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Environmental Risk Assessment for the Disposal of Clandestine Solid Waste on the Riversides of the Opamayo and Sicra Rivers in Lircay-Huancavelica

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ABSTRACT

Inadequate solid waste management causes risks to the environment. This is exacerbated when local governments fail to conduct a relevant environmental risk assessment. The objective of this research was to evaluate the environmental risks of clandestine solid waste disposal sites on the banks of the Sicra and Opamayo rivers in the district of Lircay in the department of Huancavelica, Peru. For the collection of spatial information, the location of clandestine dumps was identified. Seventeen points were mapped in the urban area of Lircay. The estimation of severity and environmental risks was carried out according to the UNE 150008:2008 standard and the Peruvian Environmental Risk Assessment Guide proposed by the Ministry of the Environment (MINAM). Environmental risk zoning maps were then generated. Finally, the result of the environmental risk focused on 4 points of clandestine dumps in medium environmental risk zones and 5 points of clandestine dumps in high environmental risk zones within these riverbanks.

Keywords: solid waste, natural environment, environmental risk.

INTRODUCTION

Solid waste is organic and inorganic waste that is produced due to the manufacturing, transformation or use of goods and services [MINAM, 2014], due to its composition, the majority of these wastes are organic; kitchen and food waste give a result of 47%, plastic waste 9.48% and hazardous waste 6.37% [MINAM, 2010]. There are also those wastes that represent risks to people's health, such as mining tailings and industrial or hospital waste representing 13% [Gutberlet and Uddin, 2017]. Therefore, it is important to manage it appropriately to avoid environmental contamination and public health risks [Vega et al., 2020].

According to the World Bank, municipal waste reaches 2,010 million tons annually, of which only 33% is recycled [Kaza et al., 2018]. This implies that, in the next 30 years, the amount of waste will increase by 70%, as a consequence of the disproportionate growth, in terms of planning, of cities, population and economic development, as stated by [Cuz et al., 2022]. Global solid waste generation will increase to more than

3.5 million tons per day, up from 6 million tons per day in 2010. In the 20th century, as the global population grew and became more urban and prosperous, waste production increased tenfold and 8 million tons of plastic waste were dumped into the oceans annually [Pon, 2019], leading to an unprecedented rampant generation of solid waste.

MINAM reported that in 2021, approximately 21 thousand tons of municipal solid waste were generated in Peru; The inhabitants of the coast are those who produce the largest amount of garbage in Peru [El Peruano, 2021]. In Lima alone, where more than 10 million people live, in 2019, 230.7 thousand tons of municipal solid waste were generated in the city, an amount that is equivalent to a generation of 2.40 kg/ha/day [Deputy Operations Management, City Services Management and Environmental Management, 2019].

In the city of Huancavelica, the total generation of solid waste on average is 27.47 tons per day, including solid waste from household origin, businesses, street sweeping and markets, with the characterization of 61.88% of material waste. organic, and the rest of inorganic matter. Likewise, 21% of the population takes it to a nearby dump and a lower percentage is burned [Municipalidad de Huancavelica, 2015]. In Lircay, district of Huancavelica, residents generate enormous amounts of waste, causing environmental problems. Instead of reducing the production of waste, it increases more and more. This is due to consumerism, population growth as well as the growth of new and varied products, where finally, it ends up being carried out on the banks of the nearby rivers. [Rodriguez Deza, 2018].

According to Ferronato and Torretta [2019], local governments are those that have the mission of guiding residents towards good practices in waste management, implementing comprehensive projects that seek to develop capacities to educate the community [Constanza and Cusaria, 2013]. The government entity, such as the municipality must be in charge of managing the aforementioned issues [Poldnurk, 2015]. More and more local governments are developing solid waste segregation or separation and minimization actions, promoting education, awareness and citizen participation actions [Debrah et al., 2021], likewise, efficient, effective and sustainable management of solid waste [Limache Flowers, 2021]. However, some municipalities do not carry out a relevant environmental risk assessment, adding to a lack of updated information.

Therefore, the objective of this research was to evaluate the environmental risks of clandestine solid waste disposal sites on the banks of the Sicra and Opamayo rivers in the district of Lircay in the department of Huancavelica, Peru, following the methodologies of UNE 150008:2008 standards, in order to estimate the risks in the natural environment, to subsequently evaluate the characterization of environmental risk in the main rivers of the city.

MATERIALS AND METHODS

Study area

The research was carried out in the district of Lircay, which is located in the province of Angaraes, department of Huancavelica, south-central zone of Peru, at an altitude of 3278 meters above sea level, with an area of 818.84 k, the geographic coordinates 13º10'a 13º6' south latitude and 74º43' to 74º44' west longitude, as seen in Figure 1.

The proposed area is located in the central area of the city of Lircay, since the Sicra River and the Opamayo River flow through the urban area, passing through the Pueblo Viejo, Pueblo Nuevo, Bellavista and Santa Rosa neighborhoods [Segama Janampa, 2021].

Spatial information collection

First, the location of the solid waste was identified. For the study, spatial information was collected from the clandestine dumping points, with the support of GPS (Global Positioning System) and through the Geographic Information System (GIS) [Hernandez et al., 2020], in the QGIS software, 17 points found in the urban area of Lircay were automatically organized and mapped as shown in Table 1.

Assessment of the severity and environmental risks of the natural environment

The estimation of the severity and environmental risks was carried out according to the UNE 150008:2008 standard [Ávila Caro, 2022], and with the Environmental Risk Assessment Guide [MINAM, 2010], in order to assess the severity of the consequences in the natural environment of the study area.

Given the conditions in the collection of information, only the natural environment was considered for this study, as a first step to future research in the area.

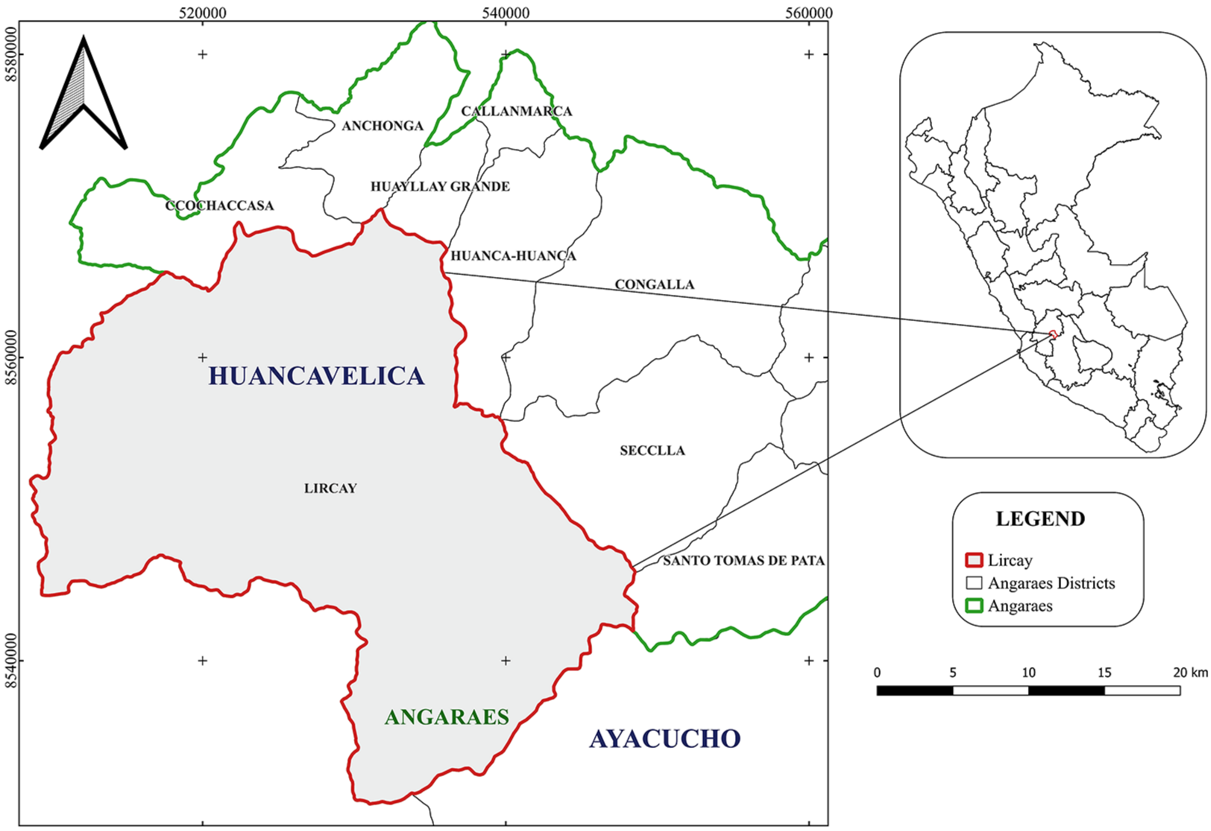

Figure 1. Geographic Location of the Lircay-Huancavelica District

Table 1. Clandestine solid waste points captured in the Qgis software

Solid waste disposal points	Coordinates		Area m²	Percentage (%)
	X	Y		
V-1	530115	8564353	6.88	4.32
V-2	530374	8564117	18.40	11.54
V-3	530122	8564176	4.52	2.84
V-4	530147	8564579	5.31	3.33
V-5	529680	8563911	4.68	2.93
V-6	529750	8564164	12.19	7.65
V-7	530104	8564010	5.98	3.75
V-8	529584	8563775	17.65	11.07
V-9	529879	8563705	9.08	5.70
V-10	530067	8563721	3.27	2.05
V-11	530023	8563407	13.33	8.36
V-12	529896	8563234	10.75	6.74
V-13	529891	8562931	3.53	2.21
V-14	530215	8563480	15.07	9.45
V-15	530372	8563688	10.07	6.31
V-16	530429	8563932	7.84	4.92
V-17	530178	8564111	10.87	6.82

Table 2. Form for estimating the severity of the consequences of the Environmental Risk Assessment Guide

Gravity	Environment limits	Vulnerability
Natural environment	= quantity+2 of danger +extension	+Quality of the medium

In Table 2, there are the formulas to consider for calculating the value of the severity of the consequences for the natural environment. Where:
- Quantity: The presumed volume of substance or element emitted to the natural environment.
- Danger: Substance or element that produces possible accumulation or toxicity
- Extension: The space of influence of the pollution impact.
- Quality of the environment: The negative environmental footprint and impact is considered and whether it has possible reversibility.

After this assessment, the categories for the natural environment were arranged as shown in Table 3.

Once the categories have been established, the consequences for the natural environment are assessed following the parameters in Table 4.

Finally, regarding the natural scenario, a score ranging from 1 to 5 is assigned to assess the severity of the consequences of said environment, as presented in Table 5.

Characterization of environmental risks

Characterize the environmental risk based on the natural environment on the banks of the Sicra River and the Opamayo River using the methodology proposed by the MINAM, [2010] Environmental Risk Assessment Guide Environmental risk zoning maps were generated.

Table 3. Range of limits of the natural environment Environmental risk assessment guide [MINAM, 2010]

Worth	Amount	Dangerousness	Extension	Affected population
4	Very high	Very dangerous	Very extensive	Very high
3	high	Dangerous	Extensive	Elevated
2	little	Little dangerous	Not very extensive (Location)	Half
1	Very little	Not dangerous	Specific (affected area)	Low

Table 4. Assessment of consequences natural environment. Environmental Risk Assessment Guide [MINAM, 2010]

Quantity (ton)			Dangerousness		
4	Very high	Greater than 500	4	Very dangerous	Very flammable Very toxic Causes immediate irreversible effects
3	high	50-500	3	Dangerous	Explosive Flammable Corrosive
2	little	5-49	2	Little dangerous	Fuel
1	Very little	less than 5	1	Not dangerous	Minor and reversible damage
Extension(m)			**Assets and productive capital**		
4	Very extensive	Radius greater than 1 km	4	Very high	Very high damage: Indiscriminate exploitation of HR. NN, there is a moderate level of contamination
3	Extensive	Radius up to 1 km	3	Elevated	High damage: High level of HR exploitation. NN and there is a moderate level of contamination
2	Not very extensive (Location)	Radius less than 0.5 km	2	Half	Moderate damage: Moderate level of HR exploitation. NN and there is a slight level of contamination.
1	Specific (affected area)	Not dangerous	1	Low	Minor damage: conservation of RR. NN, and there is no contamination.

Table 5. Assessment of the identified scenarios of the Environmental Risk Assessment Guide

Worth	Assessment	Assigned Value
Critical	20-18	5
Serious	17-15	4
Moderate	14-11	3
Mild	10-8	2
Not relevant	7-5	1

To determine the Risk Analysis, the product of the probability and the severity of the consequences was employed, allowing for the estimation of environmental risk through a modified scale of the Weighting Matrix or Simplification of Bartell. This takes into account the following equation [Neira and Quilla, 2020].

Equation 1 is used by Mendoza Vásquez, [2021]:

$$R = PA \times M \quad (1)$$

where: R – quantifies the level of risk (units);
PA – the probability of the threat;
M – the magnitude of damage or severity of the consequences as seen in Figure 2. [Valencia Barriga, 2016].

The magnitude of the damage and the probability of threat can be taken as follows:
- 4 = High.
- 3 = Medium.
- 2 = Low.
- 1 = Negligible.

The environmental risk for this work has 3 categories:
- High risk = 12 to 16.
- Medium risk = 8 to 9.
- Low risk = 1 to 6.

Considering variables such as the volume of solid waste stored in the area of solid waste dumping points, close to the town, proximity to the Sicra and Opamayo rivers, the corresponding assessment of environmental risks must be carried out [Salas-Jiménez and Quesada-Carvajal, 2006], to obtain the level of environmental risk. Figure 3 outlines the process of Methodology.

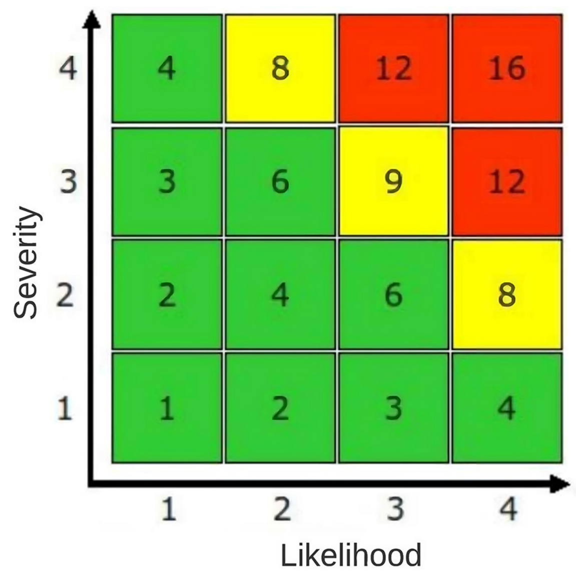

Figure 2. Risk matrix [Valencia Barriga, 2016]

RESULTS AND DISCUSSION

First, to achieve reliability in the calculations of the results, the data was processed using the geographic information systems program QGIS 3.22.10. The 17 solid waste disposal points were identified, analyzed and found with the GIS [Sendra, 2001]. To delimit the entire territory of the study area, two large-scale maps were used, shown in Figures 4 and 5. However, for this work, 9 points located on the Sicra and Opamayo River banks were considered as shown in Table 6, of which, according to the risk assessment guide environmental specifies that the causes of ecological danger are the inadequate management of solid waste [Guerrero Mendoza, 2022].

While the original methodology identified 17 points, the study focused on specific locations along the Sicra and Opamayo rivers. This refined approach enhances the relevance of the results by pinpointing the areas with potentially higher environmental impact.

Results were presented in Table 7, detailing the potential exposure of water, atmosphere, and soil to contamination. Notably, the ecological dangers arising from inadequate solid waste management were highlighted [Rondón Toro et al., 2016]. The soil exposure due to the management of domestic waste, altering soil quality, loss of nutrients and appearance of leachate was determined.

According to Quispealaya et al., [2021] the knowledge of the existence of harmful metals outside the permissible limits obtained as a result of a study in the channels of the Sicra and Opamayo rivers, leaving these solid waste in the body of surface water, retained in the streams.

Emissions of polluting gases and particulate matter into the air are often due to sources such as open burning of solid waste, recognizing that black carbon is one of the most polluting sources of air.

Inhaling the fumes from burning organic or inorganic waste can increase the risk of respiratory and cardiovascular diseases [Negrón Martínez et al., 2019].

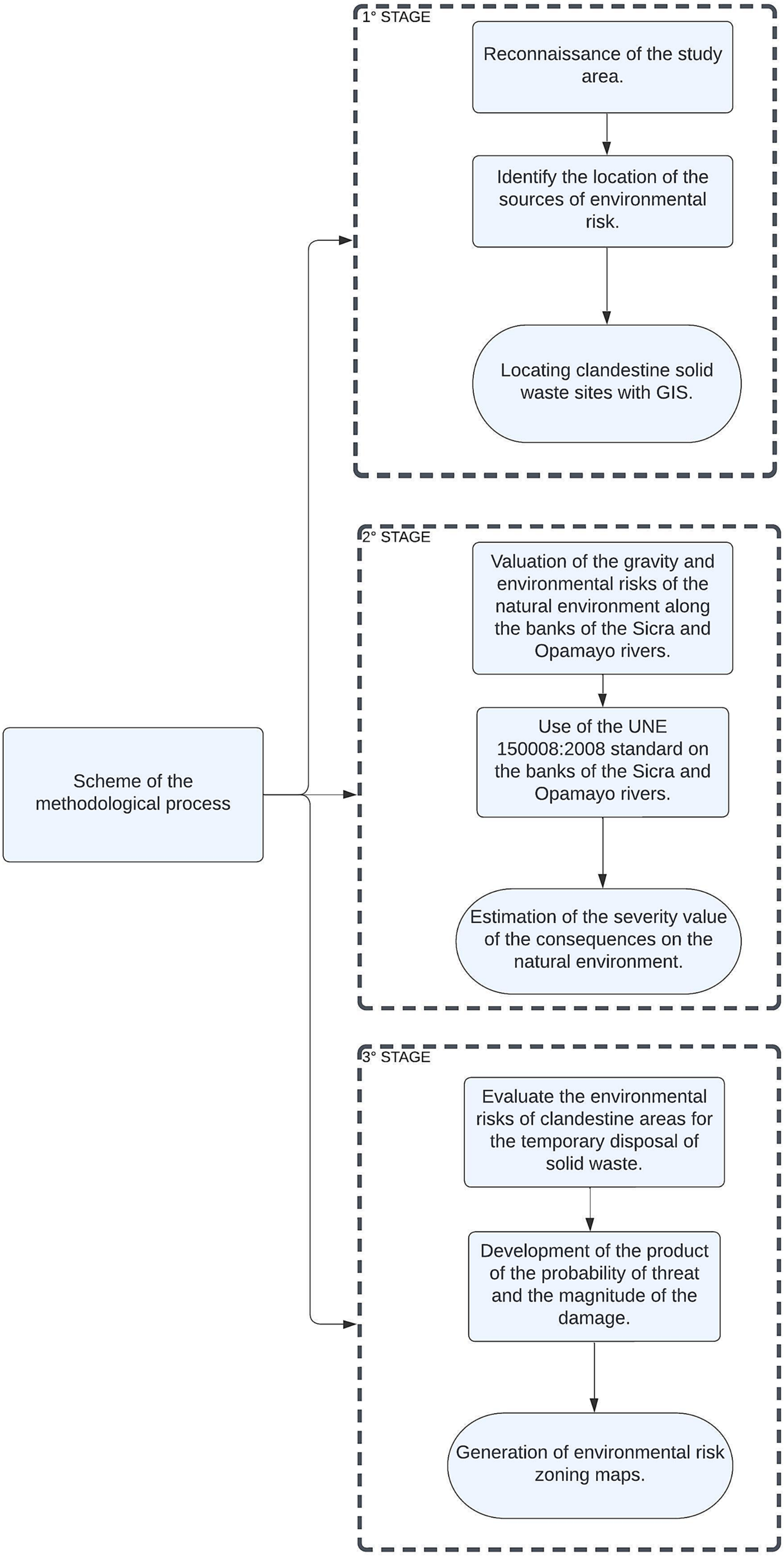

Figure 3. An outline of methodology

Table 6. Clandestine solid waste disposal areas through geographic information systems

Solid waste disposal points	River	Coordinates		Area m²	Percentage (%)
		x	y		
V-3	Sicra River	530122	8564176	4.52	5.81
V-4	Sicra River	530147	8564579	5.31	6.83
V-5	Opamayo River	529680	8563911	4.68	6.01
V-6	Opamayo River	529750	8564164	12.19	15.67
V-7	Sicra River	530104	8564010	5.98	7.69
V-8	Opamayo River	529584	8563775	17.65	22.68
V-10	Sicra River	530067	8563721	3.27	4.2
V-11	Sicra River	530023	8563407	13.33	17.14
V-17	Sicra River	530178	8564111	10.87	13.97

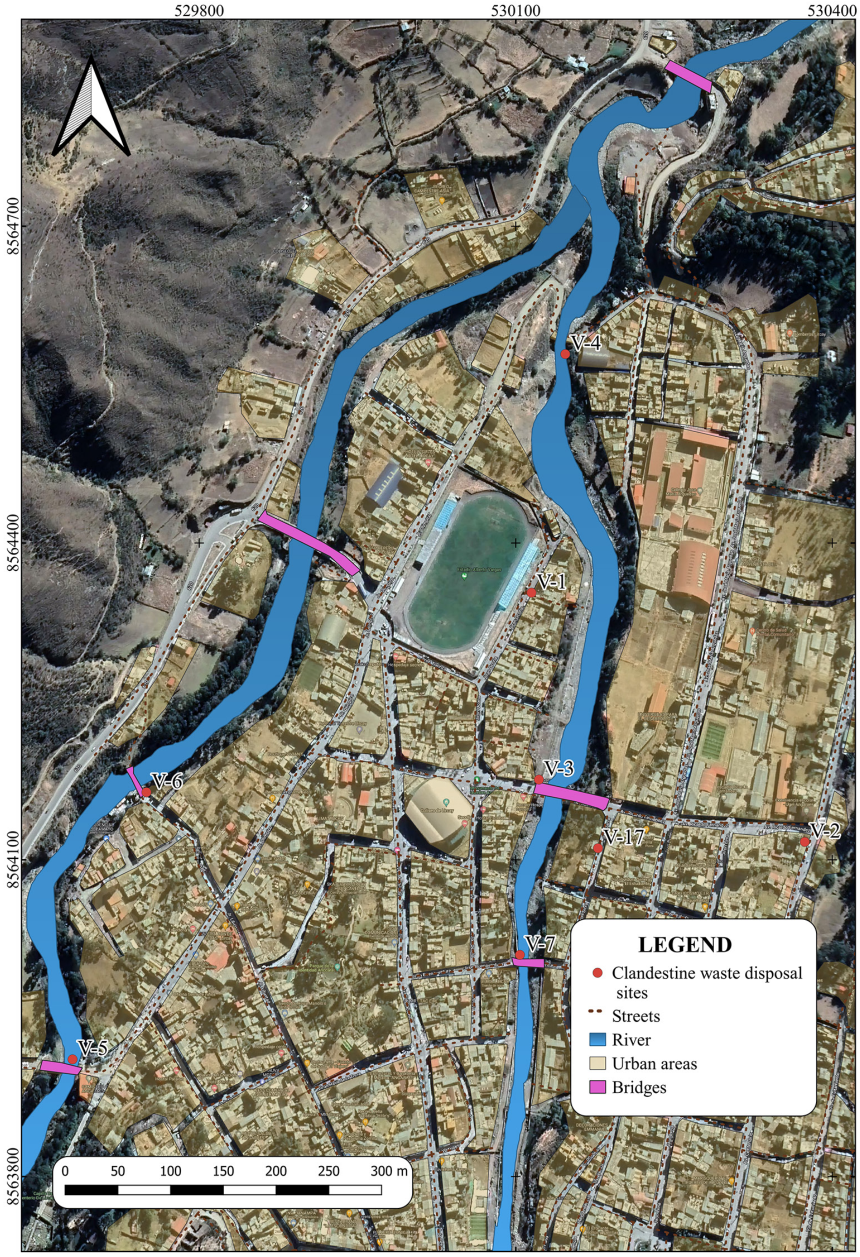

Figure 4. Location of the disposal areas of the clandestine solid waste points V-3, V-4, V-7 and V-17 belonging to the area of influence of the Sicra River, and the clandestine dumping points V-6, V-5 belonging to the area of influence of the Opamayo River

Figure 5. Location of the disposal areas of the clandestine solid waste points V-8 belonging to the area of influence of the Opamayo River, V-10 and V-11 belonging to the area of influence of the Sicra River

Table 7. Analysis according to the natural environment

Risk element	Initiating event / evaluation parameters
Potential water exposure to: Surface contamination	Waste from livestock and domestic activities.
Potential exposure to atmosphere Particulate pollution	Indiscriminate burning due to irregular waste collection.
Potential soil exposure to: Residue contamination	Handling domestic waste, which is buried in the soil, alters its quality and produces the loss of nutrients, as well as the appearance of leachate.

In the case of Lircay, 2.61 tons/day of solid waste is produced by its 5,194 inhabitants [Ccahuana, 2001]. The soil is constantly exposed, since clandestine solid waste points are degrading the element, affecting its erodibility, vegetation cover, and generating leachates [Guerrero Mendoza, 2022]. The consequences to the natural environment are presented in Table 8.

The assessment of severity value and environmental risks brought attention to the ecological dangers resulting from inadequate solid waste management practices. The study emphasis on

Table 8. Consequences to the natural environment

Natural environment				
Factor	Environment limits	Vulnerability	Gravity	Worth
Potential water exposure to: Surface contamination	10	3	13	Moderate (3)
Potential exposure to the atmosphere: Particulate pollution	10	3	13	Moderate (3)
Potential soil exposure to: Waste contamination	10	3	13	Moderate (3)

Table 9. Risk classification of clandestine solid waste points

Solid waste disposal points	Threat probability (A)	Damage magnitude (M)	Risk level (R)	Risk classification
V-3	4	3	12	High
V-4	4	4	16	High
V-5	4	4	16	High
V-6	3	3	9	Medium
V-7	4	4	16	High
V-8	3	3	9	Medium
V-10	4	3	9	High
V-11	3	3	9	Medium
V-17	4	2	16	Medium

Table 10. Result of environmental risk areas

Risk classification	Risk area (m)	Percentage %
High	54.04	30.54
Medium	23.76	69.46
Total	77.8	100

water, atmosphere, and soil exposure underscores the potential ecological consequences and the need for targeted interventions.

The environmental risks on the banks of the Sicra and Opamayo rivers were characterized using MINAM methodology. Risk Analysis was conducted through a modified Weighting Matrix. It is evident in Table 9 that there are 9 clandestine solid waste points, located on the banks of the Sicra and Opamayo rivers, points V-6, V-8, V-11 and V-17 were recorded within a classification Medium risk. Points V-3, V-4, V-5, V-7 and V-10 are within the High-risk classification. Finally, Table 10 shows the environmental risk results.

Where the total coverage of the medium risk type is 23.76, which represents a percentage of 30.54% of risk area coverage in the area of influence of the banks of the Sicra and Opamayo rivers; while the total coverage of the high risk type is 54.04, which represents a percentage of 69.46% of risk area coverage in the area of influence of the banks of the Sicra and Opamayo rivers.

Figure 6 depicts the location of environmental risk areas in the areas of influence of the Sicra and Opamayo rivers.

The risk stratification into Medium and High categories provides a nuanced understanding of the environmental threats posed by clandestine solid waste points. The area coverage percentages further contribute to prioritizing areas for intervention. The High-risk classification indicates the zones requiring urgent attention and mitigation measures.

CONCLUSIONS

The utilization of georeferencing with QGIS software proved instrumental in precisely identifying 9 critical solid waste points situated along the Sicra and Opamayo rivers. This approach allowed for a focused analysis, distinguishing points within riverbanks and those in proximity, within 50 meters from the water bodies.

Employing the UNE 150008:2008 standard, the assessment of the natural environment revealed a risk value of 3. This moderate risk signifies the vulnerability of the environment to direct

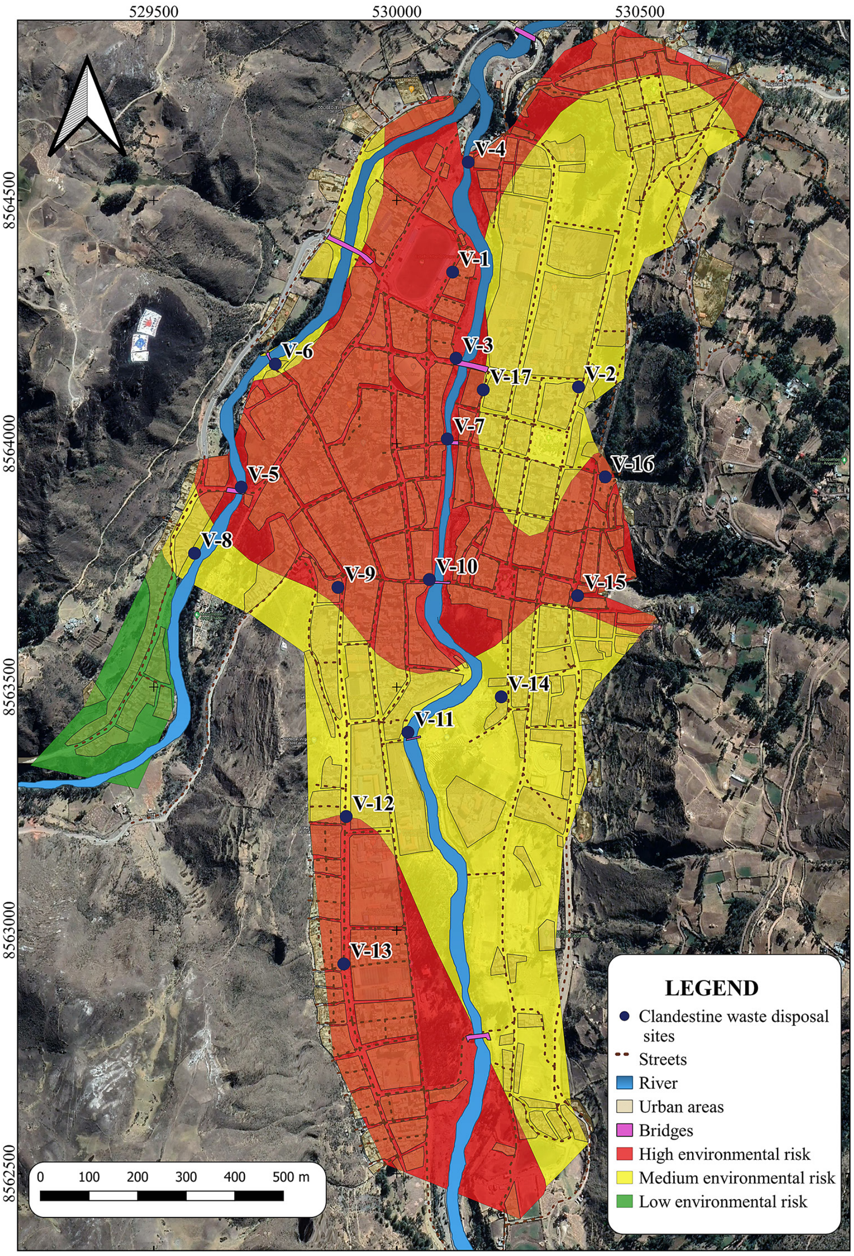

Figure 6. Location of environmental risk areas in the areas of influence of the Sicra and Opamayo rivers

or indirect contact with solid waste elements, emphasizing the potential for environmental damage. This result provides valuable insights for subsequent environmental management decisions.

The environmental risk analysis identified 4 clandestine dump points in areas of medium environmental risk, covering 23.76 square meters, and 5 points in high-risk areas within the riverbanks, covering 54.04 square meters. The cumulative result delineates a substantial environmental risk area of 77.8 square meters for the city of Lircay. This comprehensive analysis, based on MINAM methodology and a modified Weighting Matrix, offers a nuanced understanding of the spatial distribution of environmental risks.

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