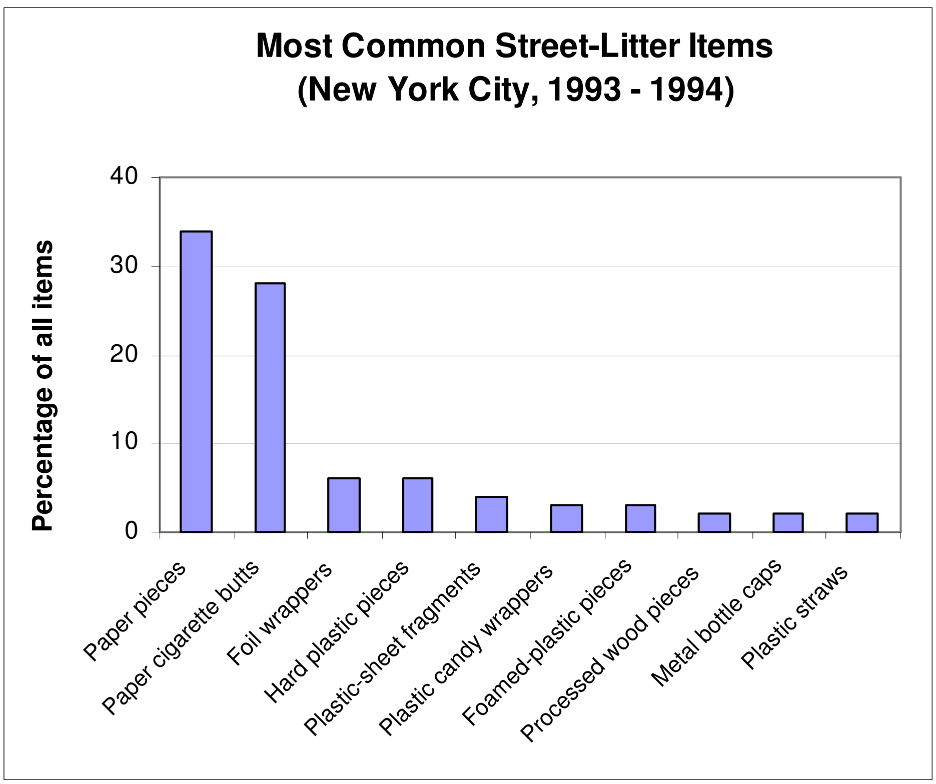
Early analyses of street litter conducted by the New York City Department of Sanitation involved surveys of item types found on a number of streets and sidewalks. Results of the surveys indicated that the material composition of street and sidewalk litter was, on an item-count basis: paper (55 percent), plastic (25 percent), metal (9 percent), broken glass (2 percent), and other materials (10 percent). After removing nonfloatable items such as porous paper(which absorbs water and degrades) and broken glass, the material composition would be plastic (51 percent), metal (17 percent), paper (14 percent), and miscellaneous (17 percent).

The more comprehensive surveys conducted in 1993 and 1994 indicated that the composition of floatable street litter on item-count, surface-area, weight, and volume bases were plastic (57, 64, 44, 56 percent), metal/foil (19, 12, 12, and 8 percent), waxed/coated paper (6, 7, 4, and 5 percent), processed wood (6, 3, 5, and 3 percent), foamed plastic (5, 4, 1, and 8 percent), cloth (2, 7, 12, and 6 percent), sensitive items (2, <1, <1, and <1 percent, including condoms, bandages, feminine napkins, syringes, etc.), rubber (1, 1, 1, and <1 percent), glass (<1, 1, 16, and 13 percent), and miscellaneous (1, 1, 4, and 1 percent). Note that these statistics do not include porous-paper items, such as cigarette butts, napkins, newspaper, paper bags, etc., which were considered nonfloatable because of their tendency to absorb water and degrade. Materials found on sidewalks were generally similar, with the notable exception of the weight percentages for glass (more prevalent on sidewalks, with 49 percent of the total floatable-litter weight), metal/foil (less prevalent on sidewalks, with 5 percent of the total floatable-litter weight), and plastic (less prevalent on sidewalks, with 23 percent of the total floatable-litter weight).

Most Common Item Types (Trash/Litter Only)

The 1985/1986 New York City litter surveys found only slight differences between the prevalence of items on the streets versus on the sidewalks. Results of the 1986 surveys shows that the top-ten most prevalent items found on the streets were plastic candy wrappers (15 percent), paper napkins/tissues (10 percent), paper pieces (10 percent), metal beverage cans (9 percent), paper cups (8 percent), paper bags (8 percent), paper cigarette-related items (8 percent), plastic straws (5 percent), paper food wrappers (4 percent), and plastic lids for cups (4 percent). The top ten items found on sidewalks were plastic candy wrappers (18 percent), paper pieces (18 percent), metal beverage cans (9 percent), paper bags (8 percent), paper cigarette-related items (7 percent), paper napkins/tissues (6 percent), paper cups (6 percent), paper food wrappers (5 percent), paper cartons (3 percent), and newspaper (3 percent).

The results of the 1993/1994 street litter surveys conducted as part of the New York City Floatables Study found a greater skew toward a few frequently occurring items. The top-ten litter items, including non-floatable items, found on the streets were paper pieces (34 percent), paper cigarette butts (28 percent), foil wrappers (6 percent), hard plastic pieces (6 percent), plastic-sheet fragments (4 percent), plastic candy wrappers (3 percent), foamed-plastic pieces (3 percent), processed wood pieces (2 percent), metal bottle caps (2 percent), and plastic straws (2 percent). All these items were also most common on the sidewalks, with the exception of foamed-plastic pieces. The top-ten floatable and non-floatable litter items found on the sidewalks were paper pieces (40 percent), paper cigarette butts (20 percent), foil wrappers (6 percent), plastic-sheet fragments (6 percent), hard plastic pieces (5 percent), plastic candy wrappers (3 percent), metal bottle caps (3 percent), plastic straws (2 percent), hard metal pieces (2 percent).



Bulk Density of Street and Sidewalk Floatable Litter Items

Laboratory analyses of collected street and sidewalk floatable litter items included a determination of the dry, loose-packed bulk density of each material type. The determination was made by accumulating each material type into a 20-gallon bin and weighing the bin when full. The resulting densities were glass (14 lb/cf), rubber (10 lb/cf), cloth (8 lb/cf), processed wood (8 lb/cf), metal/foil (4 lb/cf), plastic (2.5 lb/cf), coated paper (2 lb/cf), foamed plastic (0.5

lb/cf), and miscellaneous (10 lb/cf). The overall average density was approximately 4.5 lbs/cf. These materials do not include porous paper and hence are not anticipated to become waterlogged. Their densities are expected to remain relatively constant throughout their journey from the streets to the beaches.

Size Distribution of Street and Sidewalk Floatable Litter Items

Although individual size distributions were not tallied in this study, an idea of the overall mean size of items is indicated by dividing the total surface area of items by the total number of items. In this manner, the overall mean item size was determined to be about 6 square inches, or about 2.5 inches on a side. Size distributions by material composition were computed to be 7 square inches for plastics, 4 square inches for metal, 8 square inches for paper, 3 square inches for processed wood, 4 square inches for foamed plastic, and 18 square inches for cloth. These statistics do not include estimates of sizes for porous paper pieces, which together with cigarette butts represent the most prevalent items found on streets and sidewalks. However, these items are typically quite small and would fit through relatively small screen spacings. Cigarette butts, which comprise about a third of all street litter items, measure approximately 0.25 inches square (0.3 inches by 0.9 inches) and would tend to pass through screen spacings as low as 3/8 inch.

Conclusions Regarding Street and Sidewalk Litter

Although nearly all of the persistent floatable items found in CSO and storm-sewer discharges originate from street litter, most of the trash/litter items found on streets and sidewalks are not of a persistent floatable nature. In fact, over 60 percent of street and sidewalk litter items are comprised of porous paper and will degrade shortly after exposed to water. Furthermore, these items are relatively small and many would pass through screen openings of down to about 3/8 inch. Plastics, including foamed plastics (Styrofoam) comprise most of the remaining litter, and this is the portion that represent the floatables problem in beach wash-ups. Many of these items are also relatively small in size, although the mean size of the plastic items is roughly 7 square inches and the mean size of foamed plastic pieces is about 4 square inches.

SUMMARY

This paper is intended as a reference document to provide basic information about the characteristics of floatables as they pertain to beach wash-ups, discharges from CSOs and storm sewers, and litter on streets and sidewalks. Beach wash-up data were compiled from studies conducted nationally, while CSO/storm-sewer data were compiled from a number of studies conducted in New York City and surrounding areas; Newark, New Jersey; Hartford, Connecticut; Montreal, Canada; and Melbourne, Australia. Street and sidewalk data were compiled primarily from studies conducted in New York City.

Floatables are herein defined as solid trash/litter items which may be transported through water courses via the action of currents and winds and which may accumulate along waterways and on beaches in the form of wash-ups. While not characteristically “sinkers” in water, floatables may be positively buoyant or close to neutrally buoyant. Other materials, such as leaves and branches, oil and grease, and fecal matter are not considered floatables in this context, primarily because they do not generally represent a problem in shoreline wash-ups. Similarly, porous paper items, such as cigarette butts, tissues and napkins, quickly absorb water and either sink or degrade. Although these items are considered trash/litter, they are not considered to be floatable materials. Specific characteristics of floatables, as well as other related materials found on streets and sidewalks and in storm- and combined-sewer discharges, are presented herein.

The data presented in the paper may help to provide a basis for the design or performance evaluation for various floatables-control devices. Because the floatables characterizations were measured at various points along the floatables pathways (from street litter, to catch basins, to sewer-system outfalls, to the open water, and finally to beach wash-ups) and because these measurements were performed in a number of different urban environments, the data may be selected or interpreted for a number of various applications. In all cases, monitoring was performed prior to implementation of floatables controls such as those specified in EPA's Nine Minimum Controls. When considering additional controls downstream of other controls, the characteristics of floatables and other materials may be significantly different than described herein, due to the action of the upstream control devices.

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