A Characterization Of Hazardous Wastes In The Solid Waste Stream At The University Of California, Berkeley

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Introduction

The University of California at Berkeley (UCB), one of the state's largest research institutions, deals with hazardous materials on a daily basis. Unfortunately, hazardous materials often become hazardous waste. Some of this hazardous waste is legally disposed of by UCB's Office of Environmental Health and Safety (EH&S). For various reasons an unknown quantity of hazardous waste is disposed of illegally in university dumpsters located throughout the campus. Some of this is "household hazardous waste," i.e., products that can be purchased for use at home (e.g. paints, batteries, solvents, cleaners, etc.); other hazardous substances such as lab chemicals or other wastes associated with research are also disposed of illegally in dumpsters.

The intent of this study is to 1) quantify the weight of hazardous material present in the solid waste stream at the Berkeley campus, and 2) correlate hazardous waste types with specific locations or academic endeavors. This has been accomplished by examination of the contents of selected dumpsters on campus. The information generated by this study is used to demonstrate the need for proper disposal management and education programs that will reduce the occurrence of hazardous waste in the solid waste stream.

Past Studies

In a series of studies known as The Garbage Project, researchers at the University of Arizona attempted to assess the dynamics of household hazardous waste disposal (McGuire, 1980 and Rathje *et al.*,1986). The Garbage Project conducted a study in Marin County, California (Rathje *et al.*, 1987) which examined the garbage of residential areas to identify the types and to project the amount of hazardous waste disposed of by residents via the solid waste stream. I used the Marin study as a model for the development of my study design since the objectives of the two studies were so closely related. The Marin study concluded that about 0.47 percent of Marin County's household waste is hazardous.

Background

The Environmental Protection Agency (EPA) has created a list of hazardous substances that are illegal to dispose of via the municpal waste stream (Code of Federal Regulations, Part 261.33, 1987). Violators of this law are subject to liability for any damage that may result from the illegal disposal of hazardous material, whether they occur during transportation to the landfill, at the landfill, or even after the landfill has closed. The EPA classifies UCB as a large-quantity generator of hazardous waste. This classification refers to facilities generating over 1,000 kg of hazardous waste per month (Code of Federal Regulations, Part 260.10, 1987). As a large-quantity generator, UCB must dispose of its hazardous waste according to state and federal regulations.

EH&S is responsible for managing UCB's hazardous waste. During fiscal year 1987, 28.32 tons of hazardous waste were collected from all areas of campus (Belk, 1988, pers. comm.). EH&S is also involved in providing information on proper disposal techniques, storage methods, and safety instructions to faculty and staff. Recognizing the problem of illegal disposal of hazardous substances in dumpsters, EH&S has placed signs on each dumpster warning against chemical disposal. As a result the collection staff has encountered fewer deposits of hazardous waste in dumpsters (Belk, 1988, pers. comm.). Still, a large amount of hazardous waste exits the campus through the solid waste stream.

Approximately 190 two-cubic-yard trash bins exist on the UCB campus. Each bin is serviced by the university's Department of Facilities Management (DOFM). Almost every building on campus has at least one trash bin and DOFM has some "free-floating" bins used for grounds maintenance. Nearly all solid waste exits the campus through these 190 bins which are serviced by DOFM, with the exception of waste produced by a few machine shops on campus; their waste is stored in locked bins that are serviced by the city of Berkeley. Wet waste produced by food service facilities is also collected by the city. DOFM collects trash on campus Monday through Friday. Nearly all the dumpsters are emptied every day, but some are emptied twice a day and others twice a week. The garbage is retrieved in DOFM's three garbage trucks and sent to the Richmond sanitary land fill for disposal (Shifrin, 1988, pers. comm.). About 4,275 tons of solid waste were collected by DOFM during the 1986-87 fiscal year (Shifrin, 1987).

Methods

Trash bins were selected to provide a representative sample of the types of wastes thrown out in the solid waste stream on campus; in this way, the data collected can be extrapolated for the whole campus and correlations can be drawn between activities carried out at each building and the amounts and types of hazardous waste generated. The buildings chosen are as follows: an art building (Kroeber Hall), a gymnasium (Hearst Gym), a library (Moffitt), two science buildings (LeConte Hall and the Life Science Building), a math building (Evans Hall), the Electrical Engineering and Computer Science building (Cory Hall), an English building (Wheeler Hall), an entertainment facility (Zellerbach Auditorium), a research facility (Oxford Tract), and a bin for grounds use only (used for the collection of trimmed grass and branches and raked material).

At each building one dumpster was selected for examination. If there were multiple bins, one was randomly selected through the toss of a coin. Once every week for anywhere from 6 to 9 weeks, depending on the building, the contents of each bin were examined for five minutes. Any hazardous waste found within the five-minute period was set aside for analysis. Hazardous waste was identified under the assumption that a container's label gave a valid description of its contents. Hazardous waste was recognized as any waste containing one or more of the chemicals listed by the Environmental Protection Agency (EPA) as hazardous (Code of Federal Regulations, Part 261.33, 1987).

The weight of the hazardous waste obtained from dumpsters was measured using a standard top-loading kitchen scale or by estimating the volume of liquid forms. Volume estimation was done to avoid including the weight of the container with the weight of the hazardous substance. However, if the hazardous substance itself could not be readily measured or estimated (e.g. batteries, solvent soaked rags, fluorescent lamps) the weight of the entire item was taken. All volumes were converted to weight using the State Health Department's conversion factor of 8.3 pounds per gallon (Belk, 1987, pers. comm.). Other data that were collected were the percentage of the bin filled with garbage at the time of the examination, the percentage of garbage examined within the five-minute time period, and a written description of the hazardous waste that was found. To avoid exposure to toxins while examining garbage I wore rubber gloves, a long-sleeved sweat shirt, and safety glasses.

Once identified, the hazardous substances were categorized according to a coded classification system similar to that of the Marin study and divided into eight major categories (Rathje *et al.*, 1987; see Appendix 1). These categories are household cleaners (general cleaning products that can be purchased for home use); automotive maintenance; general maintenance (products that are used to maintain and repair a building and articles within); pesticide and yard maintenance (pesticides and herbicides); structural (items that are essential to the mechanical operation of a building or machine); personals (products used for body care); office-related (copy toner, inks, and white out); known lab waste; and unknown (unidentifiable) lab waste.

For each building the data were analyzed to quantify the average weight of each waste types found there. This was accomplished by first calculating the average amount of each hazardous waste type found during all examination periods. This number was then divided by the average percentage of garbage examined during each visit. This was done to account for the fact that only a portion of the garbage was examined within the five-minute examination period. This figure was then divided by the number of days garbage had accumulated in the bin (based on information provided by DOFM), yielding an average amount of each hazardous waste type per bin per collection-day. The average amounts of hazardous waste calculated for each building were then extrapolated to project the total weight of hazardous waste found in the university's solid waste stream. This was accomplished by averaging the average amounts of hazardous waste found at each building to give an average amount of hazardous waste per collection-day in any dumpster on campus. This number was then multiplied by the number of bins serviced by DOFM (190) and multiplied again by the number of days garbage is collected by DOFM in one year (248). These calculations yield the average amount of hazardous waste generated by the university per year. (For a complete breakdown of methods for analysis of data over the entire campus see Appendix 2.).

Data

The results of this study reveal that UCB disposes of about 182 tons of hazardous waste per year in campus dumpsters. This corresponds to 4.3 percent of the total amount of garbage disposed of by DOFM during the fiscal year 1987. The dominant type of hazardous waste found to be disposed of in UCB dumpsters is known lab waste, which accounts for 36.1 percent of all hazardous waste entering the solid waste stream (see Figure 1). Office waste, which was composed primarily of both liquid and dry copy toner, and structural waste, which consisted mainly of fluorescent lamps, were the next largest components of the hazardous waste found in the solid waste stream, at 19.9 and 18.8 percent respectively. General maintenance, consisting mostly of paint, and unknown lab waste were also significant components of the hazardous materials found in dumpsters, at 12.2 and 9.1 percent respectively. Auto maintenance waste, cleaners, pesticides and yard maintenance were insignificant to nonexistent.

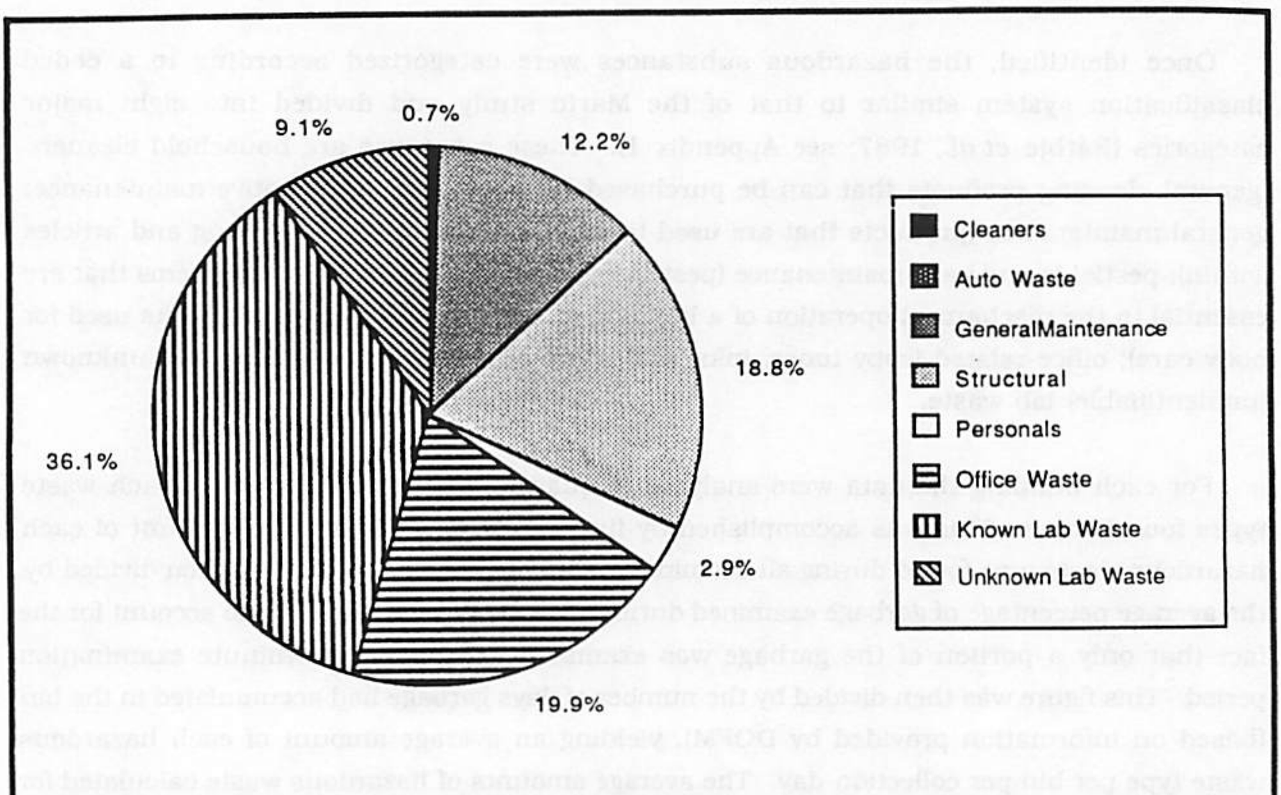

Figure 1. Percentage of Hazardous Waste Types in UCB Solid Waste Stream

The average amounts of hazardous waste found at each building in pounds per bin per day, and a description of the major waste types found at each building are presented in Table 1 and Figure 2. Of the buildings sampled, the Life Science Building (LSB) disposes of by far the greatest amount of hazardous waste, averaging 37.5 lbs per bin per day. Nearly all of this waste consisted of both known and unknown lab waste. Kroeber Hall, with an average of 3.9 lbs per bin per day disposed of primarily general maintenance waste which consisted of artists paint and solvents. The dumpster at Zellerbach Auditorium and the grounds bin contained no hazardous waste items. All other buildings disposed of either structural waste, which was usually fluorescent lamps, or office waste which was almost exclusively copy toner.

Building	Cleaners	Auto Waste	General Maintenance	Structural	Personals	Office Waste	Known Lab Waste	Unknown Lab Waste
Life Science Building	0.00	0.00	0.00	0.48	0.37	0.00	28.92	7.74
Evans Hall	0.01	0.00	6.46	7.70	0.00	0.05	0.00	0.00
Cory Hall	0.03	0.00	0.12	0.01	1.70	6.89	1.53	0.00
Wheeler Hall	0.18	0.00	0.00	0.54	0.00	7.09	0.00	0.00
Moffitt Library	0.21	0.02	0.00	4.65	0.01	0.32	0.00	0.00
Kroeber Hall	0.00	0.02	3.72	0.11	0.00	0.00	0.00	0.00
LeConte Hall	0.10	0.00	0.04	0.24	0.00	2.63	0.08	0.03
Oxford Tract	0.00	0.00	0.00	1.67	0.00	0.00	0.17	0.04
Hearst Gym	0.05	0.25	0.09	0.65	0.39	0.00	0.00	0.00
Zellerbach Auditorium	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grounds	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 1. Average Weight of Hazardous Waste at Each Building (lbs/bin/collection-day)

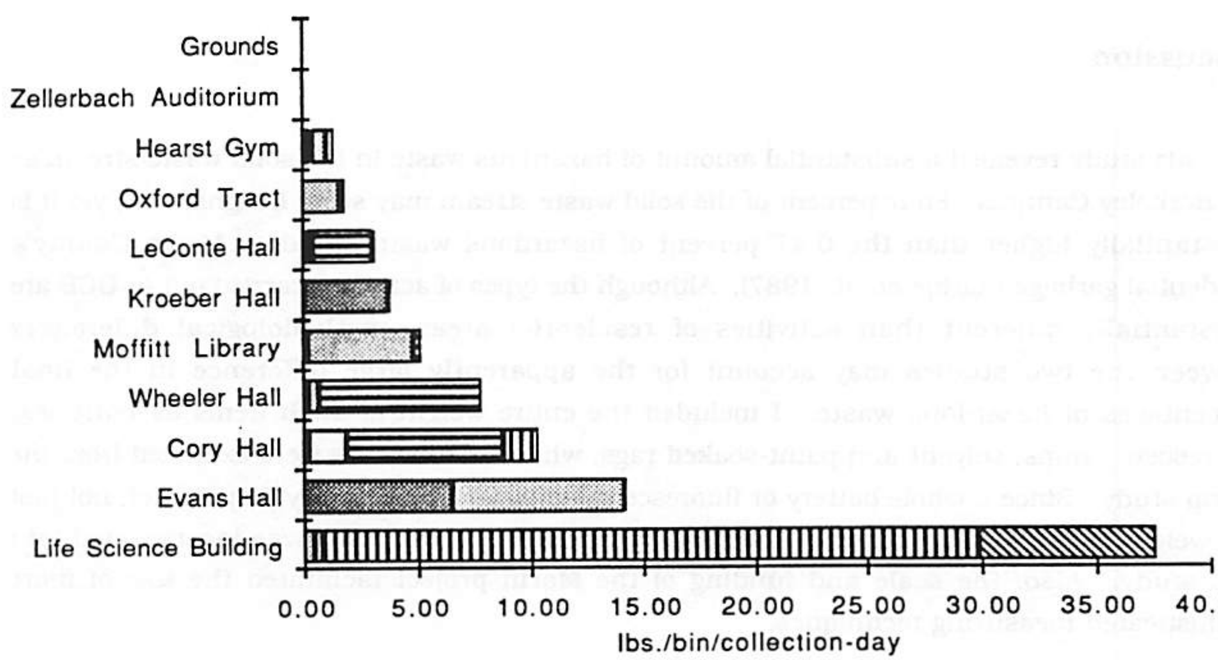

Figure 2. Average Weight of Hazardous Waste at Each Building (for legend see Figure 1)

Other interesting site specific observations were as follows. Cory Hall had reagent bottles of acid in brown plastic bags sitting next to the garbage bins nearly every time the dumpster was visited. The bottles were labeled and capped, and contained residual liquid within (usually not more than a few ounces). University policy requires that all reagent bottles be triple-rinsed and the caps and labels removed before disposal (Belk, 1987, pers comm.). Also, Cory Hall had a separate container for fluorescent lamps located outside the building near the dumpsters. No fluorescent lamps were found in the dumpster at Cory Hall, yet at every other building fluorescent lamps were present in dumpsters. This suggests that the presence of a separate container for fluorescent lamps outside each building could greatly reduce their presence in the solid waste stream.

Potentially biohazardous waste was found at Oxford Tract and to a lesser extent at LSB. This waste usually consisted of petri dishes and other lab-ware in special bags labeled "biohazardous waste/must be autoclaved before disposal" (autoclaving is the process in which the waste is sterilized by a special heating treatment), or in large garbage bags with no labels. It is very difficult to tell whether a bag of waste has been autoclaved. It is said that any plastic items will be slightly melted after autoclaving (Stedgee, 1988, pers. comm.), but most of the waste found in the labeled bags consisted of glass material. The waste in the unlabeled bags may not have been biohazardous, so biohazards were not included in my analysis. However, an average of about 25 pounds of potentially biohazardous waste was found at each visit to Oxford Tract, and several bags were found at LSB during one visit. Aside from the potential biohazardous waste and a relatively large number of fluorescent lamps, Oxford Tract dumpsters contained various lab wastes.

Discussion

This study revealed a substantial amount of hazardous waste in the solid waste stream at the Berkeley Campus. Four percent of the solid waste stream may seem insignificant, yet it is substantially higher than the 0.47 percent of hazardous waste found in Marin County's residential garbage (Rathje *et. al.*, 1987). Although the types of activities carried out at UCB are substantially different than activities of residential areas, methodological differences between the two studies may account for the apparently large difference in the final percentages of hazardous waste. I included the entire weight of such items as batteries, fluorescent lamps, solvent and paint-soaked rags, while such articles were excluded from the Marin study. Since a whole battery or fluorescent lamp must be properly disposed of, not just the weight of the toxic substance alone, the full weight of these items was incorporated into this study. Also, the scale and funding of the Marin project facilitated the use of more sophisticated measuring techniques.

Sources of error in this study may include the selection of buildings that do not adequately represent all buildings on campus. Estimation of liquid volumes and the estimation of thepercentage of garbage searched through during each examination period may represent other sources of error. It should be noted that the amounts of each hazardous waste type presented in Table 1 and Figure 1 are only averages of what was observed in each bin throughout the data collection period and should not be taken to represent the actual amounts of hazardous waste present in a bin on any given day. Some waste such as copy toner and especially fluorescent lamps were discarded intermittently and often in large quantities (20-50 fluorescent lamps in one bin was not uncommon). Large-quantity disposals would cause the average weight of hazardous material at each building to increase if they were discovered and recorded, and decrease if they were missed. This clearly was the case at Evans Hall where four gallons of paint were found during one examination period. This skewed the results for Evans Hall toward a high proportion of paint (see Figure 2). The only way to avoid such a problem would be to increase the number of examination periods by examining dumpsters every week or better still every day for a year. However, I feel the number of examination periods used in this study was adequate to reveal the types of hazardous waste produced by different buildings on campus as well as the magnitude of hazardous waste entering the solid waste stream.

The results suggest two correlations between activities within specific buildings and the types of hazardous waste found in associated dumpsters. Hazardous wastes disposed of by LSB, the University's largest science building, consisted almost entirely of lab waste. The primary type of hazardous waste at Kroeber Hall, which houses the Art Department, was artist's paint and solvents. Materials such as fluorescent lamps and copy toner were found to have no correlation with specific buildings or activities. This suggests that the typical university building is capable of producing these types of hazardous wastes regardless of the activities carried out within. This stands to reason since all university buildings are illuminated by fluorescent lamps that must periodically be changed and discarded. Additionally nearly all buildings on campus contain copy machines that produce toner waste.

EH&S, with only three technicians and one administrator working in a facility already operating at full capacity, is ill-suited to take on the responsibility of managing almost seven times the amount of hazardous waste presently managed. Due to limited funding and facilities, EH&S is forced to prioritize hazardous waste, resulting in management of only the more highly toxic wastes. Unfortunately, less toxic waste, while still illegal to dispose of in dumpsters, is overlooked. This practice allows approximately 180 tons of hazardous waste to be concentrated at the Richmond sanitary landfill. Large quantities of less toxic wastes disposed of in landfills that are directly exposed to the environment may be just as, if not more, environmentally damaging as small quantities of highly toxic wastes that are "safely" disposed. This is an important issue that demands serious thought by UCB administrators. As of now the University is contributing to the degradation of the environment by illegally disposing a large quantity of hazardous waste into the municipal waste stream.

Conclusions and Recommendations

The proper disposal of hazardous materials is a problem faced by all universities. This study of UCB's waste simply demonstrates the magnitude of the problem. However, there are measures UCB can take to reduce the amount of hazardous material entering the solid waste stream, and to bring the University into compliance with current law. The most effective change UCB can make is to expand EH&S so they can adequately manage all of UCB's hazardous waste. With increased funding and more efficiency by EH&S, programs may be implemented to reduce the amount of hazardous waste in dumpsters.

Separate labeled containers for copy toner placed next to copy machines, and accompanied by information on the hazards of different types of toners, could facilitate proper disposal of this type of waste. EH&S could periodically pick up the toner and dispose of it properly. To reduce the number of fluorescent lamps in the solid waste stream, containers for fluorescent lamps only (similar to the container at Cory Hall) should be placed outside each building next to the garbage bins. The lamps could then be picked up by DOFM and recycled using a bulb crusher (see Getz, this report). By preventing copy toner and fluorescent lamps from entering the solid waste stream, the amount of hazardous waste found in the waste stream could be reduced by 37 percent. Similarly, containers for paint and solvent waste could be placed in art studios on campus. These containers could then be periodically emptied by EH&S.

To accompany these efforts, EH&S should organize education programs that will provide information to university faculty and staff on proper disposal methods of common hazardous wastes such as fluorescent lamps and toner that are sometimes disposed of in the garbage. This information could be in the form of fliers distributed to all university employees, or stickers placed on dumpsters reading "No Fluorescent Lamps and Toners". Special education efforts should target buildings such as LSB which have been found to dispose large amounts of hazardous lab waste in dumpsters. Special attention should also be paid to activities or buildings that consistently produce the same types of hazardous waste such as LSB and Kroeber Hall. For example at Kroeber Hall, where paints and solvents were regularly found in the garbage, specific information on the proper disposal of these materials could be provided to all faculty and students in the department.

To assure that custodians do not throw hazardous items into dumpsters the University should require that existing and prospective employees attend a special training session on proper waste disposal techniques, organized by EH&S, and pass a mandatory test on the University's hazardous waste disposal policy.

To test the effectiveness of these recommendations, EH&S could create the position of "waste stream monitor" to supervise the waste stream and report on the effectiveness of hazardous waste prevention measures. Monitoring could be done by periodically examining the contents of dumpsters throughout the campus.

These are only a few possible solutions to the hazardous waste problem at UCB. University officials need to take responsibility for the proper disposal of hazardous waste produced on campus. It is in the interest of the University to direct resources toward the elimination of hazardous materials from the solid waste stream.

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APPENDIX 1. Hazardous Waste Classification Codes and Types

Hazardous Waste Code	Types
Household Cleaners	
01	Toilet Bowl Cleaner
02	Drain Opener
03	Laundry Soap
04	Bleach
05	Dish Detergent
06	Cleanser
07	Ammonia Based Cleaners
08	Polish
09	Floor Finish
10	Air Freshener
11	Other Household
Automotive Maintenance	
20	Oil
21	Transmission Fluid
22	Engine Treatment
23	Antifreeze/Coolent
24	Auto Wax
25	Other Auto
General Mantenance	
30	Paint
31	Paint Thinner
32	Stain/Varnish
33	Glue
34	Painting Tool
35	Other Maintenance
Pesticides and Yard Maintenance	
40	Fertilizer
41	Pesticide
42	Herbicide
43	Pet Maintenance
Structural	
50	Batteries and Electrical
51	Fluorescent/Mercury Lamps
Personals	
60	Prescription Drugs
62	Cosmetics/Body Care
Office	
71	Copy Toner/Inks
72	White-out
Laboratory	
81	Base/Acid (Corrosives)
85	Flamables
86	Photochemicals
87	Unknown
88	Bio-Hazards
89	Heavy Metals

APPENDIX 2. Method of Data Analysis

t_i = total amount of H.W. recorded at bin i.
e_i = number of examination periods (e.p.) at bin i.
w_i = average percentage of garbage examined over all e.p.s at bin i.
d_i = number of days garbage had accumulated prior to examination of bin i.
11 = number of bins examined.
248 = number of days the trash is collected each year.
190 = number of bins serviced by DOFM.

1) The total amount of H.W. recorded during all e.p.s for each bin is divided by the number of e.p.s, the percentage of garbage examined during each e.p., and the number of days garbage had accumulated prior to an e.p. to get the sum of H.W. in all the bins examined. This sumation is divided by the number of bins examined to get an average amount of H.W. per bin per e.p., $\overline{X}$.

$$\overline{X} = \frac{\sum_{i=1}^{11} \frac{t_i}{w_i d_i e_i}}{11}$$

2) $\overline{X}$ is multiplied by the number of days trash is collected each year to get an average amount of H.W. per bin per year, Q.

$$(\overline{X})(248)=Q$$

3) Q is then multiplied by the total number of bins serviced by DOFM to get the total amount of H.W. present in the solid waste stream for an entire year, T.

$$(Q)(190)=T$$