STORMWATER PROGRAM

California State University, Sacramento
University of California, Davis (UCD)
California Department of Transportation (Caltrans)

RESULTS OF THE CALTRANS LITTER MANAGEMENT PILOT STUDY

Presented at:

Transportation Research Record 1743, Transportation Research Board, National Research Council, Washington, D.C., 2001

Authors:

Gary Lippner, Caltrans/CSUS Storm Water Program
John Johnston, Caltrans/CSUS Department of Engineering
Suzanne Combs, Caltrans/CSUS Storm Water Program
Kimberly Walter, URS, San Diego, California
David Marx, URS, San Diego, California

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Gary Lippner, P.E.
Office of Water Programs
California State University
Sacramento, CA 95819
Phone: (916) 278-8115
FAX: (916) 278-8140
E-mail: gary.lippner@owp.csus.edu

John Johnston, Ph.D., P.E.
Depart ment of Civil Engineering
California State University
Sacramento, CA 95819
Phone: (916) 278-8113
FAX: (916) 278-8140
E-mail: johnston@ecs.csus.edu

Suzanne Combs
Office of Water Programs
California State University
Sacramento, CA 95819
Phone: (916) 278-8102
FAX: (916) 278-8140
E-mail: suzanne.combs@owp.csus.edu

Kimberly Walter, P.E.
URS Sunroad Plaza 3, Suite 1000
1615 Murray Canyon Road
San Diego, CA 92108
Phone: (619) 683-6175
FAX: (619) 293-7920
E-mail: Kim_Walter@urscorp.com

David Marx
URS Sunroad Plaza 3, Suite 1000
1615 Murray Canyon Road
San Diego, CA 92108
Phone: (619) 683-6112
FAX: (619) 293-7920
E-mail: David_Marx@urscorp.com

ABSTRACT:

Litter is receiving increasing attention as a water pollutant, especially near Southern California beaches. To investigate the characteristics of litter in freeway storm water and the effectiveness of various Best Management Practices (BMPs), the California Department of Transportation (Caltrans) conducted a two-year Litter Management Pilot Study in the Los Angeles area. New litter sampling and monitoring protocols were devised to characterize litter and test BMP effectiveness. Twenty-four freeway catchments were monitored. Half the catchments were treated with one of five BMPs; the others were controls. The BMPs tested were: (1) increased street sweeping frequency, (2) increased frequency of manual litter pickup, (3) a modified drain inlet, (4) a bicycle grate and (5) a Litter Inlet Deflector developed during the study. Litter discharges were quantified by weight, volume, and count and further classified into 11 material types. About half of freeway storm water litter was found to consist of paper, plastic, or styrofoam. With the exception of cigarette butts, the origins of most of the litter items could not be identified due to their small size. Of the five BMPs tested, only increased litter pick-up and the modified drain inlet demonstrated some apparent reduction of litter, though the data are highly variable. Increasing the frequency of sweeping, the bicycle grate and the Litter Inlet Deflector did not reduce litter effectively in storm water discharges monitored during this study.

INTRODUCTION

Historically, litter in waterways has been managed from a solid waste perspective. In California today, litter is increasingly being viewed as a water pollution concern. Litter can disturb physical habitat, attract pests and vermin, cause animal deaths and interfere with boating. Litter affects various beneficial uses in receiving water bodies such as non-contact recreation and wildlife habitat. Litter cluttering the beaches and clogging the harbors of Southern California has brought this issue to the attention of regulators and the general public.

Unfortunately, information regarding litter characteristics, transport mechanisms, loading rates, and the effectiveness of various litter removal techniques is very limited. Even a standard definition of litter in water bodies has yet to be widely accepted.

To gain a better understanding of these issues, the Californ ia Department of Transportation (Caltrans) carried out the Litter Management Pilot Study (LMPS) during 1998 through 2000. The purpose of the LMPS was to identify and measure the effectiveness of Best Management Practices (BMPs) intended to reduce the water pollution impacts of litter (1). To achieve this goal, LMPS had to accomplish five tasks: (a) select an operational definition of litter; (b) develop sampling and monitoring protocols; (c) establish appropriate characterization parameters; (d) devise a means of measuring BMP effectiveness and (e) collect and analyze field data. This paper summarizes the two-year pilot study performed in the Los Angeles region.

DEFINITION, MONITORING AND CHARACTERIZATION OF LITTER

For the LMPS, litter was defined as manufactured material larger than 6.35 mm (0.25 inch). This definition included items made of paper, plastic, cardboard, glass and metal. It did not include materials of natural origin such as soil, gravel, and vegetative debris.

To capture the litter dis charging from Caltrans facilities 6.35-mm (0.25-inch) mesh bags were installed at the outlets of drainage systems. The bags were attached with breakaway collars to prevent clogging and consequent flooding of the roadway. A typical example is shown in Figure 1. After each storm event, the bags were collected and taken to the litter laboratory where the litter was then separated from the vegetation by hand, divided into categories and weighed. After air-drying on open racks for 24 hours, the litter was we ighed again. Then its volume was measured and each piece was counted. The floatable fraction was determined by placing the air-dried litter into large containers of water. After 30 seconds of manual stirring, the floating material was collected and its volume was measured.

All of the litter collected during the course of the study was separated into the following eleven composition-based categories:

- Paper
- Cardboard/chipboard
- Moldable plastic
- Plastic film
- Styrofoam
- Wood debris
- Metal
- Glass
- Cloth
- Cigarette butts
- Other

Each piece of litter was also categorized by its probable original use – "food-related", "smokingrelated" and "other". Each litter category was quantified by air-dried weight, volume, and count.

DESCRIPTION OF BMPS EVALUATED

Five BMPs were tested in the LMPS. Two involved non-structural changes in existing management practices and three required structural modifications of the freeway drainage system. These BMPs were selected after an extensive literature search, consultation with a technical advisory group, and discussions with other interested parties. Selections were based on expected performance and compatibility with existing Caltrans drainage systems and maintenance practices.

Street Sweeping Frequency

The effectiveness of street sweeping was investigated using mechanical broom sweepers similar to those currently used by Caltrans. In treatment areas, street sweeping was done weekly. In control areas, sweeping was done monthly, to simulate typical Caltrans practice. In both cases, sweepers were operated at the manufacturers' recommended speed of 8 kilometers per hour (5 miles per hour). Other parameters such as broom strike and coning also followed manufacturers' recommendations.

Litter Pick-up Frequency

At treatment sites, litter in the right-of-way was manually picked up weekly . At control sites, litter was picked up monthly to simulate the typical Caltrans Adopt-a-Highway Program implementation frequency. In both cases, workers removed only those items large enough to be easily handled by tongs.

Modified Drain Inlet

This device was a standard drain inlet modified by the addition of a perforated metal plate on the upstream side of the grate (see Figure 2). The holes in the perforated plate were approximately 6.35 mm (0.25 inch) in diameter. It was anticipated that litter would be retained on the surface of the perforated plate and would later be removed by a street sweeper. The plate was welded to the grate so that it was flush with the freeway surface. It covered approximately one quarter of the inlet, leaving three quarters of the grate open to assure sufficient hydraulic capacity.

Bicycle Grate

The bicycle grate was constructed by adding perpendicular bars at 152 mm (6 inch) intervals to a standard parallel-bar grate. The additional bars were intended to prevent larger objects from entering the inlet and retain them until removed by a street sweeper. In the second year of the study, the Litter Inlet Deflector replaced this BMP.

Litter Inlet Deflector

The Litter Inlet Deflector (LID) is a novel device developed for the LMPS. In a separate Solids Deposition and Transportation Study, Caltrans found that significant quantities of material, including litter, could be deposited in drain inlets during the dry season (2). The purpose of the LID was to prevent this dry weather accumulation. The LID was constructed by changing a drop inlet into a curb inlet and adding a hinged gate that hangs over the open entrance (see Figure 3). The flap prevents litter from entering the inlet during dry weather. The weight of the gate is such that wind forces generated by passing vehicles will not cause it to open. Street sweepers then periodically remove the accumulated litter. During wet weather, even small water flows force the gate open so hydraulic capacity is maintained.

GENERAL METHODOLOGY

The LMPS utilized a paired watershed approach based on protocols derived from U.S. EPA methods (3) to evaluate BMP effectiveness. A paired watershed approach requires that two watersheds be identified which exhibit similar land use patterns, meteorology, and physiographic features such as size, soils, slope, and location. Under the rigorous EPA approach, two watersheds (one control and one treatment) would be monitored during a calibration period and a quantitative relationship would be established using regression equations. The BMP would then be initiated in the treatment watershed and monitored over the study period. Data would be collected for the selected study parameters and analyzed to determine a new regression relationship between the control and treatment watersheds. The calibration and treatment relationships would then be compared statistically to determine if the BMP implementation had a significant effect on the watershed.

Due to the relatively short study period and budget limitations, monitoring during a calibration period was not feasible for the LMPS. It was possible, however, to pair control and treatment areas in close proximity, on the same freeway sections, and with similar inlet and outfall configurations. The paired catchments (mini-watersheds) identified within each study area were very similar with respect to land use patterns, traffic volume, meteorology, and size. By judicious pairing of like catchments, the variance between the paired watersheds was greatly reduced.

This modified paired watershed approach utilized four study sites, each containing multiple catchments and outfalls. The catchment areas ranged from 0.07 to 0.37 ha (0.18 to 0.91 acres). All were located within the Los Angeles region and had traffic volumes representative of Caltrans freeways in that region. Within each study site, three replicate pairs of catchments were chosen. Each catchment drained to a single pipe outfall. The BMP was implemented on the "treatment" member of the pair while typical Caltrans conditions prevailed at the "control". A total of 24 catchments were monitored.

At one pair of catchments in each study site automated water and flow measurement sampling equipment was installed. Water samples were analyzed for a variety of parameters such as suspended solids, metals, nutrients, and coliform bacteria. The results of the water quality testing are presented elsewhere (1).

To assure that a storm event would produce adequate runoff for chemical water quality monitoring, a "trigger" storm event was set at 5 mm (0.2 inch) of rain. Over the course of the study 23 "trigger" storms were monitored for both chemical water quality parameters and litter; in addition nine "non-trigger" events were monitored for litter only. All of the events were used to generate yearly litter loads.

Because catchment pairs were not identical in size, litter data were normalized by both area and runoff volume. Area-normalized data were expressed in terms of weight, volume, and items of litter per unit area. Normalization by this method assumes a linear relationship between catchment size and litter load. Volume-normalized data were presented in weight, volume, and items of litter per unit volume of storm water. In essence, this normalization produces average weight, volume, and count "concentrations".

RESULTS

Samples for the LMPS study were collected during the storm seasons of 1998/1999 and 1999/2000. The results of the litter characterization and BMP testing are summarized below.

Litter Characterization

The characteristics of the litter collected in this study are summarized by air-dried weight, volume,and count in Table 1 and Figure 4. The weight and volume material distributions were generally similar, with variations explainable by considering the densities of the various materials. The distribution by count appears quite different. Of the 11 categories established for this study, moldable plastics constituted the largest fraction of the total litter captured by both air-dried weight and volume (21 and 16 percent, respectively). By count, though, cigarette butts, were by far the most numerous component, constituting 34 percent of the total litter items captured. Approximately 80 percent (by volume) of the litter collected during the course of this study was classified as floatable. The original usage of 55 to 79 percent of the captured litter (depending on the method of quantification) could not be identified due to the small sizes of individual pieces collected.

BMP Effectiveness

Area-normalized average annual loads, characterized by air-dried weight, volume, and count, are summarized in Table 2. The table exhibits the mean values, calculated from the data collected at three treatment and control replicate catchments. The differences between the treatment and control, expressed as a percent of the control, are also shown. The performance of the five BMPs is seen in the apparent reduction in litter discharged from treatment outfalls compared to the control outfalls. Negative values of apparent reduction indicate that more litter discharged from the treatment outfalls than from the control outfalls.

DISCUSSION

At the time the LMPS was initiated, there was very little information available on litter in storm water. Due to this limited state of knowledge, the LMPS team had to develop a working definition for storm water litter and establish monitoring and characterization techniques.

The monitoring technique of securing a mesh bag on an outfall with VelcroTM was generally successful in that bags rarely came off during a storm and they didn't interfere with hydraulic capacity. However, only catchments smaller than 0.37 hectares (0.92 acres) were monitored in this study. Larger catchments may need a more sophisticated breakaway mechanism or bypass system to assure that hydraulic capacity is never threatened. Furthermore, all outfalls monitored in this study were located aboveground in the right-of-way, allowing for easy access. The LMPS monitoring technique is not feasible for outfalls that directly connect to other subgrade drainage systems.

In this study, litter was characterized by weight, volume, and count because there was no prior consensus on which measuring parameter would best represent litter discharges. As might be expected, characterization by count required extensive time and labor to accomplish compared to characterization by weight and volume. The LMPS did not establish which parameter best indicates the impairment of receiving water beneficial uses due to litter.

Early in the project, particle size was another parameter of interest. After analyzing data from the first storm, however, it was observed that the litter particles were overwhelmingly small. This was most likely due to the 38-mm (1.5-inch) parallel bar spacing on the drain inlet grate which seemed to be effective at preventing larger items from entering the drainage system.

Litter was also analyzed and classified as floatable or non-floatable. The procedure used in this study resulted in a floatable percentage that seemed high (80% by volume). This procedure may have produced biased results because the turbulent conditions found in the field were not perfectly replicated in the laboratory. Lesser turbulence and detention time in the laboratory test, compared to what is found in full-scale drainage systems, may have wetted the litter less thoroughly, resulting in greater buoyancy and a higher floatable fraction than what might be found in the field.

It should be noted that this study evaluated litter in a freeway environment and that these data are specific to Los Angeles conditions. Litter in municipal storm systems may have very different characteristics. In addition, litter data are highly variable from place to place and storm to storm. This is illustrated in Figure 5, which shows the weights of litter collected from the 23 trigger events at two control sites on opposite sides of the same section of freeway. The amount of litter collected varied considerably, both from storm to storm and from site to site. Another indication of this variability can be seen in Table 2. For the same collection sites and methodologies, the amounts of litter collected were substantially different in two consecutive years. Because of this variability, long monitoring records are needed to produce statistically reliable results.

Regarding BMP effectiveness, the increased frequency of litter pick-up and the modified inlet showed apparent reductions in the range of 7 to 45%, depending on the method of quantification. As shown in Table 2, litter pick-up appears to be somewhat more effective than the modified inlet. The other BMPs were less successful at reducing the amount of litter discharged. In fact, based on average data (Table 2) implementation of some BMPs appears to have increased litter discharges. These values may be deceiving, however, because of the great variability in the data. A preliminary statistical analysis compared the pooled data from all the control outfalls with the pooled data from all the treatment outfalls for each BMP. Hypothesis testing was performed using the Wilcoxon Rank-Sum Test (the data were not normally distributed). At a 5% significance level, the null hypothesis – that the amount of litter collected at the treatment sites equaled the amount collected at the control sites – could not be rejected for any of the BMPs tested (1). This throws additional doubt on the apparent reduction figures shown in Table 2.

Why increased sweeping, the bicycle grate, and the LID appear ineffective is not clear at this time. The sweepers may have been picking up mainly material too big to enter the drainage system so there was no reduction in the amount of smaller items found discharged from the outfalls . Also, sweepers have been observed to mobilize particles and push them into drain inlets. It is possible that what litter was picked up by the increased sweeping was offset by additional material pushed into the drain inlet by the sweeper. Similarly, the bicycle grate appears to be ineffective at removing the more prevalent smaller particles. As described earlier, the LID was substituted for the bicycle grate in the middle of the study. Consequently, it was monitored only during the second wet season (October to April). Considering that the advantage of the LID is its ability to keep litter out of the drainage system in the dry season, the monitoring scheme used may have been incapable of measuring this benefit.

CONCLUSION

Litter was monitored at 24 locations in the Los Angeles freeway system. Litter discharges from outfalls were found to vary greatly from storm to storm and place to place. Paper, plastic, and styrofoam together constituted 42 percent of freeway litter by weight and 57 percent by volume. Because of the small size of the litter particles collected, it was not generally possible to identify their original usage (except for cigarette butts which constituted 34 percent of the litter by count).

Of the five BMPs tested, only two – increased litter pick-up and the modified drain inlet – appeared to substantially reduce litter. The other three BMPs – increased sweeping, the bicycle grate and the Litter Inlet Deflector – were not effective, based on the data collected in this study.

Finally, it should be noted that all the BMPs tested were upstream controls, in that they inhibited litter from entering the drainage systems. Because they were implemented on or near the traveled way, safety concerns greatly influenced their design, and possibly limited their effectiveness. The 7 to 45 percent apparent reductions observed in this study are inadequate for meeting the recently-proposed Los Angeles River Total Maximum Daily Load (TMDL) requiring zero litter discharge by 2012.

ACKNOWLEDGEMENTS

Fieldwork for the LMPS was conducted by URS Griener Woodward-Clyde. Model LID testing was performed by Michael Stenstrom at the University of California at Los Angeles. LMPS was funded by the Caltrans Storm Water Program under the direction of Steve Borroum.

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2. Camp, Dresser and McKee, Inc. *Solids Transport and Deposition Study.* Document No. CTSW-RT-99-024. California Department of Transportation, 1999.

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TABLE 1 Distributions of Litter Components by Mass, Volume, and Count

Component	Percentage of Total		
	Mass	Volume	Count
Styrofoam	5	15	11
Plastic (moldable)	21	16	11
Plastic film	7	12	12
Paper	9	14	10
Wood	16	10	7
Cardboard/chipboard	10	11	4
Metal (foil and molded)	13	5	7
Glass	1	<0.5	1
Cloth	6	5	2
Cigarette butts	10	11	34
Other	2	1	1

TABLE 2 Average Annual Weights, Volumes, and Counts of Collected Litter

BMP	Catchment Type	Air-dried Weight (kg/ha-yr)[a]		Volume (liters/ha-yr)[b]		Count (items/ha-yr)[c]	
		Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Street Sweeping	Control	9.4	16.8	109.0	104.9	15272	17208
	Treatment	12.1	26.7	103.5	101.4	16066	21544
	Apparent Reduction	*-29%*	*-59%*	*5%*	*3%*	*-5%*	*-25%*
Litter pick-up	Control	14.1	22.9	144.1	146.8	19243	20196
	Treatment	9.7	15.8	84.1	81.1	12406	13456
	Apparent Reduction	*31%*	*31%*	*42%*	*45%*	*36%*	*33%*
Modified inlet	Control	12.6	13.4	113.9	78.8	17344	13465
	Treatment	11.5	9.5	106.4	53.9	13983	9700
	Apparent Reduction	*9%*	*29%*	*7%*	*32%*	*19%*	*28%*
Bicycle grate (Year 1 only)	Control	8.5	N/A	53.1	N/A	7675	N/A
	Treatment	8.0	N/A	55.9	N/A	10018	N/A
	Apparent Reduction	*6%*	*N/A*	*-5%*	*N/A*	*-31%*	*N/A*
Litter Inlet Deflector (Year 2 only)	Control	N/A	6.7	N/A	35.8	N/A	6502
	Treatment	N/A	9.3	N/A	43.1	N/A	5872
	Apparent Reduction	*N/A*	*-38%*	*N/A*	*-20%*	*N/A*	*10%*

[a] 1 kg/ha-yr = 0.893 lb/ac-yr
[b] 1 liter/ha-yr = 0.107 gal/ac-yr
[c] 1 item/ha-yr = 0.405 items/ac-yr

FIGURE 1 Litter collection bag.

FIGURE 2 Modified drain inlet.

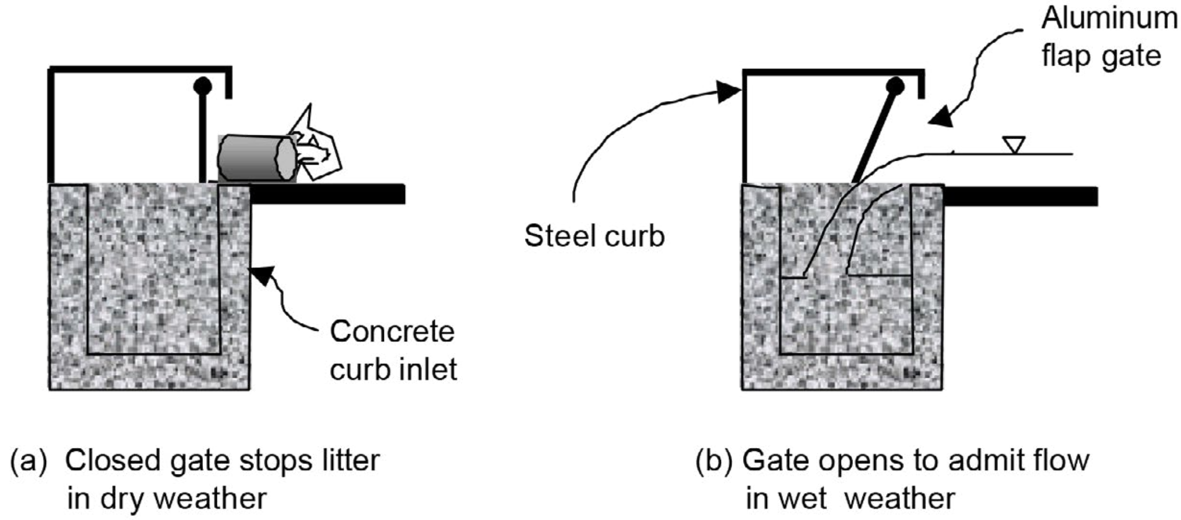

FIGURE 3 Schematic of the litter inlet deflector (LID).

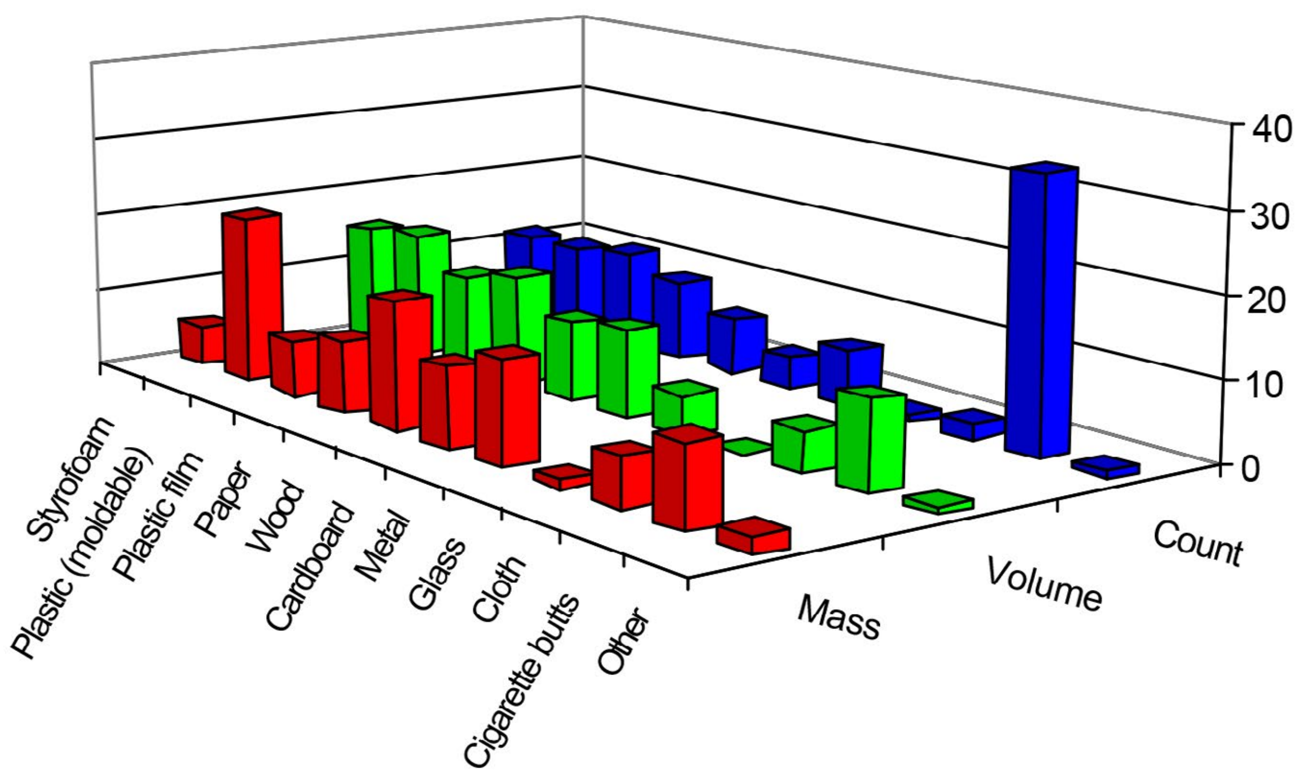

FIGURE 4 Litter component distributions by mass, volume and count.

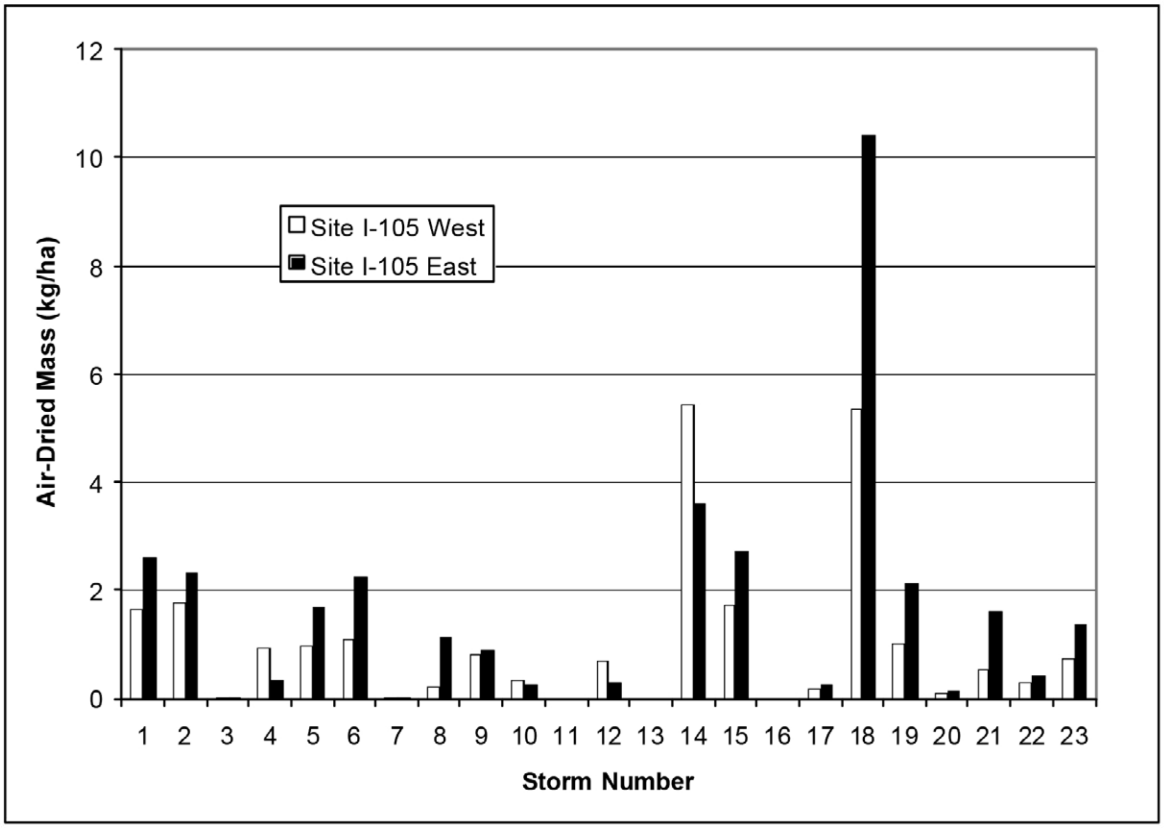

FIGURE 5 Comparison of litter collected at two control sites on opposite sides of the same section of freeway.

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