



# Assessment of environmental impact risks arising from the illegal dumping of construction waste in Brazil

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## Abstract

The objective of this research is to develop a methodology for assessing environmental risks arising from the construction and demolition waste (CDW), considering some environmental criteria to identify the most critical locations. A field survey was conducted in seven municipalities in Brazil, which involved obtaining the CDW illegal dumping sites, through direct observation and photographic registration in the municipalities studied, for assessing environmental risks arising from the CDW illegal dumping and to identify areas with the highest risk of impacts according to environmental criteria. Each site was classified according to aspects such as distance between the irregular disposal points and water resources, plant cover, subnormal clusters, mean family income, parks and plazas, and health and education equipment. A total of 1252 irregular dumping sites were registered in the study area, distributed among the seven municipalities analyzed. In all municipalities surveyed, high-risk dumping sites were identified, although they do not represent most of the sites. Based on the application of this methodology in other municipalities, it will be possible to calibrate the score according to the social and environmental characteristics of each region, and it can be consolidated as a standard tool for assessing environmental impacts from the illegal CDW dumping.

**Keywords** Environmental impacts · Public health · Waste management · Civil construction

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## 1 Introduction

The rapid urbanization of large urban centers contributes significantly to the increase in consumption of natural resources. In addition, it favors the production of construction and demolition waste (CDW) and its associated environmental impacts (Passarini et al. 2014; Wu et al. 2016).

The construction industry has contributed significantly in recent years to the increase in inadequately disposed solid waste, mainly in developing countries (Chanakya et al. 2017) causing considerable environmental impact (Estanqueiro et al. 2016). Contractors are encouraged to deposit the waste in unlicensed areas due to a lack of adequate supervision and a management model that favors the reduction in management costs (Zainun and Othman 2015).

Some studies refer to the risks caused by the excessive production of these materials and the places where they are improperly deposited (Esin and Cosgun 2007; Baniyas et al. 2011; Won et al. 2016). Contamination of soil, air, and water can be easily perceived through its effects on flora and fauna, by the silting up of water resources and by the increase in municipal expenses, which is worrying because it has not received proper attention (Lawson et al. 2001; Ye et al. 2012; Seror et al. 2014).

The goal of improving environmental management and sustainable development has pressured waste generators to adopt measures that reduce environmental impacts (Tam 2009). Being able to minimize impacts presupposes knowledge of their causes through studies regarding the amount, composition, and flow of the generated waste in a geographical area (Gallardo et al. 2015; Wu et al. 2016), which provide information for decision-making in terms of priority, being able to define technologies and actions of a managerial nature and establishing the resources that need to be used.

One way to reduce the impact of waste is by recycling some of the products that are discarded into the environment. When used correctly, this approach can be considered to have a positive economic factor, since inclusion in the production process may facilitate a reduction in the consumption of certain materials.

Waste recycling is a promising market in several European countries, largely due to the scarcity of natural resources. The production and use of recycled aggregates are common practices in the construction industry in several countries such as the USA, Australia, and Japan (Tam 2009).

Efficient waste management is one of the most fundamental steps taken by developed countries. In Brazil, it has become a national concern, as waste has increased at a rate three times faster than the population and a large number of the 5570 Brazilian municipalities are unable to find suitable locations for waste disposal (Abrelpe 2017).

There is a perception that the environmental impacts resulting from the illegal dumping of CDW have not received their due attention from the local governments (Santos et al. 2015), through planning and efficient management, involving economic, environmental, and social dimensions. These actions would reduce the amount of waste generated and improve its management (Shen et al. 2010; Ajayi et al. 2017).

The National Sanitation Policy (Law No. 11,445/2007) establishes that public basic sanitation services will be provided based on the principle of articulation with urban and regional development policies, housing, poverty reduction, environmental protection, promotion of health, water resources, and other relevant social interest, aimed at improving the quality of life, for which basic sanitation is a determining factor (Brazil

2007). Inadequate waste management infrastructure causes a number of health impacts, affecting schools, hospitals, and public squares, especially in the poorest areas.

The study of areas in the cities of the Metropolitan Region of Recife (MRR), in the Northeast of Brazil, that suffer from constant illegal dumping and the analysis of the impacts to the environment and quality of life is important in order to demonstrate the relevance of the issue to public organizations and provide information that can influence decision-making that can minimize the problem.

Research shows that the Northeast of Brazil has the worst coverage of urban solid waste collection, with 79.6%, while the national average is 91.4% (Abrelpe 2017). In metropolitan areas, the greatest concern is the high generation of CDW.

The main objective of this research is to develop a methodology for assessing environmental risks arising from CDW in Brazil, considering various environmental criteria in order to identify the most critical locations.

## 2 Materials and methods

### 2.1 Development of the methodology for assessing the environmental risks

As a way of analyzing which areas are most vulnerable to cause environmental impacts and which, therefore, should receive special attention from the urban agencies, environmental parameters were established in relation to the distance from the illegal dumping sites of CDW. For the definition of these parameters, a bibliographic review was carried out on the environmental impacts caused by the CDW, as well as a survey of the Brazilian legislation.

The distance parameter of the watercourses was based on the Brazilian Forest Code (Law No. 12,651/12), which determines the Protection Margin Bands (FMP). In areas protected by law, a distance was considered to reduce the impacts that may be generated near the preservation areas, as established by the National System of Conservation Units (SNUC—Law No. 9,985/2000) for municipal, state and municipal Conservation Units and national.

For the other parameters, was considered the guidelines established by Law No. 10,257/2001 (City Statute), as well as the CONAMA Resolution No. 307/2002, the National Policy on Basic Sanitation (Law No. 11,445/2007), and the National Policy on Solid Waste (Law No. 12,305/2010).

### 2.2 Characterization of the case study

To validate the methodology for assessing the risks of environmental impacts of the illegal CDW dumping, the Metropolitan Region of Recife (MRR) was chosen, located on the eastern side of Pernambuco State, Northeast region of Brazil, as described below.

The MRR is located along the eastern edge of the state of Pernambuco, in northeastern Brazil. It contains 14 municipalities (Recife, Olinda, Paulista, Abreu e Lima, Igarassu, Itapissuma, Itamaracá, Araçoiaba, Ipojuca, Cabo de Santo Agostinho, Moreno, São Lourenço da Mata, Camaragibe, and Jaboatão dos Guararapes) and the district of Fernando de Noronha. With an area of 2785.44 km<sup>2</sup> and a total population of 3,693,177 inhabitants (IBGE 2017), it has a population density of 1325.89 inhabitants per km<sup>2</sup>.

For this study, seven municipalities within the MRR were defined as the study area (Fig. 1).

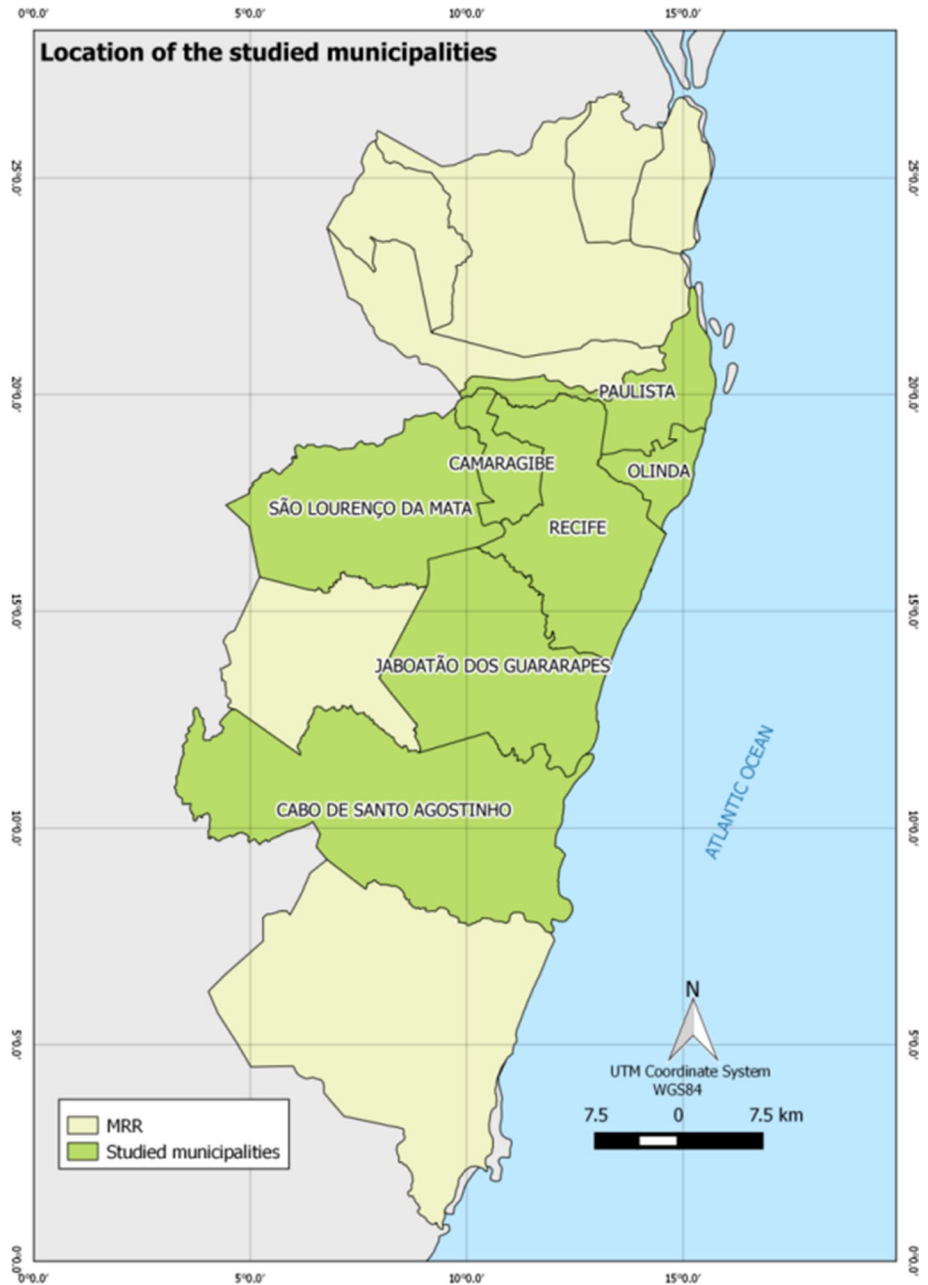


Fig. 1 Location of the study area

This choice was made by the fact that they are the largest municipalities in the region in terms of population and urban area, which provides a greater risk of environmental impact, because the municipality of Cabo de Santo Agostinho, Olinda, Camaragibe, Paulista, and São Lourenço da Mata does not have environmental impact data due to the illegal dumping

of the CDW to complement studies in this subject, which were already conducted in Recife (Lima et al. 2014a, b) and Jaboatão dos Guararapes (Santos et al. 2015). The results will be able to give information to the public organizations for an adequate waste management.

The MRR currently shows significant signs of environmental degradation, specifically deforestation, inadequate solid waste disposal, contamination/salinization of surface and deep water resources, emission of atmospheric pollutants, visual pollution, landslides and slope erosion, and floodplain and coastal erosion, all resulting from anthropic action (Pernambuco 2011).

### 2.3 Classification of environmental impact risks

In order to identify the areas with the highest environmental impact risk according to environmental criteria, a field survey was conducted, which involved identifying the inadequate CDW dumping sites through direct observation and photographic registration in the municipalities studied, serving as key information to evaluate the environmental impacts caused by this waste. The streets that have difficult access were mapped with the help of Street View tool, Google Earth software, using images from the same period of direct observation. On the other hand, the streets without access and without available images were excluded from the mapping, which corresponds to 5% of the study area.

Following identification of these sites, the geographical coordinates were determined with a GPS device (smartphone) and plotted in the Google Earth application. A classification of the areas was then performed according to the current Brazilian CDW classification, based on National Council for the Environment (CONAMA) Resolution No. 307/2002, which divides the waste into Class A (recyclable as aggregates), Class B (recyclable to other destinations), Class C (non-recyclable), and Class D (hazardous). In addition, other factors were considered such as the location in each neighborhood, type of existing pavement, vegetation.

The sites collected were plotted in a geographic information system (GIS) environment, using the free QGIS 2.8.1 software, which included information such as coordinates, municipality, neighborhood, streets, and waste composition.

The socioeconomic characteristics of each municipality were then identified, such as population, permanent private households, and average income, in order to correlate the illegal waste dumping sites with the local characteristics. The socioeconomic characteristics of each region were obtained from the Brazilian Institute of Geography and Statistics (IBGE 2017). All data collected were tabulated in a spreadsheet and later imported into the QGIS software, where several spatial correlation analyses with the socioeconomic characteristics were performed.

## 3 Results and discussion

In order to analyze which areas were most prone to environmental impacts and which, therefore, should receive special attention from urban agencies, a classification was performed according to the parameters presented in Table 1, where impact scores were defined by taking into consideration aspects such as distance between the irregular dumping sites and water resources, plant cover, subnormal clusters, mean family income, parks and plazas, and health and education equipment (Albuquerque 2015). The closer the point to the considered criteria, the higher the score and, therefore, the

**Table 1** Criteria and scores used to classify risks of environmental impacts

| Parameters   | Score  |
|--|--|
| Urban health facility ( $S_h$ )<br>(Law No. 10,257/2001)           | Distance (the closer the equipment, the greater the impact risk)<br>Up to 20 m—10 points<br>40 m—7.5 points  |
| Urban education facility ( $S_e$ )<br>(Law No. 10,257/2001)        | 80 m—5.0 points<br>160 m—2.5 points<br>> 160 m—0.5 point   |
| Mean family income ( $S_i$ ) <sup>a</sup><br>(Law No. 10,257/2001) | Monthly average household income per capita (R\$) <sup>b</sup><br>Up to 324.00—10 points<br>325.00 a 648.00—8.5 points<br>649.00 a 1,164.00—7 points<br>1,165.00 a 1,764.00—5.5 points<br>1,765.00 a 2,564.00—4.0 points<br>2,565.00 a 4,076.00—2.5 points<br>4,077.00–9,920.00—1 point<br>Greater than 9,920.00—0.5 point |
| Watercourses ( $S_w$ )<br>(Law No. 12,651/12)                      | Distance (the closer the watercourses, the greater the impact risk)<br>Up to 20 m—10 points<br>40 m—7.5 points<br>60 m—5.0 points<br>120 m—2.5 points<br>> 120 m—0.5 point   |
| Protection areas ( $S_{pa}$ )<br>(Law No. 9,985/2000)              | Distance (the closer the protection areas, the greater the impact risk)<br>Up to 20 m—10<br>40 m—7.5<br>60 m—5.0<br>120 m—2.5<br>> 120 m—0.5   |
| Disorderly urban clusters ( $S_c$ )<br>(Law No. 10,257/2001)       | Distance from housing units characterized by lack of property (households area inhabited but do not own the land)<br>On site—10<br>Up to 50 m—7.5<br>150 m—5.0<br>300 m—2.5 m<br>> 300 m—0.5   |
| Parks and plazas ( $S_{pp}$ )<br>(Law No. 10,257/2001)             | Distance (the closer the parks and plazas, the greater the impact risks)<br>Up to 20 m—10<br>40 m—7.5<br>80 m—5.0<br>160 m—2.5<br>> 160 m—0.5  |

<sup>a</sup>The current minimum wage in Brazil is R\$ 954.00. Studies indicate that the ideal minimum wage is R\$ 3,658.39 (Dieese 2018)

<sup>b</sup>Current value of Brazilian currency (real) compared to US\$ 1=3.229 reals—Commercial Quotation (TRADING VIEW 2018)

greater the risk of environmental impact. The delimitation of the distance limits was performed with the help of the QGIS software buffer tool.

The same degree of importance of each parameter was established, so that weights were not assigned, as used by Santiago and Dias (2012). Each parameter has a maximum score of 10 points. The definition of distances was based on environmental legislation.

It is important to compare the illegal dumping with the family income, since generally the less noble areas have less infrastructure for waste collection and sorting, which causes in a large amount of CDW disposed in the streets. In addition, in these areas, residents have greater contact with waste in street, increasing disease risks (Holanda et al. 2016).

The distances were calculated using geoprocessing tools such as buffer and the differences between vector files. The sum of the scores was calculated using map algebra with the QGIS software. Each vector file generated with the distances was transformed into a raster file, giving each pixel a single value representing the final score when adding all the parameters.

The score for the environmental impact risks of each illegal disposal point in relation to distance ( $S_d$ ) was defined according to Eq. 1:

$$S_d = S_h + S_e + S_i + S_w + S_{pa} + S_c + S_{pp} \quad (1)$$

where  $S_d$  is the sum of distance score,  $S_h$  is the score due to the distance from urban health facilities,  $S_e$  is the score due to the distance from urban education facilities,  $S_i$  is the score due to mean family income,  $S_w$  is the score due to distance from watercourses,  $S_{pa}$  is the score due to the distance from protection areas,  $S_c$  is the score due to the distance from disorderly urban clusters, and  $S_{pp}$  is the score due to the distance from parks and plazas.

In addition to the score due to the distance from the dumping sites, a score was also given for the size of the CDW piles ( $S_s$ ) (Table 2). Those coming from small generators and generating less than 1 m<sup>3</sup>/day of waste were considered to be small sites, whose collection is under the responsibility of the urban agency. Medium-sized sites are those that fill a 6 m<sup>3</sup> dumpster, while large points are those that need more than one dumpster to collect, generally being consolidated points on vacant lots. A large point indicates a greater probability of existing hazardous waste, besides making it difficult for public agencies to collect.

The final score of environmental impact risks from each illegal dumping site ( $S_f$ ) is calculated in accordance with Eq. 2, ranging from 10 to 100 score.

$$S_f = S_d + S_s \quad (2)$$

where  $S_f$  is the final score due to the environmental impact risks.

The final score defines the class of environmental impact risks of each point, which was divided into four classes, as given in Table 3.

With this score, the urban agency can find the most critical area with environmental impacts, and choosing which illegal dumping sites are priority to be collected.

**Table 2** Score due to the size of CDW sites ( $S_s$ )

| Size   | Score (Points) |
|--------|----------------|
| Small  | 6.5            |
| Medium | 15             |
| Large  | 30             |

**Table 3** Classification of dumping sites due to the final score ( $S_f$ )

| Classification | Scale            | Final score |
|----------------|------------------|-------------|
| Class I        | Low impact       | 10.0–25.0   |
| Class II       | Medium impact    | 25.5–40.0   |
| Class III      | High impact      | 40.5–60.0   |
| Class IV       | Very high impact | 60.5–100.0  |

To test the developed methodology, it was applied in MRR as a case study. The data collection registered a total of 1252 illegal dumping sites in the study area, distributed among the seven municipalities analyzed as presented in Fig. 2.

Table 4 presents the number of illegal CDW dumping sites mapped in the MRR, and Fig. 3 shows the number of sites surveyed per area of each municipality.

The municipality of Recife, capital of Pernambuco State, obtained almost 50% of the total mapped sites. On the other hand, São Lourenço da Mata, the municipality which has the lowest Human Development Index (HDI) among the municipalities surveyed, obtained the highest concentration of sites per km<sup>2</sup>, twice as much as most of the municipalities.

Figure 4 presents the result of the illegal dumping sites' size analysis by direct observation. It was observed that half of the sites (630 sites) are medium size, which means that they fit in a waste container.

From the spreadsheet containing the data tabulation, the CDW dumping sites were inserted into the QGIS software, generating a shapefile type layer (vector file), with all the information related to the place where the site was found. Table 5 presents the percentage of illegal dumping sites in relation to the size for each municipality surveyed.

It was observed that São Lourenço da Mata has the highest percentage of large sites (32%) (Fig. 5a), while Olinda has the highest percentage of small sites (39%). Furthermore, the largest sites are those located in places already consolidated, i.e., those were the nearby residents and some construction companies that have been dumping CDW generated in construction sites along with domestic waste, voluminous waste and hazardous waste from other sources (Fig. 5b). In these areas, the waste collection becomes very costly, and the recycling rate is very low, due to the mixture of different types of waste (Lockrey et al. 2016; Ajayi et al. 2017).

At small-size dumping sites, wastes are mostly generated by small refurbishment services that are left on the footpaths for collection by the municipalities (Fig. 6), as observed in field research.

The materials most commonly found in CDW sites were concrete, mortar, ceramics, wood, and plastic, classified as recyclable as aggregates (Class A) and recyclable for other destinations (Class B), according to CONAMA Resolution No. 307.

In order to correlate the CDW illegal dumping sites with the parameters of environmental impact risks in MRR municipalities, the buffer operation was performed to delimit the distances, obtaining the average score for each parameter, as presented in Table 6.

São Lourenço da Mata (scoring 32.74) and Cabo de Santo Agostinho (scoring 32.36), the smallest municipalities of MRR in terms of urban area, presented the greatest risks of environmental impacts due to the CDW illegal dumping. It is favored by the income score, since the two municipalities have the lowest family mean income. Figure 7 presents the average score for each parameter.



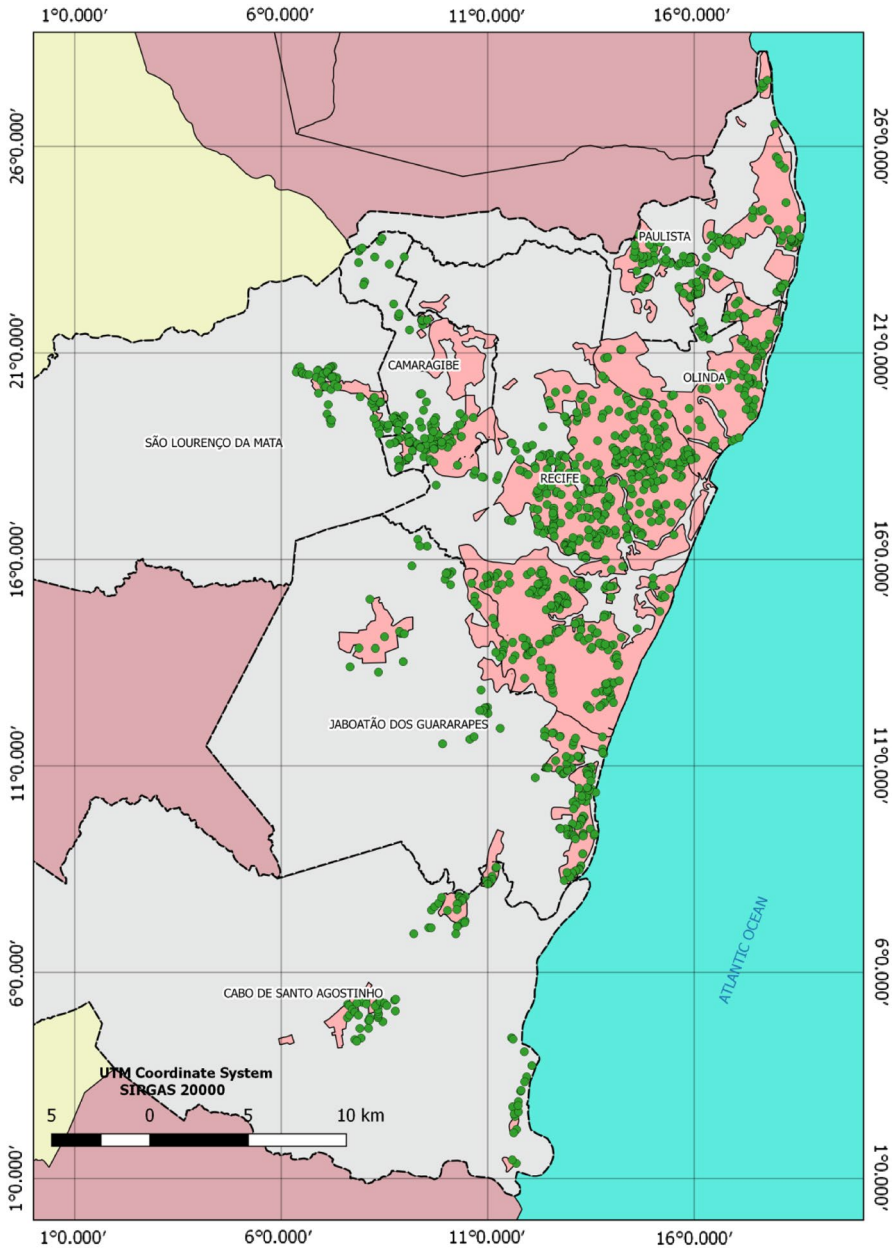
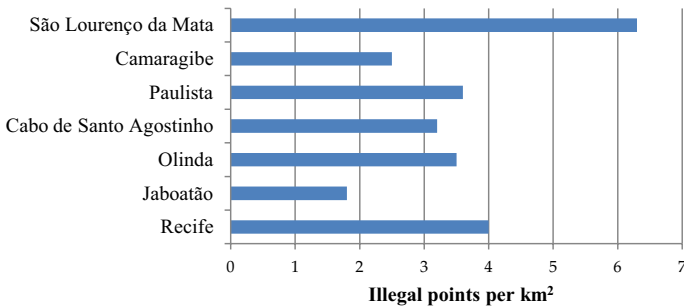
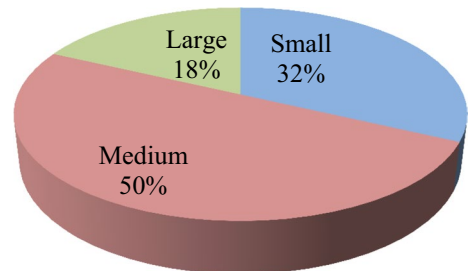


Fig. 2 Location of the illegal CDW dumping sites in MRR

The final score for each illegal dumping site was obtained by summing the parameters. Table 7 presents risk categories for environmental impacts of every illegal dumping site surveyed.

**Table 4** Illegal dumping sites from each municipality

| Municipalities          | Population (2017) | Urban area (km <sup>2</sup> ) | Illegal dumping sites |
|-------------------------|-------------------|-------------------------------|-----------------------|
| Recife                  | 1,633,697         | 142.7                         | 565                   |
| Camaragibe              | 156,361           | 50.1                          | 124                   |
| Jaboatão dos Guararapes | 644,620           | 85.1                          | 153                   |
| Olinda                  | 377,779           | 31.5                          | 109                   |
| Paulista                | 300,466           | 41.2                          | 148                   |
| Cabo de Santo Agostinho | 185,025           | 26.7                          | 85                    |
| São Lourenço da Mata    | 102,895           | 10.8                          | 68                    |
| Total                   | 3,400,843         | 388.1                         | 1252                  |

**Fig. 3** Number of CDW illegal dumping sites per area of the municipality surveyed**Fig. 4** Size of CDW illegal dumping sites

Illegal dumping sites surveyed were classified mostly as Classes I and II, considered as low risk and medium risk. However, 216 sites were classified as high risk, mostly located in Recife, the main municipality in the study area (Fig. 8). Only four sites classified as very high impact were found, two in Recife.

As a way to compare the amount of illegal waste disposal with the waste generation in each municipality, was estimated the CDW generation, through the index presented by Paz et al. (2013), to be 0.77 kg/inhab. day, or 280 kg/inhab. year. Table 8 shows the irregular CDW deposition index in each municipality.

**Table 5** Percentage of illegal dumping sites in each municipality in relation to the size

| Municipalities          | Size of waste sites |            |           |
|-------------------------|---------------------|------------|-----------|
|                         | Small (%)           | Medium (%) | Large (%) |
| Recife                  | 33                  | 49         | 18        |
| Camaragibe              | 28                  | 50         | 22        |
| Jaboatão dos Guararapes | 30                  | 54         | 16        |
| Olinda                  | 39                  | 51         | 10        |
| Paulista                | 27                  | 53         | 20        |
| Cabo de Santo Agostinho | 29                  | 54         | 17        |
| São Lourenço da Mata    | 25                  | 43         | 32        |

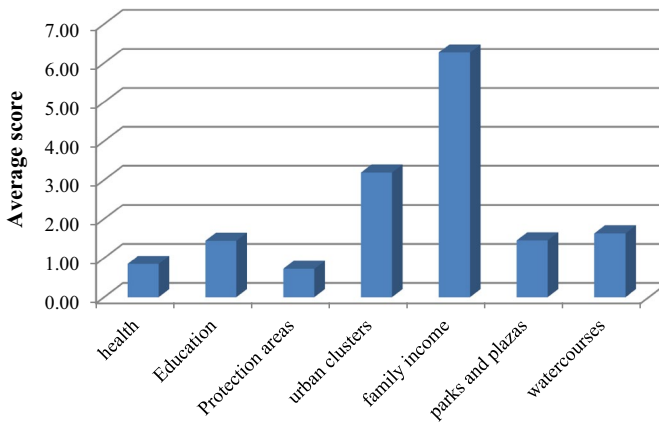
**Fig. 5** Illegal dumping sites: **a** large-size illegal dumping site. **b** Illegal dumping site with various types of waste**Fig. 6** Dumping site left on the footpath for collection

A low illegal deposition sites index presented in Table 8 indicates that the rate of deposition points is reduced in relation to the amount of waste generated in the municipality, which may represent a lower level of construction, or the waste collection on the streets has been more effective, which can be answered by later studies.

Jaboatão dos Guararapes had the lowest rate of illegal deposition, despite being one of the municipalities with a higher level of building construction (0.3). On the other

**Table 6** Score of environmental impact risks parameters for each municipality

| Municipality            | $S_h$ | $S_e$ | $S_{pa}$ | $S_c$ | $S_i$ | $S_{pp}$ | $S_w$ | $S_s$ | Final score |
|-------------------------|-------|-------|----------|-------|-------|----------|-------|-------|-------------|
| Recife                  | 0.81  | 1.17  | 0.55     | 3.38  | 5.64  | 2.16     | 1.56  | 14.85 | 30.13       |
| Jaboatão dos Guararapes | 0.88  | 2.25  | 0.51     | 4.36  | 6.21  | 0.63     | 1.34  | 14.80 | 30.98       |
| Paulista                | 0.58  | 1.66  | 0.68     | 2.69  | 6.49  | 0.92     | 1.30  | 15.74 | 30.06       |
| Olinda                  | 0.70  | 1.11  | 0.50     | 3.40  | 5.65  | 1.44     | 1.89  | 13.24 | 27.94       |
| Cabo de Santo Agostinho | 0.67  | 1.24  | 0.77     | 4.68  | 7.04  | 0.87     | 2.12  | 14.97 | 32.36       |
| Camaragibe              | 1.47  | 1.78  | 2.11     | 1.15  | 6.92  | 0.56     | 2.06  | 15.87 | 31.92       |
| São Lourenço da Mata    | 1.04  | 1.58  | 0.50     | 1.65  | 7.60  | 0.90     | 1.74  | 17.73 | 32.74       |



**Fig. 7** Average score for each parameter

**Table 7** Classification of dumping sites per municipality surveyed

| Municipalities          | Categories of impacts risks |          |           |          |
|-------------------------|-----------------------------|----------|-----------|----------|
|                         | Class I                     | Class II | Class III | Class IV |
| Recife                  | 211                         | 249      | 103       | 2        |
| Camaragibe              | 34                          | 67       | 23        | 0        |
| Jaboatão dos Guararapes | 45                          | 85       | 23        | 0        |
| Olinda                  | 44                          | 53       | 12        | 0        |
| Paulista                | 54                          | 72       | 21        | 1        |
| Cabo de Santo Agostinho | 27                          | 42       | 15        | 1        |
| São Lourenço da Mata    | 17                          | 32       | 19        | 0        |
| Total                   | 432                         | 600      | 216       | 4        |

hand, Camaragibe obtained the highest index (1.0), being one of the municipalities with greater quantity of small works.

The results obtained by this research demonstrated the public health and environmental risks related to the CDW illegal dumping in urban areas. Even in smaller municipalities, it

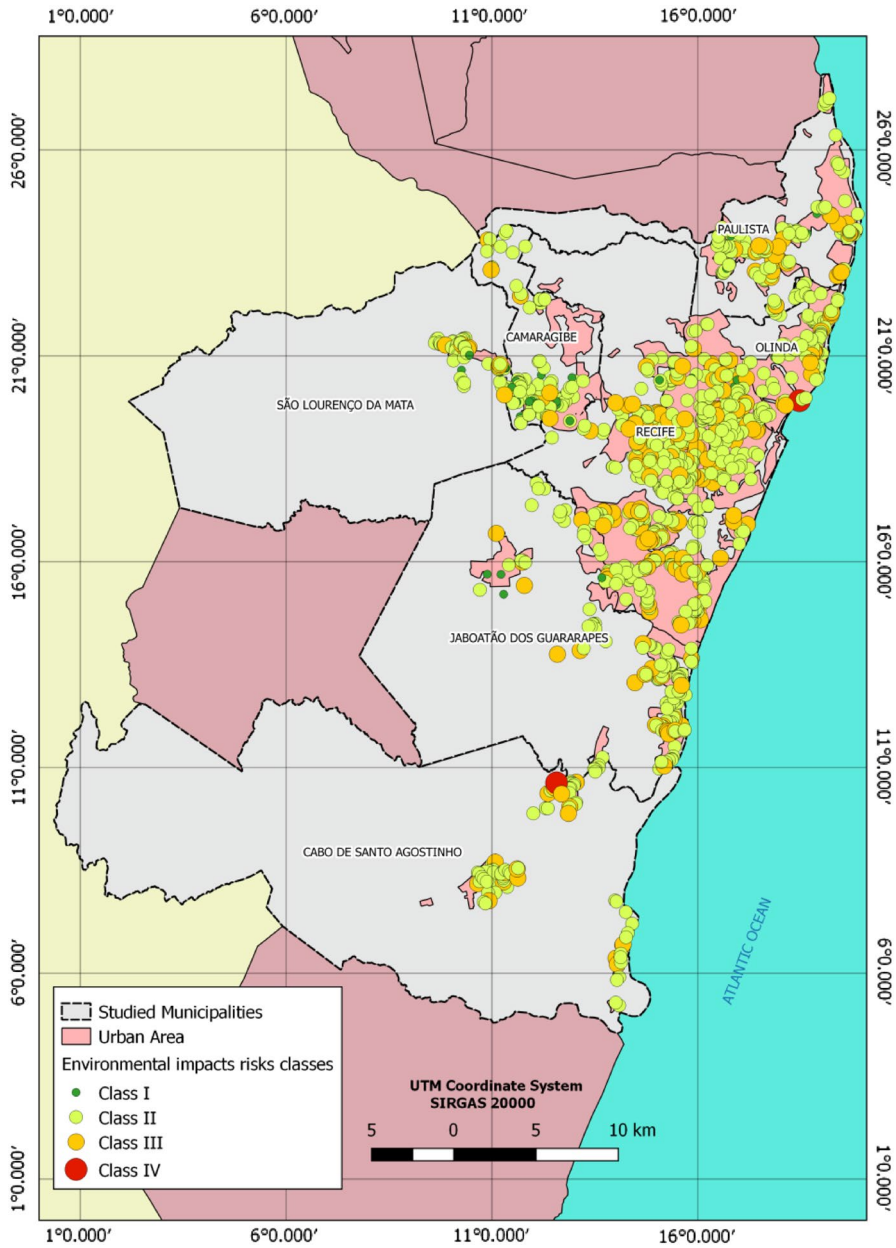


Fig. 8 Location of irregular dumping sites in relation to the classification

**Table 8** Irregular CDW deposition in each municipality

| Municipalities          | Population (2017) | Illegal dumping sites | Estimated CDW generation (tons/day) | Illegal deposition sites index |
|-------------------------|-------------------|-----------------------|-------------------------------------|--------------------------------|
| Recife                  | 1,633,697         | 565                   | 1257.9                              | 0.4                            |
| Camaragibe              | 156,361           | 124                   | 120.4                               | 1.0                            |
| Jaboatão dos Guararapes | 644,620           | 153                   | 496.4                               | 0.3                            |
| Olinda                  | 377,779           | 109                   | 290.9                               | 0.4                            |
| Paulista                | 300,466           | 148                   | 231.4                               | 0.6                            |
| Cabo de Santo Agostinho | 185,025           | 85                    | 142.5                               | 0.6                            |
| São Lourenço da Mata    | 102,895           | 68                    | 79.2                                | 0.9                            |
| Total                   | 3,400,843         | 1252                  | 26,186                              | –                              |

is important to implement programs to control and supervise the works so that there is a substantial reduction in illegal dumping (Mazza et al. 2015).

It is observed that most of the illegal dumping sites are from small generators, because they are concentrated in areas of low average family income, while the large generators are located in higher income neighborhoods, mainly in the city of Recife.

In addition to the income, many sites are located in illegal areas from the disordered occupation of empty land, which often makes it difficult for the public organizations to collect and transport the waste.

The materials found predominantly in CDW sites are in agreement with the survey carried out in other researches (Zainun and Othman 2015), where most are recyclable waste, demonstrating the misuse of the waste in the work itself or its sending to the recycling plants.

The risks of environmental impacts on water resources and conservation units were considered low due to the difficulty of access to these places for people and trucks. The risks of impacts on education facilities were higher than in health facilities.

The methodology was considered validated, since it was possible to identify the most critical sites to be managed as a priority, through a mathematical calculation using the GIS tools, providing an easy approach to analyze the results and present management alternatives (Mahmood et al. 2017). In addition, the validation occurred after field survey, comparing the results of the research with the local reality.

However, the methodology needs to be improved through the addition of new environmental criteria, so that there is a more efficient identification of the risks of environmental impacts from CDW.

## 4 Conclusions

According to the final classification for risks of environmental impacts, it was found that in all municipalities surveyed, high-risk dumping sites were identified, although they do not represent most of the sites.

It was observed that the illegal dumping in urban areas of the analyzed municipalities represents a serious environmental problem. Not only does it contribute to the deterioration

of surface water and groundwater, it also contributes to the occurrence of flooding in the urban area and to the proliferation of vectors of several diseases.

The development of this classification methodology for risks of environmental impacts allows to obtain information previously unknown about the location of the most critical areas. From these data, it will be possible to conduct an environmental zoning to allow a more efficient inspection of the greater risk areas, reducing costs with environmental monitoring.

As a result of this diagnosis, there is a clear need for the implementation of an integrated CDW management plan in MRR, based on this diagnosis and other surveys developed for the implementation of this management plan by the local authorities, thus contributing to the preservation of the environment.

Based on the application of this methodology in other municipalities, especially in other countries, it will be possible to calibrate the score according to the social and environmental characteristics of each region, and it can be consolidated as a standard tool for assessing environmental impacts from the CDW illegal dumping.

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