

LANDFILL MINING IN FLANDERS : METHODOLOGY FOR PRIORITIZATION

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SUMMARY: Within the ELFM-policy that is being developed by OVAM, a three step approach (mapping, surveying and mining) is followed. In a first step (mapping), in addition of a ELFM-database, a methodology is set up to prioritize possibilities for ELFM and prioritize risks due to contamination (remediation necessity). The *Flamenco*-model is a smart combination of those two methods to prioritize. Each part of the model is based on a multi-criteria analysis using specific weighing factors and different criteria.

1. INTRODUCTION

Use of waste as a valuable material for the economy of Flanders is a key factor in transforming the waste policy into al material policy and building a green economy. The overall goal is to diminish the input of primary raw materials and recover resources from the technosphere.

The OVAM is the environmental agency in Flanders (Belgium) which is dealing with the issues of Soil Remediation and Waste and Material Management. In 2011, a vision on Enhanced Landfill Mining (ELFM) was approved by the board of directors and resulted in an operational program over the period 2011 – 2015. The main idea of this concept is the approach of gathering materials (in its most broad definition) of a recent or an old landfill site or dumping site and reuse it for some purpose by introducing it again in the material chain. The approach makes it possible to gain important resources: materials, energy resources, drinking water and free space. A secondary benefit is that the approach is also suitable for purposes on soil remediation.

Since 1981, OVAM set up several databases containing information on (former) landfill sites. These inventories reveal the existence of more then 2000 landfills and dump sites. There is a lot of variety between the listed sites and also the level of accuracy and detail of the available data is versatile. In order to improve the quality of the data and elaborate a comprehensive ELFM-policy, a specific approach program was set up.

The OVAM developed a three step approach towards ELFM: mapping (inventory of the number of landfill sites on level of the Flemish Region, with indication of specific characteristics of the area), exploring of individual landfill sites (identification of the specific landfill body, identification of the composition of the landfilled waste, identification of the geo-physical and

-chemical characteristics of specific surroundings of the landfill site), mining of a specific landfill site (digging up of the waste, (pre-)treatment of the waste to make it suitable for material reuse or valorisation). Investigating moreover 2000 sites in a short period was unrealistic, therefore a methodology for prioritization of potential for Landfill Mining based on a multicriteria-analysis calculation tool was developed.

2. SITUATION

2.1 OVAM – Public Waste Agency of Flanders

The Public Waste Agency of Flanders (OVAM) is responsible for waste management and soil remediation in Flanders. It is established after the decree of July 2nd, 1981 covering waste management and prevention, including waste removal and soil remediation.

OVAM works out and implements its policy on waste management and soil remediation. The soil remediation decree (1995 and changed in 2007) is a powerful instrument to address historical as well as recent pollution. One of its objectives is to remediate historical pollution and prevention of new soil pollution.

Combining those two responsibilities, OVAM is best suited for developing a policy concerning (enhanced) landfill mining.

2.2 Project (Enhanced) Landfill Mining within OVAM

2.2.1. ELFM – the origin

Enhanced Landfill Mining meaning :”The safe conditioning, excavation and integrated valorisation of landfilled waste streams as both materials and energy, using innovative transformation technologies and respecting the most stringent social and ecological criteria.” is a definition used within the ELFM-consortium (<http://elfm.eu/>). This consortium is developing the concept of ELFM since 2008. Since OVAM is participating the consortium and there is no legal framework for landfill mining, the goal of the project of ELFM within OVAM is setting up that framework either by changing the decree hence by formulating a code of best practice.

The concept of landfill mining fits in the overall ambition of Flanders to reduce the consumption of resources (energy, water, material, space) by 2020. In the vision of sustainable material management the classic approach on waste management (ladder of Lansink) should change towards a green circular economy in which waste as an end-product will be transformed into a new resource. In that way, OVAM doesn't only wants to “mine” the landfills, but rather manage the available stock in a sustainable way so that it won't pose a possible risk towards the environment.

2.2.2. OVAM – ELFM – the past examples

The concept of landfill mining may be new in the above mentioned definition, in the past OVAM already set the first steps in the process. Future mining of a landfill is determined by the filling history. With that in mind and the fact that OVAM was the permitting and supervising authority, OVAM introduces in the eighties the principle of mono landfill sites. By storing for example dredging sludge on a mono landfill, the filling of the landfill site is uniform. When there will be a high-end application of the sludge, future mining will be considered rather easy and at a minimum cost. Other typical sites are landfill sites with gypsum, goethite and fly ash. A well known

example of landfill mining avant la lettre is the valorization of coal slag heaps in Limburg (eastern Flanders). In the eighties, the overburden that was removed during coal mining contained enough economical removable coal, that the slag heap was mined and 'new' coal was shipped to the coalplant.

Another example of considering future mining was the division of different type of waste to different types of landfills, example, industrial waste, municipal solid waste...

In the area of remediation, the first steps of landfill mining were taken with the remediation of an ancient landfill Terra Cotta in Brecht at the end of the nineties. OVAM invested ca. 40 million euros in the excavation and separation of the illegal dumped waste. Separation of the excavated waste produced 4 types of material: sand, iron, bricks and a residual fraction. Sand, iron and bricks were given a second life, the residual fraction was deposited on a nearby landfill site. In that way, the total cost of the remediation was lower because only a small amount of waste had to be deposited again (<http://www.decnv.com>).

Another example was the remediation of an acid tar lagoon in Mariakerke (western flanders) in 1993. The acid tar was pre-treated on-site and carried off a fuel for the cement industry.

Both examples were far from economical, but were driven by the need to remediate in a BATNEEC way (BATNEEC meaning Best Available Techniques Not Entailing Excessive Cost).

2.2.3. OVAM – ELFM – the present

In 2011, a vision on Enhanced Landfill Mining (ELFM) was approved by the OVAM board of directors and resulted in an operational program over the period 2011 – 2015. The main idea of this concept is the approach of gathering materials (in its most broad definition) of a recent or an old landfill site or dumping site and reuse it for some purpose by introducing it again in the material chain. The approach makes it possible to gain important resources: materials, energy resources, drinking water and free space. A secondary benefit is that the approach is also suitable for purposes on soil remediation.

2.2.4. A 3-step approach

The OVAM developed a three step approach towards ELFM: *mapping* (inventory of the number of landfill sites on level of the Flemish Region, with indication of specific characteristics of the area), *surveying/exploring* individual landfill sites (identification of the specific landfill body, identification of the composition of the landfilled waste, identification of the geo-physical and -chemical characteristics of specific surroundings of the landfill site) and *mining* of a specific landfill site (digging up of the waste, (pre-)treatment of the waste to make it suitable for material reuse or valorisation). This paper concerns the first fase, the mapping fase and the work done in 2012

2.3 Strategy

Since the establishment of OVAM in 1981, OVAM set up several databases containing information on (former) landfill sites. These inventories reveal the existence of about 2000 landfills and dump sites. There is a lot of variety between the listed sites and also the level of accuracy and detail of the available data is versatile. In order to improve the quality of the data and elaborate a comprehensive ELFM-policy, an investigation program was set up. Investigating moreover 2000 sites in a short period was unrealistic, therefore a methodology for prioritization of potential for Landfill Mining based on a multicriteria-analysis calculation tool was developed.

The tool was given the name '*Flaminco* (Flanders landfill mining challenges and opportunities)'.

Together with the development of the tool, a specific database was set up containing the available information on landfills and landfill sites. A fresh database contains always a lot of blanks, so one of the objectives in the next years is filling those gaps. First the Flaminco-tool will be applied on de landfill-database. Landfills with a high potential will be investigated more in detail the next years.

3. SITUATION IN FLANDERS

In preparation of the Flemish decree on soil remediation (1995) some provincial institutes made an inventory of all the possible sites where there were activities which could potentially cause soil contamination. So most of the historical landfills in Flanders were inventorised. For each site, an file was composed containing information about the location (XY-coordinates, topographical map...), kind of landfill (MSW, IW, cover, excavation...), period of landfilling, actual use, permits, ownership, underground.... In total 1738 landfills were described. Although not every description was as detailed, this inventory is a good starting point for the database.

As the Flemish decree on soil remediation came into force in 1995, whenever a ground on which a activity was carried out which could cause soil contamination, a soil investigation report had to be made and handed over to the OVAM. Such a report had to be made whenever such a ground was transferred or periodically dependion on the kind of activity (every 5, 10 or 20 years – in 2007 the periodicity changed a bit). In the period between 1995 and January 2013 65% of the known former landfill sites were investigated. All those reports were evaluated by OVAM and the investigated soils were added to a database. Thus that database (*“the soil information register”*) contains certain information on landfill sites, although it was information concerning the situation of pollution of the underground. All the relevant information was added to the ELFM-database.

The last source of information was the database containing landfill permits. Every landfill operator has to ask a permit for landfilling. When the permit is granted, there are certain obligations concerning aplying barriers, covering, landfilling, groundwatermonitoring... Every year, the landfill operator has to submit a report on the landfill activities of the past year and the results of the groundwatermonitoring wells. That data is stored in a database and added to the ELFM-database. This ads circa 323 landfill sites, of which 40% is investigated within het decree on soil remediation.

Combining the different databases into one overall ELFM-database the is a pretty good view on the landfill sites in Flanders and which data is available and which data is missing.

The information is also available in a GIS-application, so all the information can be visualized and eventual be transferred to a GPS-device, so it can be carried out on the field.

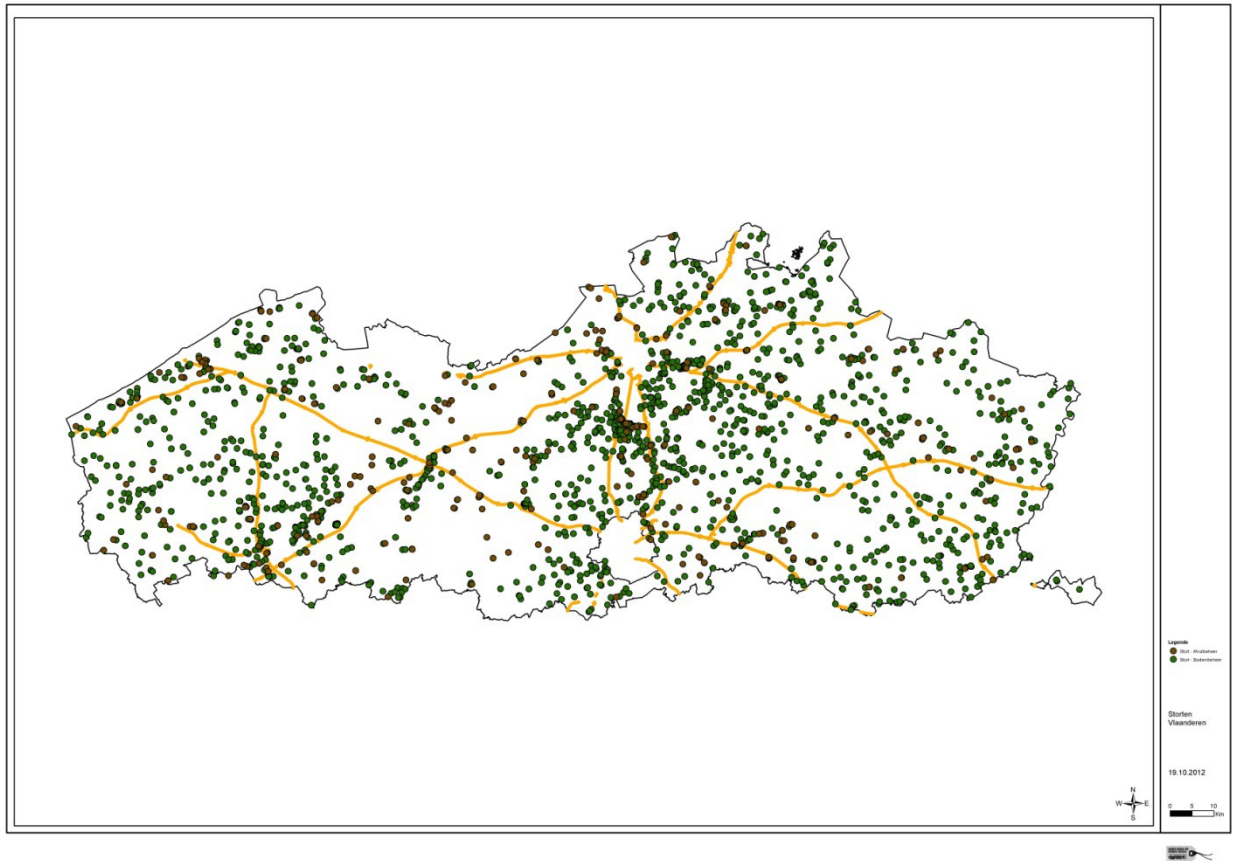


Figure 1 : landfill sites in Flanders

4. DEVELOPING LFM-CRITERIA AND ENVIRONMENTAL PRIORITIZATION

4.1 Introduction

In 2011 Van Passel et al proposed a methodology to '*Explore the socio-economics of Enhanced Landfill mining*'. Based on the 5-step procedure by Van der Zee et al. (2004) they investigated the ELFM-potential of landfills in Flanders.

OVAM wanted to add a few extra criteria and decided to develop a methodology for prioritization of landfills in Flanders. Together with the partners Tauw and Witteveen+Bos the Flaminco-decision support tool was developed in 2012.

4.2 Goals

The final result of the methodology had to be a tool by which the government easily could prioritize the different landfill sites and set up an investigation program to fill out the blanks in the ELFM-database.

The methodology had to be flexible, take into account different parameters, different aspects of landfill mining and the overall objectives of OVAM (i.e. developing a sustainable material policy and remediation soil- and groundwater pollution). The different aspects of landfill mining were defined as (1) Waste to Energy, (2) Waste to Materials, (3) Waste to Land, and (4) Resource Management - *Temporary Storage*. Depending on the policy, the importance of those criteria

could change in the future, so the methodology had to be flexible enough to deal with different objectives and policy decisions.

4.3 Criteria and weighing factors

As indicated above, the different aspects of landfill mining are evaluated based on a set of criteria. OVAM started from the criteria mentioned in the paper by Van Passel et al (2012) – type of landfill, landfill period and volume of the landfill - and added additional criteria (use of the landfill, landfill surroundings and proximity of other landfills). In what's next, the different criteria will be illustrated.

4.3.1 Type of landfill

There are different kind of landfills, every kind of landfill gets its own score varying the contribution to the LFM-potential. As mentioned in the article by Van Passel (2012 MSW and IW gets the highest score. Within one landfill, there can also be a combination of various kinds of waste, that is also taken into account (ex 1/3 MSW, 1/3 fly ash and 1/3. inert waste).

Because not every landfill is homogeneous composed, a factor of uniformicity (uncertainty) is build-in.

4.3.2 Period of landfilling

The period of landfilling is important because it reflects the content of the landfill. In Flanders, the 'upper limit' is set at 1980. In 1981, the OVAM was established. With the establishment of OVAM and the decree on waste management and prevention, recycling was initiated and the most interesting components for LFM were already recycled before they were landfilled. The 'lower limit' is set by the coming of mass production and mass consumption and thus the throwaway-way-of-life around 1950-1960. So the interesting period was somewhere between 1950 and 1980.

4.3.3 Volume of landfill

The bigger the investment that needs to be done for a LFM-project, the bigger the volume of waste that is needed. The kind of waste will also be decisive for the economical value of a project. A high value metalslag will need less volume to be economical than a large landfill of dredging sludge. As for the most landfill exact volumes are unknown, the surface of the land is available. So based on expert judgement and case studies, we calculated a level of 7m in case of clay pits and other quarries, and 3 m for the other landfills.

4.3.4 Landuse of the landfill site

For this criterium we looked at the actual use according to available urban plans and the existing buildings. We also have taken the future use into account. An existing building is less favourable for a LFM-project than a fallow land. This criterium has to be evaluated with a certain caution, because an ancient industrial site might have some potential for a group of investors.

4.3.5 Distance to roads, navigable waterways and railway depots

A LFM-project needs transportation, not only to reach and develop the site, but more important, to carry off the mined waste or recycled material. Another issue is that a group of smaller landfills with the same composition and lying next to a navigable waterway can become interesting in means of a LFM project. The material can thereby be concentrated and the project

upscaled. With that in mind, the distance between a road, railway or waterway and a landfill is calculated.

4.3.6 Proximity to other landfills

Clustering the same kind of landfills that are nearby, can increase the number of potentially interesting landfills in the meaning of LFM. In that way, its even a easy way to find out to what extend resource management can be done in Flanders by combining smaller landfills. Located close to each other.

4.3.7 Weighing factors

In the methodology for environmental prioritization, there are 2 types of weighing factors:
 - weighing based on the criteria to evaluate the LFM-potential; and
 - weighing based on the characteristics of the individual landfill.
 Those weighing factors are flexible, so they can be changed at all times in order to be tuned with the ongoing policy, economical changes, evolving technologies...

4.4 Matrix and results

The table below shows the different goals of LFM and the combination with the criteria. Smart combination leads to a prioritization of the Flemish landfills. Note that the obtained priority is not absolute. The priority is relative because the different landfills are evaluated relative to each other.

	Type of LF	Period of LF	Volume of LF	Use (actual and future)	Distance to transport	Proximity to other LF
WtE	X	X	X	X	X	X
WtM	X	X	X	X	X	X
WtL	X	-	X	X	-	X
Resource Management	X	-	-	-	X	X
X : criterium taken into account - : criterium not taken into account LF: landfill						

Table 1 : different goals and corresponding criteria

In the following example, the result is shown of a landfillsite in Willebroek. The first figure (figure 2) shows the environmental potential for this landfill for the different goals (WtE, WtM, WtL and resource management) and for the different criteria (type, period, volume, use, distance to transport and proximity). The ‘overall’ score of the individual landfill is compared with the average of all de landfills in Flanders. The second figure (figure 3) zooms in on the 4 specific goals.

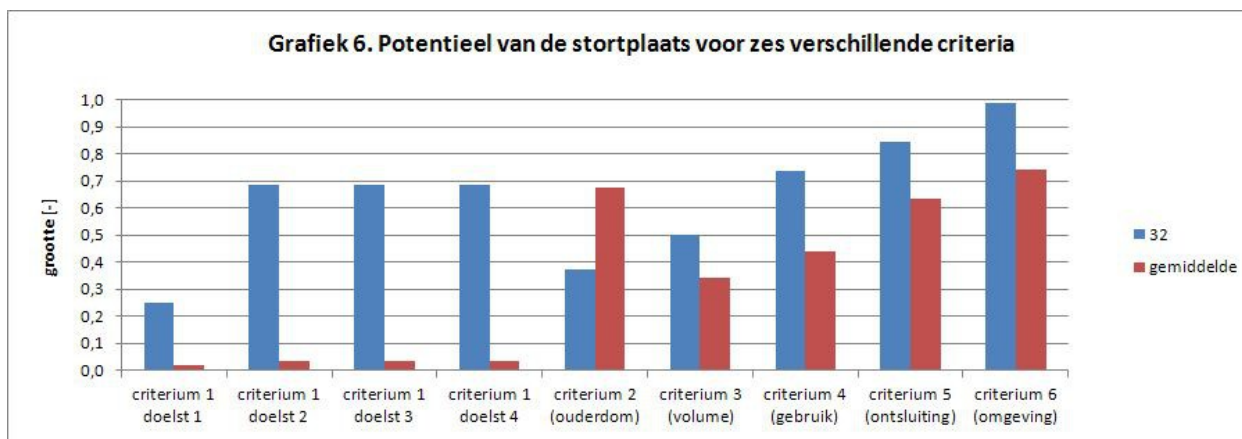


Figure 2 : landfillsite in Willebroek, number 32 and the LFM-potential for the different goals and criteria. The blue bar is the score of the individual landfill, the orange bar is the average value. On the horizontal axis from left to right: goal 1 (WtE), goal 2 (WtM), goal 3 (WtL), goal 4 (RM), criterium 1 (type), criterium 2 (period), criterium 3 (volume), criterium 4 (use), criterium 5 (transport), criterium 6 (proximity)

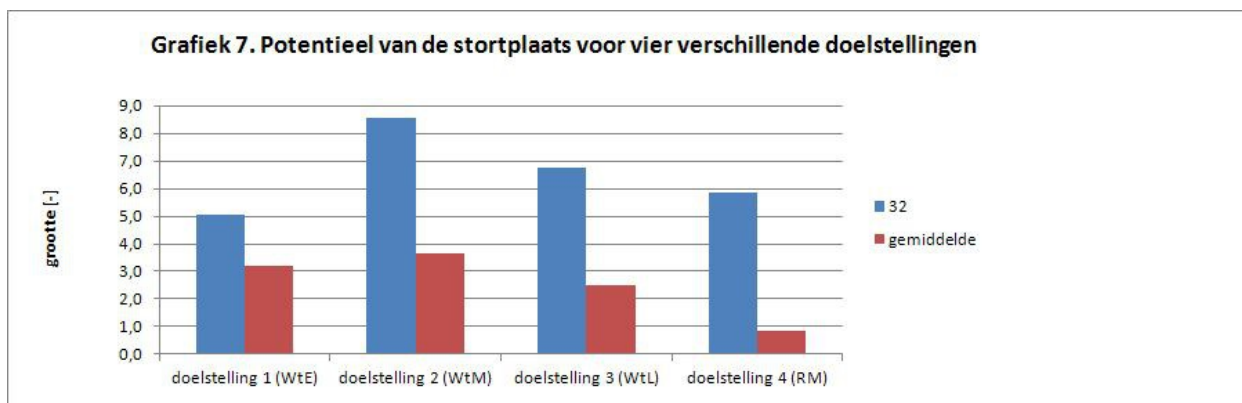


Figure 3 : landfillsite in Willebroek, number 32 and the LFM-potential for the different goals. The blue bar is the score of the individual landfill, the orange bar is the average value. On the horizontal axis from left to right: goal 1 (WtE), goal 2 (WtM), goal 3 (WtL), goal 4 (RM)

5. DETERMINATION METHODOLOGY: NEED TO REMEDIATE

5.1 Introduction

In Flanders, when a parcel is being sold and on that parcel is or was a activity which could cause soil contamination a soil investigation is needed before the transfer can take place. Landfilling is such an activity. A large number of known landfill site have been investigated in that way. The others have not yet been examined in the context of the decree on soil remediation, so there is only limited information available for those landfills (only the information that was collected during the inventory – see chapter 3). Because one can not at random start to investigate a landfill, a methodology is needed. OVAM chose a methodology which can assess the need to remediate based on a set of criteria. Landfills with the highest chance of needing remedial actions will be investigated first.

5.2 Goals

The methodology had to be ‘simple’ in a way that only general and easily collectable information is needed for the first step. During the next steps more specific and analytical information is collected. So the approach is phased, going from a general assessment of the need to remediate to a detailed environmental investigation and risk evaluation of the landfill.

The result of this incrementally and cost efficient methodology is again a ranking of the Flemish landfills.

5.3 Criteria and weighing factors

The starting point is composing a conceptual site model for a landfill: starting from the source (the landfill) the different paths are described (routes and exposure) which are leading to a possible receptor.

The CSM defines the different criteria which should be taken into account. In that way to create a general idea of the influence of the source on the receptors.

In that way, following criteria were defined:

- source : kind of landfill, period of landfilling and size of the landfill,
- receptor: location in relation to actual and potential residential area, industrial area, agricultural area, recreational area and ecological valuable area, vulnerability of the groundwater, location in relation to surface water, water wells and flooding area.

Next, the different criteria were filled out and each category gets a score. Each criteria was given a specific weighing factor according to the relative relevance of the impact. For example: the size of a landfill gets a smaller weighing factor than the kind of landfill because a small landfill containing MSW can cause more pollution than a large landfill filled with inert material. Or the probability that a landfill with MSW causes a groundwater pollution that needs remediation is higher in relation towards the same landfill with inert material.

	Category	Score	Weighing factor	Maximum overall score
Kind of landfill	MSW	70	3	
	IW	100		
	Dredging sludge	40		
	Flyash	40		
	...			300
Size of the LF	Small (<6500 m ²)	30	1	
	Medium	40		
	Large	70		
	Extra larger (>43000 m ²)	100		
				100

Table 2 : example of criteria, score and weighing factor

Finally all the individual scores are summed and a relative ranking is obtained. Note that the result is again relative. An absolute ranking won't be obtained unless the full investigation is conducted

(see below).

5.4 The next steps

Once this preliminary ranking is obtained, in the second step the landfills that need further investigation can be chosen: a high potential to remediate, or one with little available information, or one with an interesting location, one with a specific problem, combination of previous...

Further investigation can be done by requesting and searching for detailed and missing information about the landfill. This first phase of desk study is followed by a field campaign. During the fieldwork, the missing information about potential risks is gathered: samples of the top layer are collected and analysed (risk of exposure), impact of the landfilled material to the groundwater is investigated (risk of spreading and contamination of available resource, namely drinking water) and analytical investigation of potentially endangered receptors (ex. drinking wells...) is carried out.

Finally, the third step is performing a thorough risk assessment: human risks, ecological risks and risk of spreading will be calculated and when there is a possibility of some kind of risk, remedial actions are required. Based on the kind of risk and seriousness, the urgency of that remedial action can be determined.

6. RESULTS

Combination of LFM-criteria and need to remediate gives an overall ranking of landfills which can be interesting in case of landfill mining. The results of both methodologies are put opposite each other in an interaction matrix (figure below). A landfill with a high potential to LFM and a high risk of contaminating the environment, results in an interesting case for LFM.

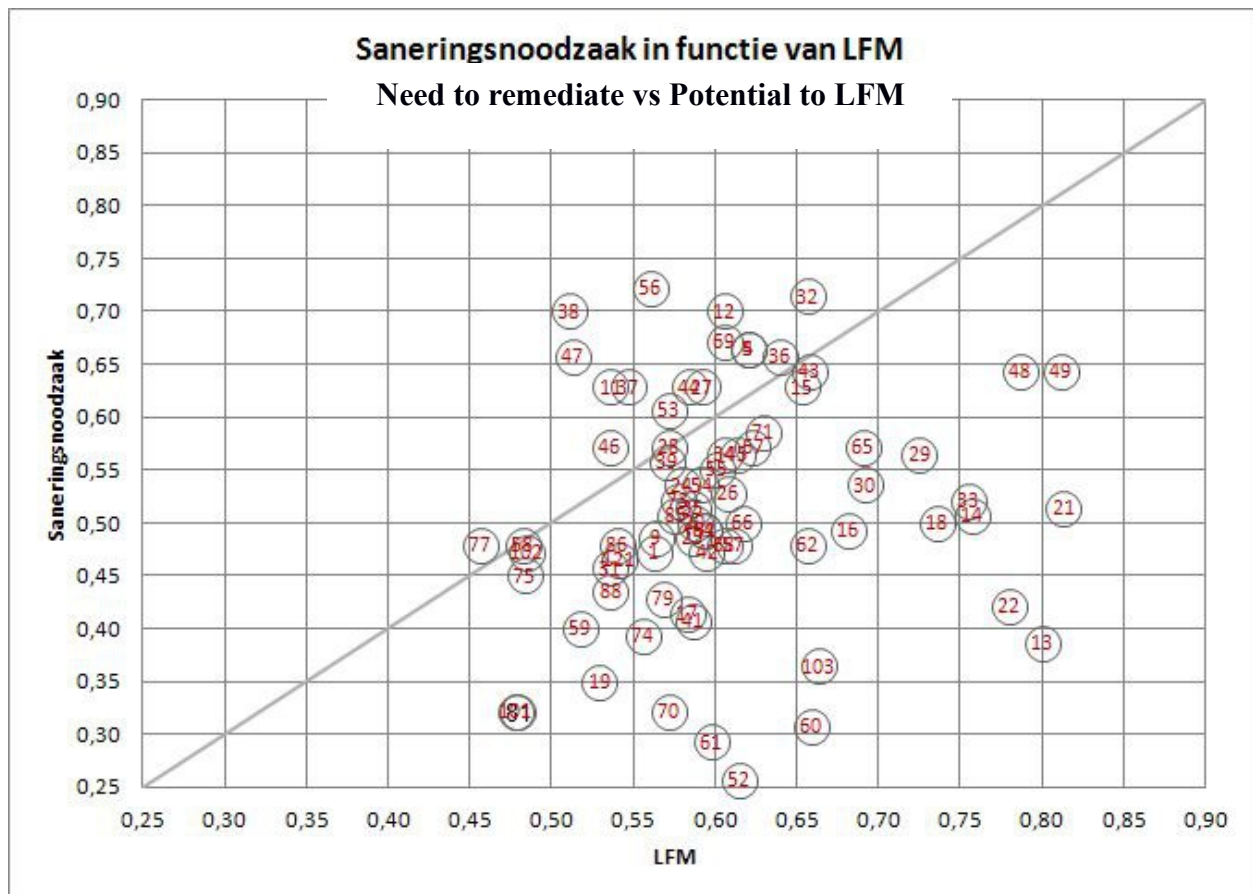


Figure 4 : Interaction matrix : need to remediate vs potential to LFM

This decision support tool **Flaminco** (Flanders landfill mining challenges and opportunities) delivered a ranking of landfills and more detailed investigations are and will be executed on a high level (mapping the region of Flanders) and a low level (surveying of individual landfills).

Both results are based on the database which we have now. In the future soil investigation on the most interesting landfills will be carried out and, the blanks and uncertainties in the database will be filled. That another reason why the database had to be flexible. The database will become more and more accurate and policy and mining can follow.

7. FUTURE WORK

Over the next years, OVAM will be carrying out soil investigations of different landfill-sites in Flanders in order to obtain more information on the landfills, the risks that might occur, the size and content of landfills, filling out blanks in the ELFM-database, etc.

Those soil investigations will reveal whether the proposed methodology needs finetuning or not.

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For Journal Title Abbreviations see:

http://www.efm.leeds.ac.uk/~mark/ISlabbr/A_abrvjt.html