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Forecasting household waste generation

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Abstract

Developing countries do not have comprehensive systems for urban solid waste management (USWM). Only big cities maintain some kind of treatment, meanwhile, in other towns and small cities waste management consists solely of its recollection and final disposal. The data for USWM planning is poor. Much of the data used for planning purposes are from other countries. The use of theoretical models is common. Important data related to waste generation is difficult to obtain in Mexico. Municipal authorities are responsible for providing free public services (e.g., street cleaning, waste collection, etc.), however, systems to obtain data on waste generation do not exist and they are not perceived as necessary neither for economic goals nor for planning. Scientific or technological objectives have minimum resources.

This paper describes the methodology for forecasting the amounts of household waste (HW) generated in Mexico. The database consists of 39 studies on HW generation and composition undertaken across the country from 2003 to 2008. This study was based on Mexican standards NMX-AA-61-1985 and NMX-AA-22-1985. For the extrapolation we used linear regression in the municipalities, which according to the number of inhabitants were classified into 6 types. The limits were 10000, 25000, 75000, 200000 and 750000 habitants per municipality. The amount of waste and its separate fractions generated per person per day are estimated for households in each municipality class.

KEYWORDS: Generation, Composition, Residential Solid Waste, Mexico

Introduction

Mexico is one of the biggest economies in the world and has more than 105 million inhabitants. However, urban solid waste (USW) generation and management are severe problems faced in its cities. Large cities have simple systems of waste management while in medium and in the smallest towns only recollection service and dump-sites exist. Public services are free in this country; hence, there are no special funds for them. These services are funded from the “municipal big bag”. That is why, due to the municipal policy, minimum expenditures occur. Therefore, systems to obtain data on waste generation do not exist and they are not perceived as necessary neither for the implementation of economic goals nor for planning. Both scientific and technological objectives have minimum resources. USWM planning is poor. Much of the data used for planning purposes are adopted from other countries. Additionally, the use of theoretical models is common. Important data related to waste generation is difficult to obtain in Mexico.

USW is defined by its precedence in Mexico and includes household waste and residues from small trade and services providing entities. USW contains plastics, papers, organic matter, metals, and other fractions. NMX-AA-61-1985 and NMX-AA-22-1985 are the Mexican standards designed for data calculation on waste generation and composition. These standards are not obligatory. NMX-AA-61-1985 refers to the determination of waste generation, meanwhile, NMX-AA-221985 relates to- products’ selection and quantification. Standards are used mainly for Landfill projects. Data on trade and services is not included in this study; we only concentrated on the household waste.

Methodology

The methodology has four important parts. The first one is related to the estimation method for municipal waste generation. The second one is the method to obtain the composition of USW. Both are standardized methods in Mexico. The third part is the core of this work and is based on regression estimation for a stratified sample. Finally, the fourth part of this study describes the forecasting of household waste (HW).

Estimation of waste generation

Mexican standard NMX-AA-061-1985 “Environmental protection - soil contamination - municipal solid residues - determination of generation” (SECOFI, 1985) is the method used for the estimation of waste generation. References used in this work apply this method. The summary of the steps is as follows:

1. Selection of three simple samples of 50 - 115 households each in a city or town.
1. Interviewing the people of the households and explaining the process.
2. Daily waste collection from chosen households (for a week).
3. Daily waste weighting.
4. Obtaining the ratio of residues per person per house and per day.
5. Obtaining the mean average of this ratio per house in one week.

6. Elimination of the means that do not fulfil the criterion of Dixon.
7. Obtaining the ratio of waste generation for each sample derived from the results of each household.
8. Obtaining the mean average of the three samples with the base on the total amount of the houses.

This estimator is bias and the standard does not explain the method for confidence interval calculation. Some references do not have error related information or data on its estimation.

Estimation of waste composition

This method is described in the Mexican standard NMX-AA-22-1985 “Environmental protection - soil pollution – municipal solid residues- by-products selection and quantification” (SECOFI, 1985). The summary of the method is presented below:

1. By Quarter Method (NMX-AA-15-1985), choosing a waste sample of 50 kg.
2. Division of waste factions into 27 categories.
3. Weighting the fractions.
4. Calculation of the percentage of each fraction.

The full version of the method described is not used in the references; some small modifications are applied. The main change is made in the list of the sub-products. The standard of 27 fractions used in our method is reduced to 7 (Table 1).

Table 1. Classification of HW

Fraction	Contents (from NMX-AA-15-1985)
A. Plastic	Soft plastic, hard plastic, polystyrene
B. Metals	Tins, ferrous metals, not ferrous metals
C. Glass	Colour, transparent
D. Cellulose	Cardboard package, other cardboard, paper
E. Organic	Leather, hard vegetable fibber, bone, food scraps, garden waste
F. Others	Cotton, synthetic fibre, oilcloth, wood, polyurethane, Cloth, Diaper, fines, crockery, pottery, construction

Stratified sample ratio estimation

Empirically one affirms that HW generation depends on the characteristics of the population. The main indicator used is HW generation per capita ($IGHW$); some studies (Sancho, et. al., 2005) have proposed diverse values for this indicator. Table 2 shows the variation between IG and total population in a city/town. It is also observed that the auxiliary variable follows logarithmic normal distribution (Figure 1) with the Jarque-Bera normality indicator (Jarque & Bera, 1980) (JB) equal to 0.007017. This induces the use of stratified sampling. The stratification diminishes the JB indicator to six classes based on the number of inhabitants in the municipality.

Table 2. Waste generation ratios in Latin-America and the Caribbean (Acurio, et. al., 1997)

City size (1000 persons)	Generation for person (kg/person/day)
< 2,000	0.97
500 a 2,000	0.74
> 500	0.55

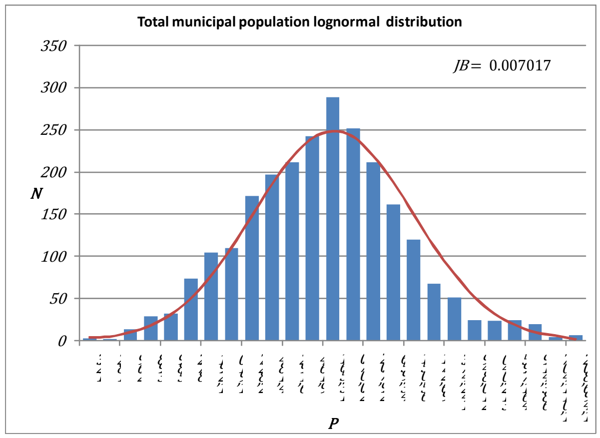

Figure 1. Lognormal distribution of the total population in Mexican municipalities (Based on INEGI[1], 2005).

Regression method is used and high correlation between two variables is observed. It is possible to calculate linear coefficients that relate both variables. In the present work, the total number of inhabitants in the municipalities is an independent variable; meanwhile, HW generation and the sub-products (Table 4) are the dependent ones.

Procedure

The next steps were followed in waste generation and characterization study in the municipalities for each class (h):

1. Referring to the studies conducted, the IG coefficient and the proportion of each of the determined waste fractions ($IPa_{h,t}$ - $IPf_{h,t}$) are obtained.

$$IGHW_{h,t}, IPa_{h,t}, IPb_{h,t}, IPc_{h,t}, IPd_{h,t}, IPe_{h,t}, IPf_{h,t} \qquad (1)$$

2. Estimation of the total amount of HW ($HW_{h,t}$) according to the number of inhabitants in the municipalities ($P_{h,t}$).

$$HW_{h,t} = P_{h,t} \cdot IGHW_{h,t} \qquad (2)$$

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3. Estimation of the share of each fraction (a - g) in the total amount of HW calculated.

$$a_{h,i} = HW_{h,i} \cdot IPa_{h,i} \qquad (3)$$

4. Obtaining sample waste generation ratios ($\widehat{IGHW}_h$, IGa_h - IGb_h) for each class.

$$\widehat{IGHW}_h = \frac{\sum_{i=1}^{n_h}(HW_{h,i} \cdot P_{h,i})}{\sum_{i=1}^{n_h}(P_{h,i})^2} \qquad (4)$$

5. Obtaining the standard error for each waste generation ratio.

$$\hat{\sigma}^2(\widehat{IGHW}_h) = \frac{1}{n_h - 1} \frac{\sum_{i=1}^{n_h}\left(HW_{h,i} - \widehat{IGHW}_h \cdot P_{h,i}\right)^2}{\sum_{i=1}^{n_h}(P_{h,i})^2} \qquad (5)$$

6. Calculation of the total amount of HW generated and its different fractions for each municipality of the country according to the class.

$$\widehat{HW}_{h,i} = \widehat{IGHW}_h \cdot P_{h,i} \qquad (6)$$

7. Obtaining the total amount of HW generated and the share of its different fractions for each federal state of country.
8. Obtaining the total amount of HW generated and the share of its different fractions for few next years.

Results

There are five results achieved. The first one is the stratification of Mexican municipalities by the number of inhabitants (Table 3). The second one is a formation of a set of municipalities in the sample. The main result is the forecast of HW generation in 32 federative entities. Error forecasting is the fourth outcome and the validation is the last one.

Stratification

The stratification into six stratums diminishes JB indicator as shown in Table 3. Here the value for each municipality appears confirming that without the stratification the calculation of the JB indicator does not meet the criteria of normal distribution. Another important aspect is the variance of the population, which increases with each stratum.

Table 3. The Main stratification statistics of Mexican municipalities by the number of inhabitants (Based on INEGI 2005).

h	1	2	3	4	5	6	Total
Min	0	10,000	25,000	75,000	200,000	750,000	
Max	9,999	24,999	74,999	199,999	749,999	1,999,999	
N_h	1,127	624	465	141	81	16	2454
P_h	4’638,612	10’178,037	19’769,285	16’421,991	33’022,960	19’232,503	103’263,388
$\bar{\bar{P}}_h$	4,115.9	16,311.0	42,514.6	116,468.0	407,690.9	1’202,031.4	42,079.6
$S^2_{P_h}$ [1]	7.41 x 10^{+06}	1.76 x 10^{+07}	1.88 x 10^{+08}	1.03 x 10^{+09}	2.68 x 10^{+10}	1.16 x 10^{+11}	1.60 x 10^{+10}
$\alpha 3_{P_h}$ [2]	0.459	0.394	0.662	0.676	0.597	0.237	7.578
$\alpha 4_{P_h}$ [3]	-0.928	-0.958	-0.650	-0.431	-0.776	-0.961	72.646
JB_{P_h} [4]	0.071	0.064	0.091	0.084	0.084	0.048	229.461

[1] variance. [2] Skewness. [3] Kurtosis. [4] Jarque-Bera normality indicator.

Sampling of the municipalities

The samples are not random since they are taken from a set of municipalities in which studies on waste generation were accomplished during the Census of INEGI. Some of the studies were carried out for the executive project of the municipal landfill. Others were implemented for the integrated waste management municipal program. There are also some studies that aim only at the obtainment of the amount of waste generated.

Table 4. HW generation indicators from each sample investigated (Several references)

Municipality (*State*)	h	i	$IGHW$ kg/day/ person	IP_a %	IP_b %	IP_c %	IP_d %	IP_e %	IP_f %	Year
San Andrés Ixtlahuaca (*Oaxaca)*	1	1	0.300	0.156	0.041	0.056	0.054	0.420	0.272	2005
Ayapango (*México)*	1	2	0.808	0.048	0.005	0.067	0.068	0.729	0.084	2007
San José de Gracia (*Aguascalientes)*	1	3	0.666	0.143	0.014	0.034	0.072	0.276	0.461	2006
Tenango del Aire (*México)*	1	4	0.473	0.106	0.026	0.046	0.077	0.439	0.306	2007
Cosío (*Aguascalientes)*	2	1	0.471	0.257	0.022	0.052	0.139	0.208	0.323	2005
Ahuacatlán (*Nayarit)*	2	2	0.620	0.176	0.050	0.019	0.069	0.520	0.166	2006
San Antonio de la Cal (*Oaxaca)*	2	3	0.336	0.163	0.029	0.043	0.085	0.441	0.239	2005
Jala (*Nayarit)*	2	4	0.590	0.136	0.058	0.044	0.121	0.439	0.202	2006
Ixtlán del Río (*Nayarit)*	3	1	1.040	0.178	0.025	0.054	0.095	0.461	0.187	2006
San Francisco de los Romo (*Aguascalientes)*	3	2	0.445	0.103	0.023	0.035	0.059	0.378	0.402	2006
Tepecoacuilco de Trujano (*Guerrero)*	3	3	0.505	0.097	0.000	0.038	0.066	0.528	0.271	2005
Huitzuco de los Figueroa (*Guerrero)*	3	4	0.511	0.107	0.000	0.025	0.042	0.532	0.294	2005
Calera (*Zacatecas)*	3	5	0.597	0.225	0.004	0.029	0.385	0.167	0.190	2007
Tecuala (*Nayarit)*	3	6	0.806	0.282	0.018	0.014	0.183	0.345	0.158	2006
Pabellón de Arteaga (*Aguascalientes)*	3	7	0.607	0.475	0.014	0.043	0.086	0.010	0.372	2006
Puerto Peñasco (*Sonora)*	3	8	0.377	0.192	0.033	0.036	0.085	0.377	0.276	2007
Rincón de Romos (*Aguascalientes)*	3	9	0.644	0.298	0.020	0.025	0.057	0.089	0.510	2006
Valle de Bravo (*México)*	3	10	0.530	0.066	0.023	0.044	0.150	0.500	0.218	2004
Santa Cruz Xoxocotlán (*Oaxaca)*	3	11	0.446	0.098	0.016	0.026	0.113	0.596	0.151	2005
Corregidora (*Querétaro)*	4	1	0.676	0.129	0.030	0.051	0.166	0.459	0.165	2007
Iguala de la Independencia (*Guerrero)*	4	2	0.580	0.154	0.000	0.049	0.146	0.288	0.364	2005
Zacatecas (*Zacatecas)*	4	3	0.822	0.087	0.051	0.062	0.167	0.533	0.099	2004
Solidaridad (*Quintana Roo)*	4	4	0.575	0.171	0.051	0.060	0.119	0.425	0.174	2006
San Juan Bautista Tuxtepec (*Oaxaca)*	4	5	0.750	0.093	0.047	0.037	0.110	0.521	0.192	2007
Guanajuato (*Guanajuato)*	4	6	0.910	0.148	0.018	0.060	0.142	0.487	0.145	2006
Campeche (*Campeche)*	5	1	1.050	0.126	0.037	0.074	0.190	0.448	0.124	2007
Oaxaca de Juárez (*Oaxaca)*	5	2	0.610	0.108	0.027	0.050	0.109	0.576	0.130	2005
Matamoros (*Tamaulipas)*	5	3	0.878	0.093	0.031	0.044	0.116	0.581	0.134	2007
Atizapán de Zaragoza(*México)*	5	4	0.797	0.101	0.040	0.091	0.153	0.433	0.182	2006
Cuautitlán Izcalli (*México)*	5	5	0.555	0.120	0.032	0.044	0.131	0.395	0.279	2004
Benito Juárez (*Quintana Roo)*	5	6	0.834	0.187	0.055	0.108	0.266	0.219	0.166	2007
Saltillo (*Coahuila de Zaragoza)*	5	7	0.763	0.121	0.008	0.031	0.064	0.544	0.232	2007
Querétaro (*Querétaro)*	5	8	0.578	0.116	0.038	0.065	0.193	0.369	0.219	2005
Chihuahua (*Chihuahua)*	6	1	0.920	0.121	0.027	0.074	0.144	0.543	0.091	2007
Naucalpan de Juárez (*México)*	6	2	0.781	0.101	0.037	0.088	0.163	0.364	0.248	2003
León (*Guanajuato)*	6	3	0.923	0.110	0.023	0.058	0.124	0.577	0.107	2007

National forecasting

Applying the equations of the section 0, the $\widehat{IG}$s were calculated for each stratum. The results are shown in Table 5. The units for all waste generation indicators are kg/day/person. Standard errors are also calculated and shown in Table 5.

Table 5. HW generation indicators and its standard errors in the sample (Own calculation)

h	Class					
	1	2	3	4	5	6
N_h	1,127	624	465	141	81	16
P_h	4 115.9	16 311.0	42 514.6	116 468.0	407 690.9	1 202 031.4
n_h	4	4	11	6	8	3
$\bar{p}_h$	6 191.8	14 735.8	39 996.5	133 021.3	486 575.1	952 773.3
$s^2(\bar{p}_h)$	$1.20 \times 10^{+07}$	$1.13 \times 10^{+06}$	$1.39 \times 10^{+08}$	$2.81 \times 10^{+08}$	$2.95 \times 10^{+10}$	$8.04 \times 10^{+10}$
$\widehat{IGa}_h$	0.0616	0.0912	0.1066	0.0937	0.0906	0.0983
$\hat{\sigma}^2(\widehat{IGa}_h)$	1.76×10^{-04}	2.05×10^{-04}	7.03×10^{-04}	1.14×10^{-04}	1.37×10^{-04}	6.60×10^{-05}
$\widehat{IGb}_h$	0.0096	0.0230	0.0094	0.0243	0.0238	0.0238
$\hat{\sigma}^2(\widehat{IGb}_h)$	3.74×10^{-06}	5.32×10^{-05}	2.88×10^{-06}	3.71×10^{-05}	2.26×10^{-05}	4.27×10^{-06}
$\widehat{IGc}_h$	0.0288	0.0201	0.0177	0.0395	0.0461	0.0601
$\hat{\sigma}^2(\widehat{IGc}_h)$	5.72×10^{-05}	1.62×10^{-05}	7.63×10^{-06}	2.55×10^{-05}	8.51×10^{-05}	2.61×10^{-05}
$\widehat{IGd}_h$	0.0437	0.0546	0.0689	0.1025	0.1127	0.1212
$\hat{\sigma}^2(\widehat{IGd}_h)$	2.16×10^{-05}	1.35×10^{-04}	2.92×10^{-04}	1.38×10^{-04}	4.52×10^{-04}	2.78×10^{-05}
$\widehat{IGe}_h$	0.2809	0.2178	0.2023	0.3426	0.3054	0.4678
$\hat{\sigma}^2(\widehat{IGe}_h)$	8.65×10^{-03}	2.72×10^{-03}	1.16×10^{-03}	2.12×10^{-03}	1.87×10^{-03}	5.21×10^{-03}
$\widehat{IGf}_h$	0.1777	0.1124	0.1447	0.1306	0.1415	0.1178
$\hat{\sigma}^2(\widehat{IGf}_h)$	2.76×10^{-03}	2.12×10^{-04}	6.10×10^{-04}	3.21×10^{-04}	7.46×10^{-05}	8.87×10^{-04}
$\widehat{IGHW}_h$	0.6022	0.5191	0.5496	0.7333	0.7201	0.8892
$\hat{\sigma}^2(\widehat{IGHW}_h)$	6.33×10^{-03}	4.28×10^{-03}	2.09×10^{-03}	3.28×10^{-03}	2.47×10^{-03}	1.79×10^{-03}

The total amount of waste generated in the states and country are shown in Table 6.

Table 6. The total amount of HW generated by fraction and federal entities in 2005 (t/day) (Own calculation)

Federal entity	$\hat{A}$	$\hat{B}$	$\hat{C}$	$\hat{D}$	$\hat{E}$	$\hat{F}$	$\hat{G}$	$\widehat{HW}$
Aguascalientes	100	22	41	107	303	29	120	722
Baja California	277	67	160	336	1 233	55	293	2 420
Baja California Sur	49	11	19	50	149	14	57	349
Campeche	72	15	26	71	218	20	85	506
Coahuila de Zaragoza	233	53	96	247	723	68	280	1 696
Colima	53	13	21	54	183	15	59	396
Chiapas	415	73	122	348	1 104	107	490	2 649
Chihuahua	312	68	156	336	1 276	62	347	2 554
Distrito Federal	814	208	442	1 005	3 164	217	943	6 793
Durango	139	31	55	139	419	41	170	989
Guanajuato	471	105	206	500	1 658	117	528	3 583
Guerrero	299	57	93	260	804	81	347	1 930
Hidalgo	226	40	59	173	569	59	259	1 375
Jalisco	645	143	295	677	2 364	151	726	4 988
México	1 332	303	614	1 469	4 676	344	1 532	10 262
Michoacán de Ocampo	375	76	120	327	1 051	104	435	2 473
Morelos	155	31	51	140	442	41	179	1 036
Nayarit	92	18	30	84	253	25	106	606
Nuevo León	394	92	190	448	1 419	103	464	3 109
Oaxaca	293	52	93	219	897	70	454	2 064
Puebla	507	100	190	455	1 669	118	599	3 621
Querétaro de Arteaga	151	33	59	156	448	43	180	1 069
Quintana Roo	106	25	46	117	331	31	127	782
San Luis Potosí	226	48	81	214	659	64	267	1 551
Sinaloa	249	58	119	280	903	63	283	1 954
Sonora	222	49	88	228	697	63	272	1 617
Tabasco	189	43	76	200	602	53	220	1 382
Tamaulipas	277	68	123	308	903	84	337	2 094
Tlaxcala	100	17	25	70	256	25	122	609
Veracruz-Llave	677	134	211	583	1 895	183	783	4 440
Yucatán	168	31	70	154	606	34	215	1 275
Zacatecas	130	24	36	102	355	34	152	827
TOTAL	**9 745**	**2 107**	**4 014**	**9 856**	**32 228**	**2 518**	**11 431**	**71 721**
Confidence interval total average proportion	**± 15%**	**± 20%**	**± 17%**	**± 17%**	**± 15%**	**± 15%**	**± 13 %**	**± 7%**

Forecasting of household waste generation

The forecasting of HW generation in Mexico is showed in figure 2 by each fraction.

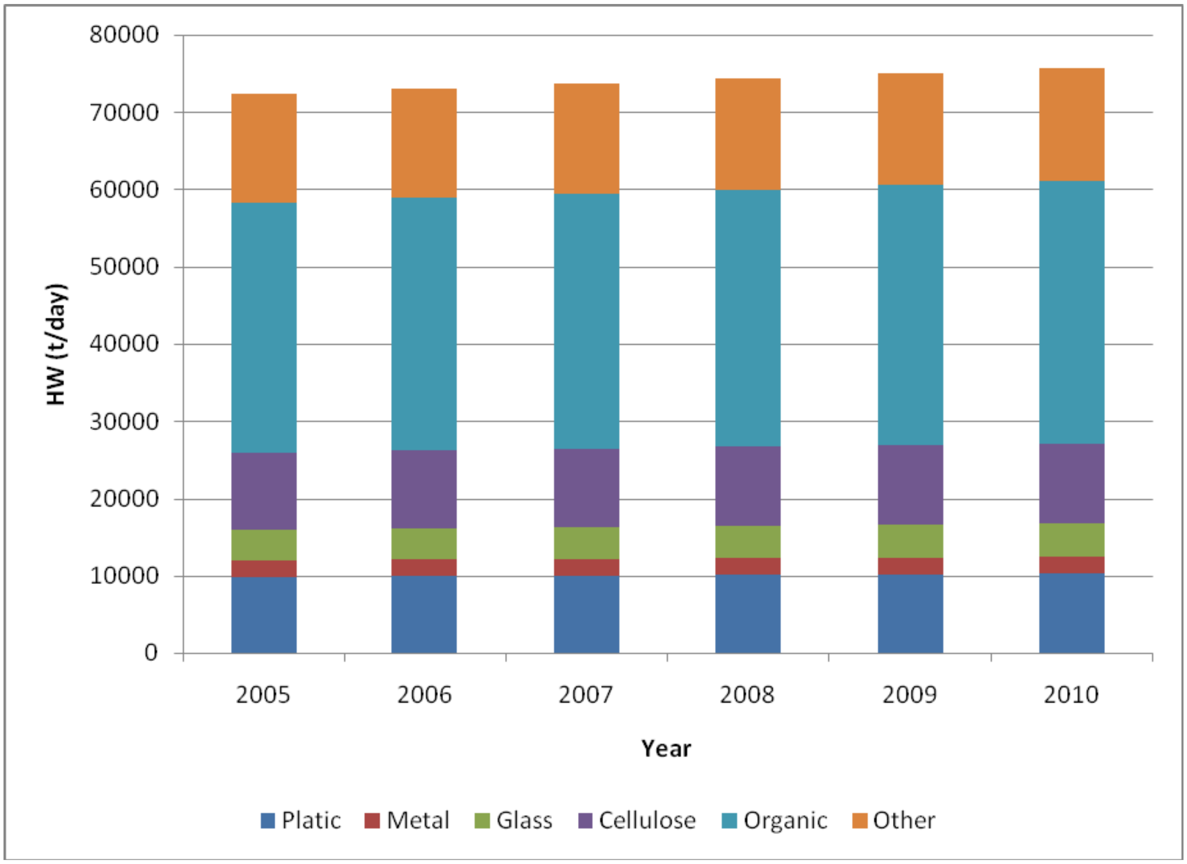

Figure 2. Forecast of HW generation in Mexico (Own compilation, based on CONAPO, 2005)

Validation

The total number of households in the municipalities used for the model validation is taken from the 2005 Census (INEGI, 2005). Households per person ratio are calculated using the following equations (7-10). The first calculation uses actual data, while the second one uses the model tested in this validation. Table 7 shows the results. The sixth confidence interval contains the real value of household per person ratio.

$$IGv_h = \frac{\sum_{i=1}^{N_h} V_i}{\sum_{i=1}^{N_h} P_h} \qquad (7)$$

$$\widehat{IGv_h} = \frac{\sum_{i=1}^{n_h}(v_{h,i} P_{h,i})}{\sum_{i=1}^{n_h}(P_{h,i})^2} \qquad (8)$$

$$\hat{\sigma}^2(\widehat{IGv_h}) = \frac{1}{n_h - 1}\frac{\sum_{i=1}^{n_h}\left(v_{h,i} - \widehat{IGv_h} P_{h,i}\right)^2}{\sum_{i=1}^{n_h}(P_{h,i})^2} \qquad (9)$$

$$t_h = \frac{(IGv_h - \widehat{IGv_h})}{\sqrt{\hat{\sigma}^2(\widehat{IGHv_h})}} \qquad (10)$$

Table 7. Estimation of the households per person ratio (INEGI 2005)

h	1	2	3	4	5	6
n_h	4	4	11	6	8	3
IGv_h	0.2345	0.2271	0.2286	0.2351	0.2491	0.2453
$\widehat{IGv}_h$	0.2271	0.2326	0.2356	0.2415	0.2466	0.2332
$\hat{\sigma}^2(\widehat{IGa}_h)$	2.90×10^{-05}	2.47×10^{-04}	2.96×10^{-05}	5.43×10^{-05}	1.23×10^{-05}	3.66×10^{-04}
t	1.378	-0.355	-1.293	-0.877	0.711	0.629

Conclusions

The method provides a simple way to estimate a complex process with a more or less acceptable confidence interval for estimation of waste generation.

The method can be divided into two parts, identifying the limit, by the calculation of IGs. In order to obtain these values, it is necessary a large number of studies to generate and execute the required regressions. After obtaining the IGs, is easier to estimate because only a few multiplications are required. Therefore, the method can be used for two different types of people according to their level of education.

The estimate of the generation of HW and fractions cannot be estimated for each municipality, because the method minimizes the total squared error, and although there is a high correlation, the size of the municipality is not the only variable that explains the generation.

In the same sense in some cases, the ranges associated with the results by state or national for some fraction is greater than 15%. Therefore the results may not be useful for some applications. This does not apply to the total household waste calculated (HW). This is a simple explication, the sample is small for a complex system.

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List of notations

h	Counter of class
i	Counter into class
$IGHW_{h,i}$	Generation Coefficient from NMX-AA-061-1985 in a municipality
$IPa_{h,i}$	Sum of proportions of plastic from NMX-AA-22-1985
$IPb_{h,i}$	Sum of proportions of metal from NMX-AA-22-1985
$IPc_{h,i}$	Sum of proportions of glass from NMX-AA-22-1985
$IPd_{h,i}$	Sum of proportions of cellulose from NMX-AA-22-1985
$IPe_{h,i}$	Sum of proportions of organic from NMX-AA-22-1985
$IPf_{h,i}$	Sum of proportions of other from NMX-AA-22-1985
$HW_{h,i}$	Total amount of household waste in a municipality
$P_{h,i}$	Total of inhabitants in a municipality
$a_{h,i}$	Total amount of plastic household waste in a municipality
$b_{h,i}$	Total amount of metal household waste in a municipality
$c_{h,i}$	Total amount of glass household waste in a municipality
$d_{h,i}$	Total amount of cellulose household waste in a municipality
$e_{h,i}$	Total amount of organic household waste in a municipality
$f_{h,i}$	Total amount of other household waste in a municipality
$\widehat{IGHW}_h$	Estimation of generation household waste coefficient for a class
IGv_h	Real house per person coefficient for a class
$\widehat{IGv}_h$	Estimation of house per person coefficient for a class
$\widehat{IGa}_h$	Estimation of generation plastic household waste coefficient for a class
$\widehat{IGb}_h$	Estimation of generation metal household waste coefficient for a class
$\widehat{IGc}_h$	Estimation of generation glass household waste coefficient for a class
$\widehat{IGd}_h$	Estimation of generation cellulose household waste coefficient for a class
$\widehat{IGe}_h$	Estimation of generation organic household waste coefficient for a class
$\widehat{IGf}_h$	Estimation of generation other household waste coefficient for a class
$s^2(\widehat{IGHW}_h)$	Standard error for estimation of generation household waste coefficient for a class
$s^2(\widehat{IGa}_h)$	Standard error for estimation of generation plastic household waste coefficient for a class
$s^2(\widehat{IGb}_h)$	Standard error for estimation of generation metal household waste coefficient for a class
$s^2(\widehat{IGc}_h)$	Standard error for estimation of generation glass household waste coefficient for a class
$s^2(\widehat{IGd}_h)$	Standard error for estimation of generation cellulose household waste coefficient for a class
$s^2(\widehat{IGe}_h)$	Standard error for estimation of generation organic household waste coefficient for a class
$s^2(\widehat{IGf}_h)$	Standard error for estimation of generation other household waste coefficient for a class
$s^2(\widehat{IGv}_h)$	Standard error for estimation of house per person coefficient for a class
$\widehat{HW}_{h,i}$	Estimation of total amount of household waste in a municipality
N_h	Number of municipalities in a class
P_h	Total of inhabitants in a class
$\bar{P}_h$	Average of inhabitants per municipality in a class
$S^2_{P_h}$	Variance for inhabitants in a class of municipalities
$\alpha 3_{P_h}$	Skewness for inhabitants in a class of municipalities
$\alpha 4_{P_h}$	Kurtosis for inhabitants in a class of municipalities

$JB_{\bar{P}_h}$	Jarque-Bera normality indicator for inhabitants in a class of municipalities
N_h	
$\bar{P}_h$	
n_h	Number of municipalities in a class for the sample
$\bar{p}_h$	Average of inhabitants per municipality in a class for the sample
$s^2(\bar{p}_h)$	Variance for inhabitants in a class of municipalities for the sample
$\hat{A}$	Total amount of plastic household waste
$\hat{B}$	Total amount of metal household waste
$\hat{C}$	Total amount of glass household waste
$\hat{D}$	Total amount of cellulose household waste
$\hat{E}$	Total amount of organic household waste
$\hat{F}$	Total amount of other household waste
$\widehat{HW}$	Total amount of household waste

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