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Performance Indicators for Leachate Management: Municipal Solid Waste Landfills in Portugal

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1. Introduction

The significant concern of leachate management refers essentially with water, groundwater, and soils pollution, determining the need of adequate treatment for discharged in water, soil, or wastewater collection networks.

Leachate generation is an inevitable consequence of landfill waste disposal. An adequate landfill leachate collection and treatment allows proper environmental protection and prevention of surface water, groundwater, and soils contamination. It also minimises operational costs in the overall landfill management. The design and construction of leachate treatment plants strongly depends on the quality and quantity of the raw leachate, which in turn is influenced by numerous factors, including rainfall, waste composition, age of fill, landfill design and construction and operational procedures (Qasin e Chiang, 1994).

A detailed knowledge of local leachate management and treatment allows the identification of specific setbacks and constrains that need resolution, on an operational management view as well as with legal decisions to be made for leachate treatment performance.

In 2008, an assessment on the status of Portugal mainland's Municipal Solid Waste (MSW) landfill leachate management was developed (Martinho et al., 2008, 2009). The main objectives of this study intended to (Martinho et al., 2009):

- Evaluate current status on leachate generation and treatment in MSW landfills;
- Develop and apply performance indicators and other relevant context information that enables benchmarking analysis, regarding leachate treatment plants;
- Identify and determine constraints (i.e. environmental, operational, and economical) related to leachate generation and treatment on a national context and possible minimisation measures;
- Identify practices and tendencies in the field of leachate treatment technologies mainly in other EU Member States, and application on a national basis.

Performance indicators have been developed for water and wastewater services. (Alegre et al., 2004; Matos et al., 2004). The structure was designed to assess the performance of Management Entities (ME) that provide these services, in terms of their activities and intervention areas. Regarding waste management, Cunha and Simões (2010) describe the existing performance indicators used by the Portuguese Water and Waste Regulatory

(IRAR), for monitoring service quality of the wholesale segment of the waste service in Portugal. These performance indicators allow IRAR to develop a benchmarking analysis, on an annual basis, for the regulated waste ME.

In the matter of leachate management and consequent proper environmental protection, performance indicators and other relevant context information may be a valuable tool. In this case, one of the activities of the MSW ME is subject to benchmarking analysis: treatment and management of leachates generated in MSW landfills, in contrast to the overall performance of the operators.

In this chapter, a set of performance indicators (e.g. environmental, economical, operational, human resources, service quality, and opinion) for MSW landfills leachate treatment and management are defined and proposed. Considering the Portuguese case, a background on national MSW landfill and leachate management is given. The results obtained with the proposed performance indicators, as well as relevant context information, applied to Portuguese ME and leachate treatment facilities, will be presented in detail. Possible future directions in landfill operation and leachate treatment technologies to be applied will also be discussed.

2. Leachate management: municipal solid waste landfills in Portugal

Landfilling is the terminal operation of the waste management system, where non recyclable waste or waste that cannot be subject to valorization, is eliminated through deposition above or below the land surface. It is an essential component in any waste management system. The efforts for reduction, reuse, valorization, recycling and incineration can reduce waste quantities, however residual materials still remain and need adequate final destination.

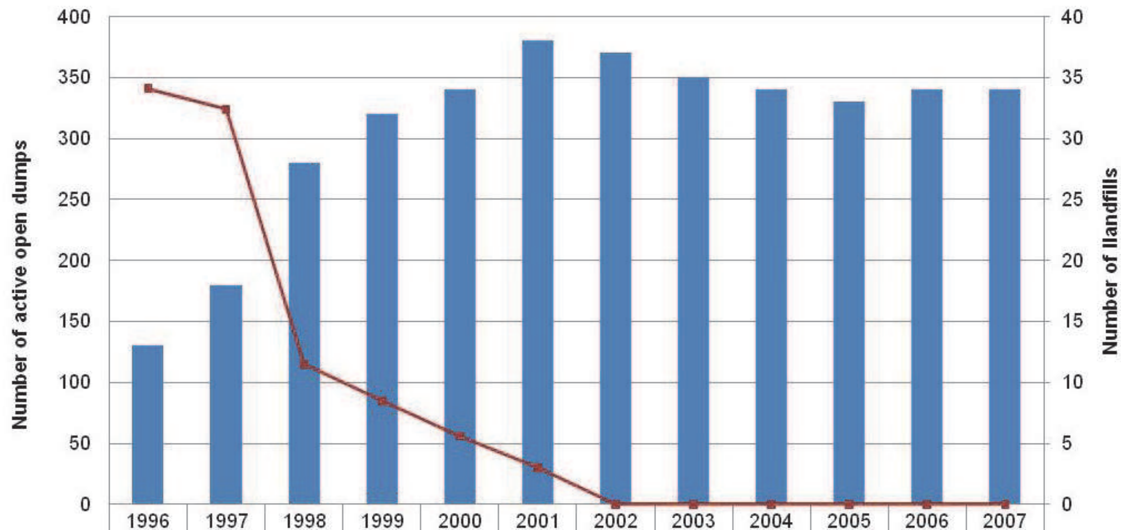
In the European Union, the Landfill Directive (Directive 1999/31/CE of the Council, 26 of April) defines legal framework on landfills. It establishes measures, processes and guidelines that avoid or reduce, as possible, the negative effects on the environment, especially regarding surface water, groundwater, soil and air pollution, as well as the risks posed by these effects on human health, resulting from landfill disposal (EC, 1999).

In Portugal, the first Municipal Solid Waste Strategic Plan (PERSU I) was published in 1997. It established the main strategic guidelines that allowed the eradication of the 341 open dumps referenced in 1995. It also promoted the construction of landfill infrastructures providing adequate MSW final destination. The Landfill Directive was transposed to the Portuguese law in 2002 by the Decreto-Lei n. º 152/2002. Figure 1 shows the evolution of the number of landfills and open dumps existing in Portugal, between 1996 and 2007 (Portuguese Environment Ministry [MAOTDR], 2007).

In 1996, 13 landfill facilities already respected part of the guidelines of the Council Directive proposal on waste disposal in landfills (97/C156/08). With the publication of Decreto-Lei n. º 152/2002, in 2002 all open dumps were closed and 37 landfills were operating according to Landfill Directive's specifications.

In 2007, five million tonnes of MSW were generated in Portugal. In the start of the second Strategic MSW Management Plan (PERSU II) that defines the existing mechanical biological treatment plants amplification and the construction of new plants in the next years, the quantities landfilled still achieved 63% of the generated MSW (IRAR and Portuguese Environment Agency [APA], 2008).

In terms of MSW management models, by the time the first strategic plan was published, in 1997 (PERSU I), there were 40 MSW management systems, where 11 were managed by



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Landfills	13	18	28	32	34	38	37	35	34	33	34	34
Open dumps	341	324	115	85	56	30	0	0	0	0	0	0

Fig. 1. Evolution of number of landfills in operation and active open dumps in Portugal between 1996 and 2007

concession entities (i.e. owned by public entities and the local municipalities) and 29 were managed by the local municipalities. Currently there are 29 MSW ME responsible for 14 closed sanitary landfills and 35 sanitary landfills in operation, all generating relevant quantities of leachate.

Considering the significant evolution of the national waste management system and the effective consolidation of the hierarchy principle for waste management options, the landfills legal framework was revised by the Decreto-lei n. º 183/2009. National legislation on landfill disposal obligates control and monitoring processes on leachate, groundwater, superficial water and leachate basins, both in the landfill operational and post-closure phases. Besides imposing on landfill operators the existence of leachate collection, adequate treatment, and final disposal, it also determines monitoring parameters and frequency for leachate, groundwater and surface water control in all landfill phases.

Discharge of leachate in streams, lakes, and soils is defined by Decreto-Lei n.º 236/98. It establishes norms for domestic and industrial wastewaters discharge to superficial and coastal waters, groundwater and soil, as well as to wastewater sewer systems.

In terms of legal requirements related to Integrated Pollution Prevention and Control (IPPC), all non-dangerous landfill operators, should obtain an Environmental License (EL) defined by Decreto-Lei n.º 194/2000. The EL defines that each operator must proceed with landfill leachate control, determining emission limit values for discharge on water and collection systems, with type and monitoring frequency. Limit values are defined for each infrastructure, although with respect to the definitions on Decreto-Lei n.º 236/98 and with the monitoring and control processes defined by landfill legislation.

3. Methodology

3.1 Performance indicators for leachate treatment and management

The performance indicators defined were based on the structure developed for water and wastewater services (Alegre et al., 2004; Matos et al., 2004). This structure was designed to

assess the performance of ME that provide these services, as the overall performance of their activities and intervention areas. The intent of this work was more restrict. It aimed to assess one of the activities of the MSW ME: the MSW landfill leachate management, in contrast with the overall performance of the management entities. However not specifically defined as performance indicators, opinion indicators were added with intention to translate managers and technicians' perception about LTP operation and performance.
Relevant context information on ME and LTP were also included to have a main outline of their characteristics in the overall performance indicators. The adopted performance indicators groups for the purpose of this study are described as follows.

3.1.1 Environmental indicators (iAmb)

Indicators included in this group allow the assessment of the ME regarding the environmental impact of Leachate Treatment Plants (LTP). In terms of leachate treatment and discharge, indicators were defined by the percentage of disposal facilities where generated leachates are treated on-site in LTP or at Public Works Treatment Plants (PWTP) and percentage distribution of landfills by leachate discharge (i.e. water lines and municipal wastewater collection systems). The conformity with legal environmental monitoring and control and discharge norms were also considered, in terms of percentage of unconformities (i.e. raw leachate, groundwater and superficial water monitoring, leachate basins and other monitoring requirements), as well as the percentage of operational and environmental landfill licences. Indicators regarding treated leachate reutilisation, production and disposal of sludge and concentrates from membrane treatments were also considered relevant. In addition, indicators of upstream conditions that could influence LTP operation were considered: leachate production per landfill area, per landfilled waste volume and weight, annual leachate production per precipitation volume and biodegradable waste fraction in landfilled waste. For this group 22 indicators were defined.

3.1.2 Human resources indicators (iHR)

In terms of human resources, eight indicators were defined to assess human resources characteristics that are directly affected to LTP operation and maintenance, namely: number per volume of treated leachate and population equivalent, percentage of gender, qualifications (i.e. graduate education, secondary or other qualifications), operators percentage with specific education in leachate treatment and formation actions, in hours per year, by operator.

3.1.3 Operational indicators (iOP)

This group of indicators aims to assess the performance on operation and maintenance activities. It includes the percentage of leachate recirculation, storm discharge frequency, frequency of damages/problems per year (i.e. operational, logistics, personnel and other) parameter analyses performed (in percentage of the legally required) to leachate, groundwater and superficial water; number of maintenance inspections per year and water and energy consumptions per volume of treated leachate. A total of 12 indicators were proposed in this group.

3.1.4 Financial and economic indicators (iEF)

With the objective of assessing financial and economic considerations with leachate treatment and management, 15 indicators were defined. These include current expenses and capital unit costs, by leachate volume and population equivalent, unit investment, expansion or substitution unit investment, amortisations in the year of reference, costs fraction by personnel, energy, and other current expenses costs components.

3.1.5 Service quality indicators (iSQ)

In the particular case of leachate management and aiming to assess the performance of ME's leachate management quality of service, five indicators were included in this group, mainly referring to leachate treatment efficiencies and conformity with discharge limits.

3.1.6 Opinion indicators (iOpin)

With the intention to translate managers and technicians’ perception about LTP operation and performance, six indicators were defined. A 5-point Likert scale was used to determine the opinion related to leachate treatment processes level of adequacy to raw leachate volume and quality, removal needs in terms of discharge option (water line or wastewater collection system), daily activities of LTP operation, number of operators adequacy and overall perception of LTP operation.

3.1.7 Context information

Aiming to account specific ME characteristics in the overall performance indicators, 28 context information variables were considered. This group included the total number of disposal facilities and distribution by operational landfill, closed landfills and old dumps existing within the ME intervention area, as well as the distribution in terms of surface area, waste volume and number of LTP. This information is relevant for a better framework on the ME.

On the other hand, information regarding disposal facilities, namely disposed waste volume and weight, percentage of biodegradable waste disposed and average annual precipitation were considered necessary variables for several performance indicators. Other information regarding landfill age, and conformity with the original design were also considered relevant for the overall analysis.

3.2 Questionnaire survey

For the purpose of application of performance indicators proposed to the Portuguese context, the analysis instrument used was a questionnaire survey to all MSW ME that managed MSW landfills LTP (i.e. 28 of 29). The objective of this survey was to collect relevant information related with the ME, quantity and origin of MSW landfilled, landfill characteristics, quantity, and quality of leachate and landfill gas generated, type of leachate treatment and final destiny.

The adopted logic for questionnaire development was broadness and flexibility, in order to adapt to MSW management models and to ensure a global and comparative result analysis. To ease questionnaire answer by the ME and improve response rate, given the extensive information to be gathered, the questionnaire was divided in two documents: Questionnaire1 and Questionnaire 2. The first was developed to collect more context information and general on ME, characteristics on MSW landfills where leachates are generated, including rainfall historical registry, type of leachate treatment and final destiny. The second questionnaire was prepared to gather more specific and technical information on characteristics, operation, costs analysis and human resources affected to LTP.

Questionnaire 1 was sent to all 28 ME that managed landfills with LTP. The one exception referred to a ME that manages two MSW landfills where leachate discharge is done directly to the local wastewater collection, for complete treatment at PWTP. With this questionnaire, a 93% (26 ME) response rate was obtained. The response rate obtained for Questionnaire 2 was 89% (i.e. 25 ME).

For the analysis phase, technical visits to all ME (i.e. 29) and LTP (i.e. 32) were also defined. These visits intended to verify actual LTP operational conditions, as well as to collect other pertinent information from landfill and LTP operators and managers. The information acquired in these visits regarded operational problems and conditions with leachate treatment and possible measures/modifications or reconversion plans previewed for the future. Another purpose for these visits was to clarify questions related with the questionnaire survey.

Taking in account the existing ME, leachates characteristics and treatment, previous studies, as well as current legal aspects landfills management, specially on leachate control and monitoring, 92 variables were selected and organised along with the questions of the survey (questionnaires 1 and 2). With these variables, 20 context information indicators and 69 performance indicators were considered.

All performance indicators, except opinion indicators, translate in general, variable ratios and refer to a one-year period (e.g. 2006).

4. Results and discussion

Main results obtained with methodology developed to apply performance indicators to leachate management in Portugal are presented in the according to the groups defined in section 3.1.

4.1 Context information

Context information was valuable to assess ME characteristics, existing disposal facilities, and LPT. Of the 29 ME, 26 reported 282 landfill infrastructures existing in their management area, with the distribution presented in Figure 2.

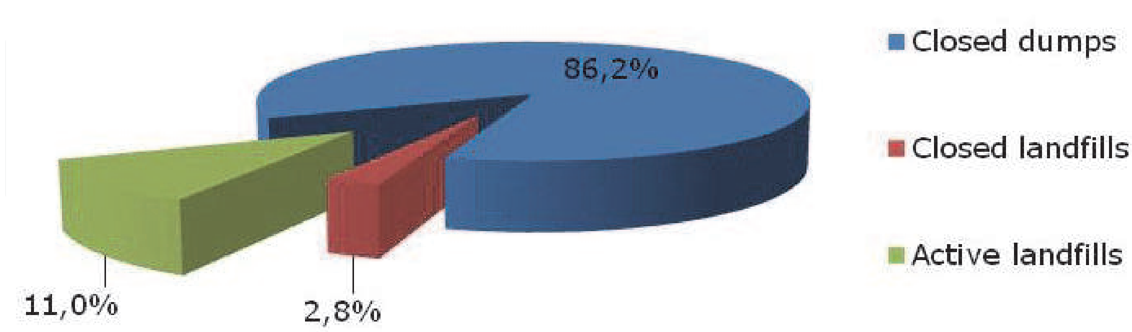


Fig. 2. Distribution of the number of disposal facilities reports by the ME

In terms of area and volume of the infrastructures where leachates produced are treated in LPT, results vary between 1.9 ha and 20.8 ha, or 190 906 m^3 to 2 501 022 m^3 of landfilled waste, which include old dumps, closed landfills and operational landfills.

The age of the 31 reported landfills (e.g. one closed landfill and 30 in operation), with the year 2006 in reference, varies between three and 10 years, or an average age of 6 years.

Most landfills (56%) were more than five years old and 34% were operational for seven years.

LTP leachate treatment processes are presented in Table 1. LTP treatments that include reverse osmosis membranes as final treatment for effluent discharge in streams represent 31% of the LTP. In two LTP (3%), macrophyte beds are used as final process. Eight LTP (25%) have treatment systems composed of activated sludge followed by physical and chemical treatments for partial treatment on-site, with following final off-site treatment at PWTP.

Treatment	Number of LTP	%
Aerated lagoon + reverse osmosis	5	15.6
Regularisation lagoon + reverse osmosis	1	3.1
Activated sludge + reverse osmosis	4	12.5
Physical and chemical treatment + evaporation + condensation + activated sludge	1	3.1
Stabilisation lagoons + aerated lagoon + macrophyte beds	1	3.1
Aerated lagoons	3	9.4
Stabilisation lagoons	1	3.1
Aerated lagoon + physical and chemical treatment	1	3.1
Aerated lagoon + macrophyte beds	1	3.1
Activated sludge	1	3.1
Activated sludge + physical and chemical treatment	8	25.0
Physical and chemical treatment + activated sludge	2	6.3
Physical and chemical treatment + Filter + activated sludge	1	3.1
Filter + activated sludge + physical and chemical treatment	1	3.1
Aerated lagoon + Filter + physical and chemical treatment	1	3.1
Total	32	100.0

Table 1. Distribution of LTP treatment processes

Of the 35 MSW landfills in operation plus one closed landfill that has a LTP, only four (11%), discharge generated leachates directly to wastewater collection systems for complete treatment at PWTP (Figure 3). The remaining 32 landfills have LTP, either to perform partial treatment for discharge to off-site treatment facility (i.e. 44% or 16 of 36 landfills) or complete treatment on site for further release to local stream (i.e. 42% or 15 of 36 landfills), existing one landfill where leachate discharge is null.

Of the 32 LTP, 19 were operating with no modifications previewed, eight had modifications previewed and five were deactivated for treatment system's modification.

In terms of LTP inclusion in the landfill original project, of the 30 LTP reported, 84% were designed and included in the landfill's design phase. In the remaining cases, landfills were designed and constructed before 1998, when it was still not legally determined LPT integration in the landfill design phase. Only 65% of the LPT were constructed according to original design. The main reasons pointed by the ME refer to the inability of the design treatment systems to comply with legal discharge limits, which resulted in LTP reconstruction.

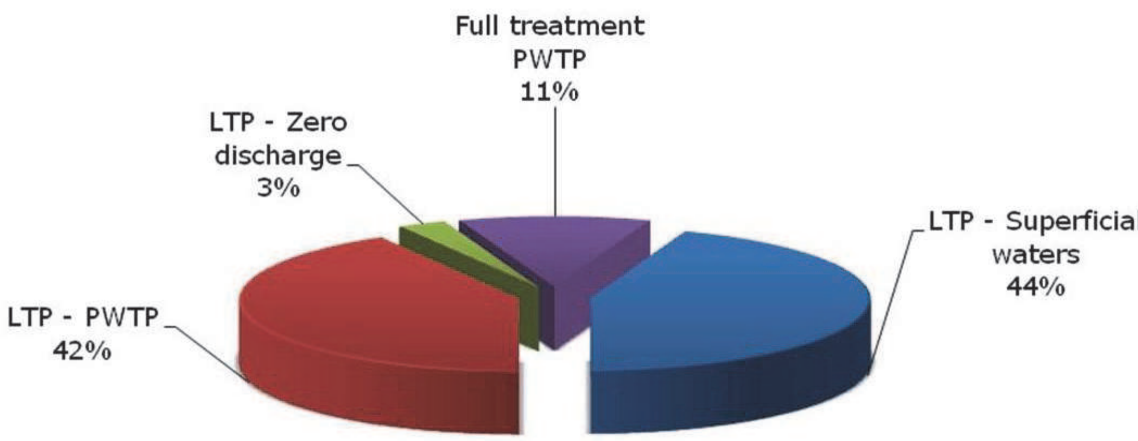


Fig. 3. Distribution of treatment systems and leachate discharge of MSW landfills

4.2 Environmental performance indicators

Leachate destination of the 282 landfilling infrastructures reported by the ME was only given for 26% of the cases. Of the total 282, final destination of leachates produced at 204 old dumps was not given (74%), 15% of the remaining infrastructures discharged produced leachates for partial or full treatment at LTP and 11% discharged leachates directly to sanitary sewers for full treatment at PWTP.

Of the remaining 38 of the 243 old dumps reported, nine discharged produced leachates in nearby landfill's LTP and 29 directly to sanitary sewers. About the eight closed landfills reported, four discharged generated leachates to nearby landfill's LPT and four to local sanitary sewers. Regarding the existing 35 landfills in operation, 89% (31) had LTP on-site either for partial or full treatment and the remaining 11% (4) discharged produced leachates directly to sanitary sewers.

Other environmental indicators refer to control and monitoring conformity with a number of legal demands, defined either in the landfill national legislation or in the landfill's environmental license, when existed. In terms of leachate control, according to the data retrieved from the ME, 61% of the 30 landfills reported did not show any unconformity. About groundwater control, 45% of the landfills revealed unconformities in the parameters that should be monitored. Considering superficial water control only 3% of the landfills revealed unconformities.

In terms of sludge produced by the leachate treatment systems, final destination reported was landfilling after dehydration processes. In the case of reverse osmosis membrane processes, concentrates are mainly recirculated to the landfill, according to the ME.

As indication of volume of leachate produced as a fraction of annual precipitation, results obtained for landfills reported by the ME were on average 41%. Only in the case of seven landfills, the values obtained were within the literature values of 15% and 50% (Ehrig, 1998).

In addition, relevant indicators for leachate production estimations were the results obtained for leachate production by area and by volume of landfilled waste (Figure 4 and Figure 5). The averages obtained were 3800 m^3 of leachate produced per hectare of landfilled waste per year and 0.039 m^3 of leachate per cubic meters of landfilled waste per year. These results exceed literature values. Bicudo e Pinheiro (1994) referred 2000 $m^3/(ha.year)$ and MacDougall et al. (2001) referred 0.005 $m^3/(m^3.year)$.

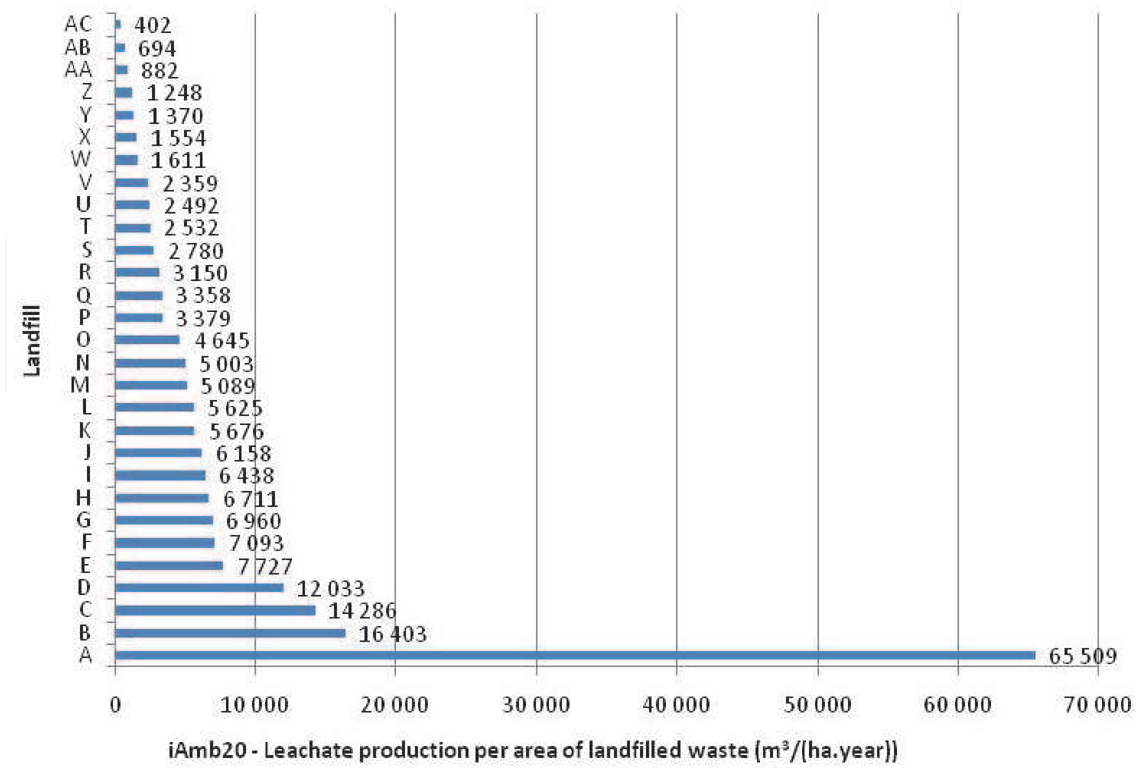


Fig. 4. Leachate production per area of landfilled waste per year for reported MSW landfills

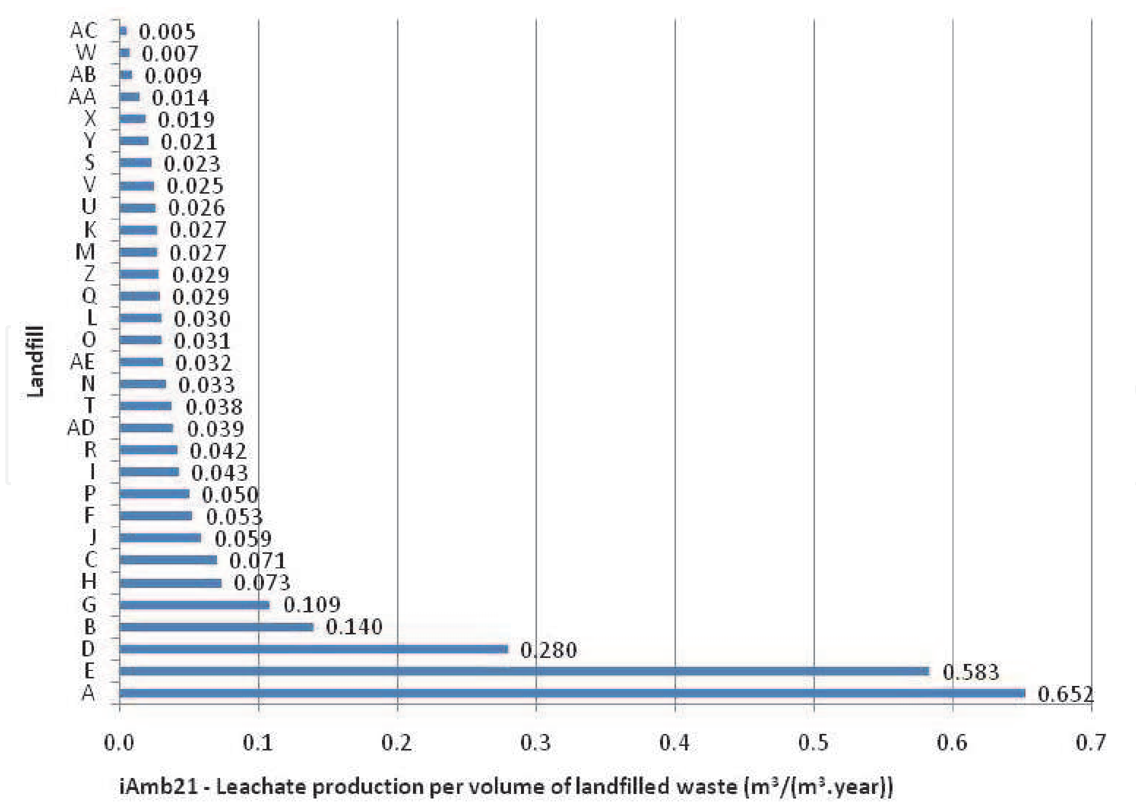


Fig. 5. Leachate production per volume of landfilled waste per year for reported MSW landfills

4.3 Human resources performance indicators

Human resources indicators determined, reveal that the 22 LPT where information was reported, 60% only have one operator, 31% two operators, and 9% three operators. It should be noticed that the number of operators reported by the ME in general do not account for the superior technician responsible for the LTP management. It is also noticed that in the case of small LTP operators are not entirely affected to LTP operation.

Concerning specific learning on LTP operation, only five cases referred conducting annually learning actions on LTP, mainly where reverse osmosis processes are used and in the case of the evaporation condensation treatment system.

4.4 Operational performance indicators

About problems identified on LTP functioning, ME reported in general operational and logistics problems and in a lesser extent personnel and other problems (Table 2). The operational problems identified were in general equipment damages, leachate storage capacity limitations, raw leachate quality treatability, as well as, in the case of reverse osmosis membrane reactors, high maintenance needs. Of the 23 ME that reported these problems, 40% indicated a monthly frequency and 32% a weekly frequency. In terms of logistic problems, eight ME reported mainly reagents supplies problems, three of them with a monthly frequency, other three rarely (i.e. once a year) and one with a daily frequency. Four ME, one with an annual frequency and three on a weekly basis reported personnel problems. The mentioned problems refer to lack of specialized personnel for the treatment system's operation. Five ME also mentioned other problems with a monthly frequency, however not specifically defined.

Problems	Operational	Logistics	Personnel	Other
Type	Equipment damages Leachate storage capacity limitations Reverse osmosis membrane reactors, high maintenance needs Raw leachate quality treatability	Reagents supplies	Lack of specialized personnel	Not specified
Frequency of occurrence	23 reported: -13% weekly -32% monthly -40% per trimester -13% yearly	8 reported: -1 weekly -1 monthly -3 per trimester -3 yearly	4 reported: -1 weekly -3 yearly	5 reported: -5 weekly

Table 2. Problem types and frequency of occurrence at reported LTP

Regarding leachate and groundwater monitoring and according to the information given by the ME in the questionnaires of 27 landfills, in 21 (78%) 100% of the number of leachate parameter analysis defined in the legislation or in the landfill environmental license were done. Five landfills performed between 80% and 99% of the total number of analysis. As for groundwater monitoring where information was given, 54% (i.e. 13 of 24 landfills)

performed all parameter analyses legally defined, seven landfills between 80% and 99%, and the remaining four landfills below 79% of the number of groundwater parameter analysis.
LTP energy consumption was also determined and an annual average of 11.1 kWh/m^3 of leachate was obtained, with values varying between 1.8 kWh/m^3 and 38.0 kWh/m^3.

4.5 Financial and economic performance indicators

Concerning LTP cost analysis, the performance indicators attempted to translate LTP overall costs. Results are based on the information reported in the questionnaires, however ME only reported this information for 17 LTP, lacking information on few cost components in some cases. On the other hand, the values obtained are relevant for reference and comparison between the LTP treatment systems.
Average overall unit costs (i.e. per unit of raw leachate treated in LTP) for the year 2006 was 8.8 €/m^3, 6.1 €/m^3 referring to current expenses costs and 2.7 €/m^3 to capital costs (i.e. capital amortizations in 2006). In terms of main treatment systems, treatments that use macrophyte beds revealed to be the less expensive (2.4 €/m^3). The evaporation /condensation process, recently being used in one LTP, presented the highest capital costs (25.0 €/m^3). The ME did not report in this case current expenses costs and total unit costs could not be determined. Other treatments refer to all remaining treatments systems presented in Table 1. Except for the evaporation/condensation treatment system, the average unit cost for these treatments is the higher obtained (8.5 €/m^3), mainly due to one of the LTP that presented higher costs comparing with other LTP with similar treatment systems (i.e. in terms of treatment system reconstruction costs and current expenses costs), thus increasing the unit cost. Comparing with other treatments systems the reverse osmosis membrane process presented on average higher capital costs (3.3 €/m^3).
Percentage distribution of current expenses costs obtained (Figure 6) revealed that on average 67% refer to other current expenses costs (e.g. reagents, equipment rental, service acquisitions and other costs), 23% refer to energy costs for LTP operation, and the remaining 10% to personnel costs.

4.6 Service quality performance indicators

The main leachate contaminants (BOD_5, COD, total nitrogen and TSS) removal efficiencies were determined for 21 LTP. Taking in account the information on raw leachate and treated leachate quality monthly information for 2006, reported in the questionnaires by the ME, Table 3 presents removal efficiencies obtained for the main treatment systems.
As previously presented, treatment systems with macrophyte beds are less expensive, although the removal efficiencies are rather low (Table 3). In the case of total suspended solids, no removal was obtained. Considering the discharge to sanitary sewers this treatment option can be economic. The reverse osmosis membrane process revealed to be the most contaminant removal efficient treatment option as it is mainly used when discharge to streams is the only option. Although only COD removal efficiency was possible to determine for the evaporation/condensation process, it also shows to be a possible option, however expensive, for full treatment on-site and discharge to streams. The remaining treatments systems of nine LTP showed various removal efficiencies for the considered parameters. These treatment processes are mainly used for partial treatment on-site, and further complete treatment at PWTP. With respect to pH, all LTP effluents complied with legal limit values (i.e. pH between 6 and 9) for discharge to stream.

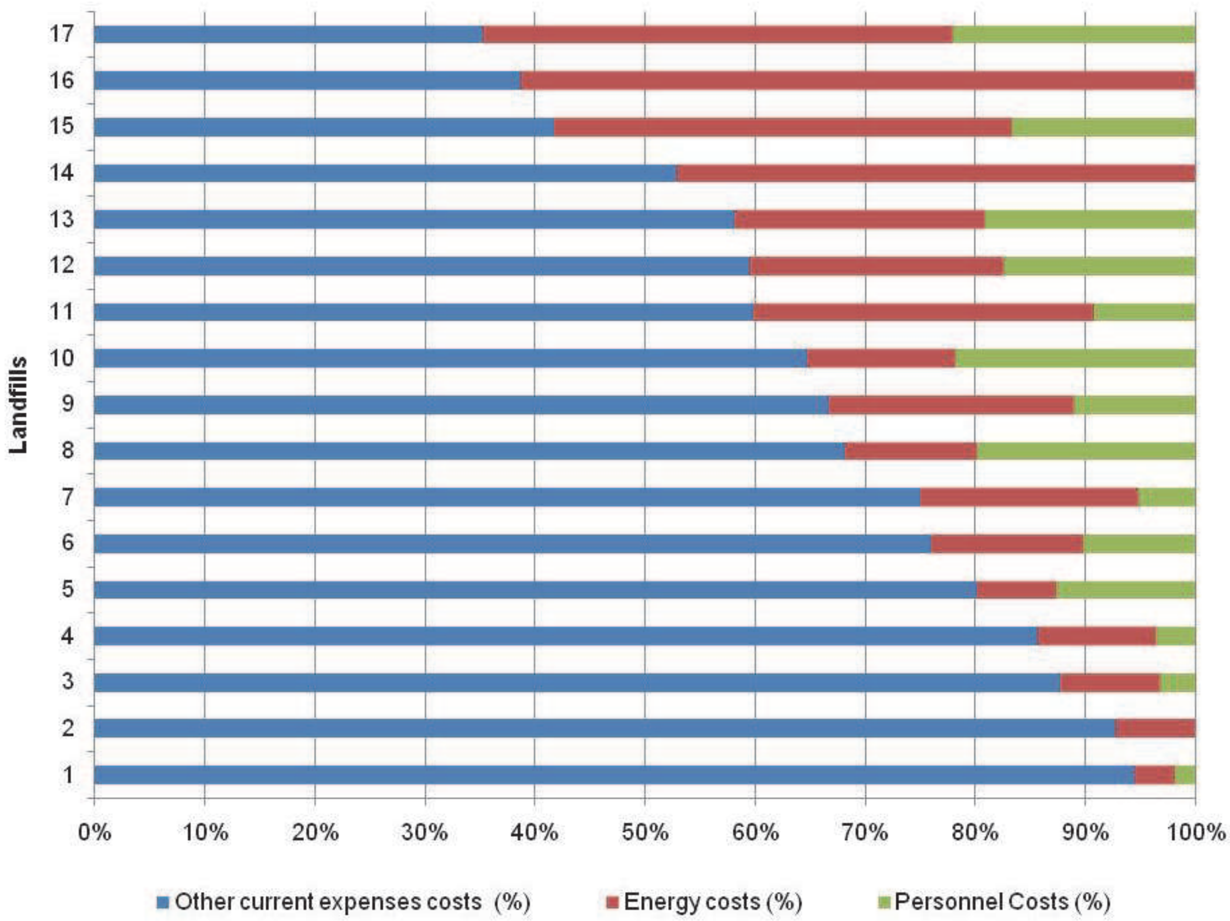


Fig. 6. Percentage distribution of current expenses costs for reported MSW landfills

Main leachate treatments	Number of LTP	Removal efficiency (%)								
		COD			Total Nitrogen			TSS		
		Min	Max	Average	Min	Max	Average	Min	Max	Average
Macrophyte beds	2	26.6	49.3	37.9	17.4	17.4	17.4	No removal		
Reverse osmosis	9	98.6	99.9	99.6	99.3	99.8	99.6	87.9	99.5	93.7
Evaporation/Condensation	1	99,9			Not available			Not available		
Other treatments	9	53.0	89.6	69.0	29.0	46.6	37.8	18.8	94.9	54.2

Table 3. Average, minimum, and maximum leachate contaminant removal efficiencies for the main treatment systems

4.7 Opinion indicators

This group of indicators pretended to transmit the questionnaires' respondent, in general LTP or landfill managers, about LTP performance. Results are presented in Figure 7. In the case of adequacy of the treatment system to leachate quantity, 48% of the respondents positioned in the middle (i.e. nor satisfied, nor unsatisfied). Similar percentage of responses

(26%) was obtained both for the positive pole (i.e. satisfied or very satisfied) and for the negative pole (i.e. unsatisfied or very unsatisfied). In terms of leachate quality, 60% of the responses were in the middle position, although 29% were negative, revealing that managers are more concerned about leachate quantity than quantity on the adequacy of the leachate treatment systems.

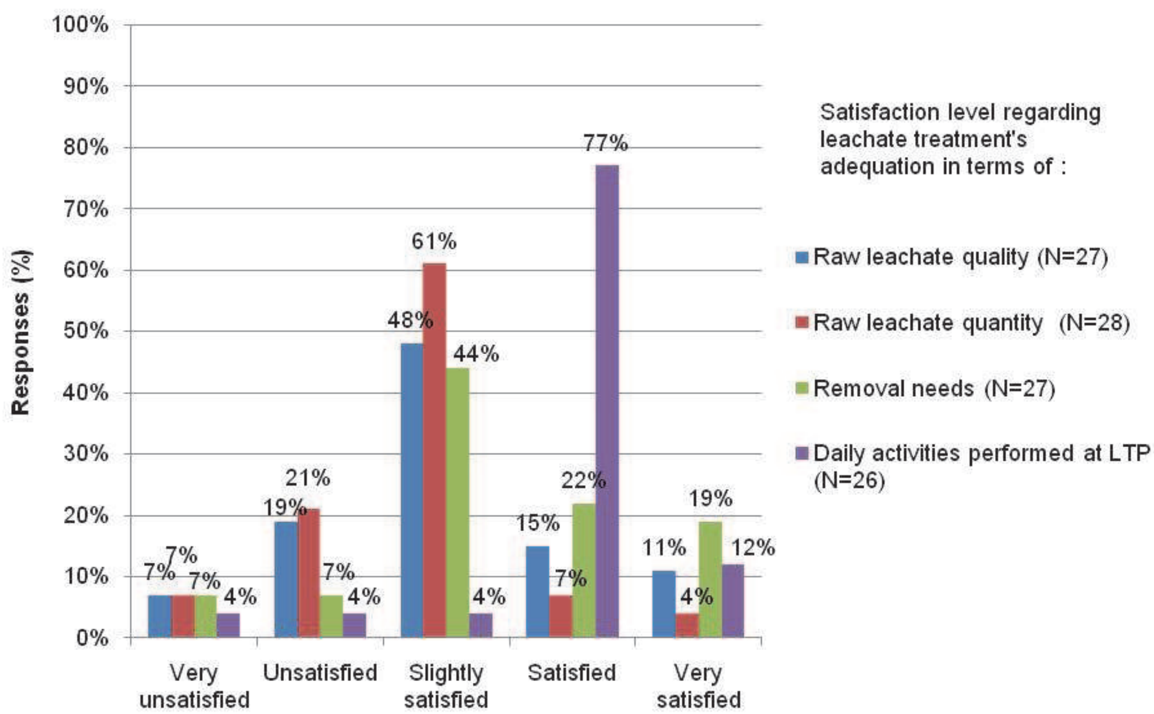


Fig. 7. Opinion indicators results

5. Conclusion

Performance indicators and relevant context information can be a valuable tool on MSW landfills leachate management assessment and benchmarking analysis. With the application of the proposed performance indicators to the leachate treatment and management in Portugal's mainland it was possible to identify the most cost and contaminant removal efficient treatments systems, among several constrains regarding the lack of specific definitions on leachate discharge quality limits to streams and lakes, considering the particular characteristics of this effluent. To discharge in sanitary systems, more economic treatments can be used, however legal definition and uniformity regarding discharge quality limits in domestic wastewater collection systems is also needed. In the case of old dumps, the monitoring and management is generally defined on national legislation. Therefore, a need for management definition and for leachate monitoring parameters generated by closed dumps would be an improvement in this matter.

On the other hand, most problems identified possibly relate to an inadaptability of general leachate production and quality models with the national specific meteorological and landfill operation conditions. On this matter, an historical assessment on MSW landfills could be developed to adapt existing models to the Portuguese context. Regarding leachate and concentrate recirculation on current operational MSW landfills, further studies to assess economic and environmental costs and benefits should also be developed. In this way, legal authorities could have relevant information for decision making in modifying existing legislation on this matter.

6. Acknowledgment

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