

Article

Household Solid Waste Management in the Dominican Republic: Case of the Municipality of Puñal, Santiago

Edian F. Franco ^{1,2,3} , Wilfredo Padrón Iglesia ³  and Karina Pérez Teruel ^{3,*} 

- ¹ Research and Innovation Department, Instituto de Innovación en Biotecnología e Industria (IIBI), Santo Domingo 10135, Dominican Republic; edian.franco@intec.edu.do
- ² Department of Basic and Environmental Sciences, Instituto Tecnológico de Santo Domingo (INTEC), Santo Domingo 10602, Dominican Republic
- ³ Department of Research and Scientific Dissemination, Universidad Abierta para Adultos (UAPA), Santiago De Los Caballeros 51000, Dominican Republic; wilfredopadron@f.uapa.edu.do
- * Correspondence: karinaperez@uapa.edu.do

Abstract: One of the biggest problems that the Dominican Republic has had in recent decades is the efficient management of solid domestic waste. This problem has worsened in recent years due to the decrease in available areas for the construction of sanitary landfills, the lack of recycling culture in the population, the deficiency in waste collection, and the scarce legal controls aimed at preserving water, air and soil among other factors. The objective of this study is to explore the management of solid waste by the population and the municipality of Puñal, province of Santiago, to evaluate and analyze the situation and generation of solid waste, municipal solid waste management services, and the attitudes of the population regarding recycling projects and waste management. A total of 275 households from 29 localities in the municipality of Puñal were surveyed, which allowed for a significant population sample. According to the results, the most significant type of waste produced by families is organic waste, followed by plastic waste and paper. Of the total organic waste produced in the municipality, 53% of solids wastes are handled through the municipal waste collection system, while 47% is used as plant fertilizers or animal feed. On the other hand, most households receive the municipal waste collection service and pay for this service, through which the municipal government collects, processes, and deposits the waste in different landfills. However, a more efficient waste collection system and the development of programs and projects that allow households to manage the solid waste efficiently they produce would be necessary.

Keywords: household solid waste; Dominican Republic; separation at source; organic solid waste; Cibao; North Region; Household Survey



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1. Introduction

The generation of solid waste in the Dominican Republic is considered a significant problem due to the decrease in available areas for the construction of sanitary landfills, the lack of recycling culture in the population, and the few legal controls aimed at preserving water, air, and soil, among other factors [1,2].

In recent years, the country has undertaken a process of ordering and regulating solid waste through mechanisms such as the Policy for the Integral Management of Municipal Solid Waste (MSW), issued by the Ministry of the Environment in 2014. This strategy establishes that the solution to the problem of solid waste in the Dominican Republic must be based on a global and long-term vision, which can respond to the needs and circumstances of the different municipalities and provinces of the country, seeking an adequate comprehensive solution from the economic, social and environmental points of view, with the active and conscious of citizens [1].

At the same time, the General Law of Integral Management and Co-processing of Solid Waste, No. 225-20 [3], established the legal regime of integrated waste management

to promote reduction, reuse, recycling, use, and recovery. These legal instruments show the need for the country to take advantage of its waste to generate new products and use its energy potential, among other possibilities offered by the adequate treatment of waste [3].

Despite these regulations, the efficient management of municipal solid waste represents one of the main challenges for most municipal managers due to the deficiencies accumulated over the years. These challenges include the deficiency in the collection of domestic and industrial waste, the inefficiency of the collection routes, the final disposal of waste that is traditionally taking place in the open air without meeting minimum sanitary and environmental standards, in addition to the lack of public policies and municipal projects for waste recycling and revaluation [2].

This situation has caused significant environmental and social impacts. It can be mentioned the degradation of the areas near the final waste disposal sites, due to the production of gases and unpleasant odors, the production of leachates that can contaminate the water sources and the surrounding land. These situations generate significant public health risks due to air, soil, and water [1]. Also, as indicated by a study conducted by the municipality of Jarabacoa demonstrated, open dumps cause the proliferation of insects, such as mosquitoes which are responsible for the transmission of Dengue, Zika, and Chikungunya viruses (*Aedes aegypti* and *Aedes albopictus*), as well as West Nile virus and lymphatic filariae. This research recommends strengthening municipal measures to reduce the health risks generated by insects in the country [4].

In general terms, the problem described above is particularly relevant when considering that population growth and economic development in recent decades have led to an exponential increase in waste in different country areas. This increase has further complicated the steps and mechanisms that must be established to implement an efficient process between waste generation, its collection, and final disposal [5].

The complexity of this first stage of the treatment process of solid waste generated by Dominican households has been highlighted in the National Multipurpose Household Survey [6]. According to their data, 85.2% of households dispose of their solid waste through the collection mechanisms of the municipalities, 7.5% burn it, and 3.5% throw them in the yard, lot, or nearby streets. These last two incorrect forms of disposal are used by 11.0% of Dominican households [6]. Regarding the waste compositions produced, 60% is organic matter; 10% cardboard; 6% paper, plastic, and glass; 4% of metals. Other unidentified materials represent 8% [1,2].

In addition to the damage to the environment, as mentioned before, and the exponential health risk that those practices cause, the incorrect handling of solid waste limits the possibilities offered by some of the generated waste, especially the organic waste, which could be used in the process of energy generation through the biogas producing biodigesters, by anaerobic digestion of organic matter. Furthermore, this process yields other by-products such as biol and biosol. Biol is a valuable complex psychostimulant fertilizer, rich in essential nutrients for plants growth and development, and its application to crops substantially improves their quality and production [7–9]. Biosol is a biodigester output effluent that, when used in plantations, significantly influences the growth and development of crops [7,8,10].

In this research, the province and municipality selected were due to inconsistent solid waste generation, collection, and management compared to the other provinces in the country. According to figures offered by the Dominican Municipal League, in 2019, the country produced approximately 16,000 tons of waste per day [11]. The North Region (Cibao) produced approximately 3713 tons per day, making it one of the central waste-producing regions, ranking only after Greater Santo Domingo [12].

In the so-called Cibao North, which in addition to the province of Santiago, Puerto Plata, and Espaillat, 90.4% of households dispose of their solid waste through the municipal collection, 6.0% burn and 1.2% throw it away in the yard, in the lot or the street. These last two incorrect forms of disposal are used by 7.2% of the households in the region [6]. However, these regional and provincial figures do not show similar indicators in Puñal.

According to the data provided by the National Statistics Office, during 2020 [13], solid waste disposal in the municipal territory behaved as follows:

- 75.5% of households dispose of their solid waste through municipal collection.
- 0.1% of households dispose of their solid waste through collection by a private company.
- 24.2% of households dispose of their solid waste by burning or dumping in backyards, lots, or nearby streets [13].

As depicted, almost a quarter of the households in the municipality of Puñal incinerate or dump their waste in open spaces, often near or over water sources. This situation causes potential effects on the environment and is a complicated scenario from an epidemiological point of view and waste from an energy point of view. This situation motivated this investigation to identify the causes that influence the manifested bad practices in the Puñal municipality, Santiago province, regarding the generation and collection of solid waste, especially organic waste.

This study aims to explore solid waste management by the population and the municipality of Puñal, Santiago province, Dominican Republic, to assess and analyze the generation, management, and disposal of solid waste, as well as the population's attitudes towards solid waste recycling and reuse projects of solid waste.

2. Materials and Methods

2.1. Description of the Study Area

The Puñal municipality is located in the province of Santiago, in the Cibao North Region of the Dominican Republic (Figure 1). It is made up of the Municipal Districts of Guayabal and Canabacoa. It has an area of 60.8 km², and in 2010 was inhabited by a total of 23,856 inhabitants, with a population density of 765 inhabitants/km². For that same year, living conditions reflected that 98.9% of households had electricity and 25.7% had a car. Regarding construction, 1.1% of the houses had roofs made of asbestos, cement, yagua, cane, or other materials. 0.7% had palm, yagua, and tejamanil board walls, while 1.8% had floors of earth or similar materials [13].

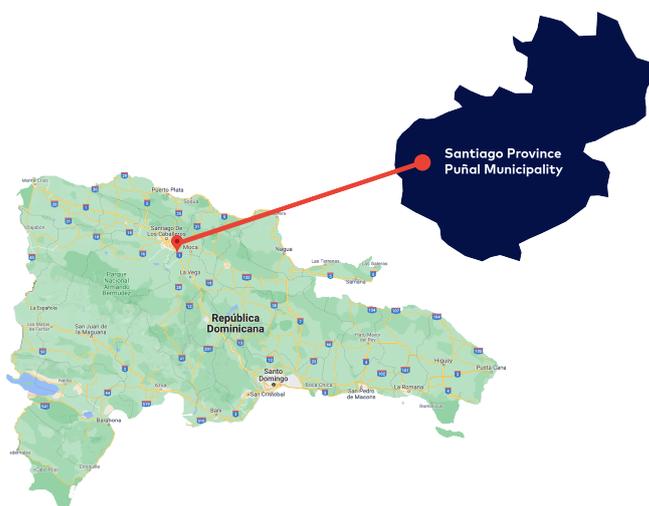


Figure 1. Provincial map and of the communities that were interviewed during the study.

As for environmental data, which includes the final disposal of waste, it indicates that 80.4% of households have access to the public water supply network. Of these, 6.0% use solid fuels for cooking, while 25.7% do not have a toilet in their living spaces [13]. From an economic point of view, Puñal is a rural community with an agricultural vocation, where livestock, fishing, and forestry activities stand out. It also has commercial and industrial establishments, among others. In 2018 it did not have hotels, country plots, or mining operations, and it had 276 grocery stores [13].

2.2. Design of the Investigation

For this research's study, it was decided to design and apply a survey with a qualitative methodological approach since it was supported by the collection of data on the variables previously selected. Through a descriptive and non-experimental study, the researchers seek to identify, classify, and categorize the variables and indicators manifested in the phenomenon under investigation without altering it. The study includes socioeconomic variables, perception of municipal services, generation processes, management, and disposal of solid waste.

The general method applied was inductive with simple probability sampling, based on collecting data from a random sample and representative of the total population. The selected technique was the survey, applying a closed and complete questionnaire of the phenomenon studied. The authors designed a 24-questions questionnaire (Supplementary File S1), which made it possible to identify the main variables related to solid waste management in the selected communities of the municipality.

The survey was divided into six sections:

1. Socioeconomic: Neighborhood/community, Education level, Member of the family, and Family Income Level.
2. Waste generation: Likert scale (1—Never, 2—Rarely, 3—Sometimes, 4—Often, 5—Always) on the generation of organic waste (food), Paper and Cardboard, Plastics, Metals, Glasses, Electronic waste, and other types of waste.
3. Storage, use, and disposal of waste: how the solid waste is stored at home, organic waste use, and solid waste disposal.
4. Municipal services: frequency of collection, payment of services, the final destination of waste.
5. Recycling: Separation of waste, participation in recycling programs, domestic waste recycling.
6. Perception of waste management: evaluation of the perception of waste management in the municipality.

2.3. Selection of Samples

The sample was selected based on the 2011 Puñal Municipal Sociodemographic Profile [14]. According to the data, the municipality of Puñal has 46,516 inhabitants, with 10,415 dwellings. The calculation of the sample has been made with the following equation:

The calculation of the sample was carried out with the following equation:

$$ss = \frac{z^2 * p(1-p)}{e^2} \div \left(1 + \left(\frac{z^2 * p(1-p)}{e^2 N} \right) \right) \quad (1)$$

where, *SS* sample size; *z* confidence level (*z*-score equal to 1.96 for a 95% confidence level); *e* acceptable level of sampling error (margin of error 0.06% ± 6%); *N* population size (*p* = 10,415); and *P* proportion of the population (50%; i.e., 0.5 default). From the data, a sample with a reliability of 95% and a margin of error of 6% was determined for a total of 266 households surveyed. The surveys were conducted during the months of May to August 2021.

Households from 29 neighborhoods and communities in the municipality of Puñal were randomly selected for the survey. The households were visited personally by the respondents.

2.4. Study Limitations

The main limitation of this research was related to the pandemic situation affecting the country and the world. The restrictions limited the mobility of the researchers and their possibilities of interaction with the population studied, which caused them to take longer than expected to collect the samples.

3. Results

3.1. Socioeconomic Data

A total of 266 household members were interviewed in 29 communities and neighborhoods in the municipality of Puñal. Forty percent of the households surveyed were from the municipal district of Guayabal, which has one of the largest populations in the municipality, 22% from Puñal, which represents the most urban area of the municipality, and 4.5% from the Canabacoa neighborhood. On the other hand, the communities with interviews of less than 1% were Colorado, El Guano, El Jobo, Los Díaz and Los Mateos. (Figure 2).

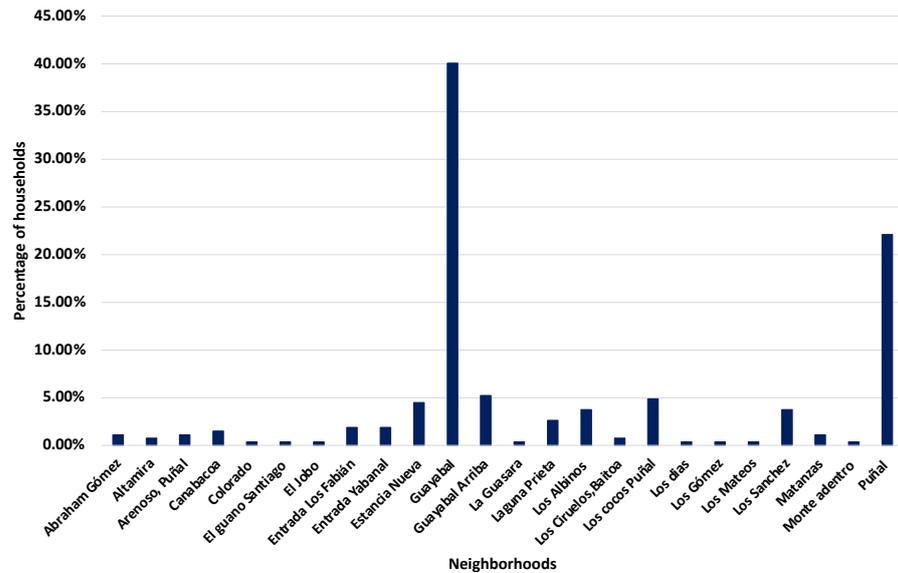


Figure 2. Distribution of households in the neighborhoods and communities of the municipality of Puñal.

Concerning the educational levels (Figure 3C) of the interviewees, 40% have completed less than high school education, followed by 18% with a high school diploma, 15% with a university degree, and 12% with some college but no degree, only 3% of the respondents had no formal education, and 10% did not report their level of education.

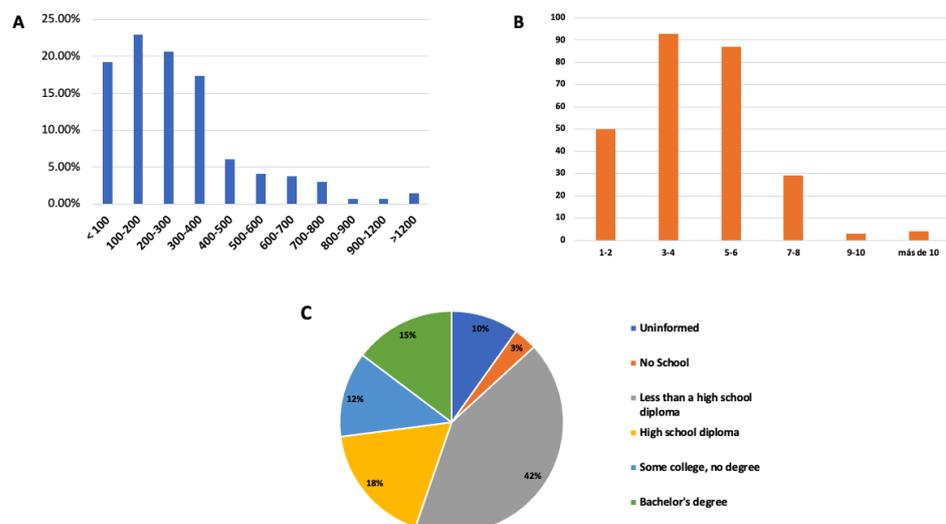


Figure 3. Socioeconomic summary of the households consulted: (A) Monthly income of the families surveyed in the studies. Values are expressed in U.S.dollar; (B) Family composition and the number of members of the surveyed families in the municipality of Puñal and (C) The highest level of education was achieved in the surveyed residences.

Regarding the number of members of the families consulted in the study Figure 3B, 35% have between 3 and 4 members, 33% have between 5 and 6 members, 19 have between 1 and 2 members, 11% have between 7 and 8 members and only 1% of the families have more than 9 members.

23% of the surveyed family has income between 100 and 200 dollars, 21% between 300 and 400 dollars, 19% income less than 100 dollars per month, 6% between 400 and 500 dollars, in the remaining 13% this distributed among households with an income higher than 500 dollars per month (Figure 3A).

3.2. Waste Generation

The generation of solid waste was evaluated by the frequency of generation of types of waste in households, through a Likert scale in which the frequency was selected. The Likert scale is used as a data collection method that allows measuring attitudes, knowledge, perceptions, values, and changes in behavior; It is based on a set of statements within a range among which individuals can choose to respond to the questions [15] (Figure 4).

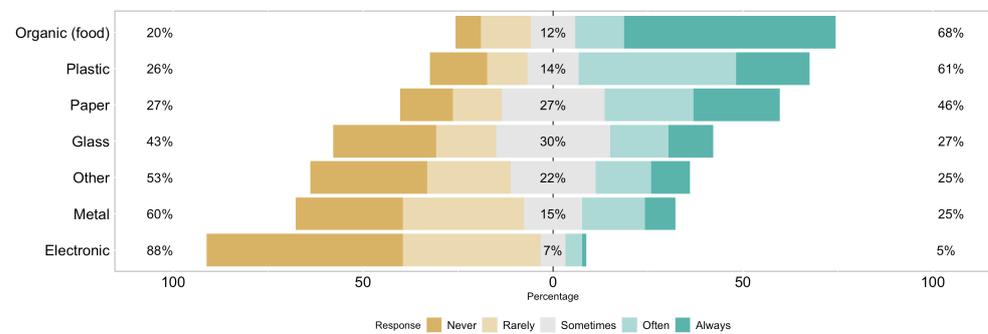


Figure 4. Likert scale for the evaluation of the generation of the different types of solid waste produced by the households surveyed in the municipality of Puñal. Each bar represents the generation of solid waste in households.

The 68% of the consulted households always produce organic food waste that is discarded through municipal collection services. As for plastic waste, 61% frequently and always produce this type of waste, compared to glass, which is only generated by 27% of households. Sixty percent of households never or almost never produce metal waste. Similarly, 88% never or almost never dispose of electronic waste in their households. Other types of waste are only generated by 25% of the households consulted in the study.

3.3. Storage, Use, and Disposal of Waste

In terms of storage, 72% of the households surveyed store their waste in waste bags, 25% in waste bins, 2% directly in the waste truck, and only 1% incinerate the waste (Figure 5).

When the use of organic waste by households was evaluated (Figure 6), 53% stated that they do not use it at all and that they are discarded directly in the waste truck and sent to the municipal landfill; 44% of those respondents stated that they use organic waste to feed farm animals; 3% stated that they compost it to be used as fertilizers for plants.

Regarding collecting solid waste in residences, 97% stated that the municipality collects it through waste trucks (Supplementary Figure S4).

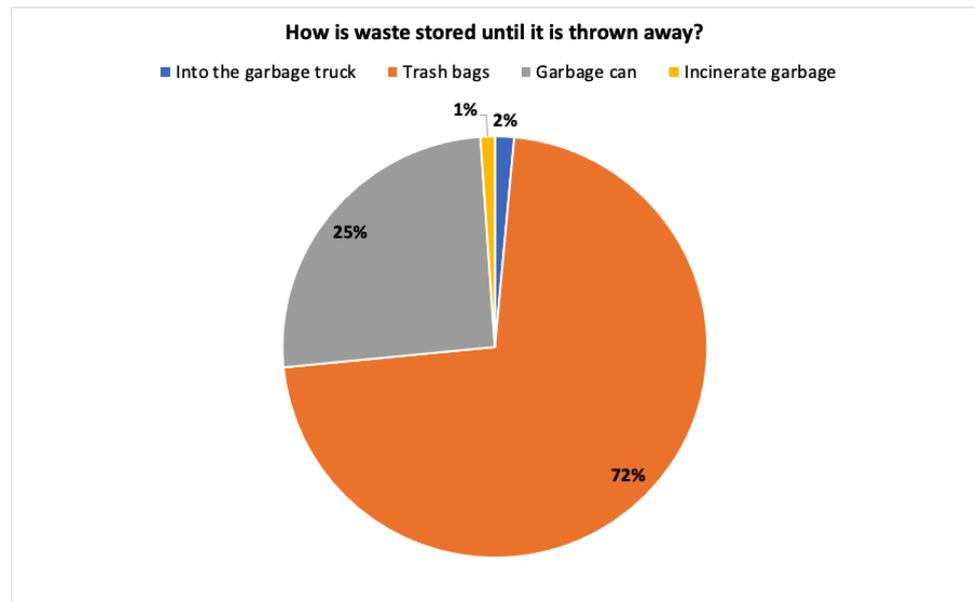


Figure 5. Methods used for waste storage in residences.

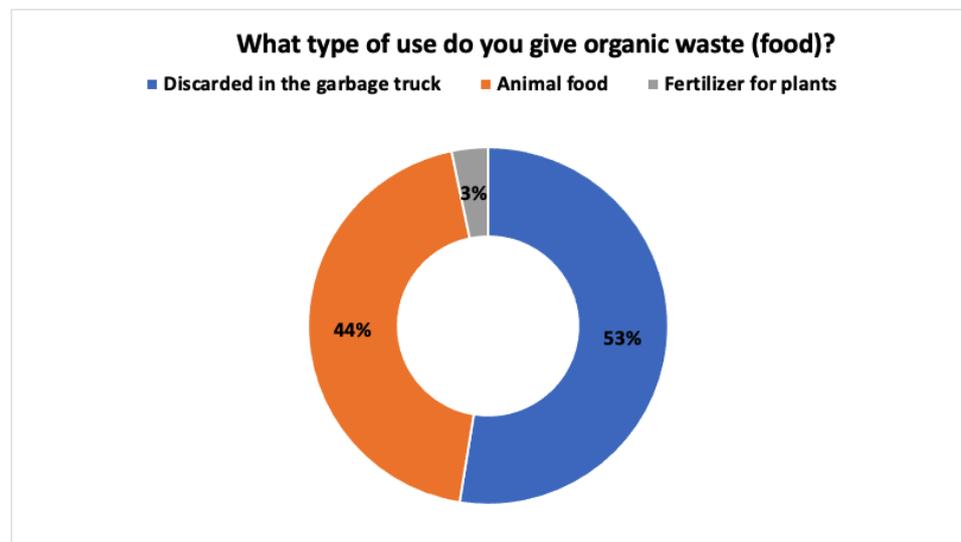


Figure 6. Use and disposal of organic waste in the surveyed residences.

3.4. Municipal Services

Figure 7 shows the frequency with which the municipalities collect solid waste, where it is observed that in 74% of the households, waste is collected once a week, while 8% collect it daily. In 13% of the households, the collection service is performed twice week, while another 4% of the respondents stated that waste is collected every other day.

Regarding the schedule for waste collection, in 69% of the households that have this service, it is done in the morning, while in 15% it is done in the afternoon, in 3.6% of the households, solid waste is collected at night (Supplementary Figure S2).

In terms of the final disposal of waste, 52% of the households interviewed stated that they do not know where the waste is taken after collection by the municipality (Supplementary Figure S3).

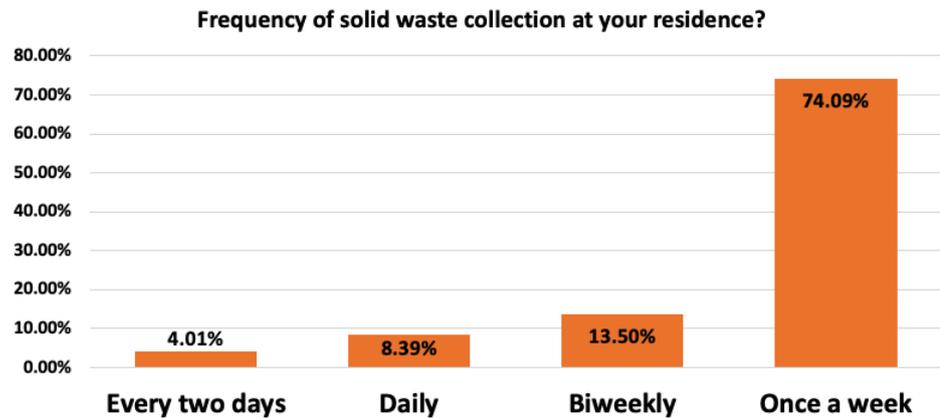


Figure 7. Frequency of solid waste collection by municipal services.

Figure 8 shows the rate of payment of the solid waste collection service to the municipalities, where it is observed that 67% of the interviewed families pay for the service, while only 27% do not pay for it, and 7% of the households declare that they do not know about the payment of the services.

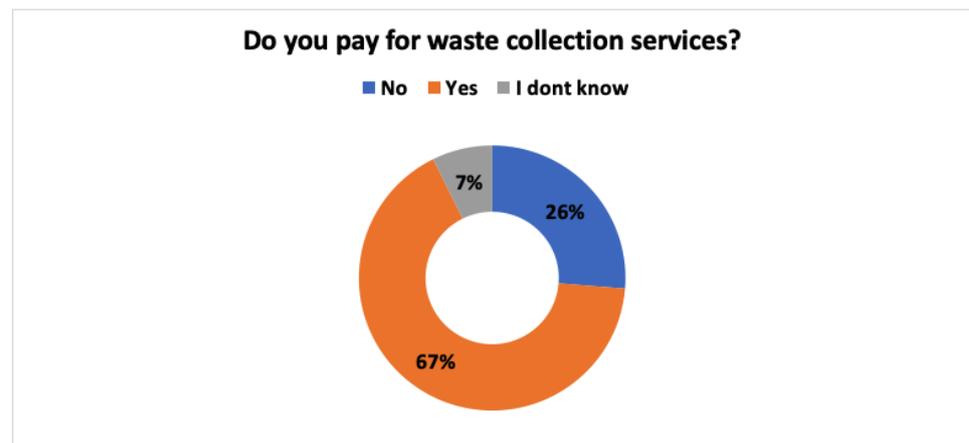


Figure 8. Distribution of the municipality’s population in terms of payment for solid waste collection and disposal.

3.5. Recycling

Regarding solid waste recycling practices, 85% of respondents stated that they do not have municipal recycling programs; only 19% of respondents practice some type of recycling at home, and only 22% perform some sorting before disposing of solid waste (Figure 9).

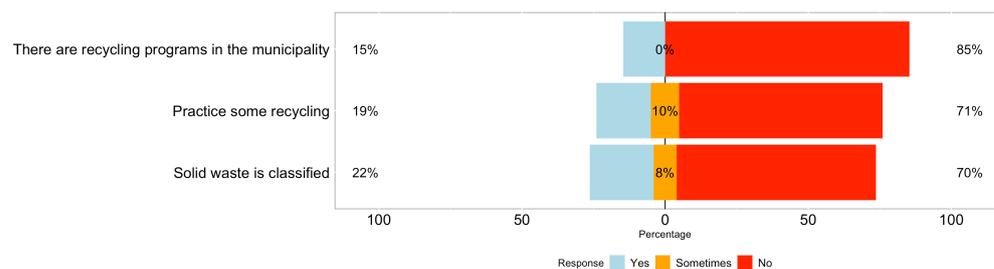


Figure 9. Representation of the recycling practiced by the inhabitants of the municipality of Puñal consulted in the study.

3.6. Perception of Waste Management

Seventy-two percent of those interviewed indicated that they would be willing to participate in 243 recycling programs (Figure 10). At the same time, 88% of the households interviewed 244 would be willing to receive some payment or bonus for their solid waste.

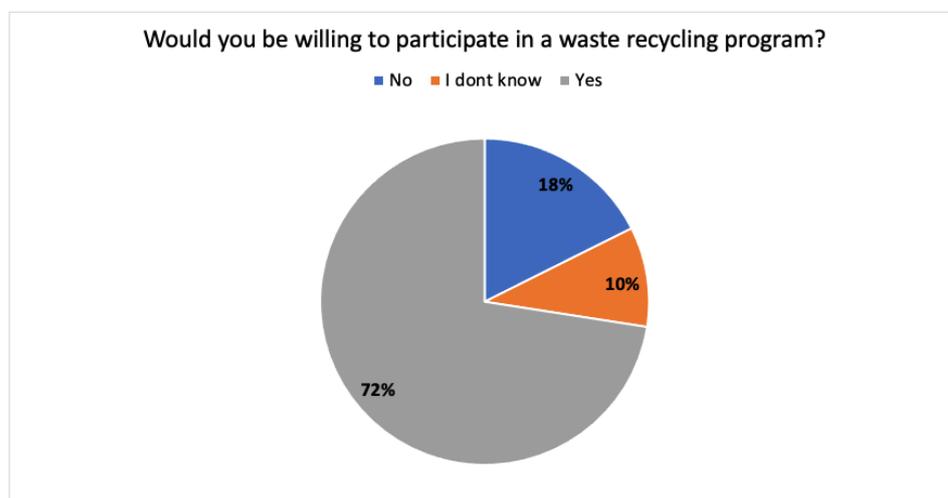


Figure 10. Motivation of the households consulted to participate in municipal solid waste recycling and revaluation programs.

Regarding the sources of waste and landfills generated in the communities, 47% of those interviewed stated that it is due to the lack of waste collection. In contrast, 27% indicated that it is due to deficiencies in waste collection, and 10% stated that it is due to the lack of education of the inhabitants of the municipality, and 8% to the deficiency in the design of the waste collection routes (Supplementary Figure S4).

4. Discussion

The present investigation allowed us to verify that 68% of the consulted households produce organic waste, especially food waste, which is collected through municipal collection services. This figure is higher than what the World Bank has estimated for Latin America. According to this entity, about half of the waste produced in the region is organic (food and green waste), while a third of it is made up of dry recyclables (plastic, paper, cardboard, metal, and glass). Internationally, the category of waste that covers the most significant amount is food and organic waste, representing 44% of global waste, dry waste considered recyclable is equivalent to 38% [16,17].

Regarding the waste classification before its final disposal, the indicators obtained in the Puñal municipality are lower than those gathered by [18] in the research carried out in Ciudad Juárez, Mexico. In Dominican territory, 31% of households carry out some waste classification prior to its disposal, while in the Mexican sample, 50% declared that they separated or classified their waste at home.

In the practice of recycling waste, the Dominican investigation showed that 21% of the households consulted stated that they carry out some recycling practice, compared to 78% that do not. On the Mexican side, recycling levels are also higher. For example, of important components such as aluminum, 86% is recycled for later sale, and 14% is reused in the household. Of the plastics, 73% were sold, 26% were reused, and 1% was used as a heating source. A similar situation presented organic waste, glass, paper, and cardboard [18].

A significant difference between the two studies is the presence in Mexico of ways to sell waste that can be recycled industrially. This possibility largely explains the high percentages of separation and recycling the waste in the home since most of the percentage is destined for sale. Although these possibilities also exist in the Dominican Republic,

the research showed less culture in this regard. However, 72% of the households surveyed would be willing to participate in recycling programs and projects developed in their municipalities or communities.

These latter values are similar to those collected by [19], who stated that 82% of the families surveyed in his research favored proper solid waste management. 8% indicated that they did not know how to do it but that they would be willing to do it correctly if taught.

Concerning the factors that threaten an adequate separation and disposal of waste and the consequent proliferation of informal dumps in the communities, the investigation carried out in the Puñal municipality of the Dominican Republic showed that 47% of the interviewees stated that it is due to lack of trash. On the other hand, 27% indicated that it is due to deficiencies in waste collection, and 10% stated that it is due to the lack of education of the municipality's inhabitants. 8% assured that the cause is the deficiency in the design of waste collection routes.

These assessments show a lack of information regarding the existing collection system in the sector mentioned above and the importance of correct waste treatment. In the same sense, [19] based on the obtained results in his study, stated that it is necessary to work on better communication and information for the population on the issue of solid waste management. In this regard, he added: "The fact of informing residents what happens with the collected waste could work as an incentive since it would make them aware that if they carry out a good separation, they could be valued and prevent them from ending up in the landfill. municipal." (pp. 64–65).

Flores and Gómez [20] reached a similar conclusion, stating that people's level of education on environmental issues favors an increase in the classification of organic waste. Likewise, Linder et al. [21] ensured that the more knowledge a person has of what materials are recyclable, when and where they are collected, the more likely they are to separate them for recycling.

The results in Figure 10 show that there are currently few policies or programs structured by the municipalities for the classification of waste at the source and its reuse for the generation of new resources, despite the fact that laws and other agreements signed by the municipalities oblige these state institutions to develop this type of programs [3]. In the municipality of Puñal, despite belonging to the "Dominican Limpia" program, no programs or projects of the municipalities were reported that encourage waste classification in the communities under study were reported [22].

The lack of a classification at source of household solid waste makes it difficult to reuse it for energy purposes due to the high levels of impurity, which would cause low efficiency in the generation of biogas [23]. On the other hand, in many of the residences interviewed, it was found that organic waste is used to feed domestic animals or residential farms. A similar result was obtained in the survey conducted by Wolf [2], where it was evidenced that many valuable resources are not used due to the treatment received by residences or transport companies.

A worrisome situation evidenced in one of the communities analyzed is that despite having a waste collection service close to homes, many individuals stated that they use rivers and streams as the main space for waste disposal. The situation leads to the contamination of water tributaries such as the Río Yaque del Norte and its tributaries, which have become a fundamental part of the interaction with waste in the province of Santiago, which can directly affect the quality of the water used for human consumption, livestock, and agriculture [24].

A system of reuse of organic solids for energy purposes can be viable by integrating large producers of this type of waste such as supermarkets or other industries such as livestock, where sorting programs can be implemented quickly and efficiently at source, with which the abundance of impurities present in the waste can be minimized, allowing the production of quality biogas for industrial use [25].

Several companies have implemented biodigesters to produce biogas thus reuse the waste produced by their economic activity. One of these cases is that of Agropecuaria Fernández Muñoz SRL (AGROFEM), which has two biodigesters, which have enabled it to produce 70% of the energy needed for its farms from the excrement of its animals, allowing this company to reduce its dependence on fossil fuels, which translates into a reduction in its carbon footprint.

According to the study conducted by Cuervo and collaborators, the generation power of organic waste in the municipality of Santiago is approximately 308.8 MWh per day through Combined Cycle Gasification (GCC) [26], which indicates that the design of a model for energy reuse of organic waste would be feasible and will allow the development of a new energy source in the province of Santiago.

5. Conclusions

This study made it possible to characterize the primary uses of solid waste in the municipalities of Puñal, making it possible to describe the management of household waste in 29 communities of this municipality and the families, to evaluate the use of this waste for energy purposes.

The results of the study show the need to implement citizen efforts in pursuit of compliance with the General Law on the Environment (Law 64-00) of the Dominican Republic [27], which establishes the need to ensure the efficient and sustainable use of natural resources of the Nation, following the need to adapt to climate change (Art. 194). In this way, it is intended to achieve the maximum possible harmony in the interrelationships of society with nature, taking into account, as established by law, the essential balance between human activities and their environmental conditions, the existing ecological imbalances due to human causes, the environmental impact of new human settlements, infrastructure works, and related activities.

Despite the deficiencies in waste management in the municipality, it has the necessary capacities to develop biogas production systems and efficient energy generation that make it possible to reuse the waste generated by its citizens. The municipality and other governmental entities should develop education and incentive programs that encourage citizens to revalue the waste at source to achieve this objective.

The reuse of organic waste can become an excellent opportunity for companies to reduce their environmental impact and generate the energy necessary for its production, which would mean savings in production costs. On the other hand, energy reuse models can become a business opportunity for entrepreneurs and a new source of employment and resources for municipalities.

This research will contribute to understanding solid waste management in the Dominican Republic and the challenges that decision-makers have to improve the services of collection, management, final disposal, and reuse of waste. Municipal managers must create programs and projects that involve households and the population to reduce waste production and better manage these.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/su14063149/s1>. Supplementary File S1: The file contains a file with the results of the surveys carried out in the municipality of Puñal. Supplementary File S2: The file contains supplementary figure generated from the results obtained from the surveys and the data collected.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Ethics Committee of Universidad Abierta para Adultos (UAPA) protocol code 001-2020 of 6 January 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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