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Location and Monitoring Unofficial Trash Places via Mobile Application

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Abstract

The generation, accumulation, and improper management of waste is a common problem. In Mexico, there are various unofficial Trash Places (on sidewalks, lots, abandoned properties), which impact the environment and increase health problems for the population. The location of these Unofficial Trash Places is not easy to locate, and they are not reported. Today, the use of information technologies has increased with the interaction between people and technological applications, primarily mobile ones. In this work, a mobile application prototype was designed and implemented that allows citizen volunteers interested in their environment to contribute by reporting the location of unofficial landfills and monitoring their progress. We divided the development of the proposed application into three main phases: the first consisted of developing the mobile application using an existing interactive web portal; the second consisted of distributing the application prototype to volunteers for field data collection; and the third, the validation of the information by an administrator user. We defined the study area for the municipalities of Tampico, Madero, and Altamira, located in southern Tamaulipas, Mexico. We shared the mobile application with 20 volunteers, which will collect data from the study area during the years 2023 and 2024. As a result, volunteer users reported 120 unofficial dumpsites, 80 of which were validated by our system administrator. Of these confirmed dumpsites, 52 were located in Altamira, 15 in Tampico, and 13 in Madero. There were limitations to the data collected due to the type of mobile devices used for GPS location and weather conditions, among others. The mobile application's insights will allow citizens to contribute to reporting and monitoring the locations of unofficial dumpsites and to promptly inform the appropriate agencies, integrating information technologies with the sustainable development of the study area.

Subject Areas

Environmental Sciences

Keywords

Unofficial Trash Places, landfills, Monitoring, Mobile Application, Web Portal

1. Introduction

Trash can be considered the residue of a region's metabolism, reflecting the political, social and cultural characteristics of the people who inhabit it [1] [2]. The practice of depositing waste in inappropriate sites results in environmental impacts and health problems [3] [4]. The indiscriminate dumping of waste, also known as unofficial dumping, unofficial garbage deposits or illegal waste disposal, is a complex waste management problem for governments around the world [5]. It represents risks to human health and well-being and the ecosystem alike. This is a consequence of the lack of an environmental culture and/or inadequate collection that, when not reported, becomes a source of pollution causing the generation of harmful fauna, the presence of leachates, bad odors, as well as land devaluation, landscape deterioration, fires, among others [3] [4]. This has generated an urgent need to develop the capacity to detect them in a timely manner, which makes regulation even more difficult [5]. Furthermore, it provokes social and political conflicts due to the demarcation of responsibilities between the corresponding authorities. This makes it difficult to detect illegal dumping in a timely manner. Illegal dumping is very likely to change over time [6].

In this Digital Age, the development of technological applications provides novel tools for the population to proactively interact as part of the solution to these environmental problems. Through the detection, demand, reporting, and monitoring of these sources of pollution [7] [8]. The rapid advancement of information technology and environmental sustainability have led to the integration of mobile technology and waste management, and there are novel application proposals that improve waste management. The digital transformation has generated greater convenience for the user. By eliminating the need for direct interactions, users can easily follow, learn, and consult content related to waste management, reflecting an ecological digital space [9] [10].

At present, Computer Science has developed technologies such as the Integrated Circuit, Internet and mobile phones which have increased communication between people. A computer application is the emergence of the "Mobile Application" (App) designed for smartphones, tablets, and other mobile devices. Frequently, they are available through distribution platforms, operated by companies that own mobile operating systems such as Android, iOS, BlackBerry OS, and Windows Phone, among others. These have facilitated the life of their users in

diverse aspects from communication, location, monitoring, and entertainment, among others; they also develop collaborative learning between groups, involving information exchange spaces that foster cooperation [11]-[13].

Some of the applications that have been developed for the generation of environ-mental awareness, recycling learning, carbon footprint, Eco-agriculture, and Sus-tainable Development, are known as "EcoApps", such as Gogreen, iHuerting, iHierbas, Irecycle, My Use, Green Meter, Movisol, Carbon traker, Ecohuerto, Zero Carbon, Pollution, Eco Footprint, iReciclart, THELMA, among others [14]-[19]. In Spain, the Foundation for the Prevention of Waste and Responsible Consumption (FPRCR), in collaboration with Caja Madrid and Retorna, has developed a project called "Desembasura", which consists of a Mobile Application with a web portal of the same name, For iOS and Android, which allows the identification of unofficial garbage dumps, marking it and building an interactive map with the location of these sites. The users' responsibilities consist in highlight the problem and carry out re-collection activities by volunteering. However, there is no activity report, or update on the detected points and addition to their validation [20]. The use of interactive maps through Geographic Information Systems (GIS) has been applied to show evidence of the environmental problems that affect the planet, such as soil erosion, the greenhouse effect, or the decrease in biodiversity. In addition, they are problems that affect society [21]-[23]. One of the most popular Web applications is Google Maps, which is an example of a GIS that from a techno-environmental point of view has promoted the generation of visual information allowing a better understanding of common environmental problems such as the location of Official landfills, or official final disposal sites that can be observed at various locations in different countries [24]-[26]. In Mexico, on the website of the Secretary of Environment and Natural Resources (SEMARNAT, by its Spanish acronym), it shows the National System of Environmental Information and Natural Resources (SNIARN, by its Spanish acronym), which is a set of statistical, cartographic and Documentaries that collect, organize and disseminate information about the country's natural environment and resources [26]-[28]. In addition, it integrates information on natural resource disclosures, monitoring of air, water and soil quality, to the ecological order of the territory and its records, programs and actions aimed at preserving the ecological balance and Protection to the environment. In which the following web tools are identified:

- SNIARN Statistical Database (BADESNIARN): Contains statistical information on topics related to the environment.
- Geographic Digital Space (ESDIG): Collection of maps with information on the country's environmental and social characteristics (vegetation, land use, water bodies, soils, climate, population, among others); As well as results of environmental and social programs dedicated to the use, conservation and recovery of the natural ecosystems of Mexico. The unfolded maps are exfetched from the geographical database of the SNIARN [26].

In addition, the National Information System for Integral Waste Management (SINGIR) is located, which shows the official information of collection centers, disposal sites, waste management, legal, technical, and financial regulations applicable to its regulation, control, and management, to the available statis-tical and geographic information, along with its web tool called Information System on Solid Waste [27] [28].

Waste management is an important environmental, social, and public health aspect. Just as there are databases containing information on waste, studies and research have explored different approaches, technologies, and strategies for good waste management practices [29]. Several mobile applications have been developed for waste reporting, highlighting the effectiveness of mobile applications in waste reporting and management. These mobile applications provide an intuitive platform for citizens to report waste-related incidents, resulting in faster response times and better coordination among waste management stakeholders [30]-[32]. Other contributions include real-time monitoring, which emphasizes the importance of real-time monitoring and analysis in waste management systems. Real-time data collection and analysis enable better decision-making, optimize resource allocation, and identify areas for improvement in waste collection, transportation, and disposal processes [33] [34].

In the study area, no mechanism has been implemented to involve citizens in the waste management process. Providing information on locations where garbage should not be dumped and ensuring proper monitoring of the treatment of these unofficial landfills is essential. Therefore, it is important to design a technological tool that allows users to contribute to the location of unofficial landfills, report them promptly to the appropriate authorities, and monitor their follow-up. The sense of relevance and contribution to improving the environment is one of the objectives of sustainable development, which benefits the community.

2. Methods

This study was developed during the period 2023-2024 for Universidad Politécnica de Altamira (UPALT), and the Center for Research and Advanced Studies (CINVESTAV), Campus Tamaulipas. For the mobile application prototype, we used the Java programming language and for the Web Portal, we used the API Google Maps, with the PHP programming language, for the data management we used MySQL database manager [30]. For the data collection in the study area, a working group of 20 volunteer students from the Energy and Information Technology Engineering academic programs was integrated. These students were sensitized to the environmental problems that the study addresses and in the management of the application. The web portal administrator identifies the new sites reported from the unofficial dump site, and then validates the location and documents the observable information for monitoring. In the end, the information on the validated sites is shared with the corresponding authorities [31]. **Figure 1** describes the interactions between the Mobile Application user, the Web Portal ad-

ministrator, and the validation information process.

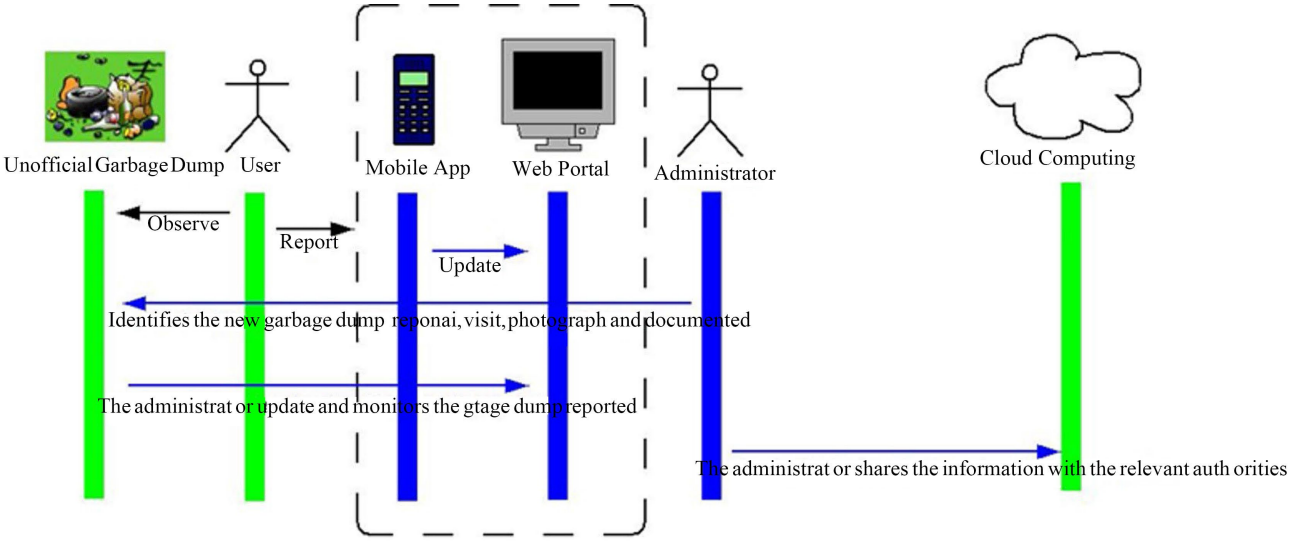

Figure 1. Interactions of the mobile application with the web portal.

Description of the Studied Zone

The selection of appropriate limits is important, the physical, economic, and political characteristics are analyzed based on the distribution that marks the state of Tamaulipas, to determine the area of study. For this work the political frontier was chosen, covering public health aspects, census tracts, air quality control zones, among others, and economic frontiers involving industrial areas, economic development zones, Sewerage and waste. The study area was the Southern Conurbation Zone of Tamaulipas (ZCST, by its Spanish acronym), corresponding to the State of Tamaulipas, which makes up the Municipalities of Tampico, Ciudad Madero and Altamira. It has an area of 1492.70 km^2 (**Figure 2**).

The ZCST, borders the north and northwest with the Municipalities of Aldama and Gonzalez, to the east with Aldama and the Gulf of Mexico, to the south physically with the Panuco River, the border with the State of Veracruz, and to the west with the same State. The 2010 population census, reports a population of 706,771 inhabitants [35]. The municipality of Altamira has a territorial extension of 1361.73 km^2 with a population for 2010 of 212,001 habitants, it is composed of 384 localities, of which only three are urban and concentrate approximately 82.5% of the total population of the same; These localities are Altamira, Miramar and Cuauhtémoc, and the rest lives in the rural environment [36]. Ciudad Madero has a land area of 62.86 km^2, equivalent to 0.078% of the State's surface, has a population of 197,216 inhabitants and the municipality of Tampico has an area of 68.10 km^2, representing 0.085% concerning the State with a population of 297,554 in-habitants [37] [38]. The structure of the economy of the ZCST is represented by 68.4% in the services, trade, and tourism sectors; 28.3% concerning the petrochemical and petroleum industry; and 3.3% in agriculture, livestock and fisheries [35].

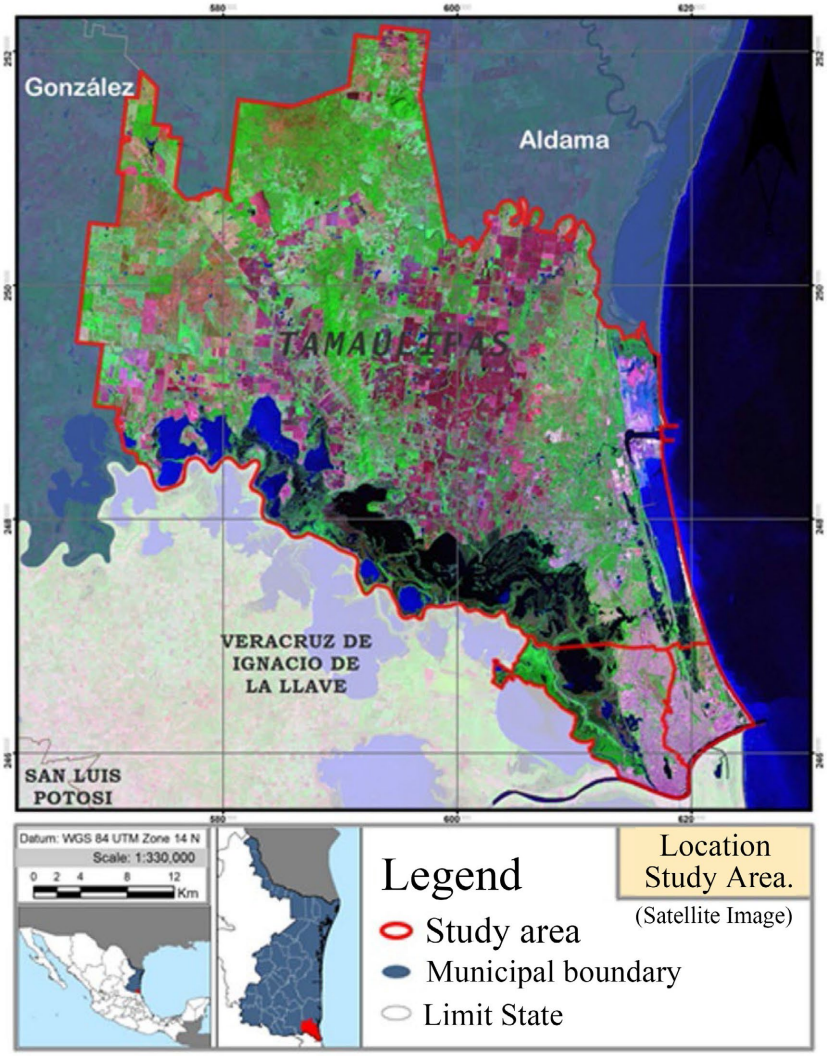

Figure 2. Location of the study area [39].

3. Results and Discussion

3.1. Application Development

Figure 3 shows the layout that was made according to the needs, selecting the Web application type GIS, integrating everything by means of PHP and MySQL language for the creation of the tool of geographical location of unofficial garbage dumps.

1) Web Portal. For the development of the layout of the portal was used the trial version of Balsamiq software, to have a guide to the design of the Web Portal. To satisfy the requirements of the problem, we take as a reference the MSW classification of the LGPGIR as well as the geographical location of the site. In the selection of a Geographic Information System (GIS), the Google Maps API was chosen, according to the results of the "KEEPING PACE with EMERGING Web Mapping Technologies" study conducted by the Department of Geography of Wisconsin-Madison University And presented at the annual Conference of American Map-

ping Society held in Portland [40]. In addition, we chose the MySQL database manager and the PHP Web programming language. To share data between mobile and web portal we used a Java Script Object Notation (JSON) message. Essentially a JSON type structure is created which allows the Api of Google Maps to visualize the geolocation of the unofficial garbage dumps.

2) Mobile Application. Once the Web Portal we generated, the Mobile Application was designed, in its layout consisting of the placement of the selection of the information to be requested to ensure the geographical location of a new unofficial waste dump. It selects the mobile devices whose operating system is Android, due to its high demand in the mobile phone market. The Java programming language is chosen to develop this application. Once validated that the Web Portal is online, tests are carried out to send data from the mobile application.

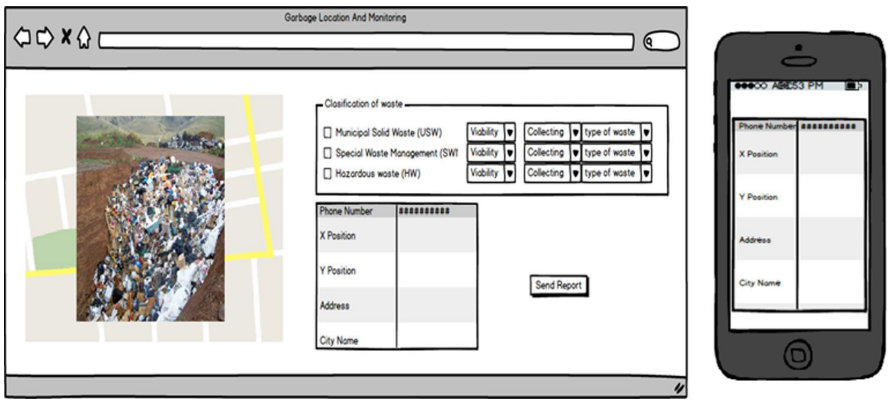

Figure 3. Web portal and mobile application layout.

3.2. Field Testing of the Mobile Application

Once created the Mobile Application and referenced in turn to the Online Web Portal, the installation is performed on some Android phones, to validate the accuracy of the geographical location in mobile phones of various models. To this end, a working group of 20 students from the UAPLT academic programs (Figure 4) was integrated. In addition, the proposed Web Portal prototype was disseminated through the social networks of the students.

Figure 4. Awareness and training in the management of the application.

3.3. Monitoring and Validation "*in Situ*"

For the monitoring of unofficial garbage dumps, the Web portal administrator identifies the new places reported, and subsequently through a voluntary observer (or the same administrator) the site is read "*in situ*", as evidence a photograph of the place was taken and the observable is documented through the identification card. Table 1 shows the format of the visual identification card of the type of waste that can be found in unofficial garbage dumps. This card was prepared according to the classification mentioned in the General Law for the Prevention and Integral Management of Residues (LGPGIR, by its Spanish acronym) [41]. In which examples are described the type of residue that can be found; It is common to mix residues in non-official dumps, which is why examples of Special Handling Waste (RME), including Hazardous Waste (PR), were annexed to the schedule.

Table 1. Identification card.

Urban Solid Waste (USW)	Code	Special Waste Management (SWM)	Code
Organic waste		Construction wastes (sand, rubble, etc.)	
Glass waste		Hospital Waste (gloves, bandages, medicines, etc.)	
Plastic waste		Waste fishing, farming, forestry, forestry, poultry, livestock inputs used for these activities	
Waste metal (cans)		Waste transport (generated due to activities in ports, airports, port terminals, rail, etc.)	
Waste Paper		Waste sludge treatment water treatment plants	
Personal hygiene waste		Waste departmental or malls in large volumes	
Special Waste Management (SWM)	Code	Hazardous waste (HW)	Code
Computers or computer parts		Boats indicate vessels containing acids, chlorides, Pinol, lead, pesticides, among others.	
Computer consumables as a dvd, cd, usb, toners, cables, cpus,, monitors, keyboards, mice, among others; cellular communication, microphones, tape recorders, radios, televisions, etc.		Waste blood, laboratory samples, syringes, tissues, laboratory containers such as flasks, pipettes, flasks, reagents, among others.	
Connecting cables as extensions or remnants of an array cabling			
Stacks		Note: You are considered to be unsafe or dangerous to acquire this evidence does not; enter only visible according to the writ foremost is the security and integrity of the participants and members.	
Traditional bulbs and savers			
Refrigerators, stoves, blenders, all those appliances			
Automobiles of use			
Auto parts (batteries, seats, metal, etc.)			

To facilitate visual identification, we propose a code-based classification. Table 2, shows the three key factors that were considered: the type of waste, the risk of access, and the approximate volume. As evidence of the reported garbage dumps, we used the uploaded photo taken of the site. These key factors, classifications, and pieces of evidence could be used to produce a report to the corresponding

authorities. These data were recollected by the mobile application, received by the web portal, and stored by the database. The web portal was used to monitoring the localized and validated points, as well as the actions regarding the report issued.

Table 2. Coding and visual description.

Viability (V)	Collecting (R)	Description of the type of waste (classification LGPGIR*)
V0—easy, V1—viable V2—more or less viable V3—with difficulty, V4—access problems, V5—no access.	C1—1 - 3 kg bags, two people, C2—4 - 10 kg in truck with five people. C3—more than 10 kg, request a pickup truck.	MSW—Municipal Solid Waste SWM—Special Waste Management. HW—Hazardous Waste. *General Law for the Prevention and Management of Waste

3.4. Results

Data were collected from 120 unofficial garbage dumps, which had to be validated for reliability of the data, this was done through the administrator of the Web Portal. In Table 3, we show the already validated data from which 80 unofficial garbage dumps were obtained in the study zone.

Because most of the volunteers are residents of the Municipality of Altamira, there are more reported landfills, followed by Tampico with 15 and Cd. Madero with 13. Of the sample obtained only 34% were duplicated landfills in some false cases. Obtaining a 66% reliability of registration of the information.

Table 3. Distribution of landfills in study zone.

Municipality name	Number of located dumps
Altamira	52
Ciudad Madero	13
Tampico	15
Total	80

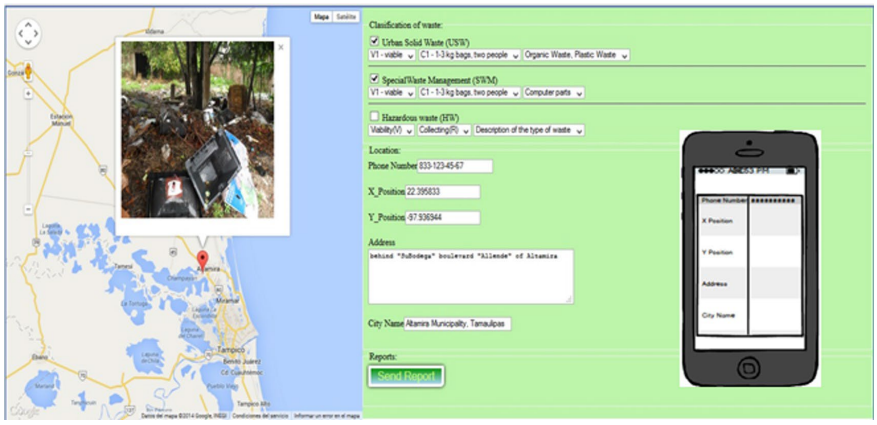

Figure 5. Administrator screen.

Figure 5 presents one example of the validated data, by the web portal administrator, of a reported garbage dump. The administrator user introduced the information annexed to the dump, such as the classification of the residues found on the site, based on the LGPGIR, as well as the feasibility, an approximate amount to be collected, geographical location, and municipality. This user is responsible for the generation of a report that would be sent to the corresponding instances like the Department of Municipal Public Services.

4. Conclusions

A real-world prototype based on the proposed Mobile Application and Web Portal for the volunteer reports of unofficial garbage dumps geolocation was developed. We share the mobile application with a set of students which lives in the study area to recollect data. The users reported 120 possible dumps, and after analyzing the data, we obtained a 66% reliability of the data granted by the users. However, our prototype presented some limitations listed below:

The inherent cost of using a mobile network provider to share and upload the waste dump location and images for the user. The main idea behind our proposed tool is to be a free application because the users are going to be volunteers. These users collect the information *in situ* and then share it with the web portal where the administrator validates or rejected it. It is mandatory to use the waste dump geolocation *in situ* by the mobile application limiting its transmission by using a mobile network. We are working with a local mobile database to store the data temporarily and then send the data by using a wireless connection. However, this scope requires more mobile grants and available storage for the user's mobile device.

Another issue detected in the prototype was the geolocalization precision. Different mobile device models have different hardware components, which varies the efficiency of the geolocation. In the same way, it could have a variation in the care that the user gives to the mobile device. Additionally, we detected variations in the geolocalization values produced by the weather conditions. It was detected that the Global Positioning System (GPS) of the mobile devices with Android operating system used by the volunteers have a deviation of 10 to 20 meters, which affects the reliability of an exact geolocation, so it was decided Request intersections of the place to improve the location, in addition is considered the collection of data *in situ*.

After analyzing the obtained data and the responses of our students, we share the idea of incorporating the technologies as tools for the citizens to interact with their environment and try to avoid problems by using resources such as your smartphones to contribute positively and participate in the solution, by reporting polluting landfills that put people's health at risk.

In future work, we are considering recollecting more data from the study area, and its adjacent municipalities. Improve the data with additional information like contact information of the corresponding department of Municipal public ser-

vices which can manage the type of waste reported to improving the environmental sustainability of the study area.

Conflicts of Interest

The authors declare no conflicts of interest.

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