Design and implementation of an efficient model for the transformation and use of organic solid urban waste

Diseño e implementación de un modelo eficiente para la transformación y aprovechamiento de residuos sólidos orgánicos urbanos

Desenho e implementação de um modelo eficiente de transformação e aproveitamento de resíduos sólidos orgânicos urba

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Abstract

Introduction: This article is the development of the “Design and implementation of an efficient model for the transformation and use of organic solid waste”, in the “El Conjunto Residencial de Ontario in Bogotá (Colombia)”. Developed at the Universidad Libre 2021.

Problem: The accumulation of solid urban waste by the residential community shows an environmental problem that results in health problems, bad odors, the attraction of rodents and a poor physical appearance in the common areas of this complex, caused by the lack of use of this organic waste.

Objective: to formulate an efficient model for the transformation and use of organic solid waste in the “Conjunto Residencial Tejar de Ontario”.

Methodology: Characterization by the method of quartering and use of organic waste through the design of a micro composting plant.

Results: Physical properties such as color, odor and texture are recognized as well as chemical parameters such as C/N, pH and humidity, with these tools we obtain a good quality and fertile compost.

Conclusion: The transformation of urban organic solid waste is an effective way of mitigating the environmental impact caused by not using it and simultaneously preventing this waste from reaching landfills.

Originality: This transformation and use design was carried out for the first time in the “Conjunto Residencial Tejar de Ontario”, it also contains management strategies that allow optimizing the composting operation.

Limitations: Find tools that are easily understood by the community to strengthen knowledge of recycling, source separation and composting.

Key Words: Bogotá, characterization, domestic, Exploitation, organic, set, waste.

Resumen

Introducción: El presente artículo es el producto de la investigación “Diseño e implementación de un modelo eficiente para la transformación y aprovechamiento de residuos sólidos orgánicos”, en el “El Conjunto Residencial de Ontario en Bogotá (Colombia)”. Desarrollada en la universidad Libre en el año 2021.

Problema: La acumulación de residuos sólidos por parte de la comunidad residencial, evidencia una problemática ambiental que traen como consecuencia, problemas de sanidad, malos olores, atracción de roedores y un deficiente aspecto físico en las áreas comunes de este conjunto, causadas por el no aprovechamiento de estos residuos orgánicos.

Objetivo: formular un modelo eficiente para la transformación y aprovechamiento de residuos sólidos orgánicos en el Conjunto Residencial Tejar de Ontario.

Metodología: Caracterización por el método del cuarteo y aprovechamiento de residuos orgánicos por medio del diseño de una micro planta de compostaje

Resultados: Se reconocen propiedades físicas como el color, olor y textura además de parámetros químicos como lo son C/N pH y humedad, con estas herramientas obtenemos un compost de buena calidad y fértil.

Conclusión: La transformación de residuos sólidos orgánicos urbanos es una forma efectiva de mitigar el impacto ambiental causado por el no aprovechamiento de los mismo y de forma simultánea se evita que estos residuos lleguen a los rellenos sanitarios.

Originalidad: Este diseño de transformación y aprovechamiento se llevó acabo por primera vez en el conjunto residencial Tejar de Ontario, además contiene estrategias de gestión que permiten optimizar la operación del compostaje.
1. Introduction

One of the main environmental impact problems generated in urban areas is the inadequate handling of biodegradable organic solid waste. [1]

In Colombia, 12 million tons of garbage are generated and only 17% is recycled, therefore the crisis of landfills is reaching dangerous levels. In the case of Bogotá, about 7,500 tons are generated per day and between 14% and 15% are recycled, even below the national average”. [2]

According to the Tunjuelito mayor’s office, the lack of environmental education on the management and classification of household solid waste generates a poor disposal of said waste, this leads to the presence of rodents and vectors affecting human health. [3]

In accordance with the problem of generating waste classified as usable, non-usable and organic, the initiative to mitigate the environmental impact caused by taking this solid organic waste to landfills, [4] taking as a strategy use and transformation...
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through solid waste recycling methods, through systems designed for housing models subject to the horizontal property regime [6-10].

The method used for the characterization and quantification of the solid organic waste generated in the complex was the quartering, [11] which provides in detail the weight and a clear classification of the waste found in the temporary storage room of the "Conjunto Residencial Tejar de Ontario".

Subsequently, a design is implemented in accordance with the needs of the complex, considering the composting area [12], percentage of composting, number of compost bins, materials, design of the use model, environmental education, budget, and the items to consider so that the implementation of the model be efficient. It is an urban composting project, which invites the community to become environmentally aware that in turn is on the path to changing habits and teaching that it is possible to make a better disposal of organic solid waste, considering that most of the waste generated in homes is of this type (figure 1).

Composting production is a recycling modality that takes advantage of the organic waste produced in residential units, by collecting prunin material, food scraps, fruits, and vegetables from the apartments, making it possible to use it as organic fertilizer for the green areas themselves. Of the whole or even its commercialization [13].

The production of composting at the urban level is an experience that has been developing for quite some time, there are multiple projects for food production and obtaining fertilizer through the practice of alternative composting generation techniques, these projects are the product of the initiative of individuals and communities [14], likewise, experience has shown that the rate of production and the type of organic waste in the urban environment, allows the formalization of this type of initiative [14] (figure 3).
<table>
<thead>
<tr>
<th>TYPE OF WASTE</th>
<th>DESCRIPTION</th>
<th>USE</th>
<th>DECOMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw waste</td>
<td>They correspond to waste before food preparation, such as fruits, vegetables in general, fruit and vegetable peels, leftover vegetables, juice preparation waste in general, grains, etc.</td>
<td>Excellent material to use in the production of organic fertilizers, it is better to add fresh residues before they decompose.</td>
<td>Slow</td>
</tr>
<tr>
<td>Lavaza</td>
<td>Consisting of foods that have gone through some cooking process, among these are: leftover food and meat, remains of aromatic plants, etc.</td>
<td>Its use in the production of organic fertilizers is not recommended due to the possible microbiological contamination generated by human saliva and its high salt content. Its use is recommended for non-agricultural activities.</td>
<td>Quick</td>
</tr>
<tr>
<td>Pasture</td>
<td>Residue generated when the lawn is mowed.</td>
<td>When it is freshly cut it contains high amounts of nitrogen, and as time goes by the nitrogen content is reduced and is replaced by carbon, it is a good material to produce organic fertilizers, in addition, once it is dry, it can be accumulated to carry out its introduction in the composting piles and balance the carbon/nitrogen ratio.</td>
<td>Quick</td>
</tr>
<tr>
<td>Sawdust</td>
<td>Coming from carpentry work.</td>
<td>This residue is very good to be able to have an adequate carbon/nitrogen ratio, and it can be stored for long periods of time and introduced when the mixture is made.</td>
<td>Very slow</td>
</tr>
<tr>
<td>Tree chipping</td>
<td>Residue that is generated in the activity of cutting trees that fall to the ground and dry.</td>
<td>Chopped or chipped, it is an excellent material to introduce into mixtures, since due to its rigidity it provides porosity to the pile and allows the passage of air into the mixture.</td>
<td>Very slow</td>
</tr>
<tr>
<td>Leaf litter</td>
<td>Residue that comes from the leaves of trees that fall to the ground and dry.</td>
<td>Good material for use in composting piles and worm bed assembly, it also has the advantage that it can be accumulated for long periods of time, so I can have accumulated material and introduce it into the mixtures as needed.</td>
<td>Slow</td>
</tr>
<tr>
<td>Eggshells</td>
<td>Shells of chicken eggs or other birds.</td>
<td>Material with a high calcium content, enriches the fertilizer, the ideal is to introduce it pulverized.</td>
<td>Very Slow</td>
</tr>
<tr>
<td>Leached</td>
<td>Liquid from the destruction of biodegradable waste, which can be collected and recirculated before passing through the thermophilic phase.</td>
<td>They are liquids that have high microbial loads, they are good to use in the first phases of degradation of the composting piles, but not after the pile increases the temperature to the thermophilic phase, since we will have to be introducing pathogenic microorganisms again.</td>
<td>Quick</td>
</tr>
<tr>
<td>Buttermilk</td>
<td>Obtained by manufacturing processes of dairy products such as cheese and yogurt</td>
<td>They are good at the beginning of the composting phase, since they lower the colonies of pathogenic microorganisms in the compost mixtures.</td>
<td>Quick</td>
</tr>
<tr>
<td>Cup of coffee</td>
<td>Waste generated from coffee preparation</td>
<td>Excellent material to cover compost piles and thus avoid the presence of flies and rodents.</td>
<td>Slow</td>
</tr>
</tbody>
</table>

*Figure 2. Typical urban area waste.*  
*Fountain: [13] (p. 33, 34)*
2. Materials and methods

2.1 Study Area

The Tejar de Ontario residential complex is located in the city of Bogotá, in the sixth town Tunjuelito, more precisely at the address Calle 56a Sur No. 27 - 75. [6] This complex comprises approximately 230 apartments, with an area of 14,007 m² that borders on the south western side with the Tunjuelito river on the east with Av. Boyacá one of the main roads of the city, this avenue runs through the city from south to north and covers about 25 km. [7]

![Figure 3. Picture of residential complex Ontario of Tejar (Calle 56a Sur No. 27 – 75) where the project was made. (a) Sight in the structure, (b) entrance of the complex. Source: Google Street view.](image)

Considering that, in the composting process, those responsible for or agents of the transformation are living beings, all those factors that may limit their life and development will also limit the process itself. [17, 18]

The factors that intervene are complex, but temperature, humidity and aeration can be pointed out as important. [19]

The residential urban organic waste composting process consists of various microbial populations degrading organic matter in the presence of oxygen and water, producing a stable product called COMPOSTING, generating gases and heat as residues of microbial metabolism (figure 4). [20]
The phases that occur in the composting production process are the following [13]

**Mesophyll phase.** The starting material begins the composting process at room temperature and within a few days (and even hours), the temperature rises to 40°C.

This increase in temperature is due to microbial activity, since in this phase the microorganisms of soluble compounds, such as sugars, generates organic acids and, therefore, the pH can drop. (up to about 4.0 or 4.5). This phase lasts a few days (between two and eight days). (p. 39)

**Thermophilic or Hygienization Phase.** When the material reaches higher temperatures, between 40 and 45 °C, the mesophilic microorganisms are replaced by filamentous bacteria (actinomycetes) and fungi. Above 45°C, thermophilic bacteria appear, which act by facilitating the degradation of more complex carbon sources, such as cellulose and lignin. This phase can last from a few days to months, depending on the starting material, the climatic conditions of the place and other factors. This phase is also called the sanitization phase since the heat generated destroys bacteria and contaminants of fecal origin such as Escherichia coli and Salmonella spp. This phase is important because temperatures above 55°C eliminate helminth eggs, phytopathogenic fungal spores and weed seeds that can be found in the starting material (figure 4), giving rise to a sanitized product. (p. 39)

**Cooling phase.** Depleted carbon sources (particularly nitrogen in the composting material) the temperature drops again to 40-45°C. During this phase, the degradation of polymers such as cellulose continues and some fungi visible to the naked eye appear. When lowering 40°C, mesophilic organisms they restart their activity and the
pH of the medium drops slightly, although in general the pH remains slightly alkaline. This cooling phase requires several weeks and can be confused with the maturation phase. (p.39)

maturation phase. It is a period that lasts months at room temperature, during which secondary reactions of condensation and polymerization of carbon compounds take place for the formation of humic and fulvic acids. (p. 40)

<table>
<thead>
<tr>
<th>Mesophilic</th>
<th>thermophilic</th>
<th>Mesophilic II or cooling</th>
<th>Maturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature up to 40°C</td>
<td>40 to 70°C or more</td>
<td>Temperature drops at 40-45°C</td>
<td>18 to 22°C</td>
</tr>
<tr>
<td>Mesophilic and thermotolerant fungi, mesophilic bacteria.</td>
<td>Bacteria Actinomycetes</td>
<td>bacteria Invertebrate fungi</td>
<td>Bacteria Actinomycetes</td>
</tr>
<tr>
<td>pH 5 – 5.5</td>
<td>pH 8 – 9</td>
<td>pH 8.5</td>
<td>pH 7-8</td>
</tr>
</tbody>
</table>

**Figure 4.** Phases in the composting degradation process, predominant microorganisms in each phase and pH

Fountain: [13] (p. 40)

### 2.2 CONDITIONS OF THE COMPOSTING PROCESS

Considering that, in the composting process, those responsible or agents of transformation are living beings, all those factors that may limit their life and development will also limit the process itself. [8]

The factors involved are complex, but temperature, humidity and aeration can be noted as important. [9]

#### 2.2.1 C / N ratio: It is the amount of carbon and nitrogen present in a material. All living things are composed of carbon and nitrogen (carbohydrates and proteins) and must take them from the food they eat. Likewise, the microorganisms responsible for degradation also need C and N to reproduce and use the material. Organic waste is largely composed of C and N in different proportions, which is very important to know in order to establish the possible mixtures when carrying out a composting process and thus achieve a compost with an ideal C / N ratio. for field application.

#### 2.2.2 pH: It is another important parameter to evaluate the process conditions and the stabilization of the residues. Its value, as well as the temperature varies over time during the process. At the beginning the material has a pH between 6-7, and in the first days it decreases due to the production of organic acids in the system. Later it can go up to 8-8.5 during the entire thermophilic phase and when cooling begins it reaches a value in the range of 7-8, in mature compost. [18]
2.2.3 Temperature: As mentioned above, a series of microorganisms intervene in each phase of the process, each with a different temperature range.

- Latency and growth phase: 15-45º C
- Thermophilic phase: 45-70º C
- Ripening phase: below 40º C [19]

According to Arenas, C. The increase in temperature during fermentation occurs mainly due to the exothermic biochemical reactions that occur there, associated with the activity of the microorganisms present. [20] [40]

2.2.4 Humidity: This factor is essential for microorganisms, since water is the environment in which they live, move and feed. In the practice of composting, high humidity must always be avoided because it would displace oxygen and, consequently, the process would stop being anaerobic (absence of air) or, what is the same, putrefaction. On the other hand, if the amount of humidity in the waste pile is low, the activity of the microorganisms decreases and consequently the process is delayed. [21] [40]

It should be considered that the heat generated in the process causes a decrease in humidity. We consider as optimal levels, humidity of 40 to 60%, depending on the mixture of more or less fibrous materials of the pile content.

2.2.5 Aeration: Oxygen is essential for microorganisms to effectively decompose organic matter. Therefore, the air supply at all times must be suitable to maintain microbial activity, without the appearance of anaerobic conditions, which, in addition
to hindering the process, lead to the appearance of odors and a lower quality product. So that the anaerobic process does not start, a minimum of 10% aeration must be exceeded. For this reason, it is important to control the materials introduced into the pile, since many of the plant debris, especially grass, tend to become caked and cause rot. [21] [40]

2.3 CHARACTERISTICS OF COMPOSTING

Composting is a process by which various organic substrates decompose and stabilize due to the action of a mixed population of microorganisms, obtaining a final product called compost, organically stable, free of pathogens and weed seeds that can be applied efficiently to the ground to improve its properties. [22]

In aerobic composting there are mainly three types of systems: Rows, static piles and closed reactors. Rows and static stacks, sometimes referred to as open systems, are used more than closed reactors. [23] In open systems the material to be composted is stacked on an impermeable platform, such as concrete or asphalt. Sometimes a layer of polyethylene is used as an extra precaution to ensure that no contaminants reach the ground through the cracks, if they exist. [24]

2.2.1 Types of Composting:

Large-scale or Industrial Composting: There are numerous systems to carry out the decomposition and maturation process on a large or industrial scale. Thus, to carry out the first classification, two main categories can be established: open systems (piles, heaps, plateaus) and closed systems (containers, tunnels). [25]

Small-scale, community, and residential composting: Community composting is developed in spaces or gardens of homes, sports or recreational spaces, schools, and urbanizations. This type of composting represents an interesting and educational social practice, although it involves a certain organization of resources and people. And residential composting is carried out at the family level, in the garden, terrace, orchard or any other appropriate place, with small amounts of waste and using the simplest systems. [25]
Table 1. Matrix of methods of composting (cost and benefits)

<table>
<thead>
<tr>
<th>Composting method</th>
<th>capacity</th>
<th>Location</th>
<th>time</th>
<th>cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flipped Stacks</td>
<td>Open system 8,775 m³ or 8,775 L</td>
<td>Surface Width 1.5 m, length 3.9 m and height 1.5 m</td>
<td>Between 10 to 12 weeks</td>
<td>Low cost of construction and maintenance. $ 500,000</td>
</tr>
<tr>
<td>Static Stacks with passive aeration</td>
<td>System closed 35 m³ or 35 L</td>
<td>Surface Width 2 m long 5 m and height 3.5 m</td>
<td>Between 6 to 10 weeks</td>
<td>High cost of construction and maintenance Approximately $ 750,000</td>
</tr>
<tr>
<td>Static Stacks with forced aeration</td>
<td>Mechanized aeration system 35 m³ or 35 liters</td>
<td>Surface Width 2 m long 5 m and height 3.5 m</td>
<td>Between 6 to 10 weeks</td>
<td>High cost of construction and maintenance Approximately $ 1,000,000</td>
</tr>
<tr>
<td>Closed Stacks</td>
<td>System closed 300-liter recycled plastic or wood composters</td>
<td>Approximate surface from 15 to 20 m²</td>
<td>Between 8 to 10 weeks</td>
<td>High cost of construction and maintenance Approximately $ 900,000</td>
</tr>
<tr>
<td>Flipped Stacks</td>
<td>Open system 8,775 m³ or 8,775 L</td>
<td>Surface Width 1.5 m, length 3.9 m and height 1.5 m</td>
<td>Between 10 to 12 weeks</td>
<td>High cost of construction and maintenance Approximately $ 750,000</td>
</tr>
</tbody>
</table>

Source: self-made.

2.4 DEVELOPED METHODOLOGIES

The execution of this project has two types of scope: descriptive (it allowed to examine the characteristics of the problem that were present in the residential complex, which is the accumulation of waste). In addition, it is part of a mixed research of a qualitative nature (through survey collection and awareness of the community) and quantitative (collection of numerical data to determine the variables of the waste generated). This process was divided into 2 phases:

- Characterize the generation and storage of solid waste of the inhabitants of the Tejar Residential Complex of Ontario. It consists of determining the various types of waste generated in the set by applying the quartering method, [18] which allows to calculate the generation in percentage according to the weight of the different residues found corresponding to the generation in a determined period of time. With the sample size and weight differentiated by type of material, it is possible to estimate the generation of each one of them on a monthly and annual basis, as well as to calculate the generation per capita. In percentage according to the waste found, generation determined time.
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- Design a comprehensive system for the transformation and use of organic solid waste that best adapts to the needs of said residential complex. Where the characteristics of the design and the alternatives for the use of urban organic solid waste were analyzed and determined in order to subsequently dimension a functional system that allowed the use of organic solid waste in the residential complex.

3. Results

Characterization of Organic Solid Waste.

For the characterization of the solid waste from the Tejar complex in Ontario, the waste that was only in 5 bins was randomly taken and that amount of waste makes up the sample to be characterized. To determine the per capita production, the average weight of the fully filled cans was used and yielded a data of 55,134 kg. According to the characterization carried out within the Tejar residential complex in Ontario, it was found that 551.34 Kg corresponds to the total production of the inhabitants of the complex in one day, therefore, 100% of the waste production corresponds to 1,102 Kg these generated every two days. [26]

Table 2. Solid Waste Characterization Format in the Ontario Tejar Complex

<table>
<thead>
<tr>
<th>DAY</th>
<th>WEIGHT IN Kg OF WASTE GENERATED</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ORGANIC</td>
<td>PAPER</td>
</tr>
<tr>
<td>1</td>
<td>22,00</td>
<td>1,11</td>
</tr>
<tr>
<td>2</td>
<td>18,52</td>
<td>2,06</td>
</tr>
<tr>
<td>3</td>
<td>20,26</td>
<td>1,10</td>
</tr>
</tbody>
</table>

(continúa)
### SOLID WASTE CHARACTERIZATION FORMAT IN THE TEJAR DE ONTARIO GROUP

<table>
<thead>
<tr>
<th>DAY</th>
<th>ORGANIC</th>
<th>PAPER</th>
<th>PAPERBOARD</th>
<th>PLASTIC</th>
<th>METALS</th>
<th>GLASS</th>
<th>TETRAPAK</th>
<th>ICOPOR</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
<td>Kg</td>
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<td>Kg</td>
</tr>
<tr>
<td>4</td>
<td>20,43</td>
<td>1,15</td>
<td>0,76</td>
<td>1,66</td>
<td>0,42</td>
<td>0,41</td>
<td>0,22</td>
<td>0,83</td>
<td>0,23</td>
<td>26,11</td>
</tr>
<tr>
<td>5</td>
<td>19,78</td>
<td>1,63</td>
<td>1,42</td>
<td>2,01</td>
<td>0,25</td>
<td>0,00</td>
<td>0,52</td>
<td>0,60</td>
<td>0,16</td>
<td>26,38</td>
</tr>
<tr>
<td>6</td>
<td>19,29</td>
<td>1,88</td>
<td>1,77</td>
<td>1,68</td>
<td>0,15</td>
<td>0,00</td>
<td>0,24</td>
<td>0,40</td>
<td>0,32</td>
<td>25,72</td>
</tr>
<tr>
<td>7</td>
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<td>2,63</td>
<td>0,77</td>
<td>2,11</td>
<td>0,30</td>
<td>0,00</td>
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<td>0,20</td>
<td>0,28</td>
<td>28,29</td>
</tr>
<tr>
<td>8</td>
<td>22,24</td>
<td>2,13</td>
<td>0,67</td>
<td>2,46</td>
<td>0,29</td>
<td>0,30</td>
<td>0,22</td>
<td>0,00</td>
<td>0,51</td>
<td>28,81</td>
</tr>
<tr>
<td>9</td>
<td>17,87</td>
<td>2,23</td>
<td>1,00</td>
<td>3,40</td>
<td>0,23</td>
<td>0,00</td>
<td>0,13</td>
<td>0,00</td>
<td>0,31</td>
<td>25,18</td>
</tr>
<tr>
<td>10</td>
<td>21,45</td>
<td>1,23</td>
<td>1,10</td>
<td>2,66</td>
<td>0,55</td>
<td>0,00</td>
<td>0,22</td>
<td>0,00</td>
<td>0,11</td>
<td>27,33</td>
</tr>
<tr>
<td></td>
<td>10,18</td>
<td>0,86</td>
<td>0,47</td>
<td>1,08</td>
<td>0,16</td>
<td>0,09</td>
<td>0,13</td>
<td>0,11</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55,134</td>
</tr>
</tbody>
</table>

**Source:** self-made

### 3.1 WASTE STORAGE

In accordance with the provisions of (RAS-2000. Urban Cleaning Systems), all buildings for multi-family, high-density multi-family, institutional or commercial use, and those that the cleaning entity determines, must have a collective storage system of solid waste, designed as a minimum with the requirements and criteria presented below and other current provisions related to the matter. [27]

The collective storage system must meet the following requirements: [28]:

...
### Table 3. Collective storage system

<table>
<thead>
<tr>
<th>concept</th>
<th>verified</th>
</tr>
</thead>
<tbody>
<tr>
<td>ready-made finishes to facilitate cleaning and prevent the formation of environments conducive to the growth of microorganisms</td>
<td>☑️</td>
</tr>
<tr>
<td>They will have ventilation systems (air extractors), water supplies, sewage, electricity, prevention and control of fires</td>
<td>☑️</td>
</tr>
<tr>
<td>They will be built in such a way as to avoid the access of insects, rodents and other kinds of animals.</td>
<td>☑️</td>
</tr>
<tr>
<td>sufficient storage capacity according to the collection frequency</td>
<td>☑️</td>
</tr>
<tr>
<td>must comply with access for collection vehicles</td>
<td>☑️</td>
</tr>
<tr>
<td>The storage areas will be cleaned, fumigated and disinfected by the user, with the regularity required by the nature of the activity that takes place there, in accordance with the requirements and standards established by the competent authorities.</td>
<td>☑️</td>
</tr>
<tr>
<td>storing garbage outside the storage area is prohibited</td>
<td>☑️</td>
</tr>
<tr>
<td>The storage area must have storage containers in sufficient quantity and dimensions that do not allow the accumulation of solid waste on the floor of the same. The selection of these containers should consider the type of collection vehicle of the system</td>
<td>☑️</td>
</tr>
</tbody>
</table>

**Source:** self-made

The Tejar Residential Complex in Ontario has all the requirements for the correct operation and storage of solid waste. According to criteria established in Ras 2000. The solid waste storage room of the Tejar Residential Complex in Ontario is presented below.

![Figure 3. Temporary solid waste storage room, (a) exterior, (b) interior.](source)

**Figure 3.** Temporary solid waste storage room, (a) exterior, (b) interior.  
**Source:** Authors

### Observation

Taking into account Resolution No. 2184 of 2019 which became effective in 2021, the white, black and green color code for the separation of waste at the source, it is
essential to implement the color code within the storage room indicating the correct
disposition using the new resolution. [29]

• Usable = White
• Not usable = Black
• Organic = Green

In this way, the characterization of the waste is synchronized from the source
of generation to the temporary storage point and later to its use and final disposal.
In this way, it is guaranteed that there is no confusion when disposing of any waste.

3.1.1 Proposal for the distribution of the bins

The bins will be distributed in the waste storage room so that people can identify
where they are going to deposit their waste, counting on the fact that there will be
a greater number of bins for organic waste since the percentage of production and
accumulation is higher; total will be 10 bins for storing organic waste. For usable and
non-usable waste, there will be 6 bins and 4 bins respectively.

Figure 7. Distribution of waste storage bins inside the temporary storage place. [31]
Source: Authors
3.2 Design of the system for the use of organic solid waste

3. Design aspects

The design aspects that are considered for the construction of a compost bin [32] for the Tejar Residential Complex of Ontario are:

- Percentage of organic waste generation
- Weight of the material to be composted
- Number of containers required

The longitudinal compost bin is designed as follows at a generic level:

![Diagram of longitudinal compost bin](image)

The leachate outlet is normally a faucet that can be opened manually every week to extract the liquids.

**Figure 8. Design examples of longitudinal rotating composters**

![Diagram showing input and output of material, aeration, manivela, and support to facilitate rotation](image)

**Figure 9. Design examples of longitudinal rotating composters. [33]**
Figure 10. Rotating or rotating drum composter. [34]

Figure 11. Composter made of galvanized iron coated with anticorrosive paint, barrel completely closed and highly resistant to pests and produces minimal odor. [35]
The Prototype consists of a high-density plastic container with a cylindrical geometry which will be supported on a metallic structure that allows the weight of the container to be supported, it must have a pole that facilitates the action of turning, turning or mixing the material within it. It will also have mesh holes for air to circulate inside the compost bin [36], this will be easily removable to measure parameters such as pH, temperature, and humidity.

The tank used to build the compost bin has a volume of 30 gallons (113.55 Liters), each tank has a diameter of 0.41 m and 0.8 m high. Figure 5 shows the design of the compost bin.

**Proposed design of the proposed composting system**

![Diagram of the compost bins designed](image-url)

**Figure 5.** Diagram of the compost bins designed. (a) front view of the compost bin, (b) side view, (c) bin used to build the compost bin. Source: Own elaboration in the Google SketchUp program web version [36].
3.2.1 Sampling

To determine the size of the sample and the number of bins to sample, perform the characterization and be able to justify the design of the compost bin, what is described below was carried out.

In cases in which the population is finite, that is, the total population is known and it is desired to know how much of the total should be studied, the sample size is determined as follows. [36]

\[
n = \frac{N \times Z_\alpha^2 \times p \times q}{e^2 \times (N - 1) + Z_\alpha^2 \times p \times q}
\]

In the above equation, N is the size of the population, \(Z_\alpha \approx (2) (1,952)\) for a precision of 95%, p is the expected proportion (if you have no idea of this value, take 50%, with which maximizes the sample size), q = 1-p, e is the desired precision.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total, mass of waste</td>
<td>kg</td>
<td>850</td>
</tr>
<tr>
<td>Precision</td>
<td>%</td>
<td>95</td>
</tr>
<tr>
<td>(Z_\alpha)</td>
<td></td>
<td>1.96</td>
</tr>
<tr>
<td>p</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>q</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>e</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Number of cans to sample</td>
<td>kg</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: self-made

3.4 Composter

Next, the variables for the construction of the compost design are determined:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production per capital</td>
<td>kg/(hab*día)</td>
<td>0.648</td>
</tr>
<tr>
<td>Number of inhabitants</td>
<td>hab</td>
<td>850</td>
</tr>
<tr>
<td>Total waste production</td>
<td>kg/día</td>
<td>550.8</td>
</tr>
<tr>
<td>Organic waste percentage</td>
<td>%</td>
<td>78</td>
</tr>
</tbody>
</table>

(continúa)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of waste to compost</td>
<td>kg</td>
<td>429,624</td>
</tr>
<tr>
<td>Compost height</td>
<td>m</td>
<td>0,8</td>
</tr>
<tr>
<td>Compost diameter</td>
<td>m</td>
<td>0,43</td>
</tr>
<tr>
<td>Total volume of the compost bin</td>
<td>m³</td>
<td>0,12</td>
</tr>
<tr>
<td>Percentage of compost volume occupied with waste</td>
<td>%</td>
<td>40</td>
</tr>
<tr>
<td>Volume of waste in the compost bin</td>
<td>m³</td>
<td>0,12</td>
</tr>
<tr>
<td>Density of shredded organic waste</td>
<td>kg/m³</td>
<td>350</td>
</tr>
<tr>
<td>Mass of waste in the compost bin</td>
<td>kg</td>
<td>42</td>
</tr>
<tr>
<td>Percentage of waste to be composted</td>
<td>%</td>
<td>10</td>
</tr>
<tr>
<td>Mass of waste to compost</td>
<td>kg</td>
<td>42,9624</td>
</tr>
<tr>
<td>Number of compost bins required for 1-day waste</td>
<td>Und</td>
<td>2</td>
</tr>
<tr>
<td>Composting time</td>
<td>días</td>
<td>30</td>
</tr>
<tr>
<td>bins necessary to compost all the waste in one day</td>
<td>Und/día</td>
<td>10</td>
</tr>
<tr>
<td>bins necessary to compost all the waste generated</td>
<td>Und</td>
<td>300</td>
</tr>
<tr>
<td>Area occupied by each bin</td>
<td>m²/Und</td>
<td>1,442</td>
</tr>
<tr>
<td>Area occupied by the cans</td>
<td>m²</td>
<td>432,6</td>
</tr>
</tbody>
</table>

Source: self-made

3.4.1 Process operation manual

The inhabitants of the complex must deposit their organic waste in the manner mentioned above, that is, chopped and without plastic bags that will later be taken to the solid waste storage room and will dispose of in the organic waste area previously organized to avoid confusion (the bins for organic waste are the green bins).

1. The organic waste will be taken from the temporary storage every 2 days and will be taken to the transformation zone.
   - Once in the transformation zone, the chopped waste will be dumped into the compost bin together with efficient micro-organisms that will help accelerate the decomposition process.
   - Three compost bins will be used for one day’s waste, these compost bins will be distributed in an area of 432.6 m² and fenced to avoid accidents with the resident community.
   - The temperature and humidity will be measured twice a day, with a thermo-hygrometer.
   - or it is important to least 4 to 6 turns to the cylinder composting whenever be measured temperature, it means, 2 times a day.
2. Every day the temperature of the compost is measured in the morning and in the afternoon the temperature and humidity are measured, each time the humidity and temperature are measured, the compost is made 4 or 6 times, to turn the content and aerate it.

• Approximately 10% of mature compost should be left inside each compost bin in order to have micro-organisms that help speed up the composting process of the new waste that is loaded.

• The compost maturation point reaches when the material temperature reaches a maximum value between 60 ° and 70 °. After reaching this maximum value, the compost temperature begins to drop. When the compost begins to descend, it is left for another week and after that week the material is removed, packed in bags, mainly to be used in the gardening of the residential complex for its inhabitants or later for sale.

• Once the compost matures, the community will be able to access the organic material by requesting it from the administration.

Methodological guide
This guide describes in a general way the step by step of the implementation of the system that allows, as an objective, the reduction of the percentage of organic solid waste that is taken to the sanitary landfills and simultaneously reduce the collection fee. methodology to be used and the related aspects for the elaboration of the project. This will allow having a frame of reference to be applied in other scenarios.

Step 1. Each apartment must separate the waste of interest, in this case organic solid waste. These should be delivered chopped and taken to a storage room without a bag.

Step 2. From the storage room they will be taken to the transformation area and the chopped waste will be poured into the compost bin, along with efficient micro-organisms that will help speed up the decomposition process.

Step 3. The temperature of the compost will be measured daily in the morning and in the afternoon the temperature and humidity are measured. Each time the humidity and temperature are measured, the compost bin is turned 4 to 6 times to turn the content and air it out.

Step 4. Once the compost is mature. (The maturation point of the compost is reached when the temperature of the material reaches a maximum value between 60° and 70°. After reaching that maximum value, the temperature of the compost begins...
to drop). Subsequently, approximately 10% of compost will be left so that these new micro-organisms help with the decomposition process of organic matter.

**Step 5.** Once the compost matures, the community will be able to access the organic material by requesting it from the administration.

**Collection Fee Reduction**

According to Yanlicer Pérez Hernández, deputy director of Collection, Sweeping and Cleaning of the Special Administrative Unit for Public Services-UAESP in an interview with the Bogota mayor’s office on its website, he mentions the benefits that "all users grouped in real estate units have, housing centers, residential complexes, condominiums or any similar property that is registered as horizontal property. Multi-users must compulsorily register and production is measured every time the waste is collected". [38]

"In this new phase of the regulation of the cleaning service, where the activity of the use was duly regulated, the figure of the ‘multi-user’ is very opportune, since it allows generating appropriate behaviors from the separation at the source (differentiating the usable waste from the waste) and, to the extent that they are strengthened, they will make it possible to generate less ordinary waste, which will be reflected in a lower rate. In addition, a general benefit is generated for the entire city, such as lengthening the useful life of sanitary landfills" [38]

According to what was said by Yanlicer Pérez Hernández, deputy director of Collection, Sweeping and Cleaning of the Special Administrative Unit of Public Services-UAESP. Everything included in the concept of ‘multi-user’, for example, a residential complex, a condominium, among others, will be able to differentiate usable waste, as only organic waste is, in this particular case, separating it at the source and transforming it, allowing it to reduce the generation of waste, which will reflect a lower collection rate since this is measured by its weight, this means that the less weight of waste that must be collected and transported, the lower the collection of the cleaning fee of these people who live in called by Yanlicer Pérez Hernández as multi-user.

Next, the following matrix summarizes the content previously exposed:

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>OBJECTIVE</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue recollection</td>
<td>Take to the system where they are shredded and facilitate composting</td>
<td>Chopped and without plastic bags</td>
</tr>
<tr>
<td>Load the waste</td>
<td>Load the waste to start the composting process</td>
<td>The chopped waste will be dumped into the compost bin along with microorganisms to speed up the decomposition process</td>
</tr>
</tbody>
</table>

(continúa)
ACTIVITY | OBJECTIVE | DETAILS
--- | --- | ---
Composting | Transform biodegradable organic matter into a biologically stable product, in order to be soil amendment and as a plant substrate. | Daily or twice a day the temperature and humidity should be measured. Approximately 10% of mature compost should be left inside each compost bin. When the compost begins to descend, it is left for another week and after that week the material is removed.

Maturation | Avoid generating pollution and toxicity problems for plants. | It is packed in bags, mainly to be used in the gardening of the complex for its inhabitants or later for sale. Once the compost matures, the community will be able to access the organic material by requesting it from the administration.

Source: self-made

3.5 Design of the education and communication strategy

Environmental education is the initiative to care for the environment. It is a process which is imparted, ecological knowledge, environmental awareness and values. It is necessary to have a constant commitment from the inhabitants of the complex to be able to take advantage of organic waste and usable material. For this reason, it is important to guarantee that the subject is widely explained, understood and appropriate for the community in such a way that the system for the use of organic waste can be operated with the material previously separated by the community. Community participation is one of the strategies that are considered fundamental, since the importance of the classification and selection of waste is highlighted. Strategies were proposed to promote environmental culture in the community and to counteract the direct causes of poor management of organic solid waste[39]. The objectives of this type of education are defined by UNESCO, and are the following:

**Awareness:** make people aware of problems related to the environment

**Knowledge:** help to be interested in the environment.

**Attitudes:** acquire interest in the environment and willingness to conserve it.

**Skills:** help acquire skills to solve the problem.

**Evaluation capacity:** evaluate Environmental Education programs. The current problem regarding pollution and climate change has made the environment on
everyone’s lips and has increased the concern of citizens about the possible consequences that a harmful treatment has on the environment that surrounds us.

**Participation:** develop a sense of responsibility to take appropriate action.

After having evaluated the compost design, it is important to promote the implementation of the education and communication strategy, in order to provide the residents of the Ontario residential complex with environmental awareness.

**Educational program**

Through training, the responsibility that they have as generators of organic solid waste will be made known, promoting the correct way in which the daily work of accumulation, transfer, treatment and disposal of each type of waste within the residential complex of Ontario.

- Training through workshops aimed at groups of children.
- Training through workshops directed towards groups of adults.

<table>
<thead>
<tr>
<th>PROGRAMS</th>
<th>OBJECTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Education and Community Participation</td>
<td>Develop an educational process which changes habits, develops values and promotes participation in the community.</td>
</tr>
</tbody>
</table>

All this in order to generate habits of separation at the source in the residents. Minimize the amount of unusable solid waste to be disposed of in the sanitary landfill. Promote communication mechanisms and community participation.

**Source:** self-made

**Segregation program in the source.**

Quantitatively identify the increase in organic solid waste.

Through allusive notices, will be released, the proper way to segregate organic solid waste in the source.

**Observations**

Identify the places that are most traveled by the community of the residential complex, and thus install the notices, billboards, brochures in order to be allusive to the integral management of organic solid waste.

Stipulate a day in which all residents get involved delivering solid organic waste.
3.6 BUDGET

Next, the breakdown of the costs associated with the implementation of the project is presented to have an approximation to the investment that must be made to make the system functional. In addition to the implementation costs, the adjustment of the functions of the general services personnel must be taken into account and whether such adjustment generates additional costs to the operation of the system.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit value</th>
<th>Quantity</th>
<th>Total value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bins capacity 120L</td>
<td>$ 50,000</td>
<td>7</td>
<td>$ 350,000</td>
</tr>
<tr>
<td>Metal support for bucket</td>
<td>$ 100,000</td>
<td>6</td>
<td>$ 600,000</td>
</tr>
<tr>
<td>Adequacy of the composting area</td>
<td>$ 25,000</td>
<td>6</td>
<td>$ 150,000</td>
</tr>
<tr>
<td>Leachate collection tray</td>
<td>$ 15,000</td>
<td>6</td>
<td>$ 90,000</td>
</tr>
<tr>
<td>Microorganisms for compost inoculation</td>
<td>$ 25,000</td>
<td>10</td>
<td>$ 250,000</td>
</tr>
<tr>
<td>Mixing handle</td>
<td>$ 30,000</td>
<td>7</td>
<td>$ 210,000</td>
</tr>
<tr>
<td>Thermohydrometer</td>
<td>$ 100,000</td>
<td>1</td>
<td>$ 100,000</td>
</tr>
<tr>
<td>Compost analysis in laboratory</td>
<td>$ 250,000</td>
<td>3</td>
<td>$ 750,000</td>
</tr>
<tr>
<td>Communication education strategies and workshops</td>
<td>$ 400,000</td>
<td>1</td>
<td>$ 400,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td>$ 2,900,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>$ 3,074,000</td>
</tr>
</tbody>
</table>

Source: self-made

4 DISCUSSION AND CONCLUSIONS

The main benefits that the implementation of this system entails is a reduction in the percentage of organic solid waste that reaches the sanitary landfill and inherently achieving a reduction in the collection fee over time, which is contemplated in the cleaning bill. Since the rate is charged in terms of weight thus, with the transformation of this organic waste a significant reduction in weight will be achieved and consequently a lower rate in the cleaning service. An extra benefit that the transformation of organic solid waste provides is the reduction in the use of inorganic fertilizers, which it replaces, it also saves irrigation water due to the water retention capacity of the compost and not least provides the necessary nutrients for the development of plants naturally.

The initial cost of implementing this model is considerably low considering the types of materials that will be used and their resistance in terms of time, that is, their duration.

The total value of the implementation was $ 3,074,000 where all the variables are considered and its construction and start-up are viable since it is specially designed...
for this set, this does not mean that it cannot be adapted to different urban environments that have similar characteristics.

According to the data obtained, it was possible to determine according to the demographic characteristics, that is, a stratum 2 residential complex in the city of Bogotá, inhabited by people of medium or low income, has a per capita production of 0.648 kg / (inha * day) this indicates that the projection of waste generation has increased less than 3.7% according to DANE figures, for the year 2018 Bogotá had a per capita production of 515 kg.

The average organic waste that goes from homes to the temporary storage room was determined and it was established that the percentage of organic solid waste is 78%, this means that by transforming the total organic waste, it would be possible to reduce approximately by 50% the impacts that the poor disposal of organic waste brings, such as: methane emissions, which is a powerful greenhouse gas, contamination of aquifers by leaching and odors in inhabited areas.

![Graph 1. Total percentage of waste](image)

*Source: self-made*

The difficulties that arise when carrying out this type of project go hand in hand with the item of environmental education, where it is important to explain and encourage people so that there is a change in recycling and transformation habits, giving the community the tools enough so that by their own means they acquire the will to work hand in hand with the other inhabitants of the complex and achieve not
only the transformation of organic solid waste but also the possibility of a change in favor of a collective benefit for the residential complex and the planet.[40]

**recommendations**

Identify the places that are most traveled by the community of the complex, to install notices, billboards, brochures alluding to the integral management of organic solid waste.

Stipulate a day where all residents get involved delivering organic solid waste.

**Conclusions**

Include in the discussion as well as in the conclusion, when making the percentage of waste, say that the net production in the residential complex would be reduced by x percentage. The proposal can be expanded to other materials that can be used. The cleaning fees.

It is possible to apply methods and processes of transformation of organic solid waste in urban areas where the discipline and technical management of the tools allow a correct operation of a planned design taking into account the social, environmental and economic characteristics, in this way it is possible to guide communities to provide a collective benefit with little economic investment.

The characterization and generation of household solid waste provides detailed information that is deposited in temporary storage rooms and based on this, take measures and also find its potential for use; However, the fact that the waste reaches the deposit together reduces this possibility.

It is essential to generate qualitative and quantitative information on the quantity and characteristics of the organic solid waste produced through the management of statistical sampling methods, in order to optimize the management and quantify the management of organic solid waste from the Tejar de Ontario.

**5. REFERENCES**

Design and implementation of an efficient model for the transformation and use of organic solid urban waste


Design and implementation of an efficient model for the transformation and use of organic solid urban waste


[34] Aguyaro M, Garro M, Galarza C, & Hours R. (2019). Bokashi de un residuo proteico industrial en dos sistemas: tradicional y cerrado con aireación. 1er Congreso Argentino de Agroecología:
Design and implementation of an efficient model for the transformation and use of organic solid urban waste


