MEASURING THE EFFECTIVENESS OF VOLUNTARY PLASTIC INDUSTRY EFFORTS: AMRF'S ANALYSIS OF OPERATION CLEAN SWEEP

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Forward

First and foremost, the authors would like to acknowledge the invaluable assistance of members of the California Film Extruders and Converters Association, and the Society of the Plastics Industry, who collaborated with project personnel and drafted, on their joint letterhead, an introductory letter urging plastic industries selected by the project to cooperate with our sampling strategy. Without this support it is unlikely that 80% of the businesses contacted on a surprise first time sample visit would have agreed to participate in our assessment of voluntary measures aimed at curbing discharges from their facilities. Not only were we given permission to enter private property and take samples and photographs, we were also permitted to interview production management personnel and determine their current housekeeping practices, and subsequently to deliver to them recommendations on improving these practices based on site walkthroughs and our baseline case study monitoring.

Introduction

Land-based sources of plastic and trash, especially in urban areas of Southern California, are the most significant source of marine debris impacting coastal waters in that area[1]. The recently approved regulations for Total Maximum Daily Load (TMDL) for trash for the Los Angeles and San Gabriel River watersheds focused on larger debris (greater than 5 millimeters). However, recent trawl studies (1999-2004) conducted by the Algalita Marine Research Foundation (AMRF) and the Southern California Coastal Water Research Project (SCCWRP) aboard the Oceanographic Research Vessel (ORV) *Alguita* throughout the eastern North Pacific found that plastic fragments less than 5mm in size occur in a ratio of 30-60% of the mass of the associated zooplankton.[2,3,4]

One of the most frequently encountered components of the plastic debris studied, that is "mostly less than 5 mm across,"[5] has been pre-production pellets. These pellets come in a variety of shapes, including rounded, flattened oval, and cylindrical. Plastic producers make these pellets, then ship them to the various plastic manufacturers or processors to be melted and made into consumer products. A 1998 study of Orange County Beaches in Southern California showed plastic pellets to be the most abundant items, with an estimated count of over 105 million comprising 98% of the debris.[1]

The Society of the Plastics Industry (SPI) created and promulgated, starting in 1991, a set of voluntary Best Management Practices (BMPs) to reduce pellet loss known as *Operation Clean Sweep* (OCS). A revision of the original OCS manual was recently completed as a joint project of the Plastic Industy, AMRF and the LARWQCB.

Independent monitoring of the containment measures in the newly revised version of OCS was necessary to determine whether these measures are adequate. The existing BMPs may not adequately capture small pellets and it is necessary to quantify the magnitude of the stray plastic pellet problem in order to inform future decision making regarding management strategies. The

primary goal of this part of the project was to assess the effectiveness of voluntary implementation of OCS and other site specific BMPs developed by the project.

Methods

The focus area of this study was the Los Angeles River Watershed and the San Gabriel River Watershed in Southern California. The areas of interest for this study were evaluation of BMPs at plastic industry sites, sampling mass emission sites on each river, sampling the beaches adjacent to each river, and trawl sampling in the forebay at the mouth of each river. The mass emission site for each river was selected because it was the convergent area, at which all materials coming down the river from the watershed would have to pass before reaching the ocean, and it was also upstream enough not to be influenced by ocean tides. The mass emission samples and the forebay samples focus on the plastic particles in the rivers that were less then 5 millimeters. Many of these plastic particles were pre-production pellets, shavings from cuttings, regrinds, and sprues from drilling during the manufacturing process. They may have come from industry but cannot be linked to an individual industry site. These smaller plastic particles also may have come from post-consumer products broken down into smaller sizes.

Due to the wide variety of plastic industries in the LA basin, and the difficulty of rigorous quantification of sporadic inputs to watershed runoff from these facilities, a case study approach with qualitative goals for the project was adopted after consultation with the project's Technical Advisory Committee (TAC). While AMRF and other researchers have developed peer-reviewed methods for collecting pellets from the ocean and beach environments, no established methods have been developed for collecting pellets from plastic pellet handlers and processors or determining the amount of plastic debris in runoff from these sites. A methodology was developed that would compare each industrial facility to itself before and after implementation of BMPs recommended by the project. Many of these BMPs were taken from the newly revised version *Operation Clean Sweep,* an industry publication designed to help plastic facilities minimize pellet loss. When quantitative results are given, they should be understood to represent a "snapshot" of a facility, from which samples were taken using a methodology developed specifically for the project. This case study methodology was reviewed by the project's TAC and Advisory Board, which included plastic industry representatives. This methodology could not be based on pre-existing standards that serve as a reference to reduce uncertainties and insure repeatability, as none exist. Methods used for sorting samples and identifying types of debris, however, were previously developed and published by SCCWRP and AMRF.

Ten plastic industry sites were monitored to study the effectiveness of Best Management Practices (BMPs). These companies comprised different specialties within the plastic industry: Bulk Transporters and Shippers, Injection Molding, Plastic Bag Manufacturing, and Roto-Molding. The Bulk Transporters and Shippers deal with getting the pellets from the manufacturers to the processors. Injection Molding is the process of melting the pellets and additives and injecting the melted plastic into molds. Plastic Bag Manufacturing also use melted pellets and additives that are blown to stretch the plastic into thin sheeting to make plastic bags. Roto-Molding is a process that uses powders that are placed in a hollow mold, which is then heated and rotated so the plastic melts and lines the inside of the mold. The powder is delivered to the processors or the processors make the powder by grinding the plastic pellets.

The study area of each industrial site involved the industry property and the nearest storm drain. Two of the industrial sites had unique delivery conduit systems, a storm drain on the facility leading directly to the river or to a channel leading directly to the river. For the purpose of this study the term "storm drain" and "catch basin" are used interchangeably. We can define them as

the mouth of the delivery conduit that leads to the creek/river system in the urban environment. There were five sites selected for each river. The industry sites were identified by using publicly available sources. We first identified the pertinent Standard Industrial Codes (SIC) for the various plastic industry specialties and then we located the plastic industries through the listings of the Thomas Registry, Enforcement and Compliance History Online (ECHO), and the Regional Water Quality Control Board (RWQCB). We also located sites through the suggestions of various advisors and through personal finds by project personnel. We called each facility on the list to see if they were still in business at the listed location. The remaining industries were then visited to determine the type of facility and to rank each for cleanliness, with some consideration for property access, location of the nearest storm drain and whether the plastic industry site was the only source of the plastic pellets and industrial plastic debris for that storm drain. Each facility was given a ranking between 1 to 100 for cleanliness, 1 being the cleanest and 100 indicating massive plastic spills. All of the visits were preformed from the public access locations that surrounded each facility. The rankings were plotted on a histogram and the sites were selected across the spectrum of the histogram to avoid bias by picking only the cleanest sites or ones with the higher plastic debris rankings. The ranking visits provided only snapshots of the facilities and did not indicate what the cleanliness might be on a regular basis. This would have taken numerous visits to determine. Different types of facilities were also selected from the rankings to determine how the implementation of the BMPs at these types of facilities would differ.

Storm Drains associated with the sites were sampled using storm drain inserts, which were designed to collect the material that entered the storm drain and prevented it from reaching the rivers and finally the ocean. Inserts with 1 mm mesh were manufactured and installed at street storm drains near the monitored facility by a company with existing permits. Sampling was accomplished by having the contents of all street storm drain inserts vacuumed by this company and project personnel were on site to retain the samples for analysis at the AMRF Lab. A few industry sites already had a basket or insert installed; at other sites on private property inserts were installed with 1 mm mesh. If the storm drain was on the facility and didn't have an insert, the insert was added only with the permission of the facility. These custom inserts collected samples from one to three cubic feet in volume. The inserts installed in the catch basins on the public street had a 1 cubic foot collection volume for every linear foot of drain opening along the curb. One company decided to install a sump with a pump, to pump out any water collected and retain the debris; however, their overflow to the storm drain was not screened. At the sites which already had an insert installed, we found that the facility often removed it when a rain event occurred in order to prevent flooding. Each storm drain was sampled during a wet season and a dry season, both before and after the implementation of the BMPs. The wet season was defined in this study as greater than 0.25" of rain and a dry season was defined as a period of at least two weeks after a rain event of 0.25" of rain.

Each site selected was visited for pre-BMP purposes as a "cold call." They didn't know they were going to be visited before the project was introduced to the management. The project was described to the management, they were presented with the industry associations' letter of introduction, and they were asked if they would like to participate on a voluntary basis. If the management agreed to participate, samples were taken immediately. The reason for this protocol came from previous interactions with other plastic companies where it was found that any notification of a visit initiated some sort of clean up. Samples were taken from the grounds where there would be a potential for runoff and the debris would have a possibility to reach the storm drain system. No samples were taken inside the facility. Possibly the biggest reason the industrial sites agreed to participate in this project is that they would remain anonymous. They were identified only by code numbers and letters.

The initial (Pre-BMP) visit to each facility occurred during the dry season. This initial visit was an introduction and first site sampling that assessed of the types, quantities, and location of debris. After this initial visit Project personnel arranged for an on site walk-through with the management to evaluate the site for BMPs most relevant to that specific site, focusing on debris subject to runoff due to rain, wind, washdown water and leaky hoses. Factory operations were observed first hand during the BMP evaluation, then Project personnel created a site specific document detailing a list of possible improvements that was presented in a conference room setting to those managers who would voluntarily seek to implement the measures best suited to their particular circumstances. Project personnel reviewed in detail the Industry's recently revised housekeeping manual, OCS, and printed copies were given to management who wanted them. Some companies already had OCS manuals, and some preferred to review the document on line. Each facility was encouraged to have both management and employees sign the "OCS Pledge" located online at www.opcleansweep.org. Posters advocating pellet retention on site from the American Plastics Council were given to each facility. Any type of modification to the facility's existing housekeeping practices was strictly voluntary.

Management was informed that they had at least two months before project personnel would return to sample again, which allowed the facility time for implementation of the measures they chose from the site specific list prepared by the project or measures they themselves developed. The Pre-BMP samples were taken in June 2004. The BMP evaluations with the suggestions and recommendations were presented in July 2004. Post-BMP sampling occurred in June 2005. These visits, like our first contact visits, were unannounced. Post-BMP sampling was the same as the pre-BMP sampling. We made another "cold call" to the facility; at this time they knew we would be coming after the follow up evaluation, but they didn't know exactly when. The sampling was the same as the pre-BMP visit with industrial site samples taken during a dry period and storm drain sampling during dry and wet periods. Another on-site survey with management personnel was conducted to determine which of the BMP recommendations were implemented and their successes and challenges with these new BMPs. Post-BMP samples were originally scheduled to be taken between October and December 2004, but due to an unusually wet season and the sampling criteria of at least two weeks without a 0.25 inches of rain samples were not able to be collected until June 2005.

Results

Ten sites were monitored during this study, covering the geographic area of both the Los Angeles and the San Gabriel River's Watersheds. Five different types of plastic processors were selected for inclusion in our study in each watershed. A brief description of each site and the results of baseline and post BMP implementation monitoring will be given.

Site 6

This company manufactures plastic bags.

The following areas are on the outside grounds of the facility where spilled pellets observed by project personnel have the potential to enter the storm drain system:

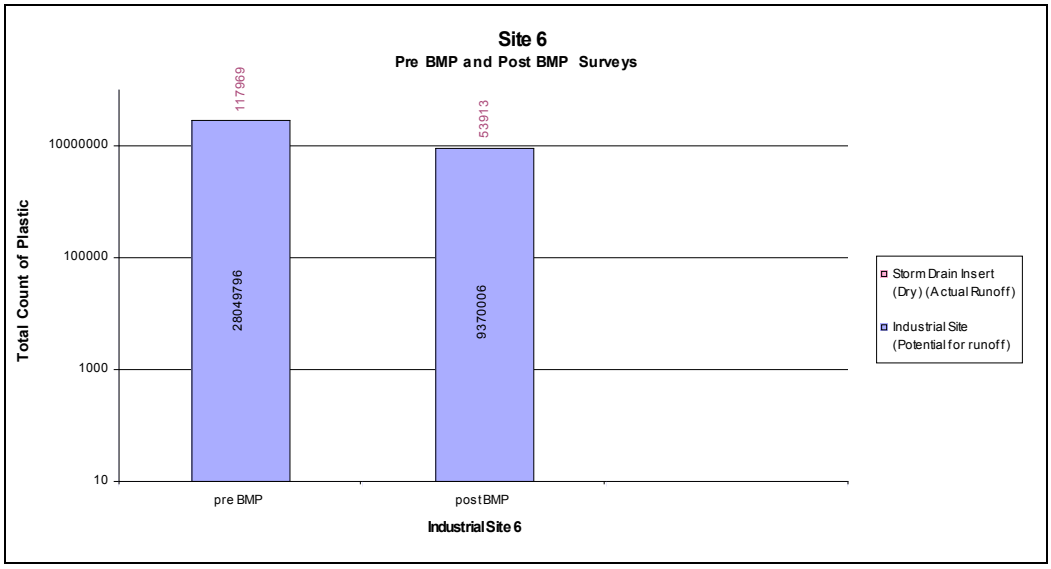
1. On the parking lot.
2. By the pellet storage silos on the west and east sides of the main building.
3. By the loading docks.

4. Covering the gravel on the railcar delivery area .
5. On the paved machinery and equipment storage area.
6. Next to the neighboring building on the east side of the facility.

All of these areas continued to contribute lost pellets to the runoff caught by the catch basin insert post BMP.

By comparing the pre BMP and the post BMP surveys, this facility has improved. However, even though the west area of the facility was cleaner, and there were fewer larger spills at the railroad track area, this facility continues to have a high rate of pellet loss on the ground. Many of these pellets are making it to the storm drain system. On several occasions, project personnel have observed the pellet trail from the facility to the catch basin. Going from one hundred thousand pre BMP to fifty thousand pellets post BMP in the catch basin insert samples while representing an improvement, still constitutes excessive pellet loss.

New BMP measures reported by the management include designating an employee to clean up spills inside the factory. Project personnel observed the use of two sock booms that had been placed in the drainage areas on the west side of the facility. Both booms had pellets trapped on the upstream side of the boom, with only a couple of pellets downstream. There was no evidence of vacuuming in the yard.



Site 9

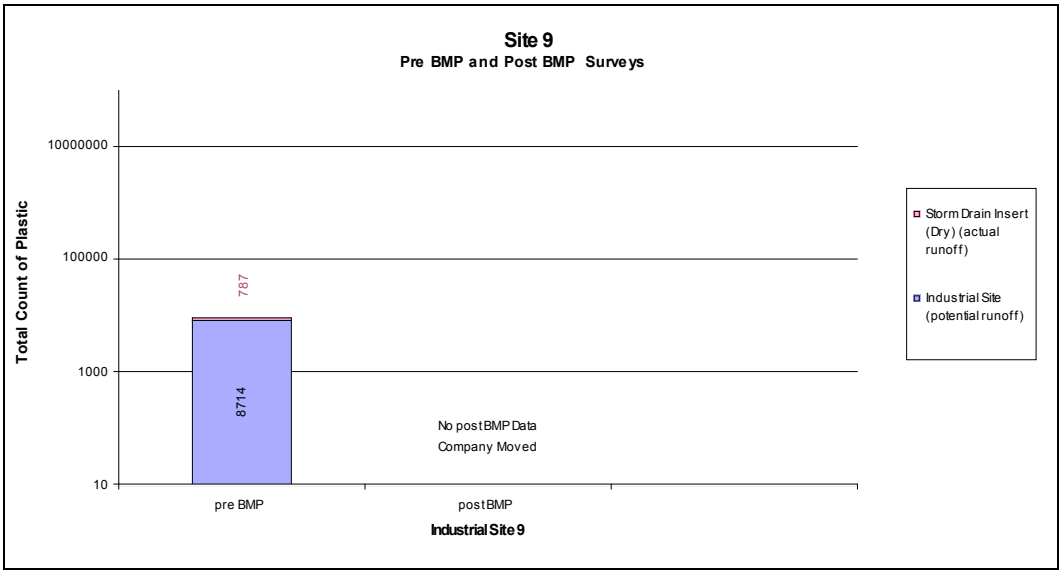
This company makes bottles for consumer products by injection molding.

Outside locations where plastic pellets and fragments have a potential to enter the storm drain system.

1. On the parking lot.
2. In the driveway by the loading dock.
3. On the platform by the silos.
4. On the gravel at the railcar delivery area.

5. On the paved machinery and equipment storage area.

There were no post BMP Industrial Site samples at this facility. The company moved. They gave permission to the project to install a catch basin insert in a sump by the loading dock. Although this sump does not connect to the storm drain system, during a rain event, it would overflow and floating pellets would come out and possibly flow to a storm drain. This catch basin was sampled during a wet period. It was the only post BMP sample that was taken. There was no indication that the company was moving. When project personnel arrived to do the post BMP sample the facility was under reconstruction. A new layer of gravel had been added at the railroad tracks, covering up many small spills. Project personnel could take pictures, but were not able to obtain permission to takes samples.



Site 10

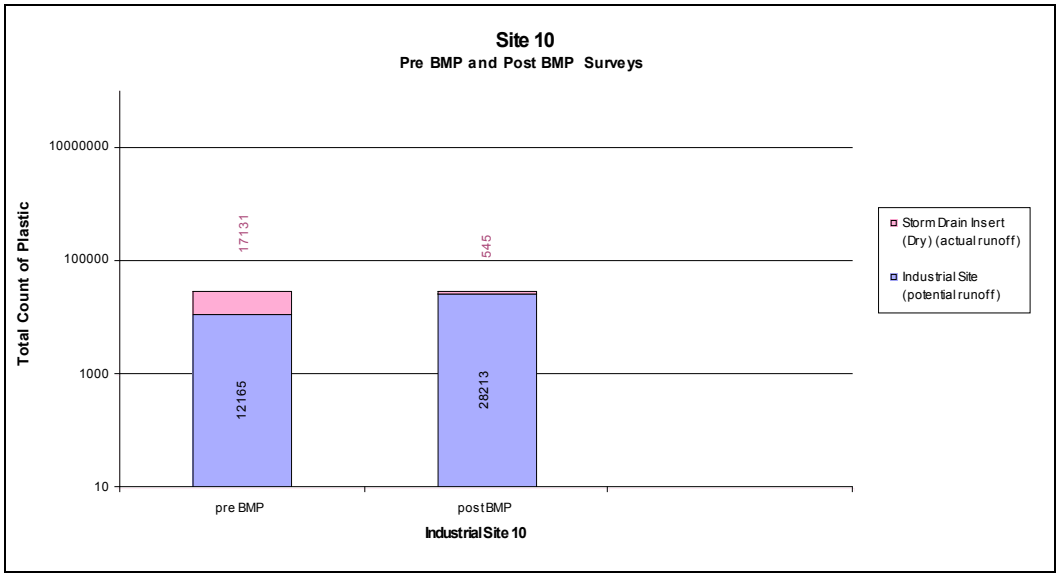
This small company makes parts, which are assembled into finished products at another facility.

Areas where pellets have the potential to enter the catch basins are:

1. The parking lot.
2. The driveway leading to the storage area.
3. The waste bin area.
4. The rear storage area.

By comparing the pre BMP and the post BMP surveys, this facility has remained almost the same, continuing to be a clean facility.

New BMP measures reported by the management included; 1) they change the storm drain insert every 90 days, 2) a vacuum was placed outside as recommended, 3) the Gaylords were covered as recommended, and 4) the dumpster was covered as recommended. Project personnel observed the continued use of the vacuum sweeper, as well as hand sweeping. The storage yard and driveway are both clean, except for very recent small spills.



Site 31

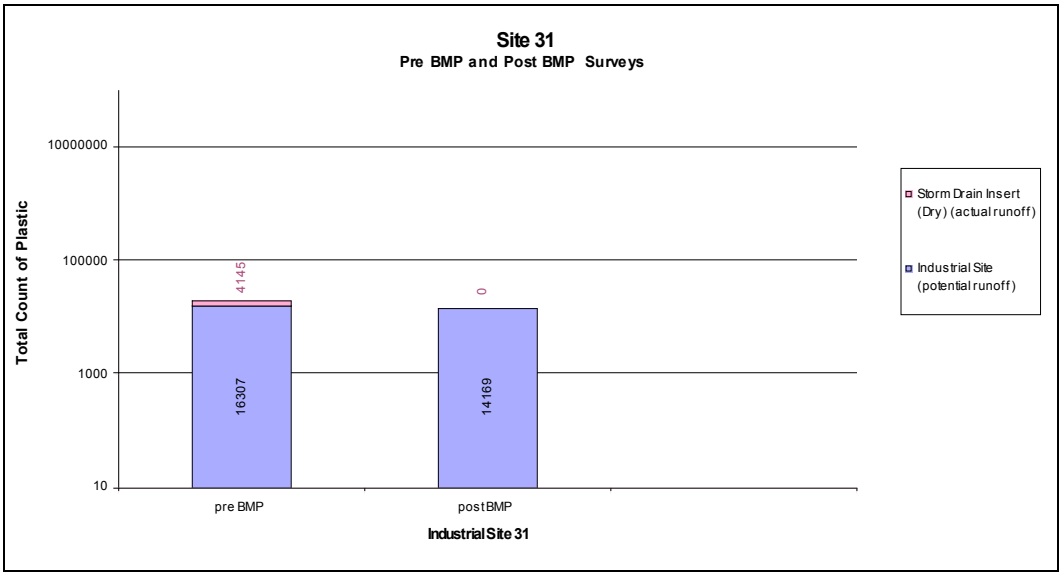
This company is a large transporter of virgin pellets of all grades by truck to processors throughout the area.

All outside areas of the facility that plastic could enter the storm drain system.

1. The parking lot.
2. The loading dock areas.
3. The two rail car siding areas.
4. Pellets and dust were also found on the edge of the creek.

By comparing the pre BMP and the post BMP surveys, this facility has slightly improved, but is overall pretty much the same. Some pellets and dust are on the ground in the washout area. The asphalt surfaces in some areas are worn down, which traps the pellets. However only a few were observed, reflecting that the area had been cleaned recently.

Project personnel are not aware of any new procedures since the pre BMP monitoring. This is a very large and relatively clean facility, with a significant pellet loss problem during rain events (all catch inserts are pulled to prevent flooding). Project personnel observed the use of manual and driven vacuum sweepers.



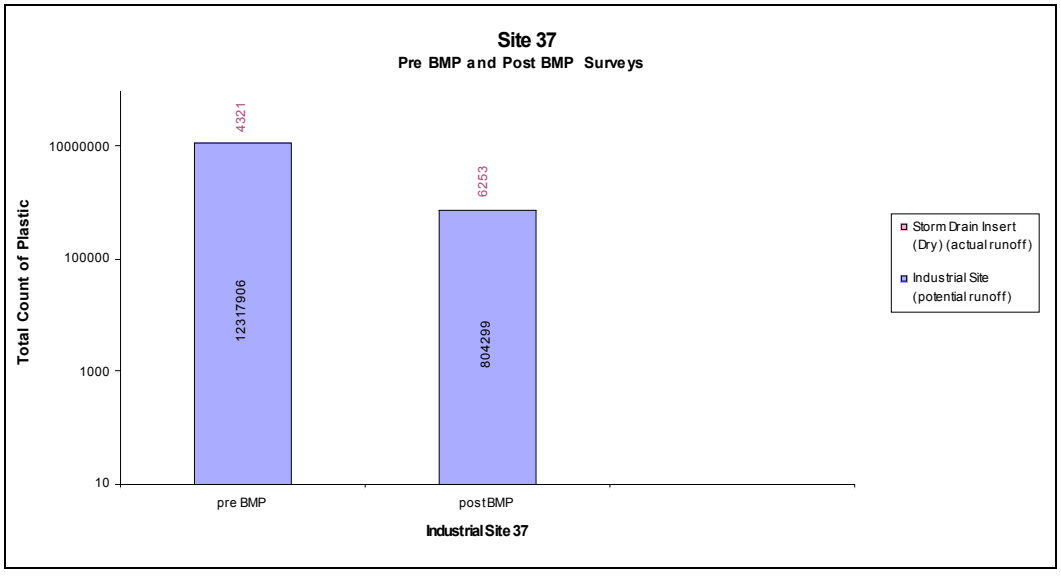
Site 37

This company is a large manufacturer of receptacles and bins.

The areas outside the facility which project personnel were able to access for sampling purposes were:

1. The public sidewalk on two of the four sides of the facility.
2. The rail yard area behind the facility.
3. The public street and gutter.
4. The catch basin near the rail yard.

This facility has improved, although it was not formally part of the BMP Evaluation sites. We did not sample on their facility, but company personnel observed that the storm drain insert and surrounding areas were being monitored. They made an effort to clean the rail tracks behind their facility, especially nearest the street. There continues to be some pellet loss on the sidewalk and in the gutter leading to the storm drain.



Site 48

This facility is a transshipping and storage facility for pellets, principally coming from abroad aboard container ships.

The project had inserts put into both catch basins. Pellets could reach them from the following locations:

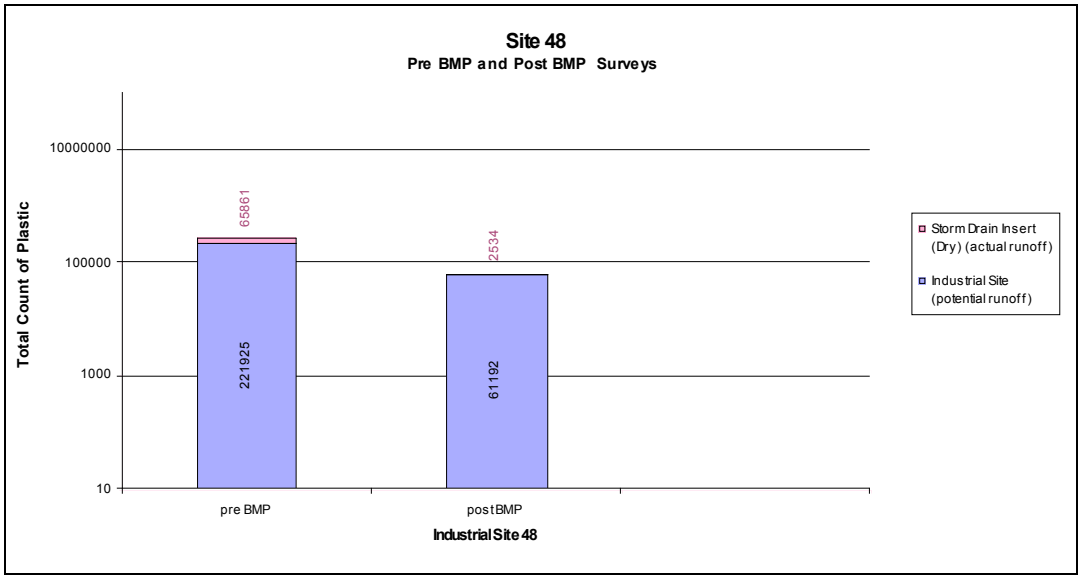
1. The front parking, loading dock area and the side of the neighboring building.
2. The waste bin area.
3. The driveway to the rear of the building.
4. The rear receiving dock area.
5. The bag house for the cutting operation.

By comparing the pre BMP and the post BMP surveys, this facility has improved.

This is the only company that has taken our advice to purchase a shop vac. It is used with a long extension cord to clean inside and outside. Deployment is based on visual assessment of need and there is no regular schedule for vacuuming. Each employee is trained to clean up spills at meetings to discuss pellet loss recommended by the project. They reported having had such meetings at the time of post BMP monitoring. They put up the OCS posters with clear acrylic sheet covers in prominent places in the warehouse front and back.

They have informed the dispatcher of delivery trucks that the truck drivers must inform warehouse employees if they are dirty and they will clean them out before they leave. No sweeping out of unloaded trucks is allowed in the parking lot.

They have looked for someone to recycle the relatively small amount of mixed pellets that they have, but have not found anyone. Trash pellets were bagged and put in the dumpster.



Site F

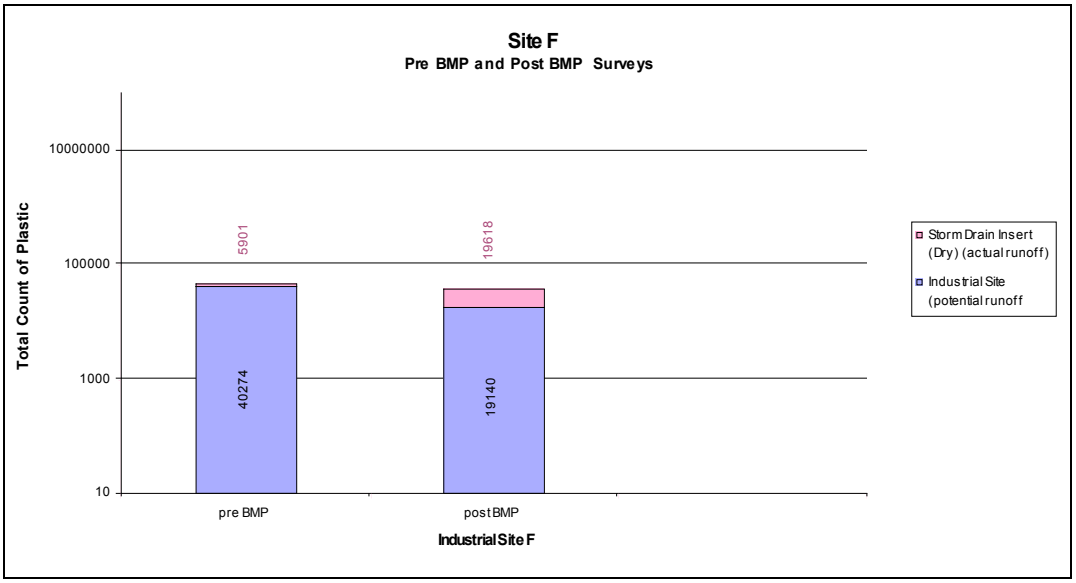
This facility is a small manufacturer of specialty plastic bags and flexible packaging products.

Pellets could reach the catch basin from the following areas:

1. The rear silo area.
2. The delivery/storage area.
3. The sidewalk.
4. The dumpster area.
5. The gutter on the street in front of the company.

By comparing the pre BMP and the post BMP surveys, this facility has improved in pellets on the ground subject to runoff, but actual pellets in the catch basin inserts have gone up.

No suggestions for BMPs were adopted. Management stated that they sweep up and recycle pellets every other day based on visual inspection at the beginning of the shift. They have one cleanup person, but others can help. Owner said he saw a delivery company sweeping pellets back into the delivery truck.



Site H

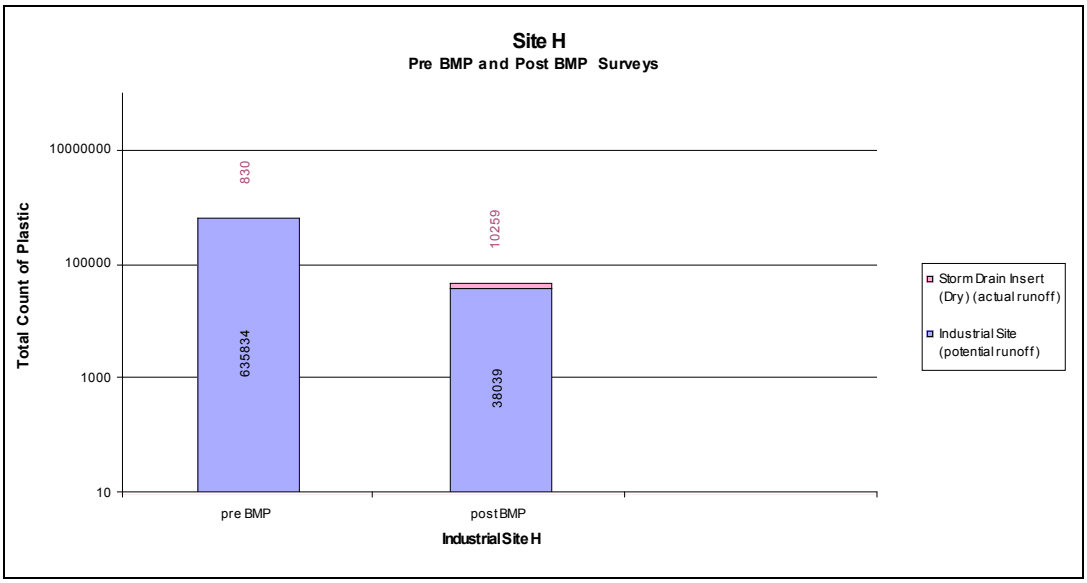
This facility is a small manufacturer of plastic pipe for various applications.

Areas where pellets and dusts could enter the storm drain system are:

1. The pipe storage area on the side of the building.
2. The parking lot.
3. The sidewalk and gutter on the street.

This facility has improved, although it was not formally part of the BMP Evaluation sites. They did allow us to sample front of the facility during the pre BMP monitoring and allowed us to come back for the post BMP monitoring to do the same area. They continue to have spills of

plastic fragments (regrind) and pellets in the driveway, and at the side of the driveway. There was considerably more plastic present in the post BMP catch basin samples.



Site J

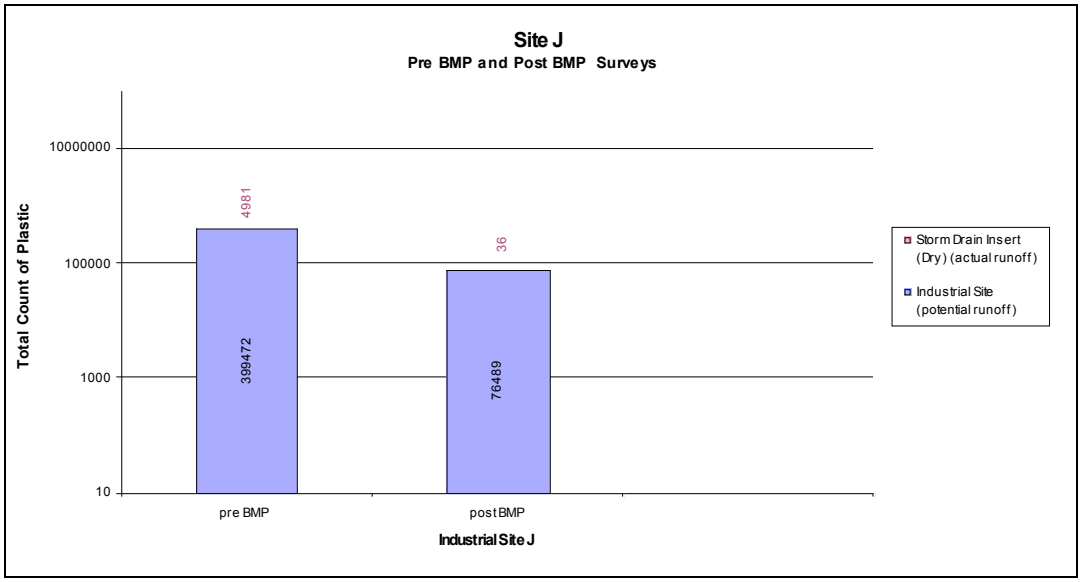
This company is a roto-molding and injection molding facility.

Outside areas where pellets and powders were observed include:

1. Street level loading and unloading areas.
2. Box and bag handling areas.
3. Regrind/recycling areas.
4. Warehouse storage area.
5. Waste disposal dumpster area.

By comparing the pre BMP and the post BMP surveys, this facility has improved.

New BMP measures reported by the management are being established all the time. They have established cleanup stations and each employee does their cleanup. The manager also said they had had a training session. They have put plastic bags inside their Gaylord containers that they use for Roto Mold Scrap to prevent sawdust from escaping. However some sawdust had escaped and was on a pallet. There was plastic debris observed on both sides of the street though in a lesser degree. Plastic shavings were observed on the sidewalk and in the tree wells. Spills of plastic feedstock powders (blue, red and green) were visible in the parking lot. And plastic dust was visible on the vertical face of the curb on the public street.



Site K

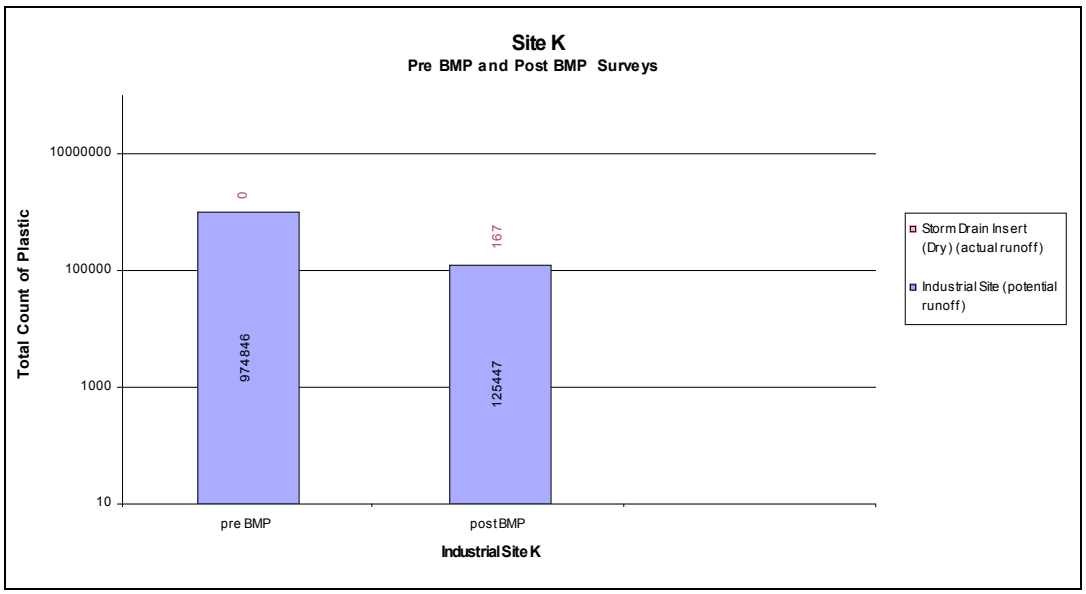
This facility is a medium large manufacturer of plastic bags for specialty purposes.

Areas where pellets and powders could wash to the sump are:

1. The parking lot and dumpster area.
2. The truck delivery and loading area.
3. The rail yard which is partially paved.
4. The area behind the facility where powders are filtered out of the pellet delivery system.

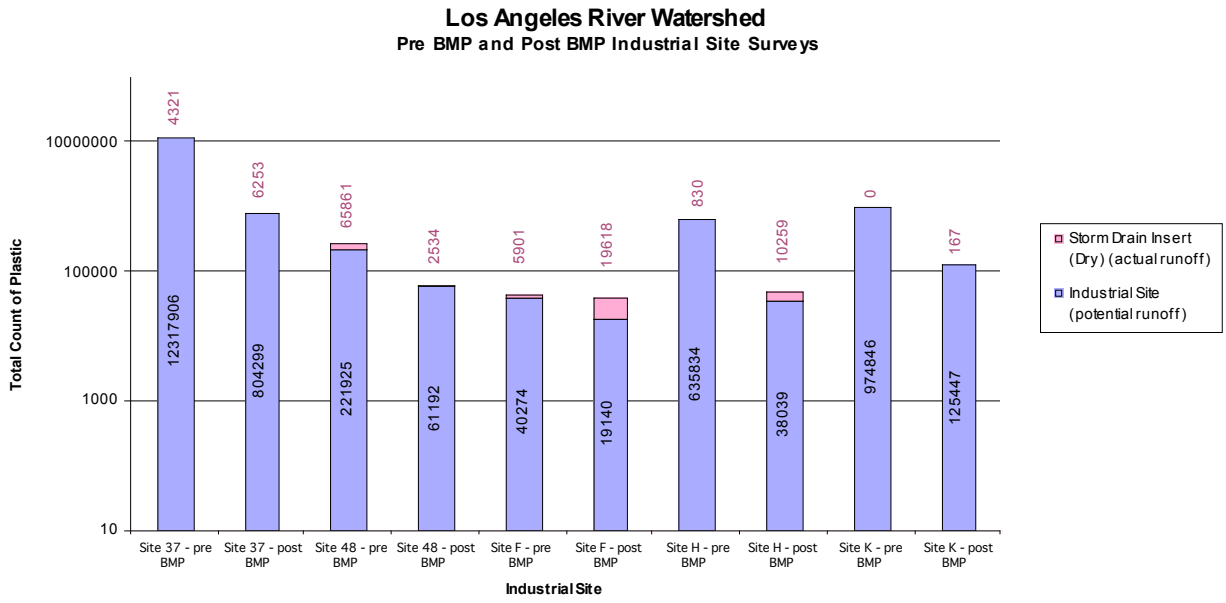
By comparing the pre BMP and the post BMP surveys, this facility has improved.

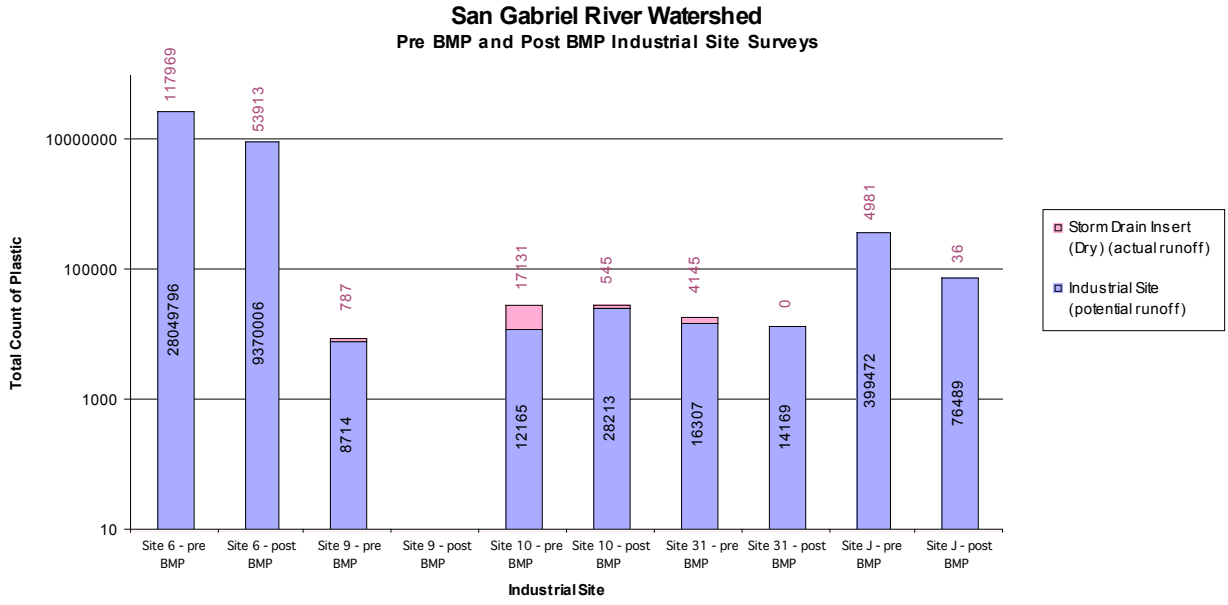
New BMP measures were observed at the back of the facility in the dust collection system, which now has a sock taped around the automatically opening valve which blows out dust, so the amount that reaches the ground is reduced. A way in which pellet loss is worse is that there were no pans under the railcar valves, and the spills on the ground by the railcars were not contained. Pellets were in evidence in the ditch leading to the storm drain by the rail car. The dumpsters had only a small amount of pellets around them, and the dumpsters were covered.



All Sites

The project found plastic pellets and particles in and on rail yard gravel, combined with on site spills, to harbor 42.7 million plastic particles greater than 1mm in size capable of running off into the storm drain system prior to BMP implementation. The count after BMP implementation was 10.5 million. Particles that would have entered the storm drain system during dry weather had the project not installed catch basin inserts near the facilities pre-BMP totaled 0.2 million and 0.09 million post-BMP. These particles were taken directly from the inserts.


Los Angeles River Watershed
Pre BMP and Post BMP Industrial Site Surveys
Total Count of Plastic
10000000
100000
1000
10
4321
6253
65861
2534
5901
19618
830
10259
0
167
12317906
804299
221925
61192
40274
19140
635834
38039
974846
125447
Site 37 - pre BMP
Site 37 - post BMP
Site 48 - pre BMP
Site 48 - post BMP
Site F - pre BMP
Site F - post BMP
Site H - pre BMP
Site H - post BMP
Site K - pre BMP
Site K - post BMP
Industrial Site
Storm Drain Insert (Dry) (actual runoff)
Industrial Site (potential runoff)


San Gabriel River Watershed
Pre BMP and Post BMP Industrial Site Surveys
Total Count of Plastic
10000000
100000
1000
10
117969
53913
787
17131
545
4145
0
4981
36
28049796
9370006
8714
12165
28213
16307
14169
399472
76489
Site 6 - pre BMP
Site 6 - post BMP
Site 9 - pre BMP
Site 9 - post BMP
Site 10 - pre BMP
Site 10 - post BMP
Site 31 - pre BMP
Site 31 - post BMP
Site J - pre BMP
Site J - post BMP
Industrial Site
Storm Drain Insert (Dry) (actual runoff)
Industrial Site (potential runoff)

Discussion

Eight facilities participated in the baseline monitoring and BMP evaluation process. Of these, seven were able to be monitored after the two month time period to implement site specific BMPs recommended by the project, and general BMPs contained in OCS. Many of the site specific BMPs recommended by the project were contained in a general form in the OCS manual. One cooperating facility moved without notice during the project, and two facilities declined to cooperate with project personnel and were not given site specific BMPs. It is interesting to note that the monitoring activities around the non-cooperating facilities resulted in an awareness by management of the goals of the project and improvements at these facilities were roughly the same as those at facilities who agreed to participate. Improvements, though apparent, were not sufficient to prevent significant pellet and production scrap losses to the storm drain system. In all cases, facilities were unable to retain pellets on site during significant rain events. In storm conditions, all catch basin inserts were either removed to prevent flooding or overflowed into the storm drain system. Our recommendation is for greater capacity filtration systems for all locations surveyed in order to prevent pellet, powder and production scrap losses to the environment. Installation of so called "zero discharge" systems, though they be maintained to manufacturers specifications, cannot be relied upon to stop plastic facility losses without monitoring to confirm zero discharge. Wind blows plastic shavings and plastic powders used in rotational molding around these systems and into receiving bodies. No monitoring for wind blown plastics was done during this project. Plastic powder feedstock losses were not contemplated during the design of this study, and the smallest size of plastic particles studied was one millimeter. Several plastic facilities were observed to have numerous plastic powder spills. These spills were not only subject to runoff, but were observed to be repositioned and transported by the wind. Further study of stray plastic powders is needed to determine the extent of this problem.

Rail yards hold by far the greatest number of plastic pellets susceptible to runoff. All facilities made increased efforts to remove large spills, and fresh gravel is applied around railroad tracks on a regular basis to stabilize the tracks and prevent runoff. Nevertheless, during this wet season's 100-year high rain totals, lines of mobilized pellets floated off from rail yard gravel were photographed, showing how they flow to storm drains and catch basins nearby. According to managers of facilities working with the project, some of these rail yards have been in use for 35 years or more for pellet delivery and pellets were found to be numerous down to at least a foot deep where core samples were taken. Since the majority of these pellets float in water, hard rain will mobilize pellets from deeper within the gravel matrix. It must be remembered that the high rain totals experienced during the post-BMP period washed many of the particles away before dry weather returned and facilitated the post-BMP catch basin sampling, so that improvement in the numbers of pellets subject to runoff may not have been due to cleanup measures alone. Even though post-BMP numbers of plastic particles on site subject to runoff were approximately one fourth of pre-BMP numbers, and plastic particles that would have entered the storm drain system if the catch basin inserts had not been installed were one half the pre-BMP count, the total number of particles on the ground and in catch basin inserts still exceeded 10 million, about half of which were pre-production plastic pellets. Post BMP wet period samples were not included because there were no pre BMP wet period samples for comparison of improvements and the post BMP wet period sampling would not be accurate because most of the catch basin inserts overflowed during the numerous rain events, making it impossible to monitor and count the amount of plastic that flowed into the catch basin.

Our results indicate that improvements in pellet and particle loss occur with implementation of BMPs. New BMPs were implemented and existing BMPs were given greater attention, but how

much of the improvement was attributed to the BMPs alone is impossible to determine due to the unusually high amount of rain during the sampling period. Our results also confirm that current strategies are inadequate to stop the monitored industrial components of anthropogenic debris from straying onto the terrestrial, and into the aquatic and marine environments. Long term monitoring would show whether these facilities improve further, stay the same, or revert to pre-BMP levels.

Afterward

What was once a "black box" behind a "plastic curtain," became a much better understood industry during the course of this study. Plastic processors and transporters struggle with day-to-day problems like all other industries, but are willing to add to their work load if significant benefits can be demonstrated.

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