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ACTIONS TO INHIBIT ENVIRONMENTAL IMPACTS ON CLANDESTINE LANDFILLS IN THE AMAZON*

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Abstract

This research studies the negative environmental impacts of clandestine landfills in the Amazon, caused by the illegal disposal of construction waste. In the city of Manaus, located in the center of the Amazon, Brazil, there is a public landfill comprising a solid waste collection complex with an area of 660,000.00 m². In 2018, this landfill received approximately 932,927.00 t of solid urban waste, an average of 2,537.20 t/day. Unfortunately, less than 1% of this waste was destined for valorization (0.92% were for composting, and 0.05% were recycled). This legalized public landfill does not accept the disposal of construction and demolition waste, claiming the decrease in the lifetime of the landfill. However, this regional public policy prohibiting the disposal of construction and demolition waste in public landfills favors the use of clandestine landfills with harmful effects on the environment of the Amazon. This research presents proposals for actions to validate a mobile phone application with the authorities responsible for the Manaus landfill for recycling construction waste, with the aim of stimulating the circular economy and inhibiting the negative environmental impacts of illegal clandestine landfills.

Keywords: Amazon region, circular economy, clandestine landfills, construction and demolition waste

1. Introduction

The city of Manaus, Amazon, Brazil, is located in the center of the Western Amazon and reached in 2019 a population of 2,182,763 inhabitants. The Manaus City Hall maintains a landfill for the collection of solid urban waste, however this landfill does not accept the disposal of construction and demolition waste (CDW) by the general population, nor by companies in the construction sector that operate in Manaus. This public policy is favoring

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the emergence of clandestine disposal on the outskirts of the city of Manaus, which leads to concern about the negative environmental impacts on the Amazon Forest. Clandestine landfills serve for the disposal of solid urban waste and, mainly, for CDW originated from renovation and construction works in general.

The negative impacts on the Amazonian environment of these clandestine disposal are related to the contamination of small streams that are connected to the flow of the Amazonian rivers, with heavy metals such as Co, Cu, Fe, Cr, Ni, Mn, Pb and Zn, as already researched and the contamination of groundwater in the Amazon, Alter do Chão aquifer, according to (Mendes et al., 2019). Bacteriological tests and physical-chemical analysis of pH, temperature, conductivity, total solids, dissolved oxygen, alkalinity, hardness, CO₂, acidity, H₂S, chlorides, sulfates, iron, manganese, NH₄, color, turbidity and suspended solids for underground water exploration, have shown constant contamination, mainly of the river that bathes the city of Manaus, Rio Solimões.

According to (de Menezes et al., 2020), contamination of arsenic in soil and groundwater in the Amazon region is a relevant environmental impact, and the continued emergence of clandestine disposal only exacerbates the situation. The Manaus Public landfill is the main final destination complex for the city's solid waste, located at km 19 of the highway AM-010, spatially positioned through the geographical coordinates 02°57'23.86"S and 60°00'47.62W. The complex has an environmental operating license provided by the Environmental Protection Institute of the State of Amazonas - IPAAM. The area of the complex public landfill is estimated at 66 hectares and its operation is carried out using backhoes and tractors, as shown in Fig. 1 and 2. In 2018, this landfill received approximately 932,927.00 t of solid urban waste, an average of 2,537.20 t/day. Unfortunately, less than 1% of this waste was destined for valorization (0.92% were for composting, and 0.05% were recycled).

Fig. 1. Machines operating in the Manaus landfill complex, located at geographic coordinates 02°57'23.86"S and 60°00'47.62W

The policy adopted by the public sector responsible for the management of the Manaus Public landfill, suppresses the disposal of CDW in this public landfill, under the justification that the CDW will reduce its useful lifetime, scheduled to operate until 2023. However, this policy, despite promoting the economy of public coffers, harms the environment because it contributes to the appearance of clandestine disposal that degrade the environment on the outskirts of the city of Manaus, contaminating the Amazon Forest. The main CDW generated in the city of Manaus are common materials used in civil construction, such as wood, paper, plastics, metals and rubber (Lamêgo Oliveira et al., 2019), and taking

into account that on average 35% of all waste generated in the world is CDW, depending on the diffuse nature of construction projects, the impact of contamination of these CDW in the Amazon should not be overlooked by public policies. Brazil is among the signatory countries of the Paris Agreement 2015, so it must follow the prerogatives for reducing CO₂ emissions suggested by the UN based on the scientific studies presented in the reports of the (IPCC, 2020), collaborating for the reduction of pollutants that degrade the soil and air in the Amazon.



Fig. 2. Backhoe operating in the Manaus public landfill

A revision of the literature shows that negative environmental impacts caused by inadequate disposal of CDW can be found all over the world. For example, in China, soil and water pollution indexes due to heavy metal contamination were detected in the Southeast of the country (Li et al., 2020b), and also in the Pearl River Delta, Canton, South China, with high levels of water toxicology (Cui et al., 2020), which led to the adoption of incentive policies and to the development of CDW recycling in China's construction industry in order to reduce soil contamination. Tajikistan, Central Asia, also presented river beds with contamination by heavy metals, an environmental impact that affects the health of fauna, flora and man (Zhan et al., 2020). The countries with the largest world economy, USA and China, have invested in sustainability policies and management of the CDWs originating from their civil construction industries, reducing negative environmental impacts, through recycling, construction of buildings with recycled materials, landfills and the circular. A correct CDW management policy is fundamental to assure sustainability through the minimization of environmental impacts, so artificial intelligence tools should not be discarded, as they are useful in decision-making by public and private managers (Abdallah et al., 2020). Smartphone technologies are also useful tools that assist in the management, control and inspection of waste (Li et al., 2020a).

In this research, it's request the validation of the Manaus City Hall regarding an application for smartphones for the management of CDW, in order to facilitate the exchange, sale and purchase of waste and the control of the conscious disposal of CDW by the population and civil construction companies of the city of Manaus.

The main objective of this research is to present to the local government of the city of Manaus, Amazonas, Brazil, the Municipality of Manaus, proposals for actions to minimize the impacts of clandestine disposal that arise in the neighborhood of the city, responsible for the contamination of rivers in the Amazon with toxic materials from construction and demolition waste (CDW).

The secondary objectives are:

- To map clandestine disposal that are used for illegal CDW discard, causing impacts on the flora and fauna of the Amazon, with toxic CDW materials (plastics, paints and heavy metals);
- To validate a mobile application for use by companies and ordinary citizens, which assists in the exchange, sale and purchase of CDW, with the possibility of assisting environmental inspection by monitoring the disposal of CDW with GPS location technologies.

2. Material and methods

During the search for clandestine landfills, two locations were identified in the Eastern region of the city of Manaus. The mapping of these clandestine disposal sites was performed using devices equipped with global positioning system - GPS. The impacts of these illegal landfills were analyzed, considering their location and the disposal conditions.

After mapping the CDW clandestine disposal sites, this research opted for the development of a mobile application for use by the population, local construction companies and private CDW collection companies, with the aim of contributing to the legalization of private companies that exploit the collection of CDW and enable transparent inspection of the destination of the CDW in the city of Manaus. The methodology used to develop the mobile application followed the technological prescriptions of the Android Studio version 4.4.0 platform and programming using the Java language, meeting the recommendations prescribed by (Manna et al., 2020; Wu et al., 2020). The algorithm was developed according to the following flow of premises:

- the application should be accessible to any ordinary user or to construction companies that intend to donate, sell or buy CDW;
- the application should contain a database with the services provided by private CDW collection companies, as long as they are legalized and have an environmental license to operate;
- the application should provide the possibility of registering ordinary citizens and contractors that want to offer services for donation, sale and purchase of CDW, with photographic record of the CDW and GPS location of the storage and disposal site;
- the application should ensure the possibility of inspection of the disposal of the CDW through real-time monitoring from the origin to the place of destination of the CDW, by the sectors of the Manaus City Hall and other government sectors of the environmental area;
- the application should provide the possibility of registering private companies that explore the collection of CDW, as long as they are legalized and with environmental licensing;
- in the option to sell services, the application should allow CDW collection companies to establish the desired price, in order to favor free market competition for better prices and quality of service for ordinary users and construction companies;
- the mobile application must meet the security requirements for users regarding notifications and privacy, as defined by the methodology proposed by different researchers, for example (Weber et al., 2015);
- the mobile application must be managed for operation through a startup or internet company, with the objective of resolving conflicts and guaranteeing the legal rights of consumers using the application.

3. Results and discussion

Table 1 shows the results of the mapping of illegal disposal sites in the city of Manaus, with their geographical locations and risks to the Amazon environment.

Table 1. Results of mapping sites of clandestine disposal in the city of Manaus

<i>Sites</i>	<i>Geographic Coordinates</i>	<i>Environmental Risks</i>
1	03°04'19.5"S and 59°53'13.1"W	Contamination by heavy metals in water and soil Co, Cu, Fe, Cr, Ni, Mn, Pb and Zn, from the CDW (Santana and Barroncas, 2007).
2	03°06'15.0"S and 59°54'52.5"W	Contamination by heavy metals in water and soil Co, Cu, Fe, Cr, Ni, Mn, Pb and Zn, from the CDW (Santana and Barroncas, 2007).

The first location is shown in Fig. 3.

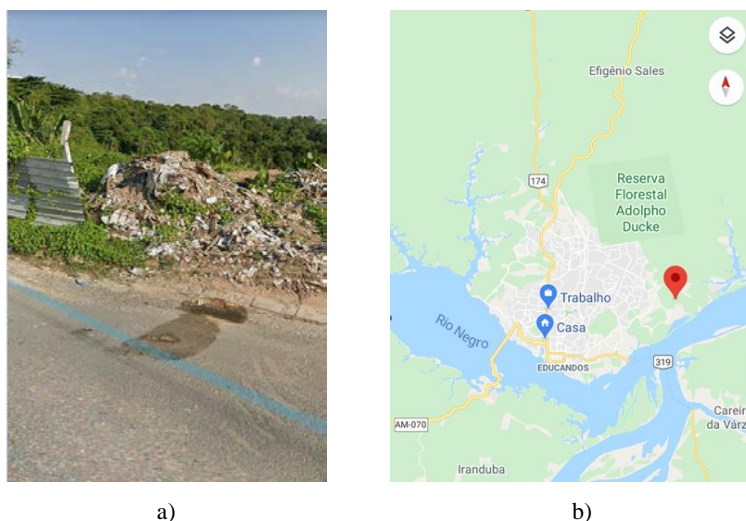


Fig. 3. Clandestine disposal in the city Manaus. a) First site of the illegal disposal; b) Located at geographic coordinates 03°04'19.5"S and 59°53'13.1"W

The clandestine disposal shown in Fig. 3 is close to Igapés, a small water course in the Amazon Forest, causing a danger of contamination for the soil and for the nearby waters. The disposal of CDW is mixed with the disposal of solid urban waste, which will generate leachates in a totally inappropriate place, which may affect the health of animals and humans. The geographical location of this illegal landfill is 03°04'19.5"S and 59°53'13.1"W.

The second clandestine disposal site in the city of Manaus is shown in Fig. 4. It is a place of difficult access, used for illegal disposal of CDW. The site is close to the Amazon Forest with a risk of environmental impact due to contamination by toxic materials originating from the CDW irregular disposal. The location is far from the city center of Manaus, and this difficult its adequate inspection by the Manaus City Hall.



Fig. 4. Clandestine disposal in the city Manaus. a) Second site of the illegal disposal; b) Located at geographic coordinates 03°06'15.0"S and 59°54'52.5"W

The geographic location of the second clandestine disposal site is close to the first one, having the geographic coordinates 03°06'15.0"S and 59°54'52.5"W, as shown in Fig. 4. The area of this second illegal disposal site is 5 times larger than the area of the first site, which aggravates the environmental impact caused in the soil and groundwater.

There are private companies that exploit clandestine disposal in the city of Manaus, transporting CDW collection boxes to these clandestine disposal sites. These private companies operate without an environmental license and without registration with the Regional Engineering Council, and therefore operate illegally and without inspection by the Manaus City Hall. These private companies do not have material separators nor waste crushers, which makes it difficult to recycle CDW. These companies are located close to residential areas (Fig. 5 and 6), which is a danger to local residents, due to contamination of soil and groundwater.

Fig. 5. Inappropriate location for the operation of CDW collection companies, as it is close to residential areas



Fig. 6. Private companies that exploit the collection of CDW without adequate supervision

These clandestine disposal sites must be eliminated as they are a danger to the environment of the Amazon, and can cause effects on the health of animals, plants and humans that are in contact with the soil and water close to these places. However, after these sites are eliminated, certainly others will be created as there is no alternative in the city of Manaus for a sustainable disposal of the CDW. In this way it was proposed to the Manaus City Hall to change the current public policy of banning the disposal of CDW in the public landfill of Manaus, so that the public landfill in the city of Manaus can receive the disposal of CDW in its area of operation, enabling the adequate inspection of the final destination of CDW. It was also proposed to install, at the public landfill in Manaus, equipment for crushing and separating CDW, to enable the recycling of materials and its subsequent donation, sale or exchange, aiming to promote the circular economy of sustainable materials originating from CDW. The Manaus City Hall must also insert tax free incentives for construction companies and ordinary citizens to discard their CDW in appropriate places that have the inspection of the environmental preservation sectors in the Amazon.

The development of the mobile application obtained the results shown in Fig. 7.

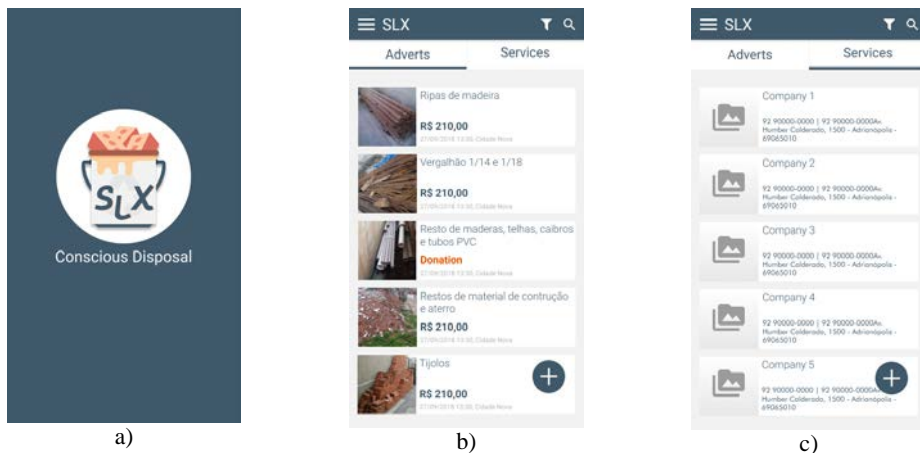


Fig. 7. Screens of the mobile application developed to contribute to the inspection of CDW disposal: a) screen with logo; b) screen of donation or sale of CDW; and c) screen of services offered

Following the methodology proposed by (Kaur and Kaur, 2019), the mobile application was subjected to surveys with users urban citizens, constructions companies and privates companies of the collection CDW, and obtained 93.1% acceptance of the group of 38 urban citizens, 92.3% acceptance of the group of 15 constructions companies and 72.5% acceptance of the group 5 privates companies of the collection CDW. The negative acceptance came from private companies that currently explore the collection of CDW in the city of Manaus, mainly due to the mandatory legalization with the Manaus City Hall and environmental inspection sectors.

4. Conclusions

This research identified several improvement opportunities regarding the management of CDW disposal sites in the city of Manaus, with consequent reduction of the negative environmental impacts caused by the inadequate handling and disposal of these waste in clandestine landfills:

- The reception of construction waste at the Manaus Public Landfill should be authorized;
- The recycling of CDW at the Manaus Public Landfill should be promoted;
- The exchange and sale of recycled materials at the Manaus Public Landfill should be encouraged in order to promote sustainable circular economy;
- Tax free favoring policies for companies and citizens that adhere to the recycling of construction waste should be implemented;
- The validation of the mobile application developed in this research would inhibit the illegal disposal of construction waste in clandestine landfills, as it facilitates the exchange, sale and purchase of CDW, in addition to enabling the mapping of disposal sites, facilitating inspections by public surveillance sectors.

These proposals were presented to the Municipal Secretariat of Urban Cleaning (SEMULSP), a sector of the Manaus City Hall, through virtual means for future evaluation of the Special Commission for the Disclosure and Orientation of Public Cleaning, whose function is to promote environmental education for the population of the city of Manaus. The proposals were received by the Manaus City Hall and will be considered after the end of "social isolation" due to the Coronavirus Pandemic.

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