

Risk Assessment of Critical Solid Waste Points in Lima, Peru, using the Grey Clustering Method

Alexi Delgado, R. Buleje, Z. Muñoz, B. Reyes, R. Tenorio, Ch. Carbajal



Abstract: *The district of Comas in Lima, Peru, is considered one of the districts with the highest number of critical points due to the accumulation of solid waste, causing the proliferation of vectors and the generation of bad smells, producing in this way a negative environmental and social impact on the population and on the landscape characteristics of the environment. The objective of this investigation is to evaluate the risk produced by the critical points of solid waste identified in Tupac Amaru Avenue, in the district of Comas, using the Grey Clustering method. This method allows to consider the uncertainty in the analysis being an adequate methodology for the evaluation of the risk of critical points since it is an issue of high level of uncertainty due to the limited information. The criteria for the evaluation of the risk of the critical points are according to the methodology of the Risk Evaluation Guide of the Ministry of the Environment. Five critical points of solid waste identified in the corresponding Tupac Amaru Avenue in all Zone 1 of the district of Comas were evaluated during 3 days. The results revealed that the three of the monitoring points present moderate risk and two slight risk. This study could be a useful tool for decision making by local and regional authorities to prioritize critical points for eradication and prevention.*

Keywords: *Grey clustering method, Risk assessment, Solid waste.*

I. INTRODUCTION

The inappropriate management of solid waste has negative repercussions on the population involved from different aspects, such as the health of the surrounding individuals, their ecosystems and their quality of life [1].

Direct health impacts mainly affect formal and informal collectors and segregators. These impacts are aggravated when hazardous wastes are not separated at the point of origin and mixed with municipal wastes [2]. Solid waste that is not disposed of properly, especially excrement and other household and community waste, can lead to the spread of infectious diseases such as dengue, leptospirosis, skin infections, etc., attracting undesirable animals such as flies, rats, among others [3].

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On the other hand, impacts on ecosystems include pollution of water resources, air, soil, and diverse tropical ecosystems. Not to mention that the accumulation of solid waste can form a barrier to contain the flow of water, causing local flooding, resulting in long-term loss of fertile soils [2].

For the reasons mentioned above, a study has been conducted focusing on the district of Comas, located in the Northern Cone of Metropolitan Lima, which has a total surface of 4,875 Has. (48.72 Km²) that represents 5% of the territory of the Northern Cone and 1.7% of Metropolitan Lima. Comas is a district that suffers from solid waste contamination in the district due to the following reasons: (a) Limited tax collection capacity of public cleaning and supervision arbiters. (b) A large part of the population is unaware of the characteristics, costs, and expenses of providing municipal public cleaning services. (c) Weak sanctioning capacity. (d) Lack of managerial integration of solid waste competency areas. (e) Lack of awareness, environmental education, and scarce citizen participation.

In addition, unfortunately, one of the main problems for the municipality of this district is the inadequate management of solid waste, since the Public Cleaning Service is a municipal responsibility and action, whose neglect affects both the health of the population and the environment, as it has been mentioned before.

In the present study, a methodology is used to evaluate the risk in the human environment produced by critical points of solid waste in the district of Comas, with the help of the Grey Clustering methodology [4], which helps to solve problems with small samples or limited information. The article is organized in the following parts: Introduction, methodology, results and discussions, conclusions and bibliographical references.

II. METHODOLOGY

The Grey Clustering method is based on the theory of grey systems [5]. Grey systems study problems with small samples or with limited information, this being an advantage due to the fact that studies of socio-environmental phenomena tend to have this characteristic, which is why this methodology has already been applied in different areas such as water management [6], environmental conflicts [7], and occupational safety management.

The Grey Clustering method was developed to classify observation indices or observation objects into categories using Grey incidence matrices or whitenization weighting functions. The method is mainly applied to test if the observation groups belong to predetermined categories.

In the present study, the Grey Clustering method based on Center-point Triangular Whitenization Weight Functions (CTWF) was used [8].

It is assumed that there is a set of "m" groups, a set of "n" criteria and a set of "s" different Grey classes, according to the sample value x_{ij} ($i = 1, 2, \dots, m; j = 1, 2, \dots, n$), in which for the group you have ($i = 1, 2, \dots, m$), and for the criterion you have ($j = 1, 2, \dots, n$). In addition, the steps for class grouping, based on CTWF can be expressed as follows:

Step 1: The individual ranks of the criteria are divided into "s" Grey classes, then determine the focal points of each rank at $\lambda_1, \lambda_2 \dots \lambda_s$ of Grey classes $1, 2, \dots, s$.

Step 2: Grey classes are expanded in two directions, adding Grey classes 0 and $(s+1)$ with their central points λ_0 and λ_{s+1} respectively. Therefore, the new sequence of central points is established $\lambda_0, \lambda_1, \lambda_2 \dots \lambda_s, \lambda_{s+1}$ (as it is shown in Fig. 1). Therefore the CTWF for class Grey k^{th} , $k=1, 2 \dots s$, from criterion j^{th} , $j = 1, 2, \dots, n$, for an observed value x_{ij} is defined by Equation 1.

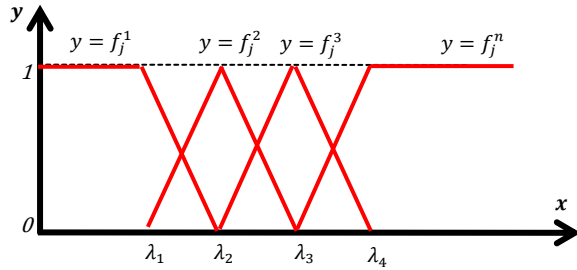


Fig. 1. Center-Point Triangular Whitenization Functions

$$f_j^k = \begin{cases} \frac{x - \lambda_j^{k-1}}{\lambda_j^k - \lambda_j^{k-1}} & x \in (\lambda_j^{k-1}, \lambda_j^k] \\ \frac{\lambda_j^{k+1} - x}{\lambda_j^{k+1} - \lambda_j^k} & x \in (\lambda_j^k, \lambda_j^{k+1}] \\ 0 & x \in [0, \lambda_j^{k-1}] \cup [\lambda_j^{k+1}, \infty) \end{cases} \quad (1)$$

$f_j^k(x_{ij})$ is the CTWF of the k^{th} class Grey of criterion j^{th} , and n_j is the weight of criterion j .

Step 3: The clustering coefficient σ_j^k , which indicates the weight of the criteria, for group i , $i = 1, 2 \dots m$, with respect to class k , $k = 1, \dots, s$ is calculated using Equation 2.

$$\sigma_i^k = \sum_{j=1}^n f_j^k(x_{ij}) \cdot n_j \quad (2)$$

If $\max_{1 \leq k \leq s} \{\sigma_i^k\} = \sigma_i^{k^*}$, we decide that object i belongs to class Grey k^* . When there are several objects in the Grey k^* class, these objects can be sorted according to the magnitudes of their clustering coefficients.

For this work the "i" groups are determined by the critical points of accumulated solid waste found throughout the study area, and the "j" criteria are determined by: quantity, degree of danger, extent, population potentially affected, as well as the ranges of these criteria are detailed below.

III. CASE STUDY

The application of the method was conducted in 5 critical points identified in the corresponding Tupac Amaru Avenue in all Zone 1 of the district of Comas, as it's shown in Fig. 2.

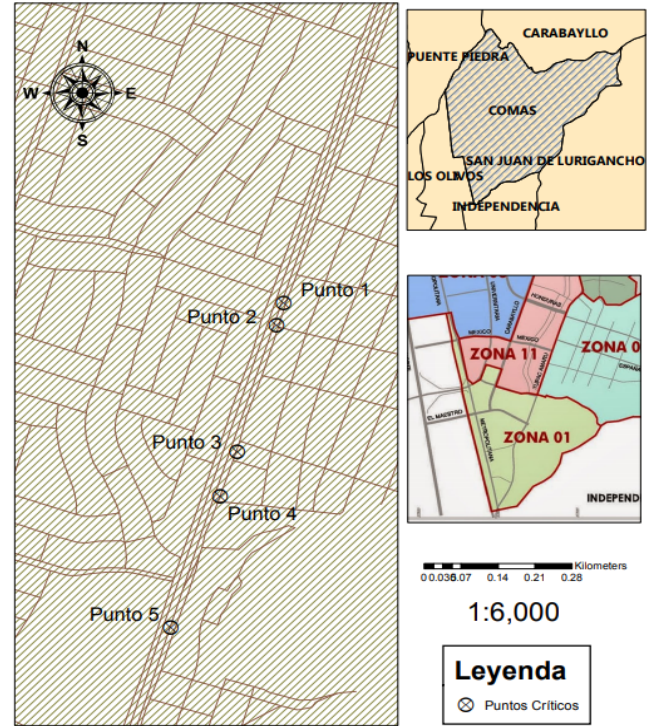


Fig. 2. Map of the location of monitoring points in the Comas district.

A. Monitoring Points

The description of the location of the five monitoring points is shown in Table I.

Table-I: Location of monitoring points

Code	Description	Coordinates
P1	Urb. Huaquillay Av. Tupac Amaru Cdra. 48	276448 E - 8677329S
P2	Policlínico Fe	276435 E - 8677284 S
P3	Av. San Martín (Paradero correo)	276360 E- 8677027 S
P4	Cerca de Mega 80 (Cuadra 6) Los Angeles	276327 E- 8676936 S
P5	Túpac Amaru 264 Urb. La Merced	276234 E - 8676669 S

B. Evaluation criteria

The criteria and values for risk assessment are based on the Environmental Risk Assessment Guide, which proposes a standardized model for the identification and assessment of the environmental risks generated by productive activities in a geographical area, as well as the consequences of hazards [9]. The following was considered to determine the risk in the human environment (Table II):

Table-II: Estimation of gravity in the human environment

Gravity	Limits of the Environment	Vulnerability
Human Environment	= Quantity+2 Level of hazard + Extension	+Potentially affected population

Based on standard UNE 15008 2008-Evaluation of environmental risks cited in the Environmental Risk Assessment Guide.

1) *Quantity:*

For the assignment of values of this factor, OEFA is taken as a reference, considering as a critical point the accumulation of solid waste with a volume of at least 1.5m³ [9].

2) *Level of hazard:*

It represents the intrinsic property of the substances and the level of affectation, for this it is necessary to identify the composition of the residues existing in the critical points, in the definition, they clarify that the critical points are municipal solid [3]:

- Household solid waste
- Non-domestic waste (roads and public spaces)
- Special municipal waste (waste that requires particular handling such as environmental tests, lubrication centers, demolition waste or remodeling of minor works, where the generator must ensure the disposal of their waste). Nevertheless, in public roads, special waste becomes public road waste.

In order to calculate the value of the degree of danger, the percentage by volume of the composition of residues present at the critical point will be considered, based on the characteristics of the residues. It is detailed as follows:

a) *Organic Waste (OW)*

These organic wastes are generated by homes and businesses, representing a greater risk to health, as they generate the presence of bad odors, pets and vectors, due to their biodegradable property [10] (Table-III).

Table-III: Range of the percentage of organic waste with its valuation

Value	Percentage of organic waste (%)
4	51-100
2	10-50
1	< 10

b) *Public cleaning residues*

The types of waste covered are: dust, soil, stone, asphalt, leaves, branches and those considered similar. Being the pruning waste which generate the greatest risk due to its biodegradable property [11] (Table IV).

Table-IV-Range of the percentage of waste from public cleaning with its assessment

Value	Percentage of organic waste (%)
2	25-100
1	< 25

c) *Hazardous waste*

The types of waste covered are those with properties: explosive, radioactive, corrosive or biological. Generally, this waste comes from hospitals, airport waste, laboratory waste, laboratory containers, WEEE, among others [12] (Table-V).

Table-V: Range of the percentage of hazardous waste with its assessment

Value	Percentage of organic waste (%)
4	25-100
3	<25

Demolition waste, plastics, paper, dust, among others, do not represent a risk, as they are inert representing a value of 0.

From the established, the degree of dangerousness is considered as the sum of (Equation 3):

$$\text{Danger Level} = \text{Organic Waste} + \text{Public Cleaning Waste} + \text{Hazardous Waste} \quad (3)$$

3) *Extension*

It is the area of influence of critical points in public spaces; for this reason, it was considered an area of influence, accumulation, persistence and geographical characteristics.

a) *Influence area:*

The valuation was performed according to the influence area as shown in Table VI.

Table-VI: Valuation according to the influence area

Value	Influence area	Description
1	Spot	If the action produces a very localized effect
2	Generalized	The effect does not admit a precise location, having as generalized influence everything (channels, roads, complete blocks)

b) *Accumulation:*

A progressive increase in the amount of solid waste at a specified point (Table-VII).

Table-VII: Valuation according to the progressive increase in the quantity of waste

Value	Range	Description
0	Nil	Volume of waste is reduced over time
2	Constant	The accumulation of waste remains constant over time
4	Cumulative	The accumulation of waste has increased over time

c) *Persistence:*

Time that solid waste remains from its appearance until it returns to its initial environmental conditions (before collection and cleaning by the lender or municipality) (Table-VIII)

Table-VIII: Persistence for evaluation

Value	Persistence	Description
1	Fleeting	Accumulation remains less than 24 hours
3	Temporary	Accumulation remains between 24 hours and 48 hours
5	Permanent	Accumulation remains for more than 48 hours

d) Geographical characteristics:

It is the characteristics of the environment (temperature and humidity), which influence the extent of the impact, the value for geographical characteristics is obtained by adding together the values designated for temperature and humidity. The criteria to establish the temperature and humidity ranges have been established using as a reference the ranges established by Digesa [13] (Equation 4) (Table-IX).

$$\text{Geographical characteristics} = \text{Temperature} + \text{Humidity} \quad (4)$$

Table-IX: Evaluation of hazard degrees

Value	Temperature(°C)
1	<20
2	>20
Value	Relative humidity (%)
1	<80%
2	>80%

The extension is obtained by adding the values assigned to each factor (Equation 5):

$$\text{Extension} = \text{influence area} + \text{accumulation} + \text{persistence} + \text{geographical characteristics} \quad (5)$$

4) Potentially affected population

a) Healthcare:

This parameter is measured through a survey of the population close to the critical points, and the perception of the evaluator's senses is considered [14] (Table-X).

Table-X: Assessment of affected population

Value	Healthcare
2	Presence of vectors
3	Unpleasant odors
1	Presence of domestic animals

b) Vulnerability:

Decreased capacity of the population to withstand and resist the effects of solid waste accumulation. This factor includes establishments close to the critical points. Values for the affected population are obtained from OEFA, 2019 [9] (Table-XI).

Table-XI: Assessment of affected population

Value	Nearby Establishments
4	Health Posts
3	School
2	Market
2	Restaurant

From the established, the degree of population potentially affected is considered as the sum of (Equation 6):

$$\text{Degree of affected population} = \text{Health} + \text{Vulnerability} \quad (6)$$

Based on the criteria mentioned above, the following Table was established (Table-XII).

Table-XII: Levels of risk in the human environment due to critical solid waste points

Levels	Mild	Moderate	Serious	Critical
Quantity (m3)	< 1.5	[1.5-5>	[5-15>	>15
Degree of hazard	[0-2>	[2-4>	[4-7>	[7-10]
Extension	[4-6>	[6-9>	[9-12>	[12-15]
Population possibly affected	[0-4>	[4-8>	[8-12>	[12-17]

c) Data obtained

During the 3-day monitoring, the following data was obtained at each critical point (Table-XIII).

Table-XIII: Data from each parameter for each monitoring point

Criteria	P1	P2	P3	P4	P5
Quantity	0,5	2,3	2,3	2,2	23,7
Hazard	4,0	3,3	4,0	3,0	3,5
Extension	4.66	8.66	4.66	4.66	4,0
Population	7,0	11,0	7,0	7,0	10,0

Then, considering the results of the monitoring and the proposed human environment risk methodology, the calculations are presented in the next section.

d) Calculations

The calculations based on the Grey Clustering method are presented below.

Step 1: It is obtained from Table XII, the central points of each grey class, the values are shown in Table XIV.

Table-XIV: Central point of grey classes

Criteria	Mild	Moderate	Severe	Critical
Quantity	0,75	3,25	10	16,75
Hazard	1	3	5,5	8,5
Extension	5	7,5	10,5	13,5
Population	2	6	10	14,5

Step 2: The values of Table XIII and Table XIV are dimensioned by dividing each value by the arithmetic average of the central points of each criterion. The results are shown in Table XV and Table XVI respectively.

Table-XV: Dimensional values of the central classes of the grey classes

Criteria	Mild	Moderate	Severe	Critical
Quantity	0,10	0,42	1,30	2,18
Hazard	0,72	0,67	1,22	1,89
Extension	0,55	0,82	1,15	1,48
Population	0,25	0,74	1,23	1,78

Table-XVI: Dimensioned monitoring values

	P1	P2	P3	P4	P5
Quantity	0,07	0,30	0,30	0,29	3,08
Hazard	0,89	0,73	0,89	0,67	0,78
Extension	0,51	0,95	0,51	0,51	0,44
Population	0,86	1,35	0,86	0,86	1,23

Table-XVII: Criteria weights

Criteria	Weight
Quantity	1
Hazard	2
Extension	1
Population	1

Step 3: The monitoring point layer is evaluated in the whitenization functions, which are assembled according to step 2 of the methodology.

Clustering coefficients are obtained by multiplying the values of each function by the weight of the criteria shown in Table XVII. These are presented at the end of each Table (see from Table XVIII to XXII).

Table-XVIII: P1 Assessment

P1	f1	f2	f3	f4
Quantity	1,00	0,00	0,00	0,00
Hazard	0,00	0,60	0,40	0,00
Extension	1,00	0,00	0,00	0,00
Population	0,00	0,75	0,25	0,00
Coefficient	0,40	0,39	0,21	0,00

Table-XIX: P2 Assessment

P2	f1	f2	f3	f4
Quantity	0,38	0,62	0,00	0,00
Hazard	0,00	0,88	0,12	0,00
Extension	0,00	0,61	0,39	0,00
Population	0,00	0,00	0,78	0,22
Coefficient	0,08	0,60	0,28	0,04

Table-XX: P3 Assessment

P3	f1	f2	f3	f4
Quantity	0,38	0,62	0,00	0,00
Hazard	0,00	0,60	0,40	0,00
Extension	1,00	0,00	0,00	0,00
Population	0,00	0,75	0,25	0,00
Coefficient	0,28	0,51	0,21	0,00

Table-XXI: P4 Assessment

P4	f1	f2	f3	f4
Quantity	0,42	0,58	0,00	0,00
Hazard	1,00	0,00	0,00	0,00
Extension	1,00	0,00	0,00	0,00
Population	0,00	0,75	0,25	0,00
Coefficient	0,68	0,27	0,05	0,00

Table-XXII: P5 Assessment

P5	f1	f2	f3	f4
Quantity	0,00	0,00	0,00	1,00
Hazard	0,00	0,80	0,20	0,00
Extension	1,00	0,00	0,00	0,00
Population	0,00	0,00	1,00	0,00
Coefficient	0,20	0,32	0,28	0,20

Step 4: For each point evaluated, the highest coefficient obtained is chosen and a denomination is assigned according to Table XII. The results are shown in Table XXIII.

Table-XXIII: Summary of the assessment

	Coefficient	Denomination
P1	0,40	Mild
P2	0,60	Moderate
P3	0,51	Moderate
P4	0,68	Mild
P5	0,32	Moderate

IV. RESULTS AND DISCUSSION

Using the Grey Clustering method it was obtained that three of the critical points of monitored solid waste are of moderate risk and two of slight risk [15]. In addition, the risk generated by these solid wastes can be ordered from greater to lesser risk, as can be seen below:

$$P2 > P3 > P5 > P4 > P1$$

This sequence indicates that the critical point 2 located in front of the Policlinico Fe, represents a greater risk to health than the other critical points located in Av, Tupac Amaru due to the fact that there is a greater vulnerability to people in a medical center.

V. CONCLUSIONS

It is concluded that the present risk assessment produced by the critical points through the Grey Clustering method could be a tool for the decision making of local and regional authorities for the prioritization of critical points for eradication and prevention; since currently OEFA, responsible for the inspection of critical points of waste, has developed a methodology for prioritization that only considers the population and environmental factors affected,

but does not include the volume of waste, the degree of hazardousness or the extension, which is considered in this study.

In addition, the Grey Clustering method presents a good potential for application in different problems to determine the environmental risk generated by productive activities in a geographical area, since these have high uncertainty due to the lack of information and the fact that it is applied in small populations or small samples.

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