Influence of socio-economic factors on household solid waste (HSW) generation of the city of Guayaquil, Ecuador.

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Abstract*– This paper estimated the household solid waste (HSW) generation and composition in Guayaquil, Ecuador. The study also determined the socio-economic factors influencing the waste generation of the households in the city by using Ordinary Least Square (OLS) regression. For this effect, a stratified random sampling methodology was used, resulting in the selection of 665 sample households for this study. The applied methodology resulted in a composition of HSW: organic waste (72,6%), plastic (8,7%), glass (2,4%), metals (1,7%), paper and cardboard (6,6%), fabrics (2,5%), dust and ashes (2,9%) and other residues, such as hazardous and electronics (2,6%). This study suggests new insights concerning the role of socioeconomic characteristics and its effects in the generation of household waste and waste composition in Guayaquil, Ecuador.

I. INTRODUCTION

Lately, the management of solid waste has become a serious problem for many countries, particularly for developing countries in which the demographic growth implies an increment in the solid waste generation. In addition, the deficient educational system and little community participation result in a lack of cleanliness. The existence of open dumps because of people throwing away their garbage in the wrong collection schedule, generate disease-transmitting vectors, bad odors and visual contamination, causing environmental pollution.

The Ecuadorian Constitution in its Section II Article 14 states the rights of nature as follows: "The right of the population to live in a healthy and ecologically balanced environment, which guarantees sustainability and good health, is recognized [1]. "It is declared of public interest the preservation of the environment, the conservation of ecosystems, biodiversity and the integrity of the country's genetic heritage, the prevention of environmental damage and the recovery of natural areas degraded furthermore". According to the Ministry of the Environment, in its Sole Text of Environmental Secondary Legislation [2], "a solid waste is any object, material, substance or solid element, that does not present any danger; resulting from the consumption or use of a good in domestic, industrial, commercial, institutional or service activities, which has no value for those who generate it, but that can be used and transformed into a new asset with an added economic value".

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According to statistical data collected from the National Institute of Statistics and Censuses (INEC) in 2017; approximately 16.62 million people live in Ecuador, from which 15% belong to the city of Guayaquil. Based on the information provided by the Ministry of the Environment, it was determined that each inhabitant of Ecuador in the urban sector produces an average of 0.58 kg/inhabitant/day of solid waste, of which 53% is organic [3].

The increase of solid waste generated in developing countries constitutes an unfavourable situation for the adequate development of human activities since it generates environmental problems. The population growth rates show an increasing tendency in the country, which implies that per capita generation of solid waste would also increase if policies of minimization and/or reuse of this waste are not adopted [4].

To plan a municipal solid waste (MSW) management strategy for a given city, it is essential to know the quantity of waste generated and its composition. The knowledge of how much and what solid waste is generated is acquired based on studies of classification of solid waste at the level of populated complexes or districts; establishing in those studies how much each inhabitant generates per day, the density of the waste, the estimated generation and the specific composition of solid waste.

For these reasons, the city will face with many problems in terms of pollution and health if the local waste management system cannot deal with the volumes of solid wastes being generated. As a first and necessary step, it is necessary to have precise data about the quantity and types of household solid waste (HSW) being generated in the city as waste as well as the factors which are responsible for HSW generation. Importantly, when influential factors can be identified, they could be a helpful tool for the environmental planners in their decision making for managing waste and environmental pollution for Guayaquil city.

Several studies have been conducted on correlating socio-economic characteristics with HSW generation. Some researchers have established that income, household size and household labor force can change the consumption patterns of households, resulting in changed composition and quantities of household waste [5] [6]. Other authors [7] [8] found that the solids per capita generation decreases with decreasing social status and solid waste composition showed variations due to the change in social status. [9] indicated that there was no much difference in the composition of wastes among different socioeconomic groups except ash residue and plastic. Furthermore, [10] found that residential solid waste generation such as food, paper, plastic and metal showed significant positive correlation with family size. [11] showed the relevance of considering social aspects, such as level of education in municipal solid waste management.

Vast amounts of solid wastes are generated from various sources such as household, markets, commercial establishments and institutions including schools, hospitals and government offices. In 2016, almost 13 thousand tons of solid waste were collected daily, of which 90.3% were collected in an undifferentiated manner and 9.7% in a differentiated manner [3]. However, this study only deals with household sector to find out correlation between HSW generation and socioeconomic factors such as household size, income level, social status, household labor force and education level. The principal hypothesis of this study is that HSW generation increases with increasing household size and income level, and that the other factors cause a decrease. The objectives of this investigation were to determine the followings:

1. Assess the types, quantity and composition of HSW generated in the city of Guayaquil;
2. Find out the correlation among household solid waste generation, and the socio-economic factors mentioned above; and
3. Find how the composition of the HSW also varies with the socio-economic factors.

Results from this study can provide inputs to the environmental management planners in their decision making towards effective and sustainable household solid waste management system for Guayaquil city.

II. THE STUDY AREA

Guayaquil is the largest and most populated city in Ecuador with around 2.70 million people in the metropolitan area. As the nation's principal commercial and manufacturing center, Guayaquil is located on the western bank of the Guayas River and is the capital of the Ecuadorian province of Guayas.

It is generally hot and humid throughout the year with an average temperature of 26ºC. The rainy season (from December to April) is very hot, oppressive and cloudy and the dry season is hot, sultry and partly cloudy. During the year, the temperature generally varies from 21 ° C to 31 ° C and rarely drops below 19 ° C or rises above 33 ° C.

This city shows much variation with respect to socio-economic conditions, for instance, in solid waste generation and it's considered to be representative for the province of Guayas. According to the last census of population and housing [12] taken in 2010, there were almost 413 thousand households, located mostly in the southwest of the city (35%) and northeast (28%), followed by southeast (25%) and finally the northeast (12%).

Waste is collected from each household by trucks. Each neighborhood has a different collection schedule (days of the week and hours), and there are no designated bins for biodegradables and no-biodegradables, so all types of waste is taken to the municipal land fill.

III. METHODOLOGY

The quantification of solid waste in the city of Guayaquil consisted of the following steps:

Calculation of number of samples

Household solid waste is a heterogenous residue, and its generation rates vary from place to place. To estimate with precision the average quantities and composition of waste, it was necessary to execute a statically designed sampling survey. Logically, the accuracy of the sampling would increase with the number of samples; nevertheless, this number had to be restricted due to the available resources.

The procedure used to determine the minimum number of samples needed to gather reasonably accurate data was based on the central limit theorem, also applied by [13]. The number of samples was determined with a 99% confidence interval and a 5% standard error, for a population of 413 thousand households, using the following equation:

$$n = \frac{k^2 * p * q * N}{e^2 * (N-1) + k^2 * p * q} \quad (1)$$

where n is the minimum number of samples, k is a constant that depends on the level of confidence (for 99% confidence k is 2.575), e is the sampling error (5%), p is the proportion of inhabitants that possess the characteristic we seek, and q is the number of inhabitants that don`t possess it (For this case is 0.5 for each one).

After using this equation, the number of households needed to obtain a 5% standard error with 99% level of confidence is 662.

Collection procedure

For determination of the HSW generation rate, a general university project was elaborated for students of two local universities of the city. A total of 140 students participated between both universities, each of them with five households including their own (4 neighbors + own home). They were given a digital hanging scale and 8 different colored polythene bags for each type of waste per household.

The project consisted in, that for two weeks they would weigh every couple of days each colored bag per household and register the data. Also, a questionnaire about socio-economic characteristics and habits was taken by the students per each household. Persons of each household were instructed by the students to use separate bags for each type of waste. Table 1 shows the quantity and color of the bags given to each household. Only the organic waste was thrown to the garbage collection place every couple of days, the other 7 types of waste were stored in each household for one week, after which they were also thrown away.

TABLE I
CHARACTERISTICS OF POLYETHENE BAGS GIVEN TO EACH HOUSEHOLD

Type of HSW	Color	Number of bags
Organic Waste (OW)	Black	14
Plastic Waste (PW)	Blue	2
Glass Waste (GW)	Green	2
Metal Waste (MW)	Gray	2
Paper/Cardboard Waste (PCBW)	White	2
Fabric Waste (FW)	Yellow	2
Dust and Ashes Waste (DAW)	Brown	2
Miscellaneous Waste (MSCW)	Red	2

Sample collection was carried out in each chosen household, during two weeks. The step by step procedure to register the data by the students was as follows:

1. Information such as neighborhood, location (northeast, northwest, southeast, southwest), telephone number and garbage truck collection schedule were taken from the students participating in the project.
2. Sample sheets formats were personalized per student to write down the weigh information.
3. Students were instructed in the project and given a digital luggage scale and 5 times the amount of color bags cited in table 1.
4. The first day of the project, students gave 1 plastic bag of each color to every household.
5. Every two days, students weighed each plastic bag and threw away the one with organic waste and the other seven were returned to the family to continue accumulating waste. These seven were thrown away each week. Whenever a bag was thrown away, they would replace it with a new one.
6. Students took the survey to each household and registered all the information in the sample sheet.

The questionnaire was administrated to 665 selected representative households to obtain information about their socio-economic factors such as household size (HS), level of income (LI), social status (SS), labor force (HL) and mid-education level (HE).

Also, the households in study area were stratified into five different socio-economic groups based on a stratification questionnaire about income, owned electronic devices, types of jobs and others. This questionnaire measures the socio-economic group on a scale from 0 to 1000.

- Low socio-economic group: threshold < 316 (LSEG)
- Middle low socio-economic group: threshold between 316,1 - 535 (MLSEG)
- Middle socio-economic group: threshold between 535,1 - 696 (MSEG)
- Upper middle socio-economic group: threshold between 696,1 - 845 (UMSEG)
- High socio-economic group: threshold between 845,1 – 1000 (HSEG)

To analyze the effect of selected independent variables to the quantity and composition of HSW, this study follows a multiple regression model. The Ordinary Least Square (OLS) method was used to estimate the parameters in multiple regression models as did by [5].

The model is:

$$Y = \beta_0 + \beta_I X^i$$

Where:

Y: Amount of waste/household/day (Dependent variable) or Composition (Dependent variable);
Xi: Independent Variables;
β_0: Constant term;
βi: Coefficient of independent variables;

The independent variables of this model are household size, level of income, social status, labor force and mid-education level shown in Table 2. All statistical analysis in this study was made by applying RStudio software.

TABLE II
DESCRIPTION OF EXPLANATORY VARIABLES

Variables	Description	Type of data
HS	Number of members in the family	Ordinal Data
LIPC	Household monthly income in total of all its members divided by the number of members	Ordinal Data
SS	Measure by an index from 0 to 1000	Ordinal Data
LF	Number of members in the family with generating income jobs	Ordinal Data
HE	Number of members in the family with at least a high school education level	Ordinal Data

IV. RESULTS

A total of 665 households from the city of Guayaquil were selected randomly for the study. The city was divided into 4 sectors and 28% came from the Southeast, 26% from the Northeast and almost equally in 22% from the southwest and northwest as shown in Fig. 1.

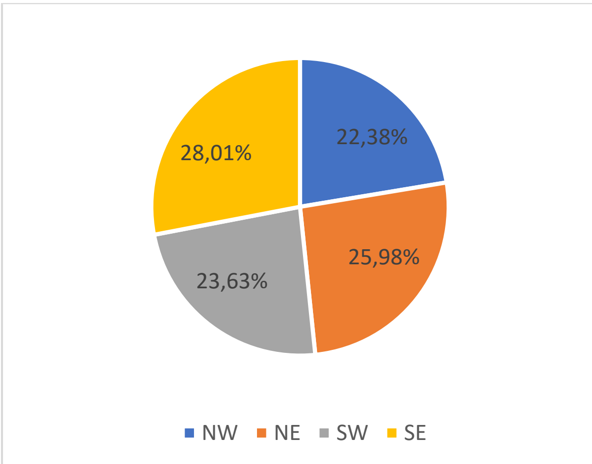

Fig. 1 Household stratification per city zone.

Socio-economic characteristics of households

An essential preliminary step in MSWM is the accurate estimation of the generation rate of solid waste and its composition. Several socioeconomic parameters affect the quantity of solid waste generated per day for each household. These include education level, monthly income, number of members, social status and labor force. Fig. 2 shows the number of members per household, as it can been seen, it shows a normal distribution and has an average of 3,9 members per household.

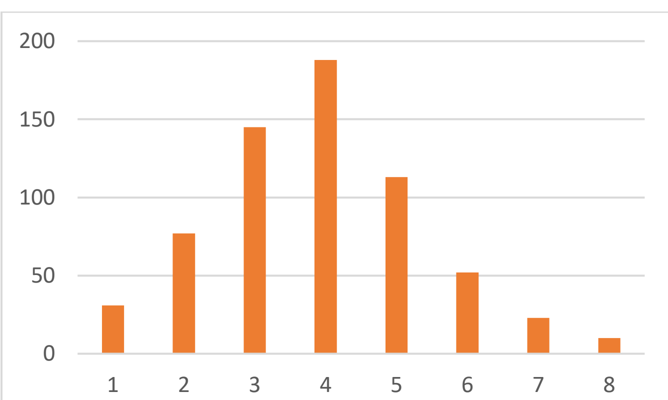

Fig. 2 Number of members per household histogram.

Mean = 3.9 members per household

Figure 3 presents the socio-economic demographic of the city of Guayaquil. Only 8,29% of the population belong to the high social class and 0,94% to the low social class. The remaining of households (91%) are divided between middle low, middle and upper middle social class. This figure demonstrates that most of the population is in the middle-class groups. Fig. 4, delivers instead the stratification of social status among all the 4 zones of the study. Most of the MSEG households (13,5%) are located in the southwest, whilst 0,5% of LSEG households live in northeast of the city.

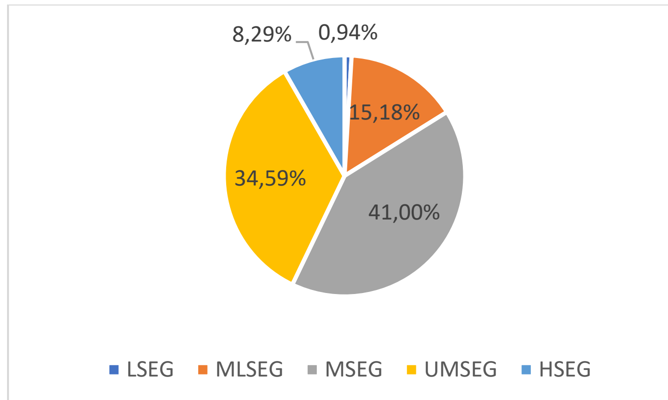

Fig. 3 Percentage of households by socio-economic group.

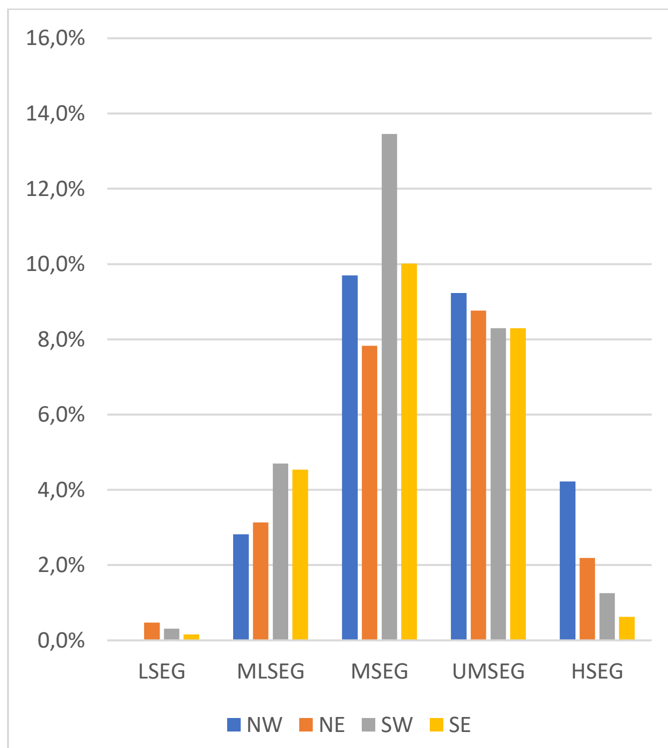

Fig. 4 Stratification of socio-economic groups among the 4 zones of the study.

Household waste generation rate and composition

Table 3 presents the daily waste generation and composition for each of the five socio-economic groups. It was found that there is a significant difference in HSW generation among the five socio-economic groups. Overall, the total HSW generation for the low and high socio-economic groups were the highest with 2,49 kg/day and 2,92 kg/day, whilst the lowest for the middle low socio-economic group with 2,21 kg/day.

TABLE III
HSW DAILY GENERATION BY SOCIO-ECONOMIC GROUP
KG/DAY

Type of Waste	SOCIO-ECONOMIC GROUP				
	LSEG	**MLSEG**	**MSEG**	**UMSEG**	**HSEG**
OW	1,7195	1,6707	1,9166	1,8070	1,9741
PW	0,3050	0,1857	0,1766	0,1944	0,2324
GW	0,0098	0,0505	0,0645	0,0692	0,1105
MW	0,0129	0,0449	0,0329	0,0373	0,0806
PCBW	0,2309	0,0912	0,1242	0,1540	0,2319
FW	0,0583	0,0707	0,0302	0,03734	0,1109
DAW	0,0523	0,0617	0,0679	0,09246	0,0889
MSCW	0,1040	0,0331	0,0379	0,6060	0,0925
TW	2,4926	2,2085	2,4509	2,4522	2,9216

Fig. 5 shows the daily generation of biodegradable and non-biodegradable wastes per capita respectively per socio-economic group. The biodegradables are considered the sum of the organic waste (OW), paper and cardboard waste (PCBW) and fabric waste (FW). The sum of the other five types of waste resulted in the amount of non-biodegradable waste. From the figure, we can infer that the high and low socio-economic groups generated the highest amount of nonbiodegradable waste, around 0,18 and 0,16 kg/capita/day, whereas the middle socio-economic group generated the smallest value with 0,12 kg/capita/day.

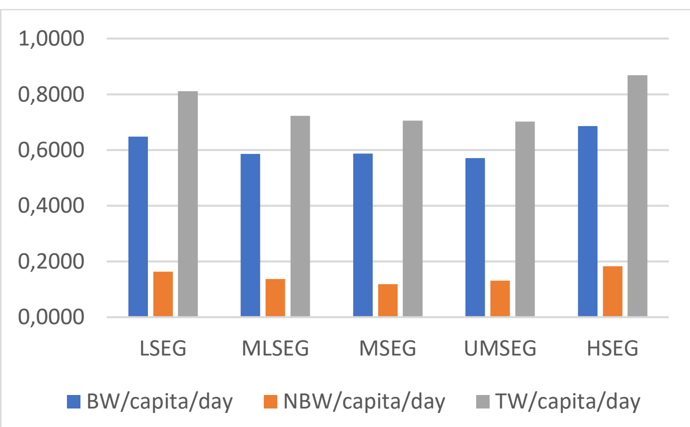

Fig. 5 Quantity of biodegradable waste (BW) and non-biodegradable waste (NBW) Vs Socio-economic Group.

Fig. 6 shows the relation between biodegradable waste generation and number of family member. The figure shows a normalized relationship, being the highest between 3 and 6 members. A similar trend was observed for non-biodegradable solid waste generation as shown in Fig. 7. The average rate of household solid waste generation in the study area was 0.72 kg/capita/day.

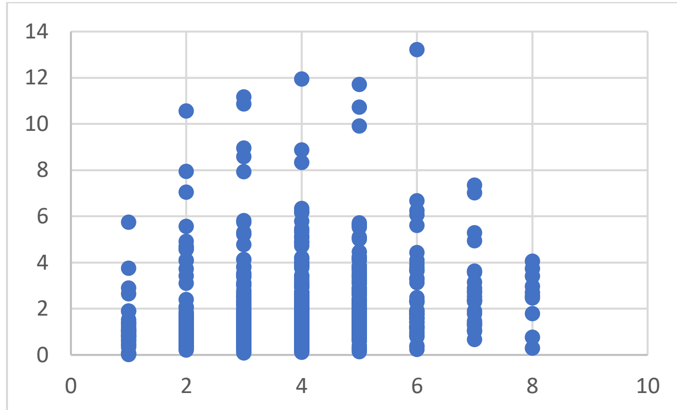

Fig. 6 Correlation between biodegradable waste generation and number of family members.

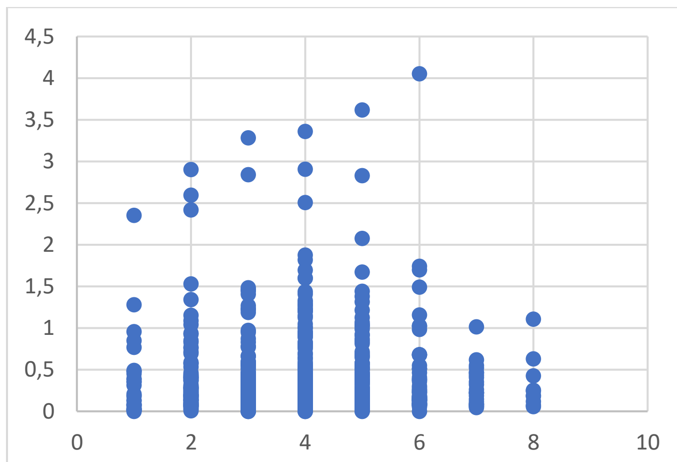

Fig. 7 Correlation between non-biodegradable waste generation and number of family members.

Regression results

Table 4 presents the OLS regression of the total HSW generation. There is a strong influence of household size, social status, household education and level of income per capita in the total generation of waste. HS, HE and LIPC give positive coefficients, meaning that an increasement in these values results in a rise of the generation of waste, whilst SS produce a decrease of it.

TABLE IV

SOCIO-ECONOMIC FACTORS AFFECTING HSW GENERATION

Variables	HSW
Intercept	2,2912 (6,384) ***
HS	0,1188 (1,427)
SS	-0,001612 (-3,712) ***
LF	-0,01689 (-0,201)
HE	0,1991 (2,237) *
LIPC	0,0004698 (1,753) .

t-student in parentheses.
Significance: 0 “***”; 0,001 “**”; 0,01 “*”; 0,05 “.”; 0,1 “ ”

TABLE V
SOCIO-ECONOMIC FACTORS AFFECTING HSW COMPOSITION GENERATION - I

Variables	OW	PW	GW	MW
Intercept	1,596 (5,165) ***	0,292 (6,4559) ***	0,08768 (3,867) ***	0,0280 (1,143)
HS	0,105 (1,465)	0,01248 (1,190)	-0,00561 (-1,068)	0,003511 (0,759)
SS	-0,001017 (-2,718) **	-0,0003018 (-5,515) ***	-0,00003316 (-1,208)	0,00002194 (0,908)
LF	-0,009424 (-0,131)	0,005326 (0,504)	-0,01195 (-2,256) *	-0,004951 (-1,062)
HE	0,1642 (2,144) *	-0,002100 (-0,019)	-0,01186 (2,110) *	-0,00294 (-0,594)
LIPC	0,00003085 (0,134)	0,00009323 (2,762) **	0,00002553 (1,508)	0,00002159 (1,450)

t-student in parentheses.
Significance: 0 “***”; 0,001 “**”; 0,01 “*”; 0,05 “.”; 0,1 “ ”

TABLE VI
SOCIO-ECONOMIC FACTORS AFFECTING HSW COMPOSITION GENERATION - II

Variables	PCBW	FW	DAW	MSCW
Intercept	0,1515 (3,514) ***	0,05556 (1,469)	0,04918 (1,616)	0,003637 (1,325)
HS	0,002738 (0,274)	-0,006404 (-0,730)	-0,002137 (0,303)	0,004938 (0,776)
SS	-0,00003547 (-0,679)	-0,00004719 (-1,031)	-0,00004558 (-1,237)	-0,0001546 (-4,653) ***
LF	0,0007225 (-0,072)	-0,005955 (-0,674)	0,003153 (0,443)	0,006187 (0,965)
HE	-0,006305 (-,059)	0,01633 (1.742)	0,003753 (0,497)	0,01239 (1,821)
LIPC	0,00005104 (1,586)	0,00002126 (0,753)	0,00009398 (4,136) ***	0,0001323 (6,456) ***

t-student in parentheses.
Significance: 0 “***”; 0,001 “**”; 0,01 “*”; 0,05 “.”; 0,1 “ ”

Also, tables 5 and 6 show the regression results for each of the eight types of waste in the study. Important to mention there is a strong negative correlation between OW, PW and MSCW with the SS. Also, the LIPC affects the production of DAW and MSCW positively, meaning that households with higher income produce more hazardous non-biodegradable solid waste.

V. CONCLUSIONS

This study aimed to analyze the current household solid waste generation rate and composition and its relationship with various socioeconomic characteristics of the city.

The collection of HSW samples were performed in Guayaquil households for two weeks to quantify and characterize its generation, determine the composition and to identify possible socioeconomic trends in the generation of it.

The present study found that, the total HSW generation for the low and high socio-economic groups were the highest with 2,4926 kg/day and 2,9216 kg/day, whilst the lowest for the middle low socio-economic group with 2,2085 kg/day.

Moreover, the solid waste composition exhibits different characteristics for different socioeconomic statuses. That means that the peoples’ socioeconomic status (usually measured by a combination of education, income and occupation) is a determining factor for solid waste generation rates and composition.

It was further found, using a multiple regression technique, a positive correlation between solid waste generation rates and household size, education and level of income. Implicitly, it means once these factors are known for a community or city, the amount of household solid waste production can then be computed.

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REFERENCES

[1] Constituyente, A. (n.d.). Constitución de la República del Ecuador. Retrieved from https://www.wipo.int/edocs/lexdocs/laws/es/ec/ec030es.pdf

[2] Ministerio del Medio AMbiente. (n.d.). *TEXTO UNIFICADO LEGISLACION SECUNDARIA, MEDIO AMBIENTE*. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwiC2tKUuYHgAhWprVkKHfHHAgIQFjAAegQICRAC&url=http%3A%2F%2Fwww.ambiente.gob.ec%2Fwp-content%2Fuploads%2Fdownloads%2F2015%2F06%2FTexto-Unificado-de-Legislacion-Secundari

[3] Instituto Nacional de Estadísticas y Censos. (2017). Estadística Ambiental Económica en Gobiernos Autónomos Descentralizados Municipales: Gestión de Residuos 2016.

[4] Instituto Nacional de Estadísticas y Censos. (n.d.). País atrevido: La nueva cara sociodemográfica del Ecuador. Retrieved from http://www.ecuadorencifras.gob.ec/wp-content/descargas/Libros/Economia/Nuevacarademograficadeecuador.pdf

[5] Trang, P. T. T., Dong, H. Q., Toan, D. Q., Hanh, N. T. X., & Thu, N. T. (2017). *The Effects of Socio-economic Factors on Household Solid Waste Generation and Composition: A Case Study in Thu Dau Mot, Vietnam. Energy Procedia, 107, 253–258.*

[6] Bandara, N. J. G. J., Hettiaratchi, J. P. A., Wirasinghe, S. C., & Pilapiiya, S. (2007). *Relation of waste generation and composition to socio-economic factors: a case study. Environmental Monitoring and Assessment, 135(1-3), 31–39.*

[7] Jonas Petro Senzige, Daniel Oluwole Makinde, Karoli Nicolas Njau, Yaw Nkansah-Gyeke. Factors Influencing Solid Waste Generation and Composition in Urban Areas of Tanzania: The Case of Dar-es-Salaam. American Journal of Environmental Protection. Vol. 3, No. 4, 2014, pp. 172-17

[8] Suthar, S., & Singh, P. (2015). *Household solid waste generation and composition in different family size and socio-economic groups: A case study. Sustainable Cities and Society, 14, 56–63.*

[9] Khan, D., Kumar, A., & Samadder, S. R. (2016). *Impact of socioeconomic status on municipal solid waste generation rate. Waste Management, 49, 15–25.*

[10] Sivakumar, K. and Sugirtharan, M., 2012. Impact of family income and size on per capita solid waste generation: A case study in Manmunai North Divisional Secretariat Division of Batticaloa. *Journal of Science of the University of Kelaniya Sri Lanka*, 5, pp.13–23.

[11] Vieira, V. H. A. de M., & Matheus, D. R. (2017). *The impact of socioeconomic factors on municipal solid waste generation in São Paulo, Brazil. Waste Management & Research, 36(1), 79–85.*

[12] Instituto Nacional de Estadísticas y Censos. (n.d.). *Censo de población y vivienda 2010*. Retrieved from http://www.ecuadorencifras.gob.ec/wp-content/descargas/Libros/Memorias/memorias_censo_2010.pdf

[13] Gomez, G., Meneses, M., Ballinas, L., & Castells, F. (2008). *Characterization of urban solid waste in Chihuahua, Mexico. Waste Management, 28(12), 2465–2471.*