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Structure and Dynamics of Household Hazardous Wastes

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STRUCTURE AND DYNAMICS
OF
HOUSEHOLD HAZARDOUS WASTES

by

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Municipal solid wastes--the majority of which are household refuse--have increasingly been implicated as a source of hazardous materials in landfill leachate discharges (U.S. EPA 1988). Data collected on the components of these wastes are critical for solid wastes systems planning--especially landfill design, hazardous materials collection systems, and resource recovery. A number of recent studies by the University of Arizona's Garbage Project have identified household products as a possible source of hazardous materials in landfills (Wilson 1985, Rathje et al. 1987a, 1987b). Studies have addressed (1) the definition of these "household hazardous wastes" (HHW), (2) the characteristics of HHW from hands-on analyses of residential solid wastes in four United States study cities and Mexico City, Mexico, (3) the relationships between derived waste characteristics and within-study city socioeconomic variability and variability between the regions studied and (4) the potential biodegradation pathways and characteristics of municipal landfill leachates.

Results of these studies suggest that: (1) While HHW comprises a very small proportion of the total residential solid wastes, total quantities generated per year are quite high. (2) Significant differences in HHW discard rates are observed between both study communities and census tracts within study communities. (3) Socioeconomic variability between census tracts (within study communities), are related to the differential discard of HHW and, we believe, can be used to estimate characteristics of HHW in U.S. cities without necessitating further large-scale, costly, refuse sorts. (4) Long-term discard trends for HHW may influence the levels of risk associated with these wastes.

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level by city and county governments, private research organizations, and university departments.

Methods

Household refuse is defined as non-hazardous by the Environmental Protection Agency (EPA) (40 CFR 261.4(b)--Office of the Federal Register 1987). Despite this, the EPA (and others) has stressed that HHW should be treated in the same manner as regulated hazardous wastes for collection and management purposes (Porter 1988). For this reason, the Garbage Project defines HHW in a manner comparable to definitions used by the EPA to identify commercial and industrial hazardous wastes. According to the Garbage Project, a **household hazardous waste** is a product or container that has ingredients which are ignitable, corrosive, reactive, or toxic (based on 40 CFR 261.21-24) or has ingredients listed in 40 CFR 261.33(e) or (f).

The Garbage Project studies of HHW all have used a standard sampling and data recording procedure. First, census tracts in each study community are selected in a judgmental fashion. The sample tracts, together, represent the range of socioeconomic characteristics (income, ethnicity, age, and household size) present in the entire community. Within the sample census tracts, sanitation personnel select "household refuse pickups" from single household dwellings with separate and identifiable refuse containers--these represent all the wastes set out on the street for removal on a scheduled pickup day. Each household's wastes are individually bagged, tagged with the census tract number, sample number, and collection date and brought to an analysis facility, usually a recycling center or transfer station. Project personnel then examine each item of refuse, in each sample, recording all packaging and commodities identified as HHW. For each item designated as hazardous, the weight of the waste, including both the weight of the container and product waste and the weight of the product waste alone, are recorded. Waste weights are recorded if they represent greater than three percent of the original product. In the rare instance when an acute hazardous waste (listed in 40 CFR 261.33(f)) is present as a constituent of a product, the waste is recorded regardless of the quantity of residue remaining. In all cases, it is noted if there are any residues remaining. In addition to wastes, each item is recorded by a special code, number of like items, the capacity and material composition of the container, brand of commodity, and specific type of commodity. Recording the brand and type allows us the flexibility to go back to the recorded data at a later point in time to specify product ingredients, the characteristics of packaging, and other critical waste composition information.

As mentioned earlier, both commodity weights and container plus commodity weights are recorded. Unless otherwise specified, all weights of HHW reported here represent the commodity plus container together.

In addition to our standard HHW recording procedure, HHW packages are recorded as part of the Garbage Project's "Regular Sort". This procedure records all packages and other items in a refuse sample. From these data, frequency counts of products that potentially contain HHW can be made. While this format does not list the weight of hazardous wastes, the number of packages (with or without wastes), the brand, and the type of product are recorded. The Regular Sort data base useable for the study of HHW, includes sample information collected from 1975 to the present. These data permit the exploration of long-term trends in the discard of packaging related to HHW (see "Dynamics", below).

To date, HHW studies have been conducted in Tucson, Arizona (1985 to the present, see Wilson 1985, Rathje et al. 1986); Phoenix, Arizona (1988, see

Rathje, et al. 1988); Marin County, California (1986, see Rathje et al. 1987a, 1987b); New Orleans, Louisiana (1986, see Rathje et al. 1987b); and Mexico City, Mexico (see Bernache 1988 and Bernache and Rathje 1988, this conference). Over sixty metric tons of household refuse have been collected and analyzed (Table 1).

In addition to refuse collected from census tracts, we have examined refuse excavated from landfills in Chicago, Illinois (two landfills), San Francisco, California (two landfills), and Tucson, Arizona (one landfill) (Table 1). The majority of HHW containers found in landfill excavations are crushed, liquid wastes having escaped their packaging. The wearing away of labels makes the recording of HHW in landfill samples additionally problematic. We do, however, procure samples for chemical and biological analyses (see Thompson 1987).

Limitations on our study community samples are threefold. First, wastes from multi-household units, such as apartment complex dumpsters, are not sampled. Second, self-haul wastes--those wastes transported by the householders to landfills for disposal--are not examined. Third, very rare events, such as the discard of auto batteries, cannot be predicted, even given the substantial size of the Garbage Project data base. For example, only two auto batteries have been found in all our studies (both were found in the Phoenix, Arizona samples). The exclusion of self-haul wastes and rare event wastes has the effect of lowering the quantities of wastes recorded. Estimates for households, census tracts, and study communities that use our data must, therefore, be considered minimal levels.

Structure of Household Hazardous Wastes

The characterization of solid wastes, including the characterization of HHW, must address two components of behavioral-based waste discard processes:

(1) the **structure**--characteristics of the waste based on the nature of the human study population at one point in time--and (2) the **dynamics**--changes in refuse characteristics based on long-term processes in waste discard, including effects on discard behavior of seasonal variations, and natural factors such as the degradation of wastes in changing environmental conditions. Attention to both of these aspects increases the quality of characterizations and results in greater precision in estimating wastes. The Garbage Project's data bases encompass multiple communities and socioeconomic strata. This wide range of social and geographic variability allows us to examine the structure of HHW in terms of these natural and behavioral patterning factors.

General Structure: Composition

The composition of HHW, based on the refuse samples collected in four United States communities, is illustrated in Table 2, Figure 1. Discard rates are formulated by dividing the weights of recorded wastes (not including the container weights) by the estimated total number of households that produced the wastes (based on those households whose refuse was sampled and those households that would have been part of the sample but did not put out refuse on the sample pickup day). While HHW represents a small proportion of the total residential solid waste stream (less than one percent--see Table 2) annual rates of generation, even for a small community, are large. The largest proportion of HHW are household maintenance items (36.6 percent), primarily paints and including adhesives, paint thinners, and sealants. Household batteries are also a large fraction (18.6 percent). Selected cosmetics, including nail polish and nail polish remover (12.1 percent), cleaners, including polishes and oven cleaners (11.5 percent), and automotive items (mostly motor oil--10.6 percent) are also important by weight. Yard items, primarily pesticides, represent a relatively small proportion of HHW by weight (see Table 2, Figure 1).

Differences in HHW characteristics between three of the study communities (Phoenix, Arizona is used as an evaluation community and, therefore, not considered here--see below) are illustrated in Table 3, Figure 2. As shown, major divergences are evident. The distribution of rates for the Tucson, Arizona sample census tracts tends toward the low-side of the three-city distribution (in terms of central tendency and range), while the distribution of rates for New Orleans tracts tends toward the high side. When HHW is compared as a percent of total solid wastes, less of a difference between the cities is observed, yet, the same general patterns are present. Using a standard non-parametric test based on ranks (Kruskal-Wallis), differences are found to be significant for cleaners (for both rate and percentage of total solid wastes) and total HHW (rate only) (see Table 3).

Structural Variability: Socioeconomic/Waste Relationships

One of the major causes for large-scale variability in waste discard characteristics from community to community is related to socioeconomic differences of the individuals producing the wastes. Within most communities there is a wide range of income levels, household sizes, ethnicities, and ages. Census tracts, as defined by the U.S. Bureau of the Census (1983), represent groups of households sharing similar socioeconomic characteristics in small, localized areas.

The significant socioeconomic variables under study are:

Percent Native (PERNAT): percentage of persons in a census tract born in the United States. This variable is a measure of the ethnic character of the census tract, especially immigrant status.

Percent White (PERWT): percentage of white persons in a census tract (excluding those white persons of spanish origin). This variable is another indicator of ethnicity for census tracts.

Persons per household (HHSIZE): a measure of the relative size of households in a census tract. HHSIZE is related to the number of children in a household and other family extensions (such as grandparents).

Median income (MEDINC): the wealth and economic access of households in a census tract (the median is a better measure of central tendency in income distributions than the mean, or average).

Median age (MEDAGE): the relative age of household members within the developmental cycle. Older median age for a census tract often indicates older persons, fewer children, and probably household in a later phase of development.

While other socioeconomic variables are studied (such as other ethnicity variables--percent hispanic for example) these have not yet been found to significantly correlated with the waste discard variables under study.

The variables are analyzed as follows: comparisons are made between rates and percentages of waste generation and socioeconomic characteristics (based on figures reported in U.S. Bureau of the Census 1983). Multiple regression procedures (using backwards selection) are employed. A number of significant relationships are evident (Table 4):

Pesticide wastes (rates and percentages) are correlated with PERNAT. While there is a trend for higher income tracts to be associated with higher rates and percentages of pesticide wastes (reported in Rathje et al. 1987a, Wilson and Rathje 1988) this trend does not explain as much refuse discard variability as PERNAT (given the present three community database).

Household battery wastes are correlated with persons per household and PERWT. In both cases, the relationships are positive indicating that census tracts with larger household sizes and increased proportions of whites have heavier weights of batteries in their waste-stream.

Prescription drug wastes are correlated with median income and median age. The relationships suggest that increased household income and lower median age will result in larger discharges of prescription drugs from a census tract.

Cosmetics wastes are correlated with the median age of persons in a census tract. In addition, the percent of total residential solid wastes that cosmetics represent is related to household size, PERWT, and PERNAT. With increased MEDAGE increased cosmetics wastes are likely to be discarded. Decreased household size, PERWT, and PERNAT result in increased fractions of cosmetics with respect to total solid wastes.

The **rate of HHW generation** (per household) is related to PERNAT, such that increases in PERNAT result in increases in the discard rate of HHW.

These preliminary findings suggest that socioeconomic variability between census tracts might be used to estimate refuse characteristics in communities without necessitating large-scale, hands-on characterizations of refuse.

As a test of these HHW generation models, the refuse data from six census tracts in the City of Phoenix, Arizona are examined. To test the validity of the HHW prediction models the following procedure is employed: (1) For each census tract, the rate of refuse generation is predicted using the regression models. (2) Discard rates are formulated based on the refuse sort data. (3) The predicted rates are, then, compared to these "actual" rates. As shown in Table 5, Figure 3, the majority of "actual" values fall within the 95 percent confidence intervals for the predictions. Some variants are observed, especially the rate of discard of pesticides and total HHW. These deviations from the expected models are probably related to (1) geographic variability--for example, variation in regional precipitation patterns which affect the types of vegetation that require fertilizers and herbicides, and (2) dynamic elements of residential refuse discard (see below).

Dynamics of Household Hazardous Wastes

While we believe that socioeconomic factors largely pattern the discard of HHW, other factors also play a part. One of the most important factors is long-term changes in product purchasing and use.

Over the last 40 years the types and constituents of consumer products have changed radically. These changes reflect, in part, the demand by the U.S. household for labor-saving products and the parallel development of new chemical products. For example, home pesticides were virtually unknown until a few decades ago (Lord 1986:18).

On a smaller scale, year to year fluctuations in the purchase and use of products is reflected in the waste stream. The Garbage Project's long-term "Regular Sort" database reflects major changes in HHW discard rates (including rates of discard per household and per ton of refuse) (see Table 6, Figure 4). While the long-term database does not include waste weights, the number of containers, including empty containers and containers with wastes, are available (for batteries, however, actual numbers of batteries are used--no packaging is included). To date we have examined household batteries, yard items, auto items, and maintenance items.

As shown in Table 6, Figure 4, household batteries (number per household refuse pickup) have been discarded in higher frequencies in the 1980's, especially in 1982 and 1984. Pesticide and other yard product containers (number per ton of refuse) dramatically increase in rate of discard for 1981 and for 1985. Auto item containers (number per ton of refuse) were discarded in higher frequencies in 1981 and 1984, while maintenance item containers (number per ton of refuse) were discarded more frequently in 1975 and 1985 with other peaks in 1977 and 1981 (see Figure 4). Overall, the four categories exhibit a great deal of variation suggesting that the discard of packages, and perhaps wastes as well, is highly variable from year to year. Based on these findings, we suggest that changes in purchasing and use behavior are resulting in relatively short-term changes in discard behavior. This implies (1) that waste characterizations based on data collected within a limited span of time may not be able to reliably predict refuse discard behavior even a few years in the future and (2) that long-term trends in waste discard of HHW must be addressed for long-term waste planning.

Other factors might also play a part in explaining the community to community variability observed in the Garbage Project databases. The role of seasonality and the efficacy of HHW education campaigns and collection days, for example, are being addressed (see Rathje et al 1987a). The fate of HHW in landfills is also an area of on-going research (see Thompson 1987).

In conclusion, the characterization of HHW must be based on the behavioral-based structural components and dynamic aspects of the waste stream as they reflect the social, economic, and environmental factors extant in a community and as they are influenced by education and collection campaigns, purchasing and use patterns, and ultimately natural processes of alteration and degradation in the landfill. With attention to both of these areas the risks associated with HHW may be realistically and beneficially analyzed.

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TABLE 1
GARBAGE PROJECT HHW STUDIES

community	year	sample weight (kilograms)
STUDY COMMUNITIES		
Tucson, Arizona[1]	1984-1988	17,057
Phoenix, Arizona	1988	14,777
Marin County, CA	1986	15,659
New Orleans, LA	1986	12,197
Total U.S. Sample		**59,690**
Mexico City	1987	3,971
STUDY LANDFILLS		
Chicago		
Greene Valley	1987	1,204
Mallard North	1988	625
San Francisco		
Durham Road	1987	537
Sunnyvale	1988	538
Tucson		
Mullins	1987	762

[1] Regular Sort data pertinent to HHW research has been collected between 1975 and the present.

TABLE 2
HOUSEHOLD HAZARDOUS WASTE ESTIMATES BASED ON U.S. SAMPLE[1]

type	COMMODITY WASTES Annual Metric Tons per 100,000 households	percent
Household Cleaners	496	11.47%
Automotive Products	456	10.54%
Household Maintenance	1,583	36.61%
Yard Products	177	4.09%
Household Batteries	803	18.57%
Prescription Drugs	138	3.20%
Cosmetics	525	12.14%
Hobby/Other	146	3.38%
Total	4,325	100.00%

TOTAL REFUSE RECORDED: 50.5 metric tons.
TOTAL HOUSEHOLD HAZARDOUS WASTES (commodity waste only): 184.6 Kg (.356%).
TOTAL HOUSEHOLD HAZARDOUS WASTES (commodity + container): 266.4 Kg (.527%).

[1] Based on refuse samples collected in Marin County, California; New Orleans, Louisiana; Tucson, Arizona; and Phoenix, Arizona. New Orleans and Marin County data from Rathje et al. 1986.

TABLE 3
CHARACTERISTICS OF HHW FROM THREE U.S. CITIES[1]

TYPE	MEAN RATE PER HOUSEHOLD (STANDARD DEVIATION) TUCSON	NEW ORLEANS	MARIN COUNTY
CLEANERS**	7.8 (1.3)	19.3 (5.9)	14.3 (2.6)
AUTO ITEMS	7.8 (3.9)	12.5 (8.1)	9.0 (7.4)
MAINTENANCE	1.4 (1.7)	12.1 (13.2)	6.7 (12.8)
YARD ITEMS	9.2 (7.5)	37.0 (32.8)	18.8 (13.9)
BATTERIES	2.2 (2.3)	2.0 (2.3)	5.6 (8.5)
PR. DRUGS	10.9 (9.6)	8.0 (4.6)	14.9 (11.2)
SEL. COSMETICS	1.2 (0.9)	2.3 (2.2)	3.2 (6.9)
TOTAL HHW*	46.8 (8.9)	104.4 (44.3)	83.8 (24.9)
	MEAN PERCENT OF SOLID WASTES (STANDARD DEVIATION)		
CLEANERS**	.069 (.012)	.110 (.023)	.102 (.005)
AUTO ITEMS	.071 (.045)	.075 (.050)	.065 (.050)
MAINTENANCE	.011 (.014)	.068 (.070)	.049 (.093)
YARD ITEMS	.087 (.077)	.196 (.155)	.140 (.119)
BATTERIES	.018 (.018)	.010 (.011)	.036 (.056)
PR. DRUGS	.095 (.074)	.043 (.018)	.107 (.075)
SEL. COSMETICS	.010 (.007)	.013 (.011)	.027 (.060)
TOTAL HHW	.417 (.107)	.576 (.163)	.609 (.196)

[1] Sample sizes= Tucson, 7 census tracts.
New Orleans, 6 census tracts.
Marin County, 8 census tracts.
Kruskall-Wallis Test
* significant at alpha = .05
** significant at alpha = .01

TABLE 4
SOCIOECONOMIC/WASTE RELATIONSHIPS

WASTE VARIABLES		SOCIOECONOMIC VARIABLES	PARAMETER ESTIMATE	t	F
YARD ITEMS					
(PER HOUSEHOLD)	+	INTERCEPT	-169.368169	-2.244 *	6.371 *
		PERNAT	2.096275	2.524 *	
(PERCENT)	+	INTERCEPT	-7.350873	-1.675	3.973
		PERNAT	0.096276	1.993	
BATTERIES					
(PER HOUSEHOLD)		INTERCEPT	-31.902720	-3.411 **	7.250 **
		HHSIZE	10.585896	3.763 **	
		PERWT	0.148502	3.256 **	
(PERCENT)	+	INTERCEPT	-2.138355	-3.497 **	7.566 **
		HHSIZE	0.696310	3.814 **	
		PERWT	0.010176	3.412 **	
PRESCRIP. DRUGS					
(PER HOUSEHOLD)	+	INTERCEPT	26.928980	2.958 **	4.889 *
		MEDINC	0.000902	3.054 **	
		MEDAGE	-0.916862	-2.640 *	
(PERCENT)	+	INTERCEPT	1.895947	2.714 *	3.303
		MEDINC	0.000056	2.475 *	
		MEDAGE	-0.059816	-2.245 *	
SELECTED COSMETICS					
(PER HOUSEHOLD)		INTERCEPT	-7.138570	-1.645	4.944 *
		MEDAGE	0.276722	2.223 *	
(PERCENT)	+	INTERCEPT	2.889456	1.942	3.417 *
		MEDAGE	0.047254	3.459 **	
		HHSIZE	-0.438278	-2.015	
		PERWT	-0.010635	-2.395 *	
		PERNAT	-0.027953	-2.010	
TOTAL HHW					
(PER HOUSEHOLD)		INTERCEPT	-156.209840	-1.176	3.104
		PERNAT	2.574346	1.762	

NOTES: '+ ' = AVERAGE OF ACTUAL WASTES FOUND IN PHOENIX TRACT WITHIN 95 PERCENT CONFIDENCE INTERVALS FOR ESTIMATE
'* ' = SIGNIFICANT AT ALPHA = .05.
'**' = SIGNIFICANT AT ALPHA = .01.

TABLE FIVE
VALIDATION STUDY OF SOCIOECONOMIC/WASTE ESTIMATION TECHNIQUE

RATE OF DISCARD (GRAMS PER HOUSEHOLD PER WEEK)

	HIGH	LOW	ACTUAL	PREDICTED
TOTAL	163.95	13.70	170.81	88.82
YARD	72.86	0.00	3.82	30.16
BATTERY	18.77	0.00	21.33	8.46
DRUGS	40.48	0.00	6.37	16.94
COSMETICS	9.32	0.00	20.29	0.58

PERCENT OF TOTAL REFUSE

	HIGH	LOW	ACTUAL	PREDICT.
YARD	0.43	0.00	0.02	0.18
BATTERY	0.12	0.00	0.08	0.06
DRUGS	0.26	0.00	0.03	0.01
COSMETICS	0.36	0.00	0.07	0.00

TABLE 5

FIGURE ONE
HOUSEHOLD HAZARDOUS WASTES
FOUR-CITY SAMPLE

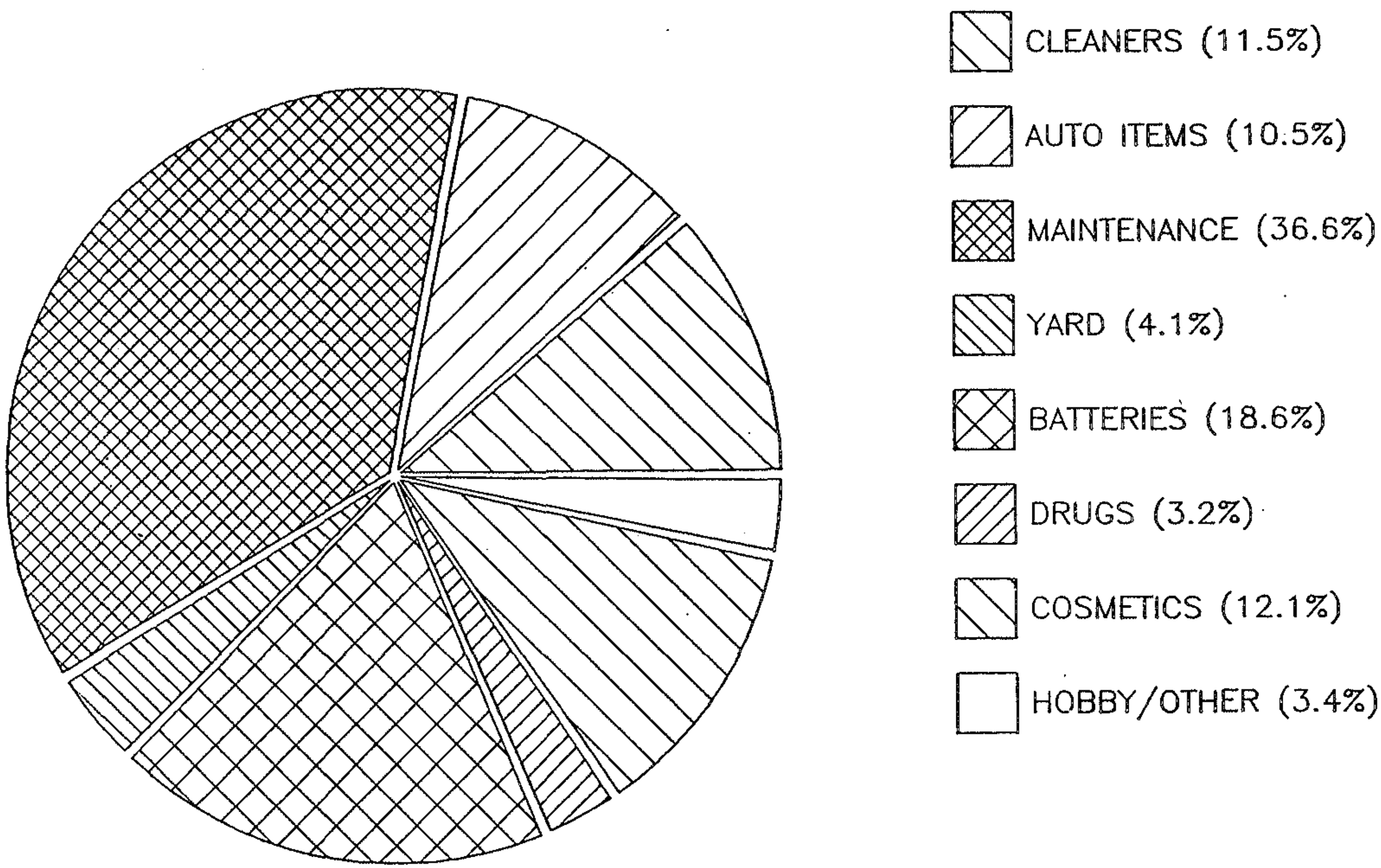
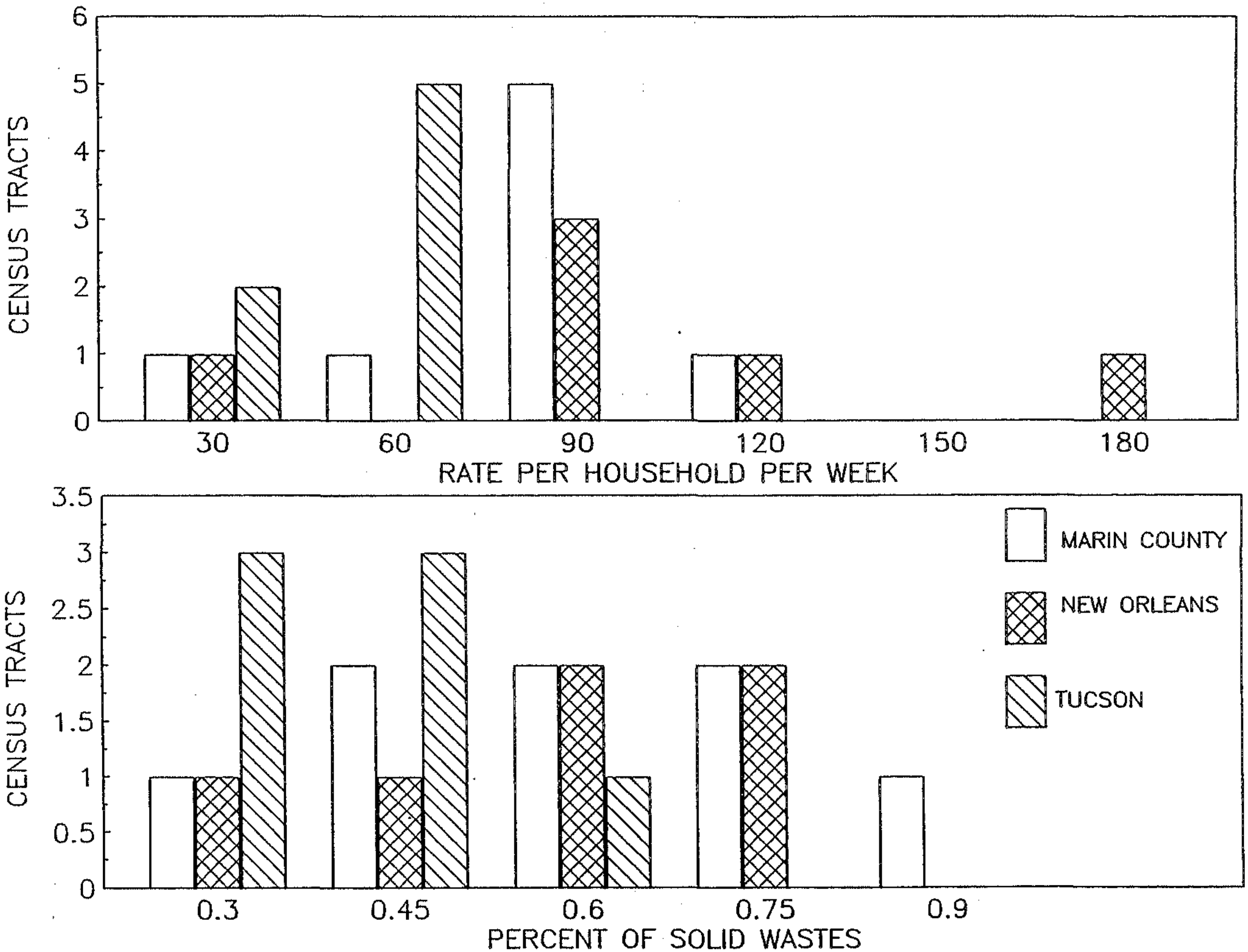


FIGURE 2
RATE OF DISCARD OF HOUSEHOLD HAZARDOUS WASTES



RATE AND PERCENT VALUES ARE MIDPOINTS

FIGURE THREE

VALIDATION STUDY OF SOCIOECONOMIC/WASTE ESTIMATION TECHNIQUES

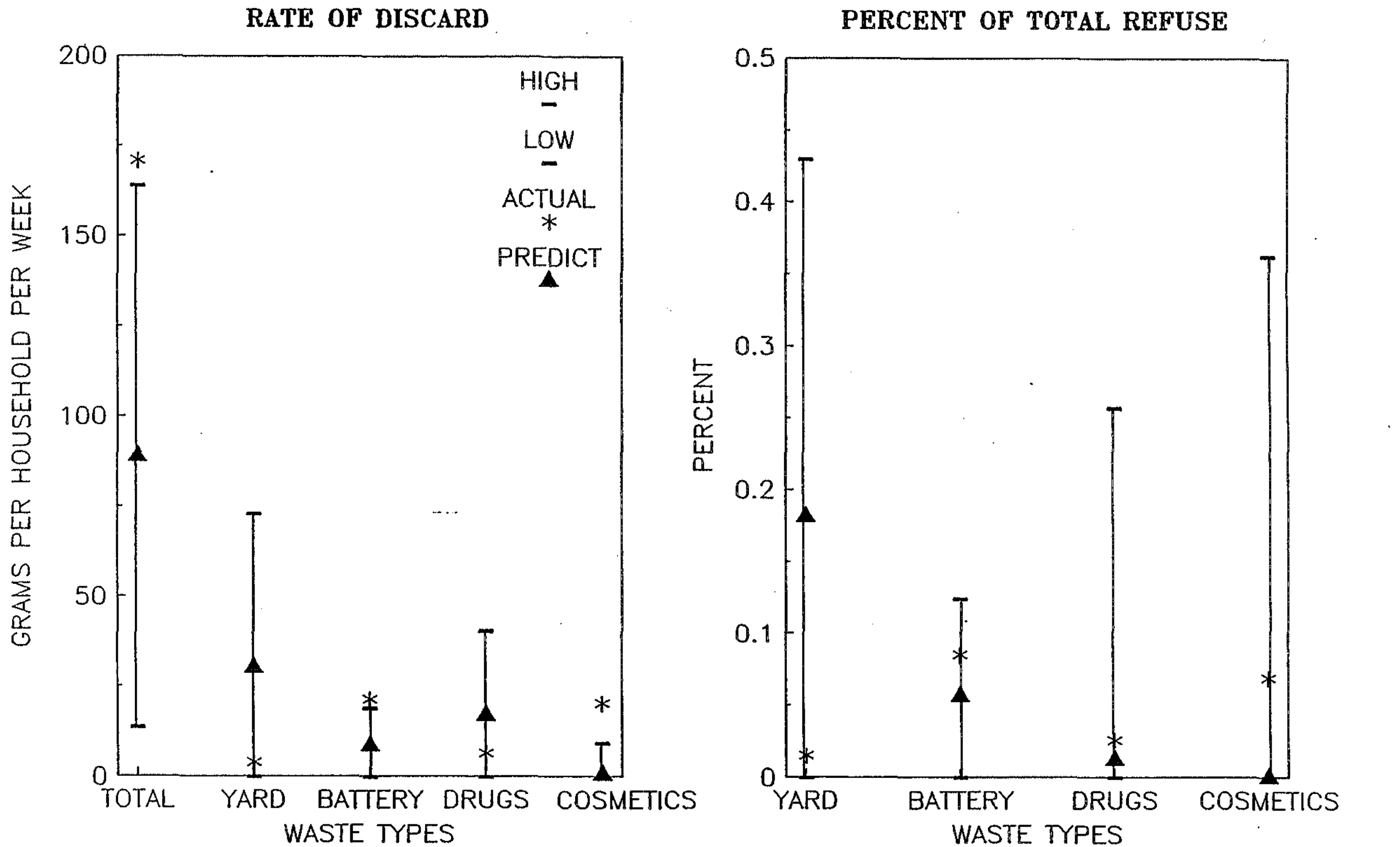


TABLE 6
TRENDS IN HOUSEHOLD HAZARDOUS WASTES

	CONTAINERS PER SAMPLE	CONTAINERS PER TON		
YEAR	HOUSEHOLD BATTERIES	AUTO MAINTENANCE	HOUSEHOLD MAINTENANCE	YARD ITEMS
75	0.129	12.29	13.11	2.87
76	0.097	6.90	7.13	3.12
77	0.094	7.64	10.00	4.18
78	0.111	6.02	5.13	3.23
79	0.052	6.11	1.53	3.05
80	0.124	5.47	8.95	4.97
81	0.110	12.06	10.64	3.51
82	0.165	6.87	1.53	4.58
83	0.106	9.90	8.91	4.95
84	0.230	13.86	10.89	1.98
85	0.180	13.33	12.73	6.67
86	0.105	NA	NA	NA

FIGURE FOUR
TRENDS IN HOUSEHOLD HAZARDOUS WASTE DISCARD