Valorization of Solid Waste Recovery in an Institution of Higher Education

Nora E. Munguía, Ángela M. Díaz, Luis E. Velazquez, Rafael Perez, Javier Esquer, David S. Zepeda*

Sustainability Graduate Program, University of Sonora, Hermosillo, México
Email: *david.zepeda@unison.mx

Abstract

One of the biggest challenges for organizations, cities and countries is waste management. Currently, 1.3 million tons of solid wastes are generated in the cities and by 2025 it is estimated that this volume will increase up to 2.2 billion tons. Considering this, it is clear that strategies for the reduction of waste generation are needed. In order to achieve this arduous and critic task changes in education, culture and public policy are required and one of the strategies that emerge as one of the most effective is the "zero waste" programs. This paper shows the foundation of a zero waste program based on previous and successful experiences in institutions of higher education. It presents the characterization and quantification of waste, as well as the valorization of it and potential environmental and economic benefits of the implementation of this kind of programs in higher education institutions. Results show that reduction and valorization of waste generation is possible in academic sectors while other outcomes emerge, such as the generation of human capital for the implementation of this kind of programs in different sectors of society and, in that way, contribute in the transition towards sustainable development.

Keywords

Zero Waste Programs, Valorization, Higher Education Institutions, Solid Waste

1. Introduction

Zero-waste programs in cities usually target the total recycling and recovery of resources from waste materials [1]. For this, it is imperative to address the valorization of the recovery of solid waste as an alternative since it can contribute to the performance of renewable and nonrenewable resources, impact positively the environment and public health public, and create opportunities for econom-

ic benefits [2].

The idea behind the concept is to foster a closed-loop system until the materials reach an optimum level of consumption [3]. Reaching this optimum level is complicated because consumption habits affect the generation of waste and have also changed the composition of the Municipal Solid Waste [4]. Different studies highlight the environmental benefits of the recovery of waste; however, financial benefits are still unclear in many cases. For example, the market demand is high enough for specific material such as aluminum, but it may still not be profitable for others. Often, a large investment is required in order to ensure the success of a zero waste program, yet it is possible to reduce waste production with only a minimal investment [5].

A zero waste approach has been implemented not only in several economic sectors but also at higher education institutions. Large amounts of waste on campuses represent an opportunity for higher education institutions to demonstrate their social responsibility by handling university waste in a more sustainable manner. The University Social Responsibility (RSU) is a strategy to build a responsible approach to the negative impacts into university's substantive functions and management activities in addition to begin a philanthropic initiative [6]. The RSU aims to address the issue of responding to the environmental impact produced by life on campus [7]; therefore, it offers valuable input towards the development of sustainability strategies that can improve students' satisfaction, attract new students, and reduce students' drop out numbers [8].

Zero waste programs on campus have been one of the most common sustainability initiatives for managing waste and encouraging students' involvement [9]. The array of these initiatives includes demonstration projects as well as waste reduction campaigns [10] [11]. Engaging people is a key factor to increasing the effectiveness of zero waste programs [12]. Usually, students are motivated to address the challenge of handling waste in a sustainable manner; however, their awareness and disposition differs according to their socio-demographic characteristics [13]. This article shows the foundation of a zero waste program, which was based on previous successful experiences at other institutions of higher education. It presents the characterization and quantification of the waste, and the valorization of that waste as well as its potential environmental and economic benefit for the higher education institution. While similar studies focus on reducing the volume of waste generated, this study presents a monetary quantification of the volume generated.

2. Materials and Methods

The study was performed at the University of Sonora (UNISON), a highly recognized institution of higher education located in Hermosillo, Mexico. The UNISON accounts for over 40,000 people including academics, students, administrative and maintenance staff. The area of study was the Division of Social Sciences, which accounts for close to 6000 people. This division was considered

in order to assess the success of smaller scale recovery with the intent to later expand the program to include the rest of the campus. The selection of the study area was made under a non-probability method, a convenience sampling, due to the fact that the administration of the UNISON showed support for the study. The study area is presented in Figure 1.

The study on solid waste for the UNISON was made based on the methodological design for a "zero waste" program, which was based on the experiences of three previous and successful programs implemented at institutions of higher education [11] [14] [15]. The program included 6 stages; 1) disclosure of the "zero waste" program, 2) the characterization of solid waste, 3) the quantification of solid waste, 4) the reduction and valorization of waste, and 5) the implementation, as is demonstrated in Figure 2.

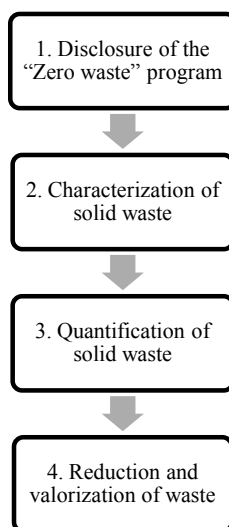
Figure 1. Study area, division of social sciences, UNISON.

Figure 2. Methodological design—"zero waste" program.

a) *Disclosure of zero waste program*:

In the first stage, disclosure strategies were performed with the intention of raising awareness and increasing the motivation among the various members of the university community to participate in the recovery of waste. The diffusion of the program was carried out in conjunction with the communication department of the UNISON through various media platforms:

- Official website of the University of Sonora
- UNISON's social media accounts, including Facebook and Twitter
- TV channels including UNISON TV channel as well as the local state TV channel
- UNISON's radio station
- UNISON's YouTube Channel
- University advertising screens

b) *Characterization of solid waste*:

The characterization stage included the collection and classification of the various types of solid waste that could be recovered. This was defined following the Mexican standards, NMX-AA-15-1985 and NMX-AA-061-1985, and had a duration of four months. In order to have representative samples and, in accordance with the Mexican standards, samples were collected in no consecutive weeks. Samples were collected within five working days of each week, from Monday to Friday. The collected solid waste was then transported to a designated area for classification.

c) *Quantification of solid waste*:

For the weight and quantification of the products, an industrial scale with a capacity of 500 kg was used. In accordance with NOM-AA-15-1985, the products were separated and homogenized using a shovel and finally split into four separate piles to obtain individual samples of 50 kg.

d) *Reduction and valorization of waste*:

For the valorization of waste, local companies were contacted in order to identify the market prices for the products and to calculate an estimate for the value of the recovered waste.

3. Results and Discussion

3.1. Disclosure of Zero Waste Program

Considering that a change in the culture of the university's community and a shift in its consumption habits were essential for the success of the zero waste program, strategies for communication of the program's goals were implemented. A series of interviews, reports, publications, and social media content were produced and published in order to facilitate a more successful recovery of waste from the university's community.

3.2. Characterization of Solid Waste

The collection of waste was conducted using containers which were installed in

the Division of social sciences and later transported to the classification area. Currently the university does not perform any type of use or recovery of the waste that is generated. There were 34 pairs of containers located in the study area that were used for the collection of solid waste, as listed in Figure 3.

Table 1 shows the total amount of samples recovered during the eight weeks of collection and the average per week. At this stage, the separation and classification have not yet been performed.

Values oscillated between 397 and 467 kg per week. In week 4 a peak was observed, which can be attributed to the fact that this sampling took place a week after the Mexican Independence Festivities that occurred on September 15. This suggests that there was a high consumption of products that were later disposed of as waste during the festivities. On the other hand, a slight decrease in weight can be observed from week 6, which corresponded to the final week of October.

The classification of waste was performed with the support of maintenance staff of the university, as is illustrated in Figure 4. Seven categories of waste were established; 1) plastic, 2) paper, 3) cardboard, 4) garden waste, 5) food waste, 6) glass, and 7) others. The designated area for classification was divided up in order to avoid a mixing of the waste and to facilitate the quantification of the various categories, as is seen in Figure 5.

3.3. Quantification of Solid Waste

The quantification of the solid waste was made based on the procedures established in the Mexican standard NOM-AA-15-1985. An average generation of solid waste per week of 427.87 kg was determined. The total averages per type of material are presented in Table 2.

Figure 6 demonstrates that 96% of the waste that was generated in the study area has a recovery potential. Only the waste that falls under the category of "others" cannot be reused, recycled, or revalued.

The material with the highest total proportion among the samples was plastic, this represent 40% of the total volume. This can be attributed mainly due to the high consumption of packaged foods and beverages.

Figure 3. Location map of containers—Division of Social Sciences UNISON.

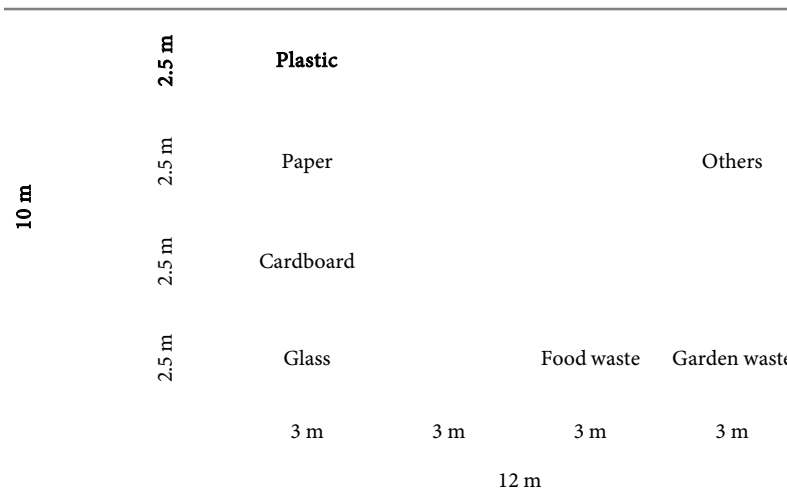**Figure 4.** Separation and classification of solid waste.

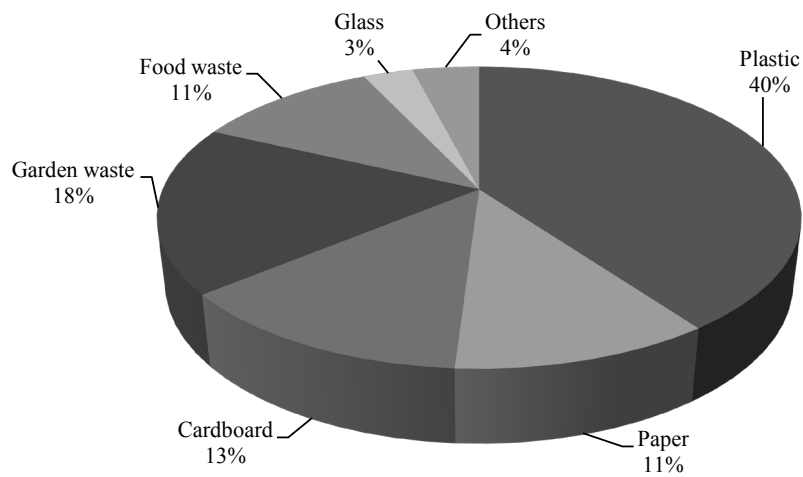**Figure 5.** Distribution of designated area for collection of waste.

Figure 6. Proportion of average generation of waste per week.

Table 1. Weight of samples.

Month	Week	Day 1	Day 2	Day 3	Day 4	Day 5	Average
Aug	1	435.20	467.30	477.50	455.50	442.60	455.62
	2	412.50	449.00	474.40	401.50	421.00	431.68
Sep	3	404.30	412.40	448.00	443.30	434.70	428.54
	4	435.50	465.30	489.50	487.20	457.00	466.90
Oct	5	422.14	420.50	433.00	431.50	426.40	426.71
	6	412.00	412.40	424.13	423.56	421.50	418.72
Nov	7	401.10	396.20	412.00	399.50	375.60	396.88
	8	394.50	403.00	403.50	390.30	398.40	397.94

Table 2. Average waste per type of material.

Type of material	Average generation per week (kg)	Percentage of volume
Plastic	171.15	40%
Garden waste	77.02	18%
Cardboard	55.62	13%
Paper	47.07	11%
Food waste	47.07	11%
Others[a]	17.11	4%
Glass	12.84	3%
Total	427.87	100%

[a]Dirty material, napkins, toilet paper, among others.

Most of the quantified waste could be used as raw material for different processes. Garden and food waste could be used for the generation of compost inside UNISON facilities. Cardboard, paper, glass, and plastic could be recycled or sold to local companies in order to reduce the generation of waste and offer an economic benefit.

3.4. Valorization of Waste

For the valorization of the waste that was generated, different local companies were contacted in order to calculate the potential economic impact of selling the recycled material according to the current market value. The garden and food waste were not included in the valorization section of the study. Only plastic, paper, cardboard and glass wastes were calculated, as demonstrated in Table 3.

Based on the quantification of the collected waste, each month around 1.2 tons of recoverable waste are generated in the Division of social sciences of the UNISON alone, and this represents a potential economic benefit of around 150.00 - 200.00 USD monthly. In order to have a clearer idea of the potential environmental and economic benefits of the implementation of a zero waste pro-

gram on the entire campus of the UNISON, a projection was estimated based on the results obtained from the study area. For the calculations, the number of people that interact in the various divisions was used as a reference. The results of the estimation are presented in Table 4.

Estimates show a potential reduction of more than 4.5 tons per month in the generation of waste and a potential economic benefit of more than 8000 USD per year just from the implementation of a waste collection program, which would then separate and sell the recoverable waste to local companies.

4. Conclusions

Zero waste programs are an innovative strategy in the path towards sustainability and social responsibility. Universities have a strong commitment to this challenging task and the results of this research present the potential contribution that the academic sector could offer by implementing programs like this.

Economic and environmental benefits can be obtained through these programs and at the same time contribute to the improvement of the current waste management systems since; when implemented in institutions of higher education, not only the generation of waste is reduced, but also it generates the human capital necessary for the implementation of this.

Table 3. Average valorization per week.

Waste category	Volume percentage	Weight[a] (kg)	Market value ($/kg)[bc]	Valorization ($)[c]
Plastic	40%	171.15	3.00	513.45
Cardboard	13%	55.62	2.00	111.24
Paper	11%	47.07	3.00	141.21
Glass	3%	12.84	0.70	8.98
Total	--	286.68	--	774.88

[a]Average per week, [b]Price per kilogram based on local companies, [c]Mexican pesos (1 USD = 18.42 MXN).

Table 4. Projection of potential reduction and valorization of waste.

Division	Population	Average generation of recoverable waste per week (kg)	Valorization ($)
Social sciences	5961	286.68	774.88
Biological and health science	5071	243.88[a]	659.19[a]
Economics and Management	4072	195.83[a]	529.33[a]
Exact and natural sciences	1281	61.61[a]	166.52[a]
Humanities and fine arts	2510	120.71[a]	326.28[a]
Engineering	4883	234.84[a]	634.75[a]
Total		1143.55	3090.94

[a]Estimated value.

While it is true that zero waste programs can be implemented solely for the economic benefits, the university community should be also encouraged to adopt a cultural and attitudinal change. The priority should be on developing programs of recovery, separation, minimization, and reuse of the waste that is generated so that to the institution can minimize the solid waste that is generated on its campuses. In that sense, the following statements can be concluded from this study:

- It is necessary to have the support of the university authorities, administrative staff, concessional businesses and the general university community in order to implement a real revaluation of solid waste.
- Dissemination campaigns must be strengthened, thus allowing the continuation of actions aimed at promoting segregation, reduction, reuse and responsible consumption.
- Environmental education is the main requirement for the successful implementation of a zero waste program, so guidelines and policies for the university community should be created in order to raise awareness and to define the role of the various actors within the program.
- Factors such as poor source segregation, joint collection, and inadequate classification and quantification processes can affect the quality of materials and may result in an inefficient recovery of waste. Another consideration that must be taken into account is that the space and logistical requirements for a zero waste program in terms of university facilities were greater than originally projected.
- Additional research is needed in order to quantify the real total volume of waste generated by the university and the potential economic benefit of it. It is advised to include social aspects in the study such as corporate social responsibility, community programs, among others, in order to create a broader program and later measure the contribution to sustainable development.

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