Domestic waste cooking oil generation in the city of Guayaquil and its relationship with social indicators.

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Abstract– This paper estimated the domestic waste cooking oil (DWCO) generation for the city of Guayaquil, Ecuador. The study also determined how social indicators influence the quantity of waste produced domestically by using Ordinary Least Square (OLS) regression. For this effect, a stratified random sampling methodology was used, resulting in the selection of 441 sample households for this study. Results show that the city produces 5.11 grams of DWCO per capita every day also, households with higher number of youngsters between 12 and 18 years old produce more DWCO and social status plays a crucial role in liquid waste generation, giving a negative coefficient for the OLS regression, meaning that households with higher social status produce less of this waste. Finally, this study suggests new insights concerning the generation of domestic waste cooking oil and sets a milestone for future research in the reuse and recycle of this liquid residue.

Keywords—domestic waste cooking oil, social indicators, ordinary least square regression, oil sample collection methodology.

I. Introduction

One of the most important global goals of recent years is raising awareness and values of human beings in the use and transformation of natural resources, so they can meet their needs without jeopardizing the development of future generations. The United Nations (UN) in their sustainable development goals 20230, seek among other things, the responsible production and consumption of goods and services, all together with an innovative industry to maintain safety of water availability and terrestrial and aquatic life. In this context, the final disposal of household waste, is of great importance, particularly due to the lack of citizens culture and availability of government or municipal waste management systems.

In previous research, the authors identified how domestic solid waste generation varies according to certain socioeconomic factors [1] and determined the energy potential of such waste by theoretically characterizing the residues with the help of literature [2]. However, to our knowledge no research exists for liquid domestic waste produced in the city. In Ecuador, usually homeowners throw away their liquid waste in the drainage whether at the kitchen or toilet. Nowadays one of the liquid products that is widely used in kitchen homes is vegetable oil, whose raw material is extracted first from the agricultural sector and after several steps such as processing, distribution among others, arrive at the homes for final usage, especially to fry our meals. However, it is during this process that the oil undergoes several physical, chemical and sensory changes which come from the moisture that food contains, the oxygen that comes from the air and the high temperatures to which it gets exposed (160-220 °C). This is the principal reason why its disposal could have huge environmental implications, because of high COD (chemical oxygen demand) levels [3].

In Ecuador there are no records of the amount of vegetable oil waste generated since, as mentioned above, most of these wastes end up in the sewers, however; from the data on oil production that is left in the country and its importation, an approximation of the amount of oil consumed in the country can be obtained. According to [4] a total of 36,121, 92 tons of oils and fats were discarded in Ecuador in 2010. Also, according to data from Arc&Pieper (2018), a company located in Quito and dedicated to recycling oil, 54 million liters of used oils are disposed of per year in Ecuador, 70% (9.45 million gallons) corresponds to domestic use and the rest (4.05 million) to the automotive and industrial sector [5]. This represents and increment of approximately 53% of waste oil generated in the country in the lapse time of 8 years.

The increase of this liquid waste generated in the country constitutes an unfavorable situation for the adequate development of human activities since it generates environmental problems. Waste generation has also become an issue in terms of cost, land use, and soil and water contamination. Wastewater treatment plants are required to dispose of all oil and grease contained in the wastewater flow in an appropriate manner. The disposal of waste costs money for pick-up, transport, and treatment method. These disposal costs can go straight to the bottom-line increasing operations cost and municipal taxes for homeowners. Once the waste has been disposed of, there is the possibility that it can contaminate local soil and water. In order to reduce environmental impacts and resource use, waste materials that are typically land filled need to be analyzed to determine feasible reuse applications. The reuse strategy for waste could be as a material feedstock or an energy source depending on the characteristics of the substance [6].

As a first and necessary step, it is necessary to have precise data about the quantity of domestic waste cooking oil (DWCO) generated in the city as well as the social factors which are responsible for its generation. Importantly, when influential factors can be identified, they could be a helpful tool for the wastewater environmental planners in their decision making for new policies and regulations. The objectives of this research are to determine the following:

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1. Assessing the quantity of DWCO produced in the city of Guayaquil and,
2. Finding out the correlation of DWCO and certain common social factors and,

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

This paper is divided in (2) literature review, where we present all state-of-the-art information on domestic waste cooking oil, how to quantify and measure and finally influence factors, (3) methodology shows the study area and the sample size calculations, also the method developed to quantify and sampled the domestic waste cooking oil and finally the regression model for the influential factors, and finally (4) results section, where we present the calculations and results.

II. LITERATURE REVIEW

A particularly polluting domestic residue type is waste vegetable oil obtained from soybeans, sunflower, olive, African palm and many other plants. This product once used is generally discharged into the sewerage network, causing an aggression to the environment. In the case of not having a total purification of these oils, they can contaminate once they reach water vessels, such as seas, rivers and aquifers, interfering with the natural life, proliferating eutrophication and microorganisms harmful to human health. For this reason, domestic waste of vegetable oil is currently one of the main causes of pollution of urban wastewater, constituting a serious problem for the treatment plants, slowing down their work and considerably increasing the operational costs of purification.

There are several options for the collection and treatment of oil and grease residues once they have been discharged into the drain. The most common is the grease trap, which avoids water pollution but maintains the problem of the final disposal. A different approach is to separate DWCO at its source and develop collecting systems for recycling. Also, DWCO can be used in soap manufacture and oleo chemical industries, it can also serve as the main raw material to produce biodiesel and as engine fuel or for lubrication of machinery [7].

In order to determine the potential of recycling the DWCO, first it becomes necessary to measure the quantities of waste oil produced in each household of the city. Several studies introduce the method of survey as a possible solution [7], [8], [9] and [10]. However, problems may occur during the execution of the surveys, since responses may have very high dispersions making the confidence of the data useless. To avoid these problems, in situ measurement of waste cooking oil can show more reliable data despite of its much harder execution potential [9] and [11]. Nevertheless, a combination of both methods appears to be the best solution, where on one hand, a survey is conducted to each household to obtain data on social factors, and on the other hand, in situ collection and after measuring to obtain confident quantification of waste oil.

After in-depth review of online literature, little information showed to be available relating social factors with the generation of waste cooking oil. However, experience in previous research [1] mention that household size and social status always influence household waste. Other findings closely related to ours revealed: the necessity for rigorous public awareness campaign in order to encourage households to properly manage their WCO through recycling for biodiesel production [12] also, access to recycling facilities evidently has most impact on recycling behavior. However, it also has a negative effect on intentions to reduce and reuse waste, a thus far unreported phenomenon. Unlike a considerable amount of literature points, sociodemographic factors only have a small effect on reduction behavior [13].

III. METHODOLOGY

3.1 The study area

Guayaquil is the largest and most populated city in Ecuador with about 2.70 million people in the metropolitan area. Guayaquil is located on the western bank of the Guayas River and is the capital of the Ecuadorian province of Guayas.; the city is the nation's principal commercial and manufacturing centre and can be representative for the province of Guayas. According to the last census of population and housing [14] taken in 2010, there were almost 413 thousand households in the city.

3.2 Sample number calculation

Estimating with precision the average quantity of domestic waste cooking oil, it was necessary to execute a statically designed sampling survey. Logically, the accuracy of the sampling would increase with the number of samples; nevertheless however, this number had to be restricted due to the availability of 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 [15]. The central limit theorem is established with the condition that the sample size is sufficiently large [16]. The number of samples was determined with a 95% 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 95% confidence k is 1.96), 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 95% level of confidence is 384.

3.3 *Sample collection methodology*

Considering that there are no previous studies for domestic waste cooking oil generation for the city of Guayaquil, this is the first attempt for determining the total amount of this liquid residue produced per each household. For this purpose, a general university project was elaborated for students of a local university of the city for the period from May to August 2019. period of two semesters in 2018. A total of 90 students that inhabit the city were chosen, each of them participated with five households including their own (4 neighbors + own home). In the process, they were capacitated and asked to give their neighbors the same capacitation.

The procedure elaborated to obtain the sample were as follows:

a) A total of five hundred plastic bottles plus caps with a capacity of 350 ml were obtained for the project.
b) From these bottles, one hundred were weighted to obtain the average mass with a result of 13 grams.
c) Five plastic bottles were delivered to each student.
d) Each student had to deliver one plastic bottle per household and asked the homeowners that for a period of two weeks to deposit all their waste cooking oil at room temperature.
e) Also, each homeowner filled a survey to determine their social status and certain influencing factors.
f) Later, the participants of the project, tagged each bottle with a codification in order to recognize the bottle with the household.
g) One week later, students brought the five plastic bottles with waste cooking oil to the university where the weight was measured, and the surveys collected.
h) All waste cooking oil was after poured into five 20 liters plastic drums for future examination and characterization.

Each household´s social status was determined by means of a survey to divide homeowners into five different socioeconomic groups based on their income, owned electronic devices, types of jobs and others. The socioeconomic groups are as follows:

- Low socio-economic group: LSEG.
- Middle low socioeconomic group: MLSEG.
- Middle socioeconomic group: MSEG.
- Upper middle socioeconomic group: UMSEG.
- High socioeconomic group: HSEG.

To analyze the effect of selected social indicators to the quantity of produced waste cooking oil, 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 [17]. The model developed was:

$$Y = \beta_0 + \sum_{i=1}^{n} \beta_i$$

Where:
Y: Amount of liquid waste/day (DWCO);
Xi: Independent Variables;
β_0: Constant term;
β_i: Coefficient of independent variables;

The independent variables of this model are household size (HS), number of adults (NBRA), number of youngsters (NBRY), number of children (NBRC) and social status (SS) as shown in Table 1. All statistical analysis in this study was made by applying RStudio software.

TABLE I
DESCRIPTION OF SOCIAL INDICATORS

Independent Data Information		
Variable	Description	Type of Data
HS	Number of members in the family	Ordinal
NBRA	Number of adults older than 18 years old.	Ordinal
NBRY	Number of youngsters between 12 and 18 years old.	Ordinal
NBRC	Number of children younger than 12 years old.	Ordinal
SS	Social Status measured from 0 to 1000.	Ordinal

The dependent variable is the amount of domestic waste cooking oil in grams per day per household (DWCOPD). This is the result of the total weight of the filled plastic bottle minus the weight of the empty bottle divided by fourteen, which are the number of days that the collection lasted.

IV. RESULTS

A total of 441 households from the city of Guayaquil were selected randomly for the study. The city was divided into 5 sectors. Northwest (36.51%), Northeast (47.85%), Southwest (4.99%), Southeast (7.26%) and Middle-Town (3.40%) as shown in Fig. 1.

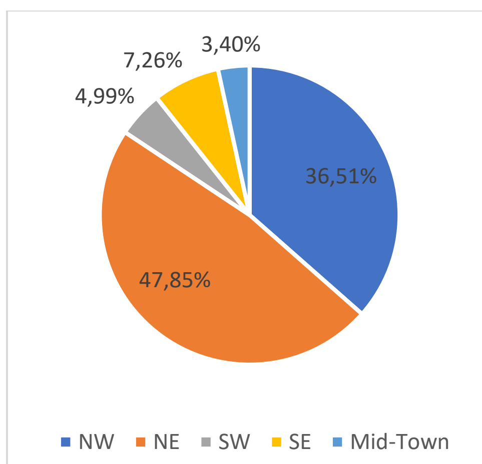

Fig. 1 Household stratification per city zone

4.1 Household characteristics

Table 2 summarizes the household characteristics and their frequencies used in subsequent analysis. Every household in the city has an average of 4.05 people, from which 2.69 are adults, 0.83 youngsters and 0.60 children. Also, the average social status of al the sample is 620.21 which is equivalent to MSEG. The socioeconomic groups can also be observed having the MSEG with the highest value (53.74%) and the LSEG with the lowest (1.59%).

TABLE II
OVERVIEW OF HOUSEHOLD CHARACTERISTICS

Variable (code)	Description
Domestic Waste Cooking Oil per day (DWCOPD)	grams (continuous: M = 17.12, SD = 9.01)
Household Size (HS)	n/a (continuous: M = 4.05, SD = 1.67)
Number of Adults (NBRA)	n/a (continuous: M = 2.69, SD = 1.19)
Number of Youngsters (NBRY)	n/a (continuous: M = 0.83, SD = 0.93)
Number of Children (NBRC)	n/a (continuous: M = 0.60, SD = 0.87)
Social Status (SS)	n/a (continuous: M = 620.21, SD = 118.48)
SS	HSE (17, 3.85%), UMSEG (108, 24.49%), MSEG (237, 53.74%), MLSEG (72, 16.33%), LSEG (7, 1.59%)

M is the mean value and SD the standard deviation.

Additionally, the average daily generation of waste cooking oil per capita is ***5.11 grams*** with a standard deviation of 4.18 grams. This means a projection of almost 5,036 tons of waste cooking oil for the city in the time of one year that reach the wastewater treatment plant.

4.2 Regression results

Table 3 presents the Ordinary Least Square regression of the total domestic daily waste cooking oil (DWCOPD) generation.

TABLE III
RESULTS OF THE OLS REGRESSION MODEL

Variable	Coefficients
Intercept	19.064864 (8.078) ***
HS	-1.111948 (-2.292) *
NBRA	1.298910 (2.056) *
NBRY	2.342235 (3.422) ***
NBRC	-1.0940 (-2.254) *
SS	-0.004358 (-1.184)

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

There is a strong influence of the number of youngsters, meaning that households with more people between 12 to 18 years old produce more waste oil. Also, regression shows negative coefficients for household size, number of children below 12 years old and social status, which means that with higher values for these factors, the generation of waste oil decreases.

All the considered social indicators together explain (R^2) 2.83% of the variability in the generation of waste cooking oil, F-statistic (3.177) and a p-value: 0.01366. This means that more detailed analysis is necessary to make a better model which can give higher values of the variability.

V. CONCLUSIONS

This study aimed to analyze the current domestic waste cooking oil generation rate and its relationship with certain social indicators for the city of Guayaquil. Also, a methodology for the collection of samples and quantification of the waste oil have been presented.

A total of 5.11 grams of waste cooking oil per capita is generated daily in the city. Moreover, the waste oil exhibits different coefficients for the selected social indicators, being of greatest importance that household with more young people with ages between 12 to 18 years generate more waste.

No surprise appears with the negative coefficient for social status, because it´s understandable that with higher status level there is more capacity to acquire food outside the house and in lower levels, there is a necessity to cook at home.

Further research could concentrate in characterizing this waste oil to measure its potential to obtain energy following the methodology of waste-to-energy, which becomes a viable choice to diminish the amount of liquid waste while providing clean energy to the city.

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