THE ENVIRONMENTAL CONDITIONS OF A LOCATION MAY INFLUENCE THE TREATMENT OF INDUSTRIAL SOLID WASTE

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Abstract. The management of industrial solid waste demands the establishment of suitable management systems. Such systems must take into consideration multiple factors that allow selecting the most adequate treatment techniques among the ones available. The selection of these techniques is a complex process that not only depends on factors inherent to the treatment or the waste itself, but also on other factors. For this reason, this study analyses the influence of location on the management of an industrial solid waste such as LD sludge. Firstly, we used a methodology developed in a previous part of this study, that can identify six treatment solutions, then, a set of environmental, regulatory and socioeconomic indicators are chosen. Going a step further in this investigation, proves through the application of the methodology in five different locations, that environmental characteristics influence the final treatment solution for the same waste. According to this, two sets of groups can be identified for the best treatment solution: one in which the highest score is 1 A Ceramization and another in which the final result is 1 B Vitrification.

Keywords: *sludge, analytical hierarchy process, management methodology, system of indicators, industrial facilities*

Introduction

Over the course of history, and as the population has grown, the needs and level of comfort for individuals have increased exponentially, resulting in an excessive generation of waste parallel to the generation of goods. This lack of social conscience that until recently was undeniable, dumping this waste in an uncontrolled manner and causing serious economic, social and environmental problems, has been giving way to the emergence of a new social conscience.

The problem of environmental pollution has its origin in the fast urbanization and industrialization produced in the last few decades. Although the amount of waste produced in cities is worrying, the generation of waste at the industrial level is even more so. In spite of being more varied and numerous, they are more dangerous and, as a consequence, more difficult to control, causing serious problems in the operations of their use and subsequent disposal. This, in combination with greater social awareness, makes the need to develop new management methods and procedures becoming more and more evident. However, just as important as their development is the way they are applied and adapted to the constantly changing technological and social environment. One-way to go a step further and make the most of these management systems, is to incorporate specific tools that allow the influence of certain external agents to be measured.

Therefore, the industrial solid waste management (ISWM) is a complex issue that industrial companies around the world must tackle on a daily basis. All of them must try

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to use the best techniques available to treat the waste material and establish the most suitable management and treatment systems.

In many cases, the selection of the most suitable treatment or set of treatments is a complex issue, due to the need to bear in mind a considerable amount of factors (technical, economic, social...). Obviously, the special characteristics of the industrial waste are often crucial, though the environmental conditions of the area where the waste is generated are also decisive.

In the managing of industrial solid waste (ISW) or any type or waste, not only should be taken into account, to study which treatment is the best according to the characteristics of the waste, if not that the process is much more complex. In addition, the performance produced should be analysed according to the environmental characteristics of the site or location where it is to be managed. Based on the measurement of this performance, it could be decided which environment is best to treat the waste.

Based on this hypothesis, it might appear that the research currently being carried out on this particular subject could be countless, but this is not the case. Since many of the existing works only study the optimal location of the industrial facilities to reduce its impact from the beginning using decision support systems (Arán et al., 2008) or multi-criteria decision making techniques (Çebi and Otay, 2015) including Analytic Hierarchy Processes (Kauko, 2006; Dey and Ramcharan, 2008; Srdjevic et al., 2007; Akıncı et al., 2013). Other researches use bi-level programming models (Wu and Yang, 2018) or analyse (Chen et al., 2014) or compare (Glatte, 2015) different models.

Some authors study the optimal location of the treatment plants using multi-criteria approaches, taking into account technical, economic and environmental aspects (Önüt and Soner, 2008; Wibowo and Grandhi, 2017; Wójcik et al., 2014; Kyriakis et al., 2017; Samah et al., 2017; Ulubeyli et al., 2017). For this purpose, different techniques and methodologies are used, including Analytic Hierarchy Processes (Önüt and Soner, 2008; Milutinović et al., 2014; Samah et al., 2017), programming models (Vaillancourt and Waaub, 2002; Haastrup et al., 1998; Paul et al., 2018), or fuzzy systems (Carniel and Schneider, 2017; Abdulhasan et al., 2019). Other select the most appropriate treatments for waste at a given location (Achillas et al., 2010; Xu et al., 2014; Nouri et al., 2018) or a comparison between two locations (Milutinović et al., 2016; Inglezakis et al., 2018).

Thus, the work here presented pursues two goals:

- Check that the environmental conditions of a location can modify the most suitable treatment for a specific industrial waste.
- Verify that the previously developed methodology by the authors (Fernández et al., 2014) is capable of providing the best solution in several geographical locations with different physical, environmental and social conditions where the waste material is generated.

Materials and methods

Methodology for the ISWM

As described above, the methodology for the selection of the most suitable solution for the waste material that has been used, is the one defended by Fernández et al. (2014)

This methodology has a series of characteristics that makes it the most suitable for the study of the treatment of industrial solid waste:

- First, its adaptability to any type of waste, either solid or semisolid.
- It can be applied to any type of environment by adjusting the location conditions of the installation where the management process is taken place (climate, soil, closeness to populated areas or green areas, etc.).
- It is a flexible methodology that can consider different criteria or environmental indicators.
- It is user-friendly, since the decision process guides and helps users through the different options.
- It is easy to update, by including new treatment methods, changes derived from evolution in technology or social and economic conditions.

All these characteristics allow the methodology to continue evolution and thus be able to comply with the future lines contemplated in the first part of the study developed in Spain (Fernández et al., 2014). For its application, the methodology is structured in four stages, defined in *Figure 1*.

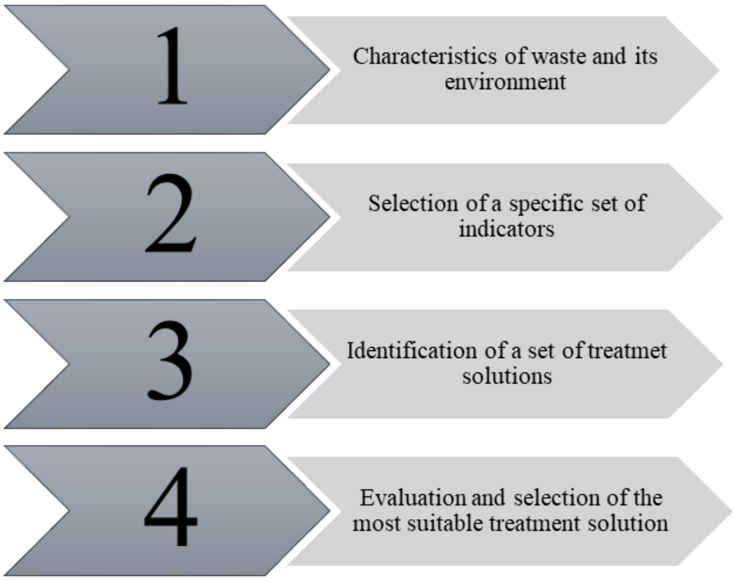

Figure 1. *Methodology development diagram*

The first thing to learn is the characteristics of the waste to be treated and the environment where the treatment will be developed. All this information is then collected in files or sheets, one with the characteristics of the waste material and the other with those of the environment, the first classifies the waste material according to information related to its identification, and the second collects information on the location where the treatment system will be set and its conditions.

The second stage involves the selection of a specific set of indicators for each case of application, the result of particularizing a system of general indicators.

For this purpose, the general Environmental Indicator System (EIS) for any area of the company, will be specific to waste management by configuring a System of Environmental Indicators for Solid Waste Management (SEISWAM) that will be the

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means of subsequent evaluation of the possible treatment solutions applicable to this waste. The characteristics of the indicators are described in the “Indicator sheet”.

In the third stage, the treatment solutions are identified thanks to an “alternative selection chart” (Fernández et al., 2014), which presents the necessary process for the treatment of a solid waste from its generation to its disposal, elimination or reuse, and functions as a decision aid system. This identification is carried out taking into account the characteristics of the waste “Waste sheet” and the set of available techniques, “Process sheet”, which collects the main data of interest of each technique and waste to which is applicable. Each of these solutions can consists of more than one treatment process.

The last stage of the methodology presents the results of the study and allows us to select the most suitable solution among all the possible solutions previously identified in the previous stage. For this purpose, the selected set of indicators is available, which evaluates each of the available solutions. This evaluation is performed through the application of the Analytical Hierarchy Process (AHP), developed by Tomas Saaty in 1980 (Saaty, 1980).

Case study

Next, the application of this methodology to a particular case is described, where the goal is to search the optimal treatment solution for the same industrial waste in different locations worldwide.

Waste product studied

LD converter sludge is the waste material resulting from the wet processing of gas in the steel-making process in the Basic Oxigen Furnace (BOF) converter or LD converter, named after the Austrian towns Linz and Donawitz where this system was first developed. This waste material involves a serious concern due to the vast amount generated, around 27 kg of LD sludge per ton of hot metal. Its physical and chemical components allow different alternatives or possibilities of treatment. On the other hand, it has a percentage of recoverable material, its metal part, which makes it a reusable product both for the steelmaking and other types of industries (*Table 1*).

Selection of locations

In order to develop this study, 5 populations close to steel mills have been selected, where the LD slag is obtained and which have different physical, environmental and social environment conditions.

Among the possible locations, areas with different climate conditions have been selected, according to the climate classification developed by Köppen. This procedure is based on empirical observations (Köppen, 1900) to establish a climate classification system that uses monthly temperatures and rainfalls to define the limits of the different types of climate worldwide. This classification was revised and updated afterwards (Köppen and Geiger, 1930, 1936; Stern et al., 2000; Peel et al., 2007) and it is widely used worldwide by meteorologists and geologists (Chen and Chen, 2013; Feng et al., 2014), apart from being the base of multiple scientific studies (Pražnikar, 2017; Almorox and Quej, 2015; Yoo and Rohli, 2016).

According to these premises, the populations of Avilés (Spain), Lázaro Cárdenas (Mexico), Tubarao (Brazil), Newcastle (South Africa) and Beijing (China) were

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selected for the study. The climatological conditions of these locations are displayed in *Table 2*. In the case of Spain, the data have been obtained from the State Meteorological Agency (AEMET, 2017) and the data of the rest of the locations have been collected from the WMO repository, World Meteorological Organization (WMO, 2017), from the official website of the NOAA, National Oceanic and Atmospheric Administration, which belongs to the USA Government.

Table 1. *Waste characterization*

Chemical description				
Component	**Density (g/cm^3)**	**Magnetic properties**	**Percentage (weight)**	**CASRN[1]**
Fe total	7.87	Ferromagnetic	64.12	7439-89-6
FeO	5.74	Paramagnetic	79.58	7439-89-6
CaO	3.30	Magnetic	8.9	1305-78-8
Fe_2O_3 (magnetite)	5.24	Magnetic	2.79	1309-37-1
MgO (periclase)	3.79	No magnetic	0.38	1309-48-4
SiO_2	2.64	No magnetic	0.71	7631-86-9
Al_2O_3 (alumina)	3.96	Diamagnetic	0.32	1344-28-1
P	1.82	Anti-ferromagnetic	0.10	7723-14-0
MnO	5.10	Anti-ferromagnetic	0.10	1344-43-0
Zn	7.13	Diamagnetic	0.20-4.10	7440-66-6
Pb	11.30	Diamagnetic	0.04-0.14	7439-92-1
S	2.07	No Magnetic	0.03-0.35	7704-34-9
C	2.26	No Magnetic	0.70-4.60	7440-44-0

Physical and chemical properties	
Moisture	35-40%
Physical condition	Semisolid
Granulometry	Mostly from 38 µm
% Weight of organic matter	4%
% Inorganic matter weight	96%
Appearance	liquefied, oily
Colour	Dark grey/black

[1] Chemical Abstract Service Register Number (American Chemical Society)

The town of Avilés is located in the North East coast of Spain, with mild temperatures in all seasons, with and average temperature of 13.5 °C, high relative humidity (78%) and frequent rain. On the contrary, Newcastle (South Africa) has a drier climate, with lower relative humidity (59%) but higher average temperatures (21.9 °C) and less rainfall. On the other hand, Lázaro Cárdenas, a town located near the Pacific Coast of Mexico, has a tropical rainforest climate, where winters are cold but the average annual rainfall is still high all year around. The average rainfall level is 1278 mm and temperatures are high, with an average temperature of 27 °C and a high relative humidity. The humidity of the Brazilian city of Tubarao (61%) is lower than the case of Mexico, while the temperatures are also high (26.4 °C), with a lower rainfall level than in the previous case (1,003 mm), although relatively similar to the town of Avilés.

In Beijing, the weather conditions are quite similar to those of the city of Newcastle in South Africa, although it is colder, (11.8 °C) and drier (47%), and the level of rainfall is a bit higher (577 mm) than that of the Chinese capital.

Table 2. *Climate characteristics according to location*

	BOF	**BOF**	**BOF**	**BOF**	**BOF**
Steel mill	Avilés (Spain)	Lázaro Cárdenas (Mexico)	Tubarao (Brazil)	Newcastle (South Africa)	Beijing (China)
Measure location	Avilés	Acapulco	Sao Goncalo	Johannesburg	Beijing
Site	Industrial	Rural-town	Rural	Industrial	Industrial
WMO number station	NA	76805	82689	68368	54511
Period (years)	1981-2010	1961-1990	1961-1990	1961-1990	1961-1990
Type of climate according to Köppen	(Cfb) warm/very wet/warm summer	(Aw) tropical rainforest climate/dry winter	(Cfa) warm/very wet/hot summer	(Cwb) warm/dry winter/warm summer	(Cwa) warm/dry winter/hot summer
Distance (km)	0	300	510	289	0
Annual average temperature (ºC)	13.50	27.50	26.4	21.90	11.80
Annual average humidity (%)	78	75.80	61	59.20	47
Anual rainfall total (mm)	1,062	1,278	1,003.30	543	577
Annual average wind speed (m/s)	3.50	2.20	2.82	2.78	2.50
Data source	AEMET	WMO	WMO	WMO	WMO

When selecting these populations, apart from the different climate characteristics, the type of location has also been taken into account, that is, if it is an industrial or rural area and if it is near or not to population centres or natural reserves. In this sense, Avilés, Newcastle and Beijing are considered as populations located in industrial areas, against Tubarao and Lázaro Cárdenas, which are closer to rural areas with small population centres and close to areas considered as natural heritage.

Selection of a specific set of indicators

The indicators system has been established as one of the most useful tools for monitoring the process information flows, which provide us with techniques to evaluate their efficiency.

The so-called SEISWAM was developed at the same time as the methodology used in this paper (Fernández et al., 2014) and it is based on the following two former systems:

- The first one is based on a system of indicators in which the principles of ISO 14031 standard are specified (ISO International Organization for Standardization), the European eco-management and audit scheme contained in the EMAS Regulation (Comision Europea, 2003; DOUE, 2009), extended with

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the present classification in the report issued by the Public Society of Environmental Management of Basque Government IHOBE (IHOBE, 1999).

- The second one is the GRI system (Global Reporting Initiative), which is the main international standard for the drafting of Sustainability and Corporate Social Responsibility Reports (CSR) (GRI, 2005).

The indicators system is specialized in the management of industrial solid waste by using a selection chart to define the methodology of waste management. This gives a more complex system called SEISWAM, which is comprised of hundreds of indicators.

Among these indicators, the most representative ones in terms of measuring the impacts of inputs and outputs processes were selected resulting eleven (*Table 3*). These indicators collect globally the different environmental impacts (environmental indicators), socioeconomic impacts (financial behaviour indicators) and those affecting the management process according to the set of treatments that waste endures (environment indicators).

Table 3. *Indicators considered*

Number	Indicator name
1	Specific energy consumption
2	Specific water consumption
3	Specific consumption of chemical agents
4	Volume of liquid effluents
5	Volume of gas emissions
6	Total share of profitable solid
7	Operational costs of environmental protection
8	Average rainfall of the area where the installation is located
9	Wind speed in relation to the average in the area where the installation is located
10	Proportion of natural heritage affected
11	Proximity to local populations

Of these eleven indicators, the first seven are dependent on the characteristics of the waste material and measure the environmental, social, economic impacts of the waste management process. Essentially, it has been decided to select those that directly and easily quantify the inputs and outputs in the flowchart, to compare the results obtained with those of the first part of the study carried out by Fernández et al. (2014). For instance, the indicator ‘Specific water consumption’ has been selected over other possible ones like ‘Rate of type of water”, because the latter does not evaluate all the water in the whole process, but only of those processes that work with a certain type of water. The same happens with indicators concerning chemical agents, effluents and gas emissions.

The selection of the indicator ‘Operating costs of environmental protection’ incorporates the economic impact from the viewpoint of environmental protection related to the operations performed in the waste management facility. This is not the case in other possible suitable indicators such as ‘Environmental aid granted by the Government’ in which, besides taking into account mainly economic factors, there is no reference whatsoever to the management process.

Regarding the quantification of the system outputs, in the case of the indicator ‘Total share of profitable solid’, this more global indicator has been chosen rather than ‘Total amount of profitable solid with respect to energy consumption’, in which the usable solids are quantified, but only taking into account the input of energy to the process.

Regarding the indicators corresponding to the environmental conditions that affect the treatment processes, it has been selected the ones referring to the climate characteristics of the area most liable to affect the waste treatment system, such as rainfall and speed. Regarding the living conditions, the most representative indicators of this level have been chosen, such as the ‘natural heritage affected’ and the ‘Proximity to local populations’ without going into details about the classification or type of soil (rural or urban).

Set of treatment solutions

By the ‘alternative selection chart’ (Fernández et al., 2014) the different treatment solutions are identified, obtaining six possible treatment alternatives:

- Alternative 1 A. Ceramization
- Alternative 1 B. Vitrification
- Alternative 2.1 A. External manager of hazardous solids
- Alternative 2.2 A. Phytoremediation
- Alternative 2.2 B. Bioremediation
- Alternative 2.2 C. On site vitrification

Each of these alternatives is comprised of a set of treatments that start when the waste enters the facility and ends when the final product is obtained. To summarize, they are identified only with the name of the last valorization treatment applied to the waste. The treatments that constitute each alternative are described below.

In the alternative selection chart, the waste material goes through a series of initial considerations such as its categorization as a non-radioactive, hazardous and valuable slag, according to its initial classification. Afterwards, the sludge is dried to be submitted to a magnetic separation process. As a result, the solid magnetic fraction is usable while the non-magnetic part goes back into the decision process. This non-magnetic solid could be recovered (alternative 1) or not (alternative 2). If the recovery of such fraction is chosen, it would be possible to apply the treatments of ceramization (Alternative 1 A. Ceramization) or vitrification (Alternative 1 B. Vitrification). In the case of not choosing to recover the waste material (alternative 2), it must be determined if it is legally disposable or not. In this particular case, it would not be disposable, since, according to the legislation and the initial characterization, this waste material contains a series of toxic components that surpass the legal thresholds. Therefore, at this point, there are two options. The first one would be not treating the waste internally but carrying it instead to an External manager of hazardous solids (Alternative 2.1 A). The second one would be treating the waste internally, with these different treatment possibilities: Phytorremediation (Alternative 2.2 A. Phytoremediation), Bioremediation (Alternative 2.2 B. Bioremediation) or onsite vitrification (Alternative 2.2 C. On site vitrification).

Results

The five proposed locations are assessed using the eleven selected indicators that constitute the decision criteria of the AHP method (Fernández et al., 2014), which corresponds to the last stage of the methodology, *Evaluation of alternatives*, giving the results of the study. This way, the influence of weather conditions is opposed to the proximity to population areas, industrial zones, rural areas, nature reserves, etc. in the treatment processes. In this stage, the environmental impacts are taken into account when assessing the indicators. Therefore, each management solution will have a different score.

In the calculation of the judgment matrix by paired comparison of the treatment alternatives for each of the criteria or indicators related to the environment, the weights of each of these criteria vary depending on each location. For instance:

- In damp and rainy locations, landfill treatments produce more leachates than in drier climates. As a consequence, in Avilés or Lázaro Cárdenas, a higher quantity of liquid effluents and alternatives such as 2.2 A Phytoremediation and 2.2 B Bioremediation would be generated and, therefore, they receive a worse assessment than others such as 1A Ceramization. On the contrary, Newcastle and Beijing have a lower amount of effluents and the alternatives 2.2 Phytorremediation and 2.2 B Bioremediation obtain a better assessment.
- In locations with high wind speed, gas pollution moves to other nearby areas such as population centres or natural parks. In these cases, the criteria or indicators ‘Affected natural heritage’ or ‘Operational costs of environmental protection’, become negative factors or criteria when assessing certain treatments. This would be the case of towns such as Avilés or Tubarao, where the scores of valorization processes such as ceramization or vitrification are lower than those corresponding to landfill or shipping to an external manager of hazardous solids.

Taking into account this calculation and the weights of indicators according to the area where the treatment facility is located, the following scores are obtained in *Table 4*.

Table 4. *Hierarchical analysis method solutions in different locations*

Alternatives	**Alternative priority vector**				
	Avilés Industrial	**Lázaro Cárdenas Rural**	**Tubarao Rural**	**Newcastle Industrial**	**Beijing Industrial**
1 A Ceramization	**0.2635**	**0.2705**	**0.2602**	0.1857	0.1857
1 B Vitrification	0.2429	0.2516	0.2459	**0.1923**	**0.1937**
2.1 External manager of hazardous solids	0.2386	0.2381	0.2371	0.1801	0.1788
2.2 A Phytoremediation	0.0794	0.0882	0.0803	0.1776	0.1853
2.2 B Bioremediation	0.0692	0.0702	0.0703	0.1378	0.1393
2.2 C On site vitrification	0.1063	0.0814	0.1062	0.1265	0.1173

It can be noticed that the best-valued treatment alternative in each location, that is, the one with the highest value or score, vary in the different sites. The alternative 1A. Ceramization is the preferred option in the first three locations (Avilés, Lázaro Cárdenas and Tubarao) while in the other two (Newcastle and Beijing) the highest score is for alternative 1B Vitrification.

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In all cases, a better assessment is given to the alternatives that end with the waste valorization (ceramization and vitrification) compared to those of final treatment (landfill, - phytoremediation and bioremediation - and external manager).

Discussion

According to the solution proposed by the methodology as the most suitable one, two sets of groups can be identified: one in which the highest score is 1 A Ceramization and another in which the final result is 1 B Vitrification.

In order to describe in a better way what is observed in *Table 4,* the distribution of two localities is shown in *Figure 2,* Lázaro Cárdenas belonging to the first site and Beijing belonging to the second, in the first case, the scores appear more concentrated in the treatment processes and external manager, while in the second the scores are similar.

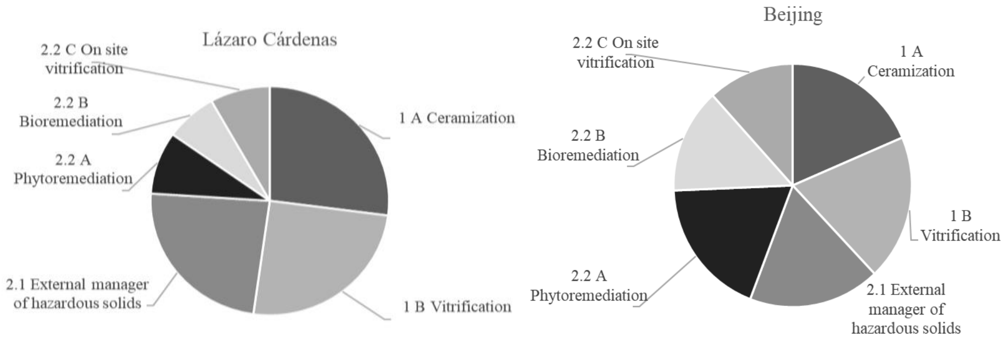

Figure 2. *Priorities of treatment alternatives according to location*

The scores given by the experts to the different treatment alternatives in the comparative analysis, depending on the selected criteria or indicators, vary due to the following causes:

1. Leachates can appear in damp and rainy climates so, as a consequence, the landfill treatment alternatives (phytoremediation and bioremediation) have poorer scores. This is what occurs in the first three locations (Avilés, Lázaro y Tubarao), for having more rainfall than the other two (Newcastle and Beijing).
2. On the other hand, the landfill treatment alternatives obtain higher scores for the good results obtained by these techniques in climates with less rainfall, as in the case of Newcastle. According to different studies (Sharma and Pandey, 2014; Liphadzi et al., 2005) the plants and microorganisms used in these areas (Yadav and Hassanizadeh, 2011; Hejazi et al., 2003) develop their activity effectively by clearing the soil of heavy metals due to favorable weather conditions.
3. Gas emissions occurring near rural areas where the natural habitat is more diverse, such as Lázaro Cárdenas and Tubarao, generate more environmental impact than in industrial areas, which favours the scoring of alternatives that include landfilling, such as 2.2 A Phytoremediation, 2.2 B Bioremediation, diminishing the scoring of the alternatives that do not include it, such as 1 B Vitrification and 2.1 A External manager. These impacts also occur in Aviles,

but since it has an industrial environment, the natural and rural heritage is less affected, so landfill scores do not rise as much as in rural locations.

4. Wind speed is similar in all studied locations, although the highest wind speed corresponds to Avilés. In this area, emissions in the form of leaks that can break into the atmosphere are more likely to be dragged to further area, thus extending the range of pollution. This makes the valorization processes more expensive than those of landfilling or manager dispatching. On the contrary, the opposite case occurs in the rest of the locations where the wind speeds are softer.

In the first analysis, the operability of the methodology was proved (Fernández et al., 2014), a locality with specific environmental conditions was chosen and the scores of the treatment alternatives were calculated, being the highest alternative 1A ceramization.

In this research, in which the type of waste and the evaluation criteria are the same, besides demonstrating the characteristics of the methodology described in the materials and methods section; adaptability, applicability, flexibility, user-friendly, easy to update; the treatment solutions obtained in each of the five locations have been compared, it can be observed that the changes in the environmental conditions of the site established at the beginning of the analysis differ significantly, therefore the evaluation of the indicators changes and, consequently, the results vary.

Conclusions

This study has implemented the methodology by Fernández et al. (2014) in order to select the most suitable treatment alternative to the same waste in five different locations. The results obtained show that the best solution may vary when environmental conditions are significantly changed.

In the case studied, the treatment of LD sludge, when analyzing the influence of the climatic and environmental conditions of the location in the different treatment processes, the following results were obtained:

A high-level rainfall constrains the suitability of the landfill treatments, since in this context there is a higher-level generation of leachates.

- The gas emissions produced at the output of some treatments (vitrification or ceramization), combined with the wind conditions may have a negative impact in rural locations or other places, as for instance natural reserves or protected areas. This makes these treatments less suitable. On the contrary, if these conditions are in industrial areas or its proximity, it has a less negative impact.
- In the case of the developed methodological process, a series of inherent characteristics of the methodology are reviewed and checked:
- Its applicability and flexibility, allow the use of the most suitable criteria or environmental indicators in each case, more or less according to the number of criteria of study required for each case.
- Its simple upgrading. This makes it easier to add new waste treatment techniques to the valorization decisions or treatment requirements included in the alternative selection chart.

Within the future lines of research in this study, the analysis developed can be perfectly extended to other similar facilities located in other cities under different climatic and environmental conditions, being able to obtain a different solution in a changing environment.

The same methodology can be applied in other industrial sectors (glass, textiles, mining, etc.) that generate other types of waste (liquid effluents, wastewater and gaseous emissions) and as a result with different treatments to those described above, allowing to personalize the system of general indicators and develop an alternative selection diagram similar to that exposed.

In the same way, another series of criteria can be incorporated into the study, either parameters related to the social or economic conditions of the environment, or other factors that could have a critical role in the security of the waste storage and other outputs, using the extensive system of indicators that includes the methodology or incorporating new indicators if necessary.

Finally, a software could be developed to support this methodology, allowing for each of the treatment alternatives, the quantitative determination of effluent outputs, energy consumption, chemical agents, etc.

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