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Management of urban solid waste in the two first decades of the XXI century in the city of San José de Cúcuta, Colombia

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Abstract. The research developed in this study is exploratory, descriptive and the quantitative method, it characterizes the urban solid waste of the ten communes of the city of San José de Cúcuta and compares the results obtained with those of a similar investigation carried out 20 years. This comparison concludes that there have been significant changes in solid waste generated in the city, increasing food waste, cardboard, plastic, glass and cans and decreasing garden waste, paper and metals. In addition, surveys were conducted indicating that about one third of the population makes waste separation evidencing the existence of the recycling culture.

1. Introduction

Municipal solid waste (MSW) is defined as “solid objects, materials, substances or elements that are abandoned, thrown away or rejected after they have been consumed or used in domestic, commercial, industrial and institutional activities and that are susceptible to use or transformed in a new good with economic value”, and garbage is defined as solid waste that has no commercial value, does not return to the economic and productive cycle, requires treatment and final disposal, and therefore generates disposal costs” [1]. Solid waste can generate value, while garbage generates a cost.

The MSW, due to cultural and environmental factors tend to diminish their quality more and more, [2] whether they are liquid, solid or gaseous waste, because the products that make up the garbage are highly polluting and even some are non-recoverable, and others are not biodegradable.

It is natural that over time the population tends to grow due to the increase in longevity, advances in the field of medicine, and consumption habits that change with the emergence of new technologies and ways of life. These factors have increased the amount of MSW generated, even more in the cities where most of the population is concentrated, which due to their multiple occupations increasingly consume more finished and packaged products, generating a greater volume of waste [2].

The accelerated increase in the volumes of solid waste, especially in cities, has reached levels of concern due to its high degree of pollutant capacity and the impact it can have on the planet, if these wastes are not treated properly [2]. There are several final disposal techniques for solid waste, among them are dumps (generally open pit) that are sites of solid waste accumulation on the ground [3].

Sanitary landfills are a technique of final disposal of solid waste in the soil that does not cause discomfort or danger to health or public safety; neither does it harm the environment during its operation or after its closure [3]. This technique uses engineering principles to confine garbage in an area as narrow as possible, covering it daily with layers of soil, and compacting it to reduce its volume. In addition, it



foresees the problems that can be caused by liquids and gases produced by the effect of the decomposition of organic matter.

Since 2,000 the city of San José de Cúcuta, Colombia, has the El Guayabal landfill, which is located at kilometer ten of the San José de Cúcuta, Puerto Santander road, and a useful life of 80 years is projected [4].

One of the inputs to manage the MSW is the characterization of this waste. The characterization of this study was carried out based on ten research projects of the Universidad Francisco de Paula Santander (UFPS) [7-16], carried out in San José de Cúcuta, which is a growing city with an economy that depends on commerce, hotels and restaurants [5]. San José de Cúcuta belongs to the North of Santander department, Republic of Colombia, and is border with the Bolivarian Republic of Venezuela.

In the present study, the results of the parameters characterized in 2017 are compared with the results obtained in a similar study entitled “Evaluation of urban solid waste from the metropolitan area of San José de Cúcuta as an energy source”, which was developed in 1997 [6]. This comparison allows to analyze the changes in the behavior of the population, in relation to the generation of solid waste of the city in the last two decades.

The research was supported by a group of twenty students of the academic program of Civil Engineering of the Universidad Francisco de Paula Santander, organized in groups of two students for each of the 10 communes that make up the city of San José de Cúcuta, in order to characterize the MSW that generates the city. Additionally, the percentage of users who recycle was determined, an activity that contributes to environmental management [7].

2. Methods

The level of depth of the research is exploratory and descriptive, where the study of urban solid waste from the city of San José de Cúcuta, Colombia, was approached based on some parameters that allow its characterization. The development of the research follows a quantitative method, based on the field work for the collection of representative samples, laboratory tests performed on solid waste, and surveys of residents of the different communes. The purpose of the investigation was to determine the characteristics of the MSW as composition, density, humidity, calorific value, production per capita, and percentage of population that recycles at the origin.

For the definition of the sample size, the database of the operator of the electric power service of the city of “Centrales Eléctricas de Norte de Santander”, San José de Cúcuta, Colombia, was considered, which is the company that invoices the collection and final disposal service of solid waste in the city. A total of 162,657 real and potential users of the solid waste collection service in the ten communes of the city were determined. A sample of 2473 users was defined based on statistical analysis [17]. The users of the sample were collected solid waste, and these wastes were classified by composition, determining the loose density, humidity and calorific value, in addition a user survey was conducted that sought to determine if it was done separation of organic and inorganic waste at the site of origin. Table 1 shows the number of properties and samples considered.

Table 1. Universe and sample of users generating MSW in the city of San José de Cúcuta.

Item	Commune										Total
	1	2	3	4	5	6	7	8	9	10	
Properties	15,836	13,179	12,165	16,190	18,556	17,349	21,430	22,696	14,541	10,715	162,657
Samples	275	303	250	175	376	295	162	230	177	230	2,473

3. Results and discussion

One of the most important characteristics of solid waste is the composition that allows determining the weight, or percentage by weight, of each of the components that comprise it. Table 2 shows the percentage by weight of the different components of solid waste in the city of San José de Cúcuta for each of the ten communes.

Table 2. Weight percentage of components of MSW in each commune of San José de Cúcuta in 2017.

Component	Percentage in weight of component by commune (%)										Media
	1	2	3	4	5	6	7	8	9	10	
Food residues	59.81	63.68	61.04	34.48	68.86	18.16	44.38	25.53	38.9	43.68	45.85
Paper	1.73	3.6	3.93	14.47	5.19	12.63	13.42	10.09	13.97	10.74	8.98
Paperboard	6.86	5.04	4.08	14.05	5.77	16.53	13.99	4.97	10.75	12.51	9.46
Plastic	9	5.55	6.57	16.78	8.06	12.97	9.69	9.19	9.09	11.52	9.84
Textile	0	3.8	2.61	0.55	0.05	0	0	0	0	0	1.75
Garden waste	0	4.94	6.15	0	0	0	0	0	0	0	5.55
Wood	0	0.22	2.76	0	0	2.49	0	0	0	0	1.82
Glass	4.63	7.94	5.67	4.76	1.72	13.24	4.48	9.31	7.89	8.73	6.84
Cans	2.39	1.39	1.41	4.15	4.25	8.68	3.32	5.77	7.51	3.82	4.27
Metal	0	0.98	2.19	0	0	0	0	0	0	0	1.59
Dirt	15.58	2.86	3.59	10.76	6.1	15.3	10.72	35.14	11.89	9	12.09
Total	100	100	100	100	100	100	100	100	100	100	

It was determined that the component “food waste” is the one with the highest percentage in the various samples analyzed, regardless of the commune, having an average value of 45.85%, the maximum value appears in commune five with 68.86% and the minimum value in commune six with 18.16%. The component with the lowest percentage by weight is the metal with an average value of 1.59%, appearing only in communes two and three, with percentages of 0.98% and 2.19%, respectively.

Table 3 shows the values of other parameters that characterize the MSW of the city of San José de Cúcuta, evaluated in each of the ten communes.

Table 3. Parameters that Characterize Solid Waste per Commune in San Jose de Cúcuta, 2017.

Parameter	Value per commune										Media
	1	2	3	4	5	6	7	8	9	10	
Loose density (kg/m ³)	58.2	96.72	226.48	52.13	70.73	183.54	41.92	55.04	48.85	48.96	88.26
Humidity (%)	38.76	80.66	54.66	42.51	49.32	63.15	26.68	54.69	36	49.93	49.64
Heat power (kcal/kg)	2135	1438.94	1732.84	4775.1	3412	1413.8	3264.74	1407.9	3764.87	3878	2722.32
P.P.R.S. (kg/inhab/day)	0.60	0.48	0.65	0.37	0.60	0.45	0.32	0.48	0.29	0.32	0.46
Population that separates in source (%)	18.00	26.00	35.60	30.50	40.00	39.93	15.00	18.00	50.00	32.00	30.50

The loose density of the MSW of the city of San José de Cúcuta is low with an average value of 88.26 Kg / m³, obtaining its maximum value in commune three with 226.48 kg/m³ and the minimum in commune nine with 48.85 kg/m³. It is observed that there is no incidence of water in this density because the two communes show similar humidity values.

The average humidity for all MSW is 49.64%, with communes two and six standing out with high values with values of 80.66% and 63.15% that could be associated with the presence of food waste, such as in commune two, but in commune six curiously has the lowest food waste. Possibly on the days of sampling there were rains that saturated the MSW in the commune 6.

The average calorific value is 2722.32 kcal/kg, which is above the average considered for the incineration of MSW, a value that should be around 2400 kcal/kg; this indicates that elimination by incineration is feasible, however, there are variations between communes.

It is observed that only 30.5% of subscribers recycle the MSW. Even when this is a low percentage, an introduction to an environment-friendly culture is evident.

Table 4 shows the parameters that characterize the MSW of the city of San José de Cúcuta in 1997 [5].

Table 4. Weight Percentage of Components of the San José de Cúcuta MSW in 1997.

Component	Index	% in weight	Component	Index	% in weight
Glass	5.79	1.00	Plastic	12.67	3.0
Metal	1.64	3.00	Wood	1.96	1.0
Textiles	2.62	1.00	Cans	0.04	1.0
Paper	8.47	8.98	Food residues	18.13	17.0
Paperboard	2.45	3.00	Tree leaves	40.74	43.0

Table 5 shows the percentages of the components of the MSW of the study of the year 1997 [5] and of the year 2017, corresponding to a period of 20 years. Figure 1 shows the weight percentages of MSW in 1997 and 2017.

Table 5. Comparison of solid waste components of San José de Cúcuta, 1997 and 2017.

No.	Component	Mean		No.	Component	Mean	
		1997	2017			1997	2017
1	Food residues	17.0	45.85	7	Wood	1.0	1.82
2	Paper	11.0	8.98	8	Glass	1.0	6.84
3	Paperboard	3.0	9.46	9	Cans	0.0	4.27
4	Plastic	1.0	9.84	10	Metal	3.0	1.59
5	Textile	1.0	1.75	11	Dirt	7.0	12.09
6	Garden residues	43.0	5.55				

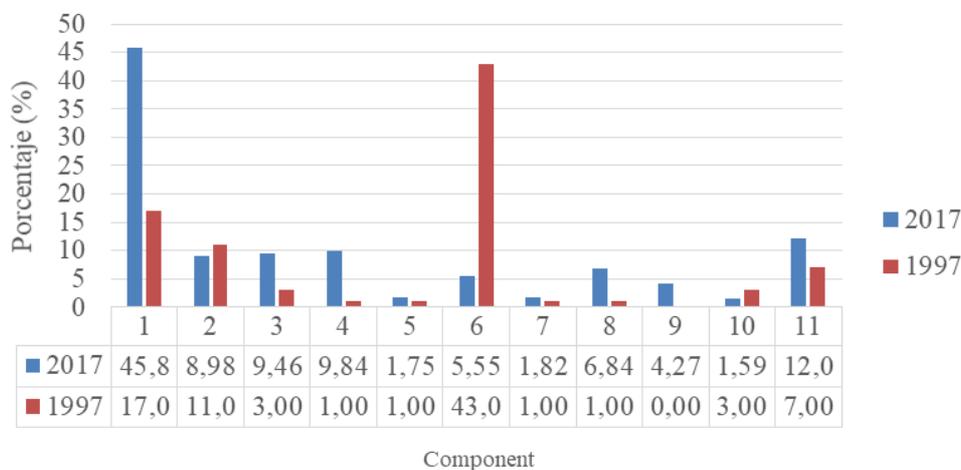


Figure 1. Comparison of solid waste components of San José de Cúcuta, 1997 and 2017.

It is observed that significantly increased, between 1997 and 2017, the components of food waste (17% rose to 45.85%) corresponding to an increase of 28.85%, growing 1.7 times; the cardboard (3% rose to 9.46%) increased by 6.46%, growing 3.15 times; plastic (1% rose to 9.84%) increased by 8.84%, growing 9.84 times, and dirt (7% rose to 12.09%) increased 5.09%, growing 1.72 times. In addition, the paper components significantly decreased (11% down to 8.98%) decreased by 1.02%, decreasing 1.11 times, and garden waste (43% down to 5.55%) decreased by 37.45%, decreasing 7.74 times.

When comparing per-capita production of MSW, it is observed that it was 0.36 kg/inhab in 1991, 0.39 kg/inhab in 1993 and 0.44 kg/inhab in 1997 and in 2017 it amounts to 0.46 kg/inhab day, which shows a growth in time, but with a tendency to stabilization.

It is also observed that the textile components, garden waste, wood, and metal were not found in all the sampling of the communes; and that communes two and three present all the components. The commune one, is the central area of the city, this concentrates the commercial and institutional use governmental and non-governmental. Communes two and five concentrate the population with the middle and upper strata of the city. The remaining communes correspond to the middle and lower socioeconomic strata.

4. Conclusions

Having information on the characterization and management parameters of MSW contributes to overcome the problem of pollution, which is one of the challenges that communities have had to face as a result of population growth and the increase in the culture of consumption, in the globalized open economies model.

In the investigation it was determined that between 1997 and 2017 significantly increased food waste, this as a result of increased consumption of shell food and / or the increase in food waste, cardboard because it is an important region of the economy local trade that uses this component as packaging, and the plastic that in recent years became a product of frequent use (disposable culture). It is also noteworthy the decrease in garden waste showing how the gardens and green areas in the city decreased, and how the built area is increasing each time. Similarly, paper waste decreased due to access to new technologies such as computers and cell phones to store and process information without paper consumption.

It is observed that the culture of recycling is emerging by the population of San José de Cúcuta, since 30.5% of users perform recycling at home, facilitating work for people who work in this activity and increasing the period of use of the landfill, considering that the city, until the end of the 90s, poured solid waste into an open pit in the Urimaco district, which later became a controlled landfill until its final closure, and finally the city has a landfill called El Guayabal.

With the results of the investigation, work can be done to manage the MSW that allows to determine the projection of gases generated by the MSW of San José de Cúcuta, and with this result you can calculate the amount of energy released that is capable of transforming and being marketed to residential use, while generating a contribution to the preservation of the local environment and lowering energy production costs and final disposal of MSW.

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