Site Characterization and Associated Disposal Costs for Illegal Dumpsites Located in the Municipality of La Granja, Chile

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Abstract. Chilean legislation dictates that Municipalities are responsible for household solid waste management, but this doesn’t include the clean-up of illegal dumpsites. These in-city dumpsites usually are located on public roads, parks or abandoned sites; have a wide variety of origins, from household trash to business waste, and feature a high component of construction debris. One of the main problems that municipalities have managing these sites is that when they are cleaned, the dumpsites immediately reappear. Therefore, a site survey and visual characterization was performed for these illegal dumpsites at the Municipality of La Granja, and a cost analysis associated with the constant clean-up costs was performed. La Granja Municipality has an established clean-up program with a frequency that varies from one to three withdrawals a week per dumpsite. Santiago is Chile’s capital and is divided into 32 municipalities, the general population of the city is 5,250,565 inhabitants according to the 2017 census. La Granja is one of Santiago’s municipalities; according to the last census, it has 116,571 inhabitants and a total of 34,423 households divided into 69 neighbourhoods. The social economical income of the municipality corresponds to medium low to lower level. The study detected 35 critical sites that were catalogued as recurring dumpsites. The mayor cause of these dumpsites corresponds to illegal dumping of construction waste, mayor appliance and household waste, and only one dumpsite didn’t present construction debris during the length of the study. The average volume measured in site, for most of the dumpsites varied from 1 to 3 m³ and only 2 sites exceeded 8 m³. The most important characteristics of the dumpsites were the ease accessibility (82,4%), followed by the total lack of public illumination, high vehicular traffic and to or more intersections (67,7%). The equipment and personnel cost were estimated for the clean-up service of the 35 dumpsites. The cost analysis showed that the associated cost of the clean-up corresponds to a 5.8% of the municipal budget for solid waste management. As a result of the study, 4 sites were intervened through the generation of green area or small parks, with an emphasis in the protection or blocking of the access and roadside.

1. Introduction

Illegal dumping is a worldwide problem that has a significant and diverse environmental, economical and aesthetic impact on local communities [1-3]. These types of illegal activities generate several environmental and social problems [4, 5]. Dumpsites can contain all kind of materials raging from household, construction and demolition waste, commercial, and industrial waste [6]. Another important

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factor is that open dumpsite can generate spontaneous fire due to the large amount of organic waste present [5,7]. Therefore, it is possible to conclude that open dumpsites are an environment hazard specially if there are located inside or near population.

The removal of illegal dumpsite is an ongoing process, this is due that local communities are used to dump illegally in that site. This makes that illegal deposit site reaper at the same site [8]. This is a special problem to Chile due to the lack of direct legislation related to the responsibilities of clean up of dumpsites. Chilean legislation only mentions that local municipalities are responsible of the recollection and disposal of household and municipal waste [9,10], but does not include responsibility of the clean-up of dumpsite. In this regard, municipalities only can control the transport of solid waste and construction debris [11] and larger producers have to register their waste at the national registration of pollutant emissions and transfers (RECT) [12].

The aim of the study was to determine the principal characteristics of the in city open dumpsites, their main components, located at the municipality of La Granja. The study also included a cost analysis estimated for the continuous clean up performed by the Municipality.

2. Description of Area of Studies
Santiago corresponds to the capital of Chile and has a population of 5,250,565 habitants according to the last census of 2017 [13]. The city is divided into 32 municipalities and the municipality of La Granja is one them. La Granja has a population of 116,541 habitants, with 34,423 households and it’s divided into 69 neighbourhoods. The total surface of the municipality comprehends 10 km2 and it’s surrounded by four rural municipalities (Figure 1).

Figure 1. Location of the Municipality of La Granja and its Surrounding Municipalities [14]

The social economical level of population of the municipality is medium low (37,8%) to lower level (60,7%). Therefore, more than half of the population is considered as vulnerable. This is an economical burden to the municipalities, because this lower segment is exempt from paying taxes on waste service.
This is a national problem because the average exemption percentage of tax for waste recollection in Chile is approximately 80% [15].

A survey performed by the Municipality of La Granja, showed that one of its main concern is the illegal dumping, and was classified as a high priority and with a high environmental impact for the community [16].

3. Characterization Method of the Dumpsite
The general objective of the study was determining the principal territorial characteristics of the site and location of the in-city illegal dumpsite located inside the Municipality of La Granja. For this purpose, the location of these sites were georeferenced, and the general territorial characteristics were recorded. The 35 dumpsite that were surveyed can be seen in Figure 2.

Initially, the general location of the illegal dumpsites was obtained by the Municipality Association Ciudad Sur, that includes the Municipality of La Granja. With the general location of the dumpsites, these were visited and georeferenced using a GPS (Garmin, model E Trex Touch 35). During the first visits to each site, the general territorial characteristics were recorded for further analysis, and photographic material taken with the help of a photographic camera and the use of a drone (DJI, Phantom 4 Pro).

The average volume of each dumpsite was determined by using two methods: topographic equipment (Total Station for Survay Topcon Es-105) and the use of aero-photographic pictures taken by the drone and processed Pix4Dmapper. The data for the survey was process with a spreadsheet and a 3D view was performed using CivilCad 3D.

Figure 2. Spatial Location of the Dumpsite [14]
3.1. Dumpsite Characteristics
The variables for the territorial characteristics that were selected for describing the dumpsite corresponded to:

- The street has ease of access to light vehicles, trucks and hand wagons.
- Lack of public illumination, low public illumination or interference on the public illumination due to tree branches.
- Located near walls, near an alley, or in front of a house.
- Streets located between two municipalities.
- Highways that cross the municipalities.
- Empty land or abandoned private land.
- Presence of people without housing.

The initial determination of the general composition of the solid waste detected at each site was performed by visual classification according to the following categories:

- Household items: general goods that are used in the house, furniture, mattress and other related elements.
- Home appliances and whitegoods.
- Household solid waste and organic matter: general packaging (food, cans, and others), food waste and yard and tree waste.
- Construction debris: any type of material that might originate form construction or demolition.
- Commercial waste: packaging material (same product), and printing material or office paper.

The visual characterization was performed by visual observation of the dumpsite, which proved to be hazardous to the inspection team, due to broken bottles, nails and other elements that could have been hazardous. Therefore, the visual inspection was change to the analysis of the aerial picture taken by the drone. It is important to mention that the percentage of the composition was not measured in this study.

3.2. Volume Determination of the Dumpsite
Two methods were employed for the acquisition of data: ground survey with a total station, and aerial survey with a drone. The reconnaissance process was onsite, defining the area of the dumpsite, and considering the minimal number of points to survey to cover. In the case of the drone a minimal of 15 pictures were required for ensuring the volume calculation and determining the waste characteristics. After the field reconnaissance was performed, the information was downloaded to a spreadsheet for analysis.

The initially determining of number of points to survey with the total station were approximately spread approximately 1,5 meters, surrounding the perimeter of the site and afterward different points inside the dumpsite. This last part was complicated due to the nature of the pile of waste and its instability and hazardous components. In the case of the drone, the flight plan was performed manually due to the small area that had to be surveyed and the additional objective of observing the composition of the waste. Therefore, a minimum of 15 pictures were taken at different heights and angles.

3.3. Nominal Cost of Cleaning the Dumpsites
The annual cost that the municipality incurs was estimated calculating workforce, machinery depreciation, petrol consumption, repairs, transport and gate fee of the landfill. The residues that
collected are shipped to Santa Marta Landfill. Because the municipality has a fix schedule for the clean-up of the sites, the number and type of the equipment and the workforce that are involved are known.

The work force is divided into two teams, each with a skid steer and a hopper truck, each with a driver and two workers. Additionally, there is a pickup truck with a flatbed, that occasionally does some removal of yard trimming waste.

The fuel consumption was estimated as an average of 7 l/h and the 6-hour workday. The petrol price was determine using the average price between June and August of 2018. The depreciation of the machinery was estimated according to Chilean tax agency [17]. Therefore, the daily cost was estimated per work team and afterword the annual value not considering weekends and holidays was calculated.

4. Results and discussions

4.1. Dumpsite Characterization
From the 35 dumpsite that where surveyed, the most frequent characteristic that was observed corresponded to the easy accessibility of the site. This was observed in 82,5% of the sites that pedestrians and vehicles could easily enter the site or park next to the dumpsite. Additionally, 67,7% of the sites had more than two main roads or intersections, followed by a heavy vehicular transit. None of the streets that were located near the dumpsite were considered to be narrow or classified as passages. Another important characteristic was that 67,7% of the sites had bad or lack of public illumination, and most of the cases that there was low public illumination was due to tree branches. This generates the perfect conditions for anonymity that helps people that are paid to dispose of solid waste that are not interested in complying with the legislation or are paid to dispose illegally.

It was observed that 47% of the sites were located near or even inside green areas or parks. Regarding this situation, initially 4 sites were intervened through the construction of green areas and playgrounds, with the support of barriers on the sidewalks.

Approximately 23,5 % of the sites had the presence of people on street situation, this allows in large part, the responsibility of these in the generation of the dumpsite. This is reflected as only 35,3% of the site are located in vacant site or the absence of green areas or parks.

4.2. Waste Characterization
From the visual inspection it was observed that the most common waste corresponded to construction debris (94,3 % of the sites). The debris observed corresponded mainly to sacs that contain concrete and debris, roofing material and construction wood. Due to the characteristics of the construction waste observed, most probable origin corresponds to small constructions such as home remodelling. The other main source of waste corresponded to old white goods and discarded household items (89% of the sites).

It is important to mention that roofing material in Chile may contain asbestos cement which can be extremely complicated to handle and has to be treated as hazardous waste. This material was prohibited by the government in the year 2001 [18].

Additionally, it was observed that in most of the dumpsite had organic waste and general household trash (86% of the sites). From the inspection of the domestic waste, it was possible to determine occasionally the origin of the waste due to the utilities bills that were found between the waste. Most of the bills where from the municipalities of La Granja and La Pintana.

With regard of commercial waste, the frequency that these types of waste where found was relatively low (28,6 %). Basically, it corresponded to packaging material, publicity and office documents.
4.3. Volume Determination
The volume determination was performed by analysing the results between the topographic method and the picture analysis using Pix4Dmapper (Figure 3). From the analysis the dumpsites were classified in 6 groups (Table 1). From the Table 1, it is possible to observed that most of the sites have a volume of 3 m$^3$ or less (62.9%). These is important, due to the number of workers, equipment needed for the clean-up and the frequency of the services.

![Image](image_url)

**Figure 3.** Example of the analysis of the dumpsite located in Las Yucas, next to the Parque Brasil

| Volume Range (m$^3$) | Number of Site | Percentage (%) |
|----------------------|----------------|----------------|
| Maximum of 1         | 3              | 8.6            |
| 1 to 3               | 19             | 54.3           |
| 3 to 5               | 3              | 8.6            |
| 3 to 8               | 5              | 14.3           |
| 5 to 8               | 3              | 8.6            |
| More than 8          | 2              | 5.7            |

4.4. Cost Analysis of the Clean-up
The cost analysis considered the actual crew that the municipality employs in the clean-up program. The cost that was considered corresponded to salary of the personal, vehicle cost and its depreciation, petrol consumption and landfill cost. The daily cost of the clean-up was estimated to 226.270 Chilean Pesos and the annual cost corresponded to 122.327.729 Chilean Pesos, which correspond to to a 5.8% of the municipal budget for solid waste management.

5. Conclusions
The study showed the extent of the problematic that municipalities in Santiago and Chile have to constantly handle. The main source of this in city dumpsite are due to small renovation and the discard of whitegoods. It was observed that one of the main characteristics of the dumpsites were the bad illumination and the easy accessibility of the sites, which permits anonymity and the rapid discarding of the waste. Additionally, it was observed in several of the site discarded roofing material that contained...
asbestos cement, which leads increases the environmental damage and risk to the local community. As a result of this study the municipality has started a program of intervention of the dumpsite with intention of eradicating these practices.

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