MUNICIPAL WASTE IN THE MANAGEMENT OF LOCAL DEVELOPMENT UNDER THE CIRCULAR ECONOMY MODEL

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Abstract

Globally, especially in the large cities of each country, the generation of household solid waste represents an indicator of management to preserve the environment, this is due to the high volumes of waste that are generated daily. The objective was to evaluate municipal waste in the management of local development under the circular economy model using primary and secondary sources of information, the study was conducted in the northern area of the province of Los Rios, and the variables of responses according to the level of economic income, category of waste (organic, recoverable and non-recoverable). The results indicate that the high medium and low-income level generates 2.92, 2.49 and 2.21 kg/inhab*day, the organic waste category is the most representative in all strata and localities, followed by paper and cardboard, plastic, glass, and construction waste. Finally, the daily generation of solid waste is influenced by the income level of the population and tends to increase related to the economic income provided by households; the higher the income, the higher the consumption and therefore the greater the generation of waste.

Keywords: Household waste management, physical composition of waste, eco-efficient MSW management.

1. Introduction

In developed countries, most food is wasted at the household level as a result of a complex interaction between economic factors, well-established routines and social norms (Piras et al., 2021). For this reason, waste and resource management is one of the areas in which urban and regional planning can make the transition to a Circular Economy (J. Cohen & Gil, 2021), and if urgent measures are not taken, by the year 2050, global waste will grow by 70% over current levels as high-income countries generate more than one third (34%) of the world's waste (World Bank, 2018).

According to the United Nations Organization (UN, 2018), in 2019 the generation of household waste in Latin America and the Caribbean was 541,000 t/day. This figure may reach at least 671,000 t/day by 2050, assuming that the current generation rate (regional average is 1.04 kg/inhab/day). Global phenomena such as population increase, the growing trend towards

urbanization, economic growth, and unsustainable consumption linked to a linear economy are some of the factors causing the constant increase in waste generation observed in Latin America.

The PNGIDS (National Program for the Integral Management of Solid Waste) through the action of the MAE (Ministry of Environment) in the period 2019 indicates in its last report that the population at the national level is 15'520,973 inhabitants of which in the generation of solid waste is 4'139. 512 MT/year, which represents a per capita production (PPC) of 0.73 kg/day*year, 61% of the waste generated corresponds to organic waste; 11% plastic; 9.4% paper and cardboard; 2.6% glass; 2.2% scrap metal; and the remaining 13.3% represents other waste. In addition, of the 221 GADs in Ecuador, 20% dispose of their waste in landfills and the remaining 80% dispose of their waste in dumps (Guerra & Paredes, 2019). The province of Los Ríos has urban areas where urban solid waste is generated that is not efficiently managed according to the hierarchical principle established in Article 226 of the Organic Environmental Code, which cites prevention, minimization of generation at the source, use or recovery, disposal, and final disposal. This study evaluated the generation of municipal waste in the management of local development under the circular economy model as well as identified the management carried out to achieve sustainable development in cities.

II. MATERIALS AND METHODS

Localization

The study was carried out in the Northern Zone of the province of Los Ríos in the cantons of San Jacinto de Buena Fe; Valencia; Quevedo, Quinsaloma, Ventanas and Mocache (Figure 1).
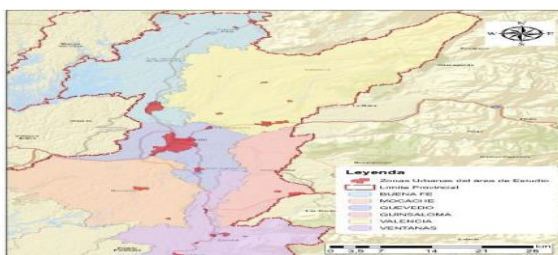

Figure 1. Map of the population, starting from the initial population (Pi).

The research is cross-sectional, descriptive and analytical; the generation of household solid waste was identified in the following areas (Cabay & Lindao Caizaguano, 2015) in the cities of Buena Fe, Mocache, Quevedo, Quinsaloma, Valencia and Ventanas, the socioeconomic levels were stratified into three categories according to the monthly salary received by the family (Villalba et al., 2020); high-income levels (above 1400 dollars), medium (between the basic salary and below 1400 dollars) and low (below the basic salary), (Baig et al., 2019). Socioeconomic levels were determined based on the criteria established by Vera & Vera (2013):

☐   Economic, referring specifically to economic terms goods and income.

☐   Social, being the goods and attributes expressed according to Education and housing.

☐   Flow, considering the current situation of the person's income or occupation.

☐   Stock is the wealth accumulated by the person in terms of education and housing.

Simple random probability sampling was applied using the statistical formula for the sample size of finite populations implemented by Brito (2006) (INEC, 2011), with a confidence level of 95% and a margin of error of 5%, equation (1).

$$PF = Pi \; x \; (1 + r)^n \quad (1)$$

Where:

Pi: Initial population; Actual population obtained from the last National Census.

r: Annual inter-census growth rate (Source: INEC).

n: Number of years to be projected.

To calculate the number of households and non-household samples, equation (2) used was the following:

$$N = \frac{1 + Z_{1 - \alpha/2}^2 \; N \; \sigma^2}{(N-1) \, E^2 \; + Z_{1 - \alpha/2}^2 \; \sigma^2} \quad (2)$$

Parameter	Domiciliary	No. Domiciliary
n: (number of samples)	Number of dwellings to be included in the characterization study	Number of establishments that will participate in the characterization study
N: (Universe)	Total number of dwellings (the number of dwellings existing in the period 2022 was determined).	Total number of establishments
σ: (Standard deviation)	The standard deviation value at 0.25.	
Z1-α/2: (Confidence level)	95% confidence level for which Z1-α/2 has a value of 1.96	
E: (Allowable error)	10% of the national GPC	

For per capita production, the sample was taken at generation, covering eight successive days, since there is a significant variation within that time frame. The weight of the sample was measured using a foot scale, and the PPC (per capita production per day) was determined as follows:

$$PPC \text{ (gr/inhab/day)} = (1/7) * \frac{(A1/B1) * P1 + (A2/B2) * P2 + (A3/B3) * P3 + (A4/B4) * P4}{P1 + P2 + P3 + P4}$$

Where: - P1, P2. P3 and P4 = Number of inhabitants in commercial and residential (high income), residential (medium income) and residential (low income) zones, respectively. - A1, A2, A3 and A4 = Weight of a full week's sample (gr/week) - B1, B2, B3 and B4 = Number of inhabitants corresponding to the sample taken.

The physical composition of waste

The physical composition (wet basis) of the wastes was determined by: a) Sorting 1m3, b) Bags were broken, and cardboard and wood contained in the garbage were cut until a size in centimeters of 15*15 cm or less was obtained. c) The sample was homogenized by mixing it all. d) The pile was divided into four parts and two opposing parts were chosen to form another representative smaller sample. The pile was divided into four parts and two opposing parts were chosen to form another smaller representative sample. The smaller sample was mixed and divided into four parts, this operation was repeated until 50 kg of garbage was obtained (Graziani, 2018).

The components of the final pile were classified according to SEDUE (1992) based on their characteristics: paper, cardboard, hazardous compounds (batteries, batteries, medicines), PET bottles, high-density plastics, plastic sleeves (low density, polypropylene, polystyrene, inert (slab, ceramic, soil), garden organics, kitchen organics, rejects (toilet paper, diapers), electronics, textiles, ferrous metallic, non-ferrous metallic, glass, wood, less than 1 cm (what falls after shaking) and other. Finally, the physical composition of the solid waste was determined based on the weight of each component recorded in the previous step, divided by the total weight of the waste contained in the cylindrical container and multiplied by one hundred to express it as a percentage. This was repeated for the following separate components, applying the following formula (Onelia & Martha, 2016):

Component = Pc/P T * 100

Where:

PC: Weight of separate components.

PT: Total weight of waste contained in the container.

Through the Organic Environmental Code (MAE, 2018), the phases of proper management of household solid waste were determined based

on the principles of hierarchization such as sweeping, collection and transportation, temporary storage, collection and transfer. Finally, matrices were developed with strategies to promote the circular economy in the residential sector, applying citizen satisfaction indicators and indicating the approximate budget for each of the strategies, to provide solutions to the problem established based on the methodology determined by Martin et al. (2006).

III. RESULTS

3.1. Influence of economic income on household waste generation

MSW production was quantified at 800 t/day, with a per capita generation of 0.50 kg/inhab/day, based on a socioeconomic level, with the highest percentage for organic waste (61.57%), followed by recoverable waste (29.29%) and non-recoverable waste (9.23%) (Table 1).

Table 1. Solid waste (%) generated in the Northern Zone of the Province of Los Ríos, 2022.

Sectors	Organics	Recoverable	Non-Recoverable
San Jacinto de Buena Fé	69.49	24.84	5.67
Valencia	65.16	29.49	5.35
Average	67.33	27.17	5.51
Quevedo	62.80	29.73	7.47
Ventanas	55.59	33.66	10.75
Quinsaloma	55.59	32.08	12.33
Average	57.99	31.82	10.18
Mocache	59.26	28.74	12.00
Total average	61.53	29.24	9.23

In Figure 2, the average solid waste generated by the population based on socioeconomic level is 2.92 kg/inhab*day corresponding to the high level, 2.49 kg/inhab*day, medium level and 2.21 kg/inhab*day at the low level, the average produced by a person per day was 2.55kg (Table 2).
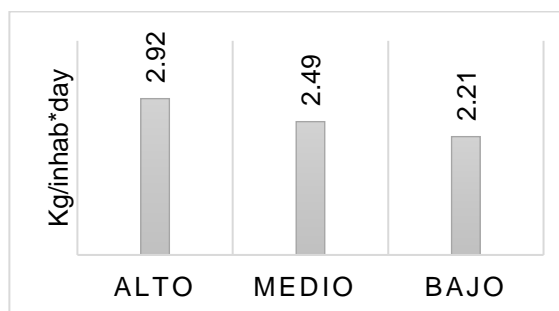
Figure 2. Solid waste by household income level in the northern zone of the province of Los Ríos, 2022.

Table 2. Average amount of MSW physical composition in the northern zone of the province of Los Ríos, 2022.

Physical composition	High		Medium		Low	
	Kg	%	Kg	%	Kg	%
Paper and Cardboard	2.10	10.28	1.9	10.89	1.78	11.49
Hazardous compounds (batteries, batteries, medicines)	0.50	2.45	0.51	2.92	0.4	2.58
PET bottles (1), High-density plastics, Plastic sleeves (low density)	1.16	5.68	1.14	6.53	0.98	6.33
Polypropylene	0.22	1.08	0.11	0.63	0	0.00
Polystyrene	2.80	13.71	2.48	14.21	1.51	9.75
Inert (slab, ceramic, earth)	0.23	1.13	0.11	0.63	0.18	1.16

Kitchen organics	11.90	58.28	10.4	59.60	10	64.56
Refusals (toilet paper, diapers)	0.14	0.69	0.1	0.57	0.08	0.52
Electronics, Textiles	0.16	0.78	0.08	0.46	0	0.00
Ferrous metals	0.32	1.57	0.26	1.49	0.16	1.03
Non-ferrous Metals, Glass, Wood	0.89	4.36	0.36	2.06	0.4	2.58
Total	20.42	100.00	17.45	100.00	15.49	100.00
Family day	2.92		2.49		2.21	
Average person kg day	0.58		0.50		0.55	
Average PPS					2.55	

Solid waste management

For the proper management of household solid waste, the Mancomunidad Mundo Verde is in charge of waste collection in the city for the next seven years. The capacity and quality of equipment of the entity are greater, 3 collection units are assigned (El Comercio, 2020), and they must comply with a protocol detailed in (Figure 3).
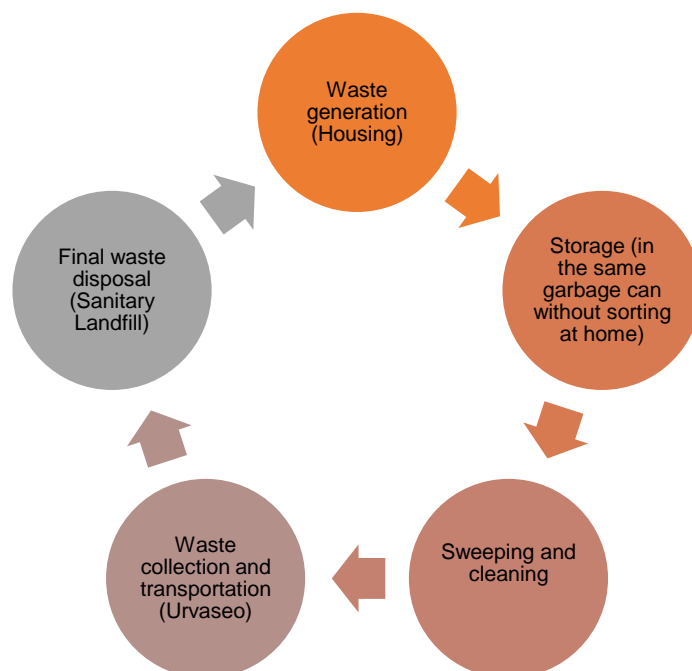

Figure 3. Phases of integrated household solid waste management.

3.2.   Waste management strategies

Waste management must be in an appropriate manner and comply with all the phases according to the planning (Table 3).

Table 3. Household solid waste management matrix.

Management	Observations
Most of the population has daily collection and transportation of solid waste, which is deposited in plastic bags that are placed in closed containers to prevent the dispersion of bad odors.	It is notorious that not all households have a better waste management system because they have the economic resources to pay for expenses that the municipality does not cover in their entirety, such as plastic containers with their respective waste classification, metal hoppers and good organization

41.18% of the citizens dispose of their solid waste four times a week, 23.53% dispose of their solid waste three times a week and 14.71% dispose of solid waste every day, 14.71% usually dispose of their waste twice a week, while 5.88% of the population disposes of their waste depending on their daily chores during the week	The cleaning of those responsible by the GADs that is done in (sidewalks and portals), usually leave in the street without adequate temporary storage producing visual pollution.
17.44% of the inhabitants dispose of their solid waste on a daily basis, using plastic bags, while 37% usually dispose of their waste three times a week.	Families leave garbage on the sidewalks at times outside the established collection schedule, which generates visual contamination and the proliferation of pests and diseases.

3.3. Household solid waste management using circular economy principles

(Table 4) shows the proposal on the valuation of household solid waste from a life cycle perspective, applying the principles of the circular economy and strategic actions determined as basic by Andersen et al. (2012).

Table 4. Household solid waste management.

Suggested actions	Strategic actions	Responsible	Costs
Plastic recycling	To recycle it is necessary to classify the waste, with plastics it is possible to make handicrafts and direct sale in the collection centers for reuse. Containers should be placed for children to learn how to recycle.	General public	Recycling does not require financial resources; however, if containers are required to carry out this action, it is estimated to cost $20-$50.
Reuse	Household appliances, computers, and smartphones are waste that generates significant environmental pollution, for this reason, it is necessary to perform a series of actions to extend the useful life of these wastes: 1) Periodically perform maintenance of electrical appliances, 2) Repair and give them a second chance to electrical appliances, 3) Create blankets, carpets with the clothes that are no longer being used, do not throw them away, preferably donate them.	General public	This cost will depend on the frequency of repairs and maintenance of electrical appliances and is estimated to be approximately $100-$200.
Energy assessment	The purpose of energy recovery is to reduce the amount of waste in landfills, for which several treatments allow to achieve this goal, among the most common are recycling, composting, and thermal treatments, among others.	Authorized managers (provincial, municipal and parish governments) and the Ministry of Environment,	The cost will depend on the type of technology implemented for energy recovery such as pyrolysis, combustion, and fermentation, among others.
Garbage cans	For the use of waste generated by household activities, the implementation of garbage cans must identify the properties of each one. In this case, provide three containers; 1). green color to deposit organic waste; 2). gray color for papers and 3). blue color for plastics. It is recommended that, when installing the containers outside the home, they should be sufficiently protected.	Family	According to the free market, the containers or ecological points with 53 liters have a value of $160.00. Budget per household.
Cardboard and paper	Before throwing waste paper and cardboard into their designated container, it is advisable to refuse		These activities do not represent any additional

recycling	in decorating or decorating artifacts, cleaning glass or covering the floor or other surfaces with stains, paints, etc. In addition to using it as handicrafts; organizers and/or gift boxes, jewelry boxes, pet houses, cardboard lamps, gift cards, and binoculars for children, among other creativities.	Family	cost.
Unnecessary purchases	The purchase of clothing and kitchen products contributes to the generation of waste in the home, in addition to increasing global warming, it is recommended, to bet on quality, and support ethical clothing brands. recycle: sell or donate the clothes you are not going to use. In addition, a measurable and very useful strategy is to buy biodegradable packaging made from cardboard, palm leaves, wood, vegetable fiber, bamboo or bioplastics. The latter are sustainable alternatives that come from certain plant resources available in the study locations.	Family	There would be no cost at all, but rather an economic saving would be generated.
Home composting	In the kitchen of many homes, a large amount of organic waste is generated, which can be re-evaluated by creating organic fertilizers, generated in backyards, and also avoids the increase of waste in landfills, which generates an environmental reduction and sustainable development for society.	Household members	There is no cost since the raw material will be the waste generated in households
Reduce plastic sleeves	Households generate large amounts of purchases that are generally always delivered in plastic bags, but to avoid the increase of these, alternatives for packaging can be used, among them are cloth bags that are more resistant and durable, environmentally friendly jute bags and cardboard packaging since its degradation time is faster than plastic. It should be avoided as much as possible to receive fewer bags, reuse the bags that are in good condition and not deposit them in bodies of water and/or places of risk.	Household members and people in the commercial sector	The cost per unit of an eco-friendly bag is less than one dollar.
Environmental education	Through lectures and interactive training, the aim is to educate society about the importance of properly managing the waste generated in households, as well as topics related to the circular economy and recycling techniques. This training should be through playful and motivating topics that make people need to improve their lifestyle habits to contribute positively to the environment and society.	Governmental entities (provincial, municipal and parish governments) and the Ministry of Environment,	Approximately $400 to pay for trainers

This proposal is supported by the 2008 Constitution of Ecuador, Art. 14, Chapter II, section two, which states "The right of the population to live in a healthy, ecologically balanced environment that guarantees sustainability, good living, Sumak Kawsay, is recognized. The preservation of the environment, the conservation of ecosystems, biodiversity and the integrity of the genetic heritage of the country, the prevention of environmental damage and the recovery of degraded natural spaces are declared of public interest. On the other hand, the National Development Plan 2017-2021 All a Life in Axis 1: Rights for All Throughout Life in Objective 3: Guarantee the rights of nature for current and future generations; where nature goes through imminent risks, such as climate change. To reduce environmental vulnerability, it is urgent to take action for the responsible management of natural heritage, its terrestrial and marine biodiversity, ensuring conditions for the regeneration of life cycles, water, waste, soil, and air, and achieving a better quality of life.

IV.   DISCUSSION

The increase in population, urbanization and industrialization have led to an increase in the rate of household solid waste on a global scale (Heidari et al., 2019), which has led to a worrying environmental degradation and a series of effects on water springs, clogging of sewage networks, groundwater contamination, degradation of the landscape resource (Cohen, 2019). On the other hand, the behavior of food consumption and waste varies from culture to culture, education, socioeconomic levels and others (Mattar et al., 2018).

The daily generation of solid waste tends to increase depending on the economic income provided by households, because they have stable salaries that contribute to making excessive purchases, which produces excess waste. On the other hand, the middle and lower social class is not far from the reality of producing waste that generates serious problems for society, since on many occasions it is not treated correctly due to the lack of resources or the collection system.

Household solid waste management is a challenging issue for low-income cities, impacting socioeconomic, health, aesthetics and infrastructure, due to the volume, treatment and final disposal, the methods applied are often affected by the transition of management mostly unsustainable (Iyamu et al., 2020). Also important is the characterization (MSW) especially coming from households (Quito, 2018). The average waste found was 2.92 kg/inhab*day with economic income above $1400 per month per family, followed by the middle social class with a production of 2.49 kg/inhab*day, while the low social class generated 2.21 kg/ inhab*day., a trend that differs with the results of (Cabay & Lindao Caizaguano, 2015; Ojeda, S. Lozano, G; Quintero, 2008; and Hidalgo et al., 2019), in their research on the generation of household solid waste by a seasonal period in Mexico City, where they determined a sampling for each socioeconomic stratum which indicates that the average generation per day of the three strata varied, the low stratum generated per day 6,618 kg, the middle 5,095 kgs and the high 6,408 kgs.

On the other hand (Pesantes, 2020) in the local news, the sectors of Monte Sinai, Ciudad de Dios, and the Suburbio which are sectors belonging to the city of Guayaquil, their socioeconomic level is reflected in the deficit of housing planning and access to basic services. This is of concern and they are considered as sectors with a low socioeconomic level, due to the living conditions and the management of solid waste generated, including plastics, cardboard, paper and organic waste, mostly resulting from daily cooking and eating activities (Borja & Tigua, 2015).

Household solid waste management complies with strategies ranging from waste generation, waste storage without prior household classification, sweeping and cleaning, waste collection and transportation (Ponce et al., 2022), in addition to the use of plastic waste with the implementation of a sustainable project for the capture and burning of biogas. Results that coincide with those mentioned by López & Franco (2020) in their study "Management of urban solid waste: An approach in Colombia and the department of Antioquia" carried out in the city of Medellín, indicating that the actions of Empresas Varias de Medellín as a service provider (Emvarias S.A. E.S.P.) and that, like the entity Urvaseo de Guayaquil, the collection activity is carried out throughout the jurisdiction of the municipality it represents.

The collection is a very important process within management according to López & Franco (2020) and Pimbo (2011), who state that the different methods used are door-to-door collection; collection by containers of 1.5 m3 or 2.3 m3 garbage cans for small waste generators; collection by stationery boxes of 12 m3 or 15 m3 mobile bins for medium waste generators, and multi-user collection for large waste generators, such as shopping centers, hospitals, and residential units, among others (Leonor & Garcés, 2013).

Strategies for household solid waste management are easy and simple and can be implemented in households to generate a circular and environmentally friendly economy. In the same way, Andrea & Cárdenas (2019), in their exploratory review article "Circular Economy: A strategy applicable to the integral management of solid waste" mention that the applications of efficient technologies such as composting, anaerobic digestion, efficient recycling systems and the advances obtained in developed countries and some Latin American countries have managed to reduce costs, reduce

greenhouse gas emissions, significantly reduce waste generation and greater process performance, articulating solid waste to the productive chain (Pimbo, 2011).

Residential and commercial, household solid waste are potential sources of energy that can help reduce problems related to energy use and the environment (Taşkın & Demir, 2020). Despite being an important urban necessity for creating sustainable and healthy living areas, waste management services are not always provided adequately and equitably to all inhabitants due to inadequate resource management approaches high volumes of urban waste and inappropriate consumption habits (Ağaçsapan & Çabuk, 2020).

V.   CONCLUSIONS

The lifestyle of a person has a great impact on the generation of solid waste in households, for this reason, it is concluded that the daily generation of solid waste tends to increase depending on the economic income that is provided in households, this is the case of the high social level since it has stable salaries that contribute to making excessive purchases which produce excess waste.

The cities of the northern zone of the province of Los Ríos have a phase of management of their domestic solid waste, however, the management of waste generated at home by each socioeconomic level of the city differs from certain health specifications, the lower social stratum finds it difficult to even agree on the established schedule to store their waste, this is how the population belonging to this social level shows, as a result, the nonconformity.

It is hoped that by applying the principles of the circular economy to the waste generated in the homes of families, a new useful life can be achieved, since the establishment of strategic environmental actions can help reduce the amount of solid waste and maintain a balanced sustainable development, regardless of the socioeconomic level to which they belong.

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