RECORDING, EVALUATION AND CLASSIFICATION OF WASTE DUMP SITES IN CYPRUS USING MULTIPLE CRITERIA DECISION ANALYSIS

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Key words (5 to 10): Landfill Directive, uncontrolled waste dump sites, risk assessment analysis, remediation methods

Abstract

The Landfill Directive was passed by Europe in 1999 and requires among other things the Cyprus waste management industry to classify landfill sites according to their hazards to the environment. In the Republic of Cyprus, 113 uncontrolled waste dump sites have been identified and recorded in past (2006) by ENVIROPLAN S.A.. Closure, reclamation and post-closure care of the sites are required by the Landfill Directive.

This study presented a comprehensive analytical framework for the prioritization of remedial counter measures of the 15 identified waste dump sites in Larnaca and Ammochostos Regions of Cyprus. Risk assessment of the sites was carried out using a method of multiple criteria decision analysis (MCDA). The method was based on the highest scores achieved for each criterion and provided a systematic and transparent approach that the Cyprus Government used to clarify the decision making process and facilitated consensus building among decision makers.

From the collected data, the waste dump sites were categorized based on their current status of operation. From the detailed study, 15 waste dump sites were recorded, which impose a potential risk to the environment and public health in the Regions of Larnaca and Ammochostos in Cyprus. Having completed this stage, it is then possible to proceed to the risk assessment and consequently to the final categorization of the sites that are a priority for closure and restoration.

The proposed remediation technologies include mainly containment technologies and in few cases relocation of the waste to a modern lined landfill. The selection of technologies is site specific and based on the needed degree of permanence, monitoring ability and system maintenance. The monitoring technologies include environmental monitoring systems for groundwater, run-off water, biogas, leachate, ground settling and top cover.

1. Introduction

Waste disposal in the member states of European Community has changed dramatically over the last decades, both with respect to its legislation and its public perception. For a long time it was considered as 'out of sight, out of mind' and somebody else's problem. The majority of the public knew that if they put their waste bin at the end of the drive it would be taken away weekly, but paid little attention to where it was going to be disposed. Only those directly affected by a landfill's location or vehicles entering or leaving waste disposal facilities knew or cared of their existence. In recent years waste disposal has had a higher public profile as the perception of pollution and the environment has grown.

The protection of the environment from the cease of operation of all uncontrolled / semi controlled disposal areas comes up to a necessity and a priority for the Republic of Cyprus as a new member of European Community. For the complete harmonization with the principles of sustainable development and European legislation (99/31/EC on the landfill of waste and 94/62/EC on packaging and packaging waste), "The strategic plan for solid waste management in Cyprus" was prepared in June 2002 (it has been approved by the Cypriot Parliament in 2003).

Waste disposal facilities, commonly called landfill sites, were originally located on the outskirts of centres of population, due to the lack of large scale transport to carry the waste away. They were normally found in hollows or depressions in land where people could easily tip their waste and where it would not be seen. As the centres of population have grown, the old landfill sites have been incorporated into the expansion plans of the towns. These sites are normally left as areas of wasteland or developed as car or leisure parks. These areas of wasteland rise in value as the land around them becomes developed. There normally comes a point in time when it becomes economical to develop these sites, and so the nature of the landfill site and

surrounding environment may have to be investigated. Modern landfill sites are now located away from centres of population as large scale transport is available to carry the waste away, and so the surrounding environment is less of an immediate consideration.

The identification of uncontrolled landfills is a central environmental problem in all developed and developing countries, where several illegal waste deposits exist as a result of rapid industrial growth over the past century. A geographic information system (GIS) database can potentially provide crucial information for the identification and recording of contaminated sites, while a multiple criteria decision analysis can provide a systematic and transparent approach for the prioritization of closure and restoration of sites.

In Cyprus the collection of household waste is the responsibility of the Local Authorities and the discharge takes place at locations varying in degrees of environmental susceptibility. During the implementation of the Strategic Plan of Rehabilitation of Landfills in Cyprus, 113 increased environmental risk Landfills where identified and recorded throughout Cyprus.

In Larnaca – Ammochostos Regions, which together constitute the region of interest of this paper, there have been 15 uncontrolled landfills identified and evaluated, of which seven had already been shut down. Of the remaining eight Landfills, the five in Larnaca have shut down after the start of normal operation of Larnaca - Ammochostos Integrated Solid Waste Treatment Plant which is located in 'Nafkias - K. Kosii" in April 2010, while the remaining three Landfills in Ammochostos will shut down during 2010.

2. Material and Methods

2.1 Identification and recording of sites

This study examined the 15 uncontrolled Landfills in Larnaca - Ammochostos, based on all environmental updates and social data and topography information, hydrology, meteorology and geology, geotechnical investigations and conditions across the region of interest, as well as data from site visits and geological and topographical surveys carried out for all Landfills.

Initially the extent and the quantity of waste were estimated for each Landfill. The volumes were calculated bearing in mind the present situation, as reflected in the topographic survey in conjunction with the state of the natural soil as shown in the graphic 1:5,000 provided by the Department of Lands and Surveys.

Table 1: Categorization of sites according to area and volume of existing waste deposits.

LANDFILL CATEGORIZATION BASED ON THE VOLUME OF WASTE DEPOSITS				
N / A	***AREA CODE***	***MUNICIPALITY /***	***VOLUME*** ***(m^3)*****	***AREA*** *(*ha**)*
1	LR08	Tersefanou	1.661.650	183
2	AM01	Agia Napa	451.000	95
3	AM02	Paralimni	300.000	95
4	AM03	Frenaros	200.000	41
5	LR10	Kellia	148.000	73
6	LR03	Mari	130.000	5
7	LR12	Xylofagou	100.000	34,5
8	LR11	Oroklini	76.000	20
9	LR09	Avdellero	53.200	9,5
10	LR05	Kornos	31.100	15,5
11	LR01	Pano Leykara	25.500	15
12	LR06	Alaminos	24.200	4
13	LR04	Kofinou	18.000	9
14	LR02	Maroni	5.300	4,5
15	LR07	Kivisili	4130	6

** The extent of the waste is given in acres. The percentage applicable is: a Ten = 1 acre = 1000 m^2*

Based on the information in the above table it is understood that the dumpsites can be grouped into two broad categories, as follows:

Category A: Areas in which consolidation works and transfer of deposits will happen, either because of the small surface area or / and the low volume of the existing waste deposits. Landfill PR 07 Maroni and LR09 Kivisili can be integrated in to this category.

Category B: Areas where works will be on-site rescue and rehabilitation projects, due to the large surface area and the large amount of existing waste deposits. This category includes the remaining 13 sites.

Next step was to assess and manage the risks for each site. In this phase for all sites were:

a) Assessment of "sources of pollution (Landfill) (volume of waste)

b) Evaluation of the "path", in other words, the means by which the pollutant was potentially carried to the site (rainfall - groundwater)

c) Evaluation of the recipient (distance from the source and final recipient)

2.2 Risk assessment of sites

A contaminated site is a potential hazard to the environment and its receptors. The negative impacts from the pollution can be illustrated by the use of the pollution mechanism, which is illustrated in Figure 1.

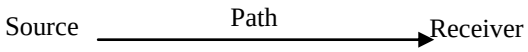

Figure 1. Pollution mechanism

The risk assessment process is based on the above described pollution mechanism, which is further customized for the needs of the particular study in the following stages:

- Source of pollution (M1) – during this stage, the evaluation parameters examined are:
    - waste volume in m^3 is estimated in relation to the four basic types of waste that are disposed of in the sites:
        - municipal waste > 30 years,
        - municipal < 30 years,
        - construction and demolition waste, and
        - hazardous waste
    - distance of industrial zones from the contaminated sites, only however where hazardous waste is a consideration

For site classification based on the pollution source, it is firstly determined which type of waste has been disposed and then the overall quantity is estimated. As there is no reliable data for construction and demolition waste and hazardous waste, assumptions were made.

- Path of pollution (M2) – during this stage, the evaluation parameters examined are:
    - annual precipitation in mm (M2A), and
    - ground permeability (Kf) in relation to the distance of the aquifer from the landfill basin (M2B)
- Receiver of pollution (Max) – during this stage, the evaluation parameter that is examined is the distance from the pollution source in relation to the type of pollution receiver. The distance plays a crucial role in the evalution of the arisen potential hazard. The receivers are divided in three sub-categories:
    - MaxA includes protected areas such as water abstraction (present and future), and protected areas (Natura 2000, SPAs., SCIs, etc.
    - MaxB includes land uses such as playgrounds, agricultural/coastal zones, residential zones, industrial zones, road axes and quarries.
    - MaxC includes surface waters such as water basins, surface waters and water related protected ares.

In cases where there is no sufficient data about the hydro geological characteristics of a site, maximum score values are given. It is important to note that the waste burial method or the years of operation of the site are not taken into consideration.

2.3 Evaluation and categorization of sites

A multiple criteria decision analysis (MCDA) was used – similar technique was developed by the Hellenic Ministry for the Environment, Physical Planning and Public Works. It is a discipline aimed at supporting

decision makers who are faced with making numerous and conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process. When using a MCDA method, different criteria are combined together into a single decision image. The criteria can be of two types:

- Constraints – serve to limit the choice of alternatives under consideration, and
- Factors – act as continuous modifiers to the suitability of a location for the objective in question

The criteria are combined in the form of weighted linear combination: $E= \Sigma wixi$ (I)
where E= hazard, wi= weight of factor i, and xi= criterion of factor i.

The method was based on the highest scores achieved for each criterion. In order to confirm the sensitivity of the results related to the significance of the criteria, 3 scenarios were examined in the current study as described in Table 2.

Table 2. Scenarios for evaluation and categorization of sites

Criteria Categories	**Scenario A**	**Scenario B**	**Scenario C**
Waste characteristics (M1)	37%	20%	40%
Area hydrogeology (M2)	14%	20%	15%
Water use / protected areas (MaxA)	22%	20%	15%
Land use (MaxB)	22%	20%	15%
Surface waters (MaxC)	5%	20%	15%
Total	100,00%	100,00%	100,00%

By using the maximum criterion weight for each scenario, Table 3 emerges.

Table 3. Highest scores for each criterion related to different scenarios

Criteria Categories	**Scenario A**			**Scenario B**			**Scenario C**		
	Max weight (%)	Max score	Weight factor	Max weight (%)	Max score	Weight factor	Max weight (%)	Max score	Weight factor
M1	37%	41	1	20%	22,2	0,54	40%	44,4	1,08
M2	14%	15	1	20%	22,2	1,48	15%	16,6	1,1
MaxA	22%	25	1	20%	22,2	0,89	15%	16,6	0,66
MaxB	22%	25	1	20%	22,2	0,89	15%	16,6	0,66
MaxC	5%	5	1	20%	22,2	4,44	15%	16,6	3,32
Total	100%	111		100%	111		100%	111	

By using the 5 criteria categories (M1, M2, MaxA, MaxB, and MaxC), as well as the resulting weight factors of Table 3, it is then possible to calculate the hazard for each site under different scenario.

Scenario A: $E_A = M1 + M2 + MaxA + MaxB + MaxC$ (II)
Scenario B: $E_B = 0,54M1 + 1,48M2 + 0,89MaxA + 0,89MaxB + 4,44MaxC$ (III)
Scenario C: $E_\Gamma = 1,08M1 + 1,1M2 + 0,66MaxA + 0,66MaxB + 3,32MaxC$ (IV)

For a better inspection of the results, the overall score can be expressed in a scale from 1 to 111.

3. RESULTS AND DISCUSSION

3.1 Recorded sites

From the collected data, the waste dump sites were categorized based on their current status of operation as shown in Figure 2. From the detailed study, 15 waste dump sites were recorded, which impose a potential risk to the environment and public health in Cyprus. Having completed this stage, it is then possible to proceed to the risk assessment and consequently to the final categorization of the sites that are a priority for closure and restoration.

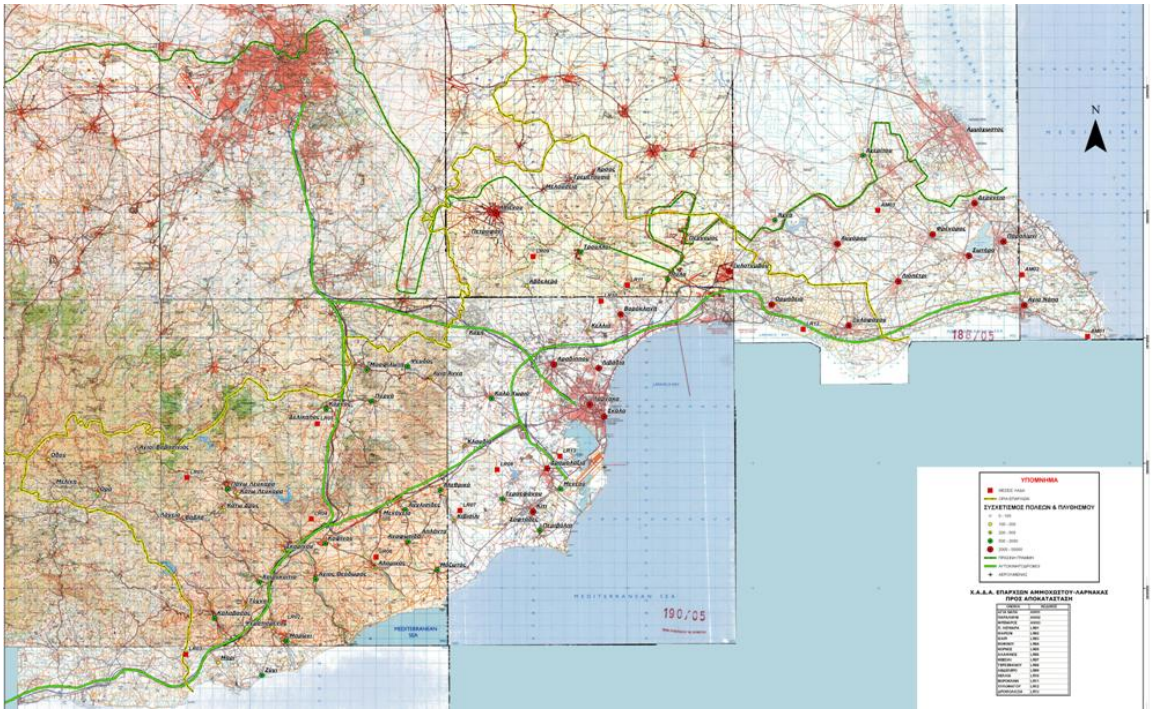

Figure 2: Waste dump sites locations in Cyprus (indicated in red triangles)

3.2 Pollution hazard evaluation

The table below shows the final prudential scores for each site, according to the scenario under consideration and the ranking of these sites based on "narrow numerical" rating that they received of each scenario.

Table 4: Aggregate scores - series of 15 risk areas every scenario

	SCENARIO A			SCENARIO B			SCENARIO C		
N / A	***Area Code***	***Municipality***	***Degree***	***Area Code***	***Municipality***	***Degree***	***Area Code***	***Municipality***	***Degree***
1	AM01	Agia Napa	80	AM01	Agia Napa	75	AM01	Agia Napa	85
2	AM02	Paralimni	78	LR12	Xylofagou	69	LR12	Xylofagou	79
3	AM03	Frenaros	77	LR08	Tersefanou	66	LR08	Tersefanou	78
4	LR08	Tersefanou	77	AM02	Paralimni	58	AM02	Paralimni	74
5	LR10	Kellia	77	AM03	Frenaros	58	AM03	Frenaros	73
6	LR09	Avdellero	74	LR10	Kellia	58	LR10	Kellia	73
7	LR12	Xylofaogou	68	LR09	Avdellero	56	LR11	Oroklini	70
8	LR04	Kofinou	67	LR11	Oroklini	56	LR09	Avdellero	70
9	LR02	Maroni	60	LR04	Kofinou	52	LR04	Kofinou	62
10	LR11	Ooroklini	58	LR05	Kornos	50	LR03	Mari	60
11	LR03	Mari	57	LR02	Maroni	49	LR05	Kornos	58
12	LR06	Alaminos	50	LR06	Alaminos	45	LR02	Maroni	55
13	LR07	Kivisili	48	LR03	Mari	40	LR06	Alaminos	52
14	LR05	Kornos	47	LR07	Kivisili	39	LR01	Pano Leukara	48
15	LR01	Pano Leukara	46	LR01	Pano Leukara	34	LR07	Kivisili	46

Upon completion of the scoring, the final ranking of the Landfills is shown, which has taken in to consideration both the extent and amount of waste that has been accepted or is still being accepted, and also the degree of risk that was obtained, which revealed the final ranking of Landfill as shown in the table below.

Table 5: Ranking of dumpsites by Potential Risk

CATEGORY	Dumpsite	POTENTIAL RISK
A.	LR02 Maroni	**Limited**
	LR7 Kivisili	
	LR05 Kornos	
B.	LR10 kellia	**Sufficient**
	LR04 Kofinou	
	LR11 Oroklini	
	LR03 Mari	
	LR06 Alaminos	
	LR01 Pano Lefkara	
C.	AM01 Ayia Napa	**Important**
	AM02 Paralimni	
	AM03 Frenaros	
	LR08 Tersefanou	
	LR09 Advellero	
	LR12 Xylofagou	

This study presented a comprehensive analytical framework for the prioritization of remedial countermeasures of waste dump sites in Cyprus. The multiple criteria decision analysis (MCDA) model provided a systematic and transparent approach that the Cyprus Government used to clarify the decision making process and facilitated consensus building among decision makers.

The criteria inputs, athough numerous, can be afforded rather easily. In certain cases, in order to overcome the problem where there is no sufficient/reliable data for the sites, either maximum scoring is given, or different ratings are selected for the execution of the categorization process (introduce sensitivity analysis). However, both solutions require careful judgment for safe conclusions. If the criterion is critical to the decision, completion of the data is necessary and then a sensitivity analysis must always be performed.

3.3 Remediation methods

The remediation technologies include mainly containment technologies and in few cases relocation of the waste to a modern lined landfill, as shown in Figure 3.

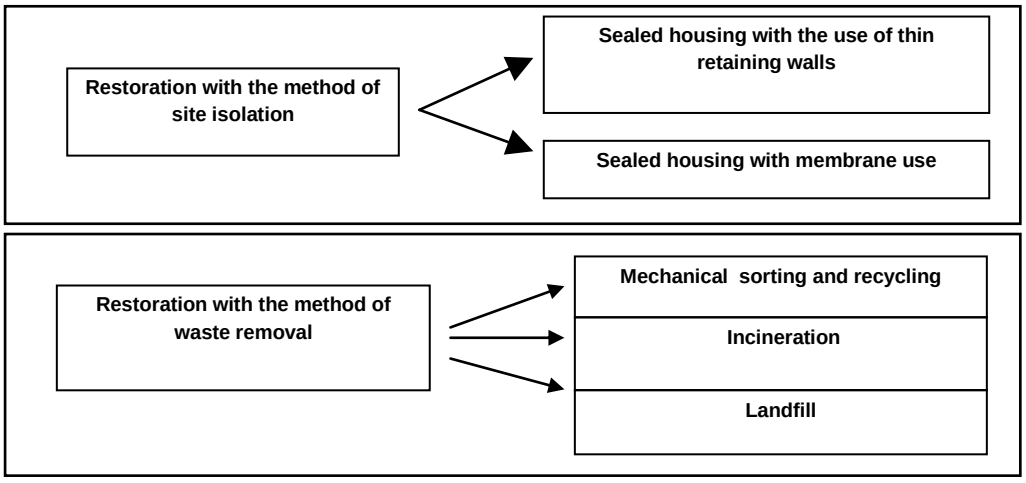

Figure 3: Restoration methods

The selection of technologies is site specific and based on the needed degree of permanence, monitoring ability and system maintenance. The monitoring technologies include environmental monitoring systems for groundwater, run-off water, biogas, leachate, ground settling and top cover. The proposed rehabilitation works for the 15 sites are shown in Table 6.

Table 6: Projects rescue - restoration of 15 dumpsites in Larnaca - Ammochostos

A/A	PROVINCE CODE	Municipality / COMMUNITY	Reject AREA .*	WASTE VOLUME (m^3) **	HAZARD CLASS	PROJECTS REORGANISATION - RECOVERY											
						TRANSPOR-TATION OF WASTE DEPOSITS	SPOT WORKS REORGANISATION - RECOVERY									ENVIRON-MENTAL CONTROL PROJECTS	NEW USES
							PROJECT FINAL COVER - PLANTING			PROJECT MANAGEMENT Drainage		BIOGAS PROJECT MANAGEMENT					
							A	B	C	COLLECTION – TRANSPOR-TATION	TREATMENT	EXPECTED PRODUCTION BIOGAS (m3 /h)	RELIEF WINDOWS	Collection - Incineration	Energy recovery		
1	AM01	AGIA NAPA	95	451 000	C				√	√	The leachate will be collected in a sealed container and driven periodically by tanker for treatment at the leachate treatment plant in Waste Treatment Station Larnaca - Famagusta at "Koshi"	228.88		√		√	√
2	AM02	PARALIMNI	94	300 000	C				√	√		153.65		√		√	
3	AM03	FRENAROS	41	200 000	C				√	√		93.22		√		√	
4	LR01	PANO LEUKARA	15	25.500	B			√		√		11.30	√			√	
5	LR02	MARONI	4.5	5.300	A	√						2.93					
6	LR03	MARI	5	130 000	B			√		√		72.53		√		√	
7	LR04	KOFINOU	9	18.000	B			√		√		9.85	√			√	
8	LR05	KORNOS	15.5	31.100	A		√					14.41	√			√	
9	LR06	ALAMINOS	4	24.200	B			√		√		13.12	√			√	
10	LR07	KIVISILI	6	4130	A	√						2.10	√				
11	LR08	TERSEFANOU	183	1661650	C				√	√		756.16			√	√	√
12	LR09	AVDELLERO	9.5	53.200	C				√	√		25.79	√			√	
13	LR10	KELLIA	73	148 000	B			√		√		78.73		√		√	
14	LR11	OROKLINI	20	76.000	B			√		√		36.51	√			√	
15	LR12	XYLOFAGOU	34.5	100 000	C				√	√		48.47	√			√	

* The extent of the waste is given in acres. The percentage applicable is: a Ten = 1 acre = 1000 m^2

** The volume of waste has been identified computationally by comparing the topographical chart of the current situation and the topographic chart before depositing waste (1:5000, digitized)

4. Conclusions

This study presented a comprehensive analytical framework for the prioritization of remedial countermeasures of waste dump sites in Larnaca and Ammochostos Provinces of Cyprus. The multiple criteria decision analysis (MCDA) model provided a systematic and transparent approach that the Cyprus Government used to clarify the decision making process and facilitated consensus building among decision makers.

The inputs to the criteria, though they are numerous can afforded rather easily. In cases, there is no sufficient/reliable data for one of the sites, in order to overcome this problem, either maximum scoring is given, or different ratings are selected for the execution of the categorization process (introduce sensitivity analysis). However, both solutions require careful judgment for safe conclusions. If the criterion is critical to the decision, completion of the data is necessary and then a sensitivity analysis must always be performed.

MCDA analysis showed that out of 15 waste dump sites in Larnaca and Ammochostos Provinces of Cyprus. The priority of the rehabilitation of the remaining sites would be also dependant upon the type of restoration works (in site/on site/off site).

The use of MCDA method in waste management sector has many advantages described below:

- The set of factors is clearly described
- If there is a lack of data, the need of completion is obvious
- The sensitivity of the data analysis reveals the main characteristics of any site
- The method can be differentiated and adapted (customization)

Although the above advantages, the users of the method should be aware of misleading conclusions in cases that there is either lack of critical data and/or the weighting of the critical factors is wrong.

The completion of the works is an intervention that will significantly improve the quality of life of the society, to the extent affected by the continued operation of Landfills, with simultaneous application of existing legislation on the management of household non hazardous waste and compliance of the Republic of Cyprus with European Union requirements. Finally, this project will contribute significantly to the Integrated Solid Waste Management in Cyprus.

References

1. Saaty T.L., 1980. *The Analytic Hierarchy Process.* McGraw-Hill Inc., New York.
2. Linkov I., Vargee S., Jamil S., Seager T.P., Kiker G., Bridges T., 2004. *Multi-criteria decision analysis: a framework for structuring remedial decisions at contaminated sites* (eds. Linkov I. and A. Ramadan).
3. Saaty T.L, 2001. *Decision making with Dependence and Feedback: The Analytic Network Process.* 2nd ed., RWS Publications.
4. Belton V., Stewart T.J., 2002. *Multiple Criteria Decision Analysis: An integrated approach*. Kluwer Academic Publishers, Dordrecht.
5. Thill J. C., 1997. Spatial Multicriteria Decision Making and Analysis: A geographic information system approach. Ashgate Publishing, England.
6. Lolos T., Koullapis G., Lolos G., Paschali-Manou K., Tsobanidis C., Georgiou I. and Panagoulopoulos A., Identification, Evaluation And Categorization Of Uncontrolled Landfill Sites In Cyprus, *Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium*
7. Hellenic Ministry for the Environment, Physical Planning and Public Works, 2005. *Standard technical specifications for the restoration of uncontrolled landfill sites.* Circular 135977/5051.
8. Promentilla, M.A.B. (2006) Development of a multiple criteria decision making method for remedial countermeasures of contaminated sites. PhD thesis. Hokkaido University.

SNIMANJE, PROCJENA I KLASIFIKACIJA ODLAGALIŠTA OTPADA NA CIPRU, KORISTEĆI VIŠEKRITERIJALNE ANALIZE ODLUČIVANJA

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Sažetak

Direktiva o odlagalištima otpada koja je donesena 1999, između ostaloga, zahtijeva da gospodarska grana koja se bavi gospodarenjem otpadom na Cipru klasificira odlagališta prema njihovoj štetnosti po okoliš. U Republici Cipru, identificirano je 113 nekontroliranih odlagališta koja su snimljena od strane tvrtke ENVIROPLAN S.A. (2006). Direktiva zahtijeva zatvaranje ovih odlagališta, rekultivaciju i održavanje nakon zatvaranja.

Ovaj rad prezentira cjelovitu analitičku okosnicu za određivanje prioritetnih sanacijskih mjera na 15 identificiranih odlagališta otpada u Larnaki i Ammochostos regijama na Cipru. Izrađena je procjena rizika svih odlagališta koristeći metodu višekriterijalne analize. Metoda se temelji na najvećim postignutim rezultatima za svaki kriterij čime je dobiven sistematičan i transparentan pristup koji je Ciparska vlada koristila za pojašnjenje procesa odlučivanja, a s kojim su se usuglasili svi koji su sudjelovali kod odlučivanja.

Temeljem sakupljenih podataka, odlagališta su kategorizirana na osnovu njihovog trenutnog operativnog statusa. Detaljnom studijom snimljeno je 15 odlagališta koja predstavljaju potencijalni rizik za okoliš i javno zdravlje u regijama Larnaca i Ammochostos. Nakon dovršetka faze snimanja, moguće je dobiti procjenu rizika i nadalje, konačnu kategorizaciju odlagališta koja su prioritet za zatvaranje i sanaciju.

Predložene tehnike sanacije sadržavaju uglavnom tehnologije sprječavanja širenja onečišćenja, i u nekoliko slučajeva, premještanje otpada na moderna sani rana odlagališta. Odabir tehnologije ovisi o karakteristikama samog odlagališta i temelji se na potrebnom stupnju trajanja, mogućnosti monitoringa i održavanju sustava. Tehnologije monitoringa uključuju kontrolu kakvoće podzemnih voda, oborinskih voda, bioplina, procjednih voda, slijeganje tla i prekrivku.

Ključne riječi: Direktiva o odlagalištima otpada, nekontrolirana odlagališta otpada, analiza procjene rizika, metode sanacije

1. Uvod

Odlaganje otpada u zemljama članicama Europske unije se drastično promijenilo tijekom zadnjih nekoliko desetljeća, kako u odnosu na legislativu tako i po pitanju javnog mijenja. Dugo vremena se odlaganje otpada smatralo "daleko od oka, daleko od pameti" i problem nekoga drugoga. Većina javnosti znala je da ako stave svoje kante za otpad na šločnik, jednom tjedno će biti odvezene, no nije ih zanimalo gdje će iste biti odložene. Samo ljudi izravno povezani s lokacijom odlagališta ili vozilima koja voze otpad znali su i marili za njegovo postojanje.

Zaštita okoliša s gledišta nekontroliranih all nekontroliranih / polu kontroliranih odlagališta postala je prioritet Republike Cipra kao nove članice Europske unije. Za potpuno usuglašavanje s principima održivog razvoja i Europskom legislativom (99/31/EC o odlagalištima otpada i 94/62/EC o ambalaži i ambalažnom otpadu), u lipnju 2002. Godine izrađen je "Strateški plan za gospodarenje otpadom na Cipru" (odobren od strane Ciparskog parlamenta 2003. godine).

Postrojenja za odlaganje otpada, uobičajeno zvana odlagališta, bila su prvotno smještena na periferijama centara populacije. Obično ih se moglo pronaći u šupljinama i depresijama u zemlji gdje bi ljudi ostavili otpad bez da ih itko vidi. Kako su naseljeni centri rasli, stara odlagališta su postala inkorporirana u planove širenja gradova. Ova područja su predstavljala otpadnu zemlju ili su pretvoreni u parkove. Njihova vrijednost je rasla s razvojem okolnog zemljišta. U određenom trenutku, kada bi postalo ekonomski isplativo razvijati ova zemljišta, počelo bi se istraživati okoliš. Moderna odlagališta su sada obično smještena izvan centara naseljenosti i njihov okoliš nije u žarištu pozornosti.

Identifikacija nekontroliranih odlagališta je centralni okolišni problem u svim razvijenim i zemljama u razvoju, u kojim postoji nekoliko ilegalnih odlagališta kao rezultat brzog industrijskog rasta tijekom prošlog stoljeća. Baza geografskog informativnog sustava (GIS) može potencijalno dati krucifijalne informacije za identifikaciju i snimanje onečišćenih područja, dok višekriterijalna analiza odlučivanja daje sistematičan i transparentan pristup za određivanje prioritetnih odlagališta koja je potrebno zatvoriti i sanirati.

Sakupljanje kućnog otpada na Cipru je obveza lokalnih vlasti, a odlaganje se odvija na lokacijama ovisno o stupnju okolišne osjetljivosti. Tijekom implementacije Strateškog plana za sanaciju odlagališta na Cipru, identificirano je 113 rizičnih odlagališta.

U regijama Larnaca – Ammochostos, identificirano je 15 nekontroliranih odlagališta, od kojih je 7 već zatvoreno. Od preostalih osam odlagališta, pet u Larnaca-i je zatvoreno u travnju 2010. ggdine, nakon početka rada Larnaca - Ammochostos postrojenja za cjelovitu obradu otpada, koje se nalazi u 'Nafkias - K. Kosii", dok će se preostalih 3 zatvoriti tijekom 2010. Godine.

2. Materijali i metode

2.1 Identifikacije i snimanje odlagališta

Ova studija obuhvaća 15 nekontroliranih odlagališta u Larnaca - Ammochostos, a temelji se na svim okolišnim i socijalnim podacima i informacijama o topografiji, hidrologiji, meteorologiji i geologiji, geotehničkim istraživanjima, te na geološkim i topografskim istraživanjima obavljenim na odlagalištima.

U početku je opseg i količina otpada procjenjivana za svako pojedino odlagalište. Volumeni su izračunati uzimajući u obzir trenutnu situaciju.

Tablica 1: Kategorizacija odlagališta prema površini i volumenu odloženog otpada

N / A	***OZNAKA PODRUČJA***	***OPĆINA***	***VOLUMEN (m^3)*****	***POVRŠINA*** *(*ha**)*
1	LR08	Tersefanou	1.661.650	183
2	AM01	Agia Napa	451.000	95
3	AM02	Paralimni	300.000	95
4	AM03	Frenaros	200.000	41
5	LR10	Kellia	148.000	73
6	LR03	Mari	130.000	5
7	LR12	Xylofagou	100.000	34,5
8	LR11	Oroklini	76.000	20
9	LR09	Avdellero	53.200	9,5
10	LR05	Kornos	31.100	15,5
11	LR01	Pano Leykara	25.500	15
12	LR06	Alaminos	24.200	4
13	LR04	Kofinou	18.000	9
14	LR02	Maroni	5.300	4,5
15	LR07	Kivisili	4130	6

** Opseg otpada dan je u njivama. Primjenjivi postotak je: a Ten = 1 njiva = 1000 m^2*

Na temelju informacije u gornjoj tablici, smetlišta se mogu grupirati u dvije glavne kategorije:

Kategorija A: Područja na kojima će biti potrebna konsolidacija tla i transfer odloženog otpada, ili zbog male površine ili/i malog volumena otpada. U ovu kategoriju spadaju odlagališta PR 07 Maroni i LR09 Kivisili.

Kategorija B: Područja na kojima će se radovi na sanaciji obavljati na licu mjesta, zbog velike površine i velikog volumena otpada. U ovu kategoriju spada preostalih 13 odlagališta.

Sljedeći korak bio je procijeniti rizike za svako odlagalište. To se odnosi na:

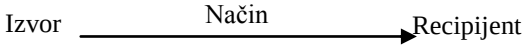
a) Procjenu "izvora onečišćenja“ (Odlagalište) (volumen otpada)

b) Procjenu "načina ", drugim riječima, na koji način je onečišćivač donesen na odlagalište (padaline – podzemna voda)

c) Procjenu recipijenta (udaljenost od izvora i konačni recipijent)

2.2 Procjena rizika na odlagalištima

Onečišćeno područje je potencijalno opasno za okoliš i njegove receptore. Negativni utjecaji od onečišćenja mogu se ilustrirati korištenjem mehanizama onečišćenja, kako je prikazano na slici 1:



Slika 1. Mehanizam onečišćenja

Proces procjene rizika temelji se na gore opisanom mehanizmu onečišćenja, koji se kasnije prilagođava za potrebe određene studije tijekom sljedećih stupnjeva:

- Izvor onečišćenja (M1) – tijekom ovog stupnja, ispituju se sljedeći parametri:
    - Volumen otpada u m^3 se procjenjuje u odnosu na četiri osnovna tipa odloženog otpada:
        - Komunalni otpad > 30 godina,
        - komunalni < 30 godina,
        - građevinski otpad i otpad od rušenja, i
        - opasni otpad
    - udaljenost industrijskih zona od onečišćenih područja, samo gdje se u obzir uzima opasni otpad.

Za klasifikaciju područja na temelju izvora onečišćenja, prvo se određuje koji tip otpada je odložen i procjenjuje se ukupna količina. Kako nisu postojali pouzdani podaci za građevinski otpad i otpad od rušenja i opasni otpad, napravljene su pretpostavke.

- Način onečišćenja (M2) – tijekom ovog stupnja promatrani su sljedeći parametri:
    - Godišnje padaline u mm (M2A), i
    - Propusnost tla (Kf) u odnosu na udaljenost akvifera od odlagališnog bazena (M2B)
- Prijemnik onečišćenja (Max) – tijekom ovog stupnja promatrana je udaljenost od izvora onečišćenja u odnosu na tip prijemnika onečišćenja. Udaljenost igra krucijalnu ulogu u procjeni potencijalne opasnosti. Prijemnici su podijeljeni u tri pod-kategorije:
    - MaxA uključuje zaštićena područja poput iskorištavanja vode (sadašnje i buduće), i zaštićena područja (Natura 2000, SPAs., SCIs, etc.
    - MaxB uključuje korištenje tla poput igrališta, agrikulturnih/obalnih zona, naseljenih zona, industrijskih zona.
    - MaxC uključuje površinske vode poput vodenih bazena, površinske vode i vode povezanih s zaštićenim područjima.

U slučajevima kada ne postoje dostatni podaci o hidrogeološkim karakteristikama područja, uzimaju se maksimalne vrijednosti. U obzir se ne uzima metoda zakapanja otpada niti godine rada odlagališta.

2.3 Procjena i kategorizacija odlagališta

Korištena je višekriterijalna analiza odlučivanja (MCDA) – sličnu tehniku je razvilo grčko Ministarstvo zaštite okoliša, prostornog uređenja i komunalnih poslova. Ona predstavlja disciplinu čija je namjena podupirati odlučitelje koji se suočavaju s brojnim i teškim evaluacijama. MCDA naglašava sve sporne situacije i daje način kako doći do kompromisa kroz transparentan proces. Kad se koristi MCDA metoda, kombinira se nekoliko različitih kriterija. Kriteriji mogu biti sljedeći:

- Ograničenja – služi za ograničavanje izbora alternativa koje su uzete u obzir, i
- Faktori – služe kao kontinuirani parametri za pogodnost lokacije za objekt od interesa.

Kriteriji se kombiniraju u formi linearne kombinacije: $E= \Sigma w_i x_i$ (I)
Gdje je E= opasnost, w_i= težina faktora i, i x_i= kriterij faktora i.

Metoda se temelji na najvišim rezultatima postignutim za svaki kriterij. Kako bi se potvrdila osjetljivost rezultata povezanih s značenjem kriterija, ispitana su tri scenarija, kako što je opisano u Tablici 2.

Tablica 2. Scenariji za procjenu i kategorizaciju područja

Kategorije kriterija	**Scenarij A**	**Scenarij B**	**Scenarij C**
Karakteristike otpada (M1)	37%	20%	40%
Hidrogeologija područja (M2)	14%	20%	15%
Korištenje vode/zaštićena područja (MaxA)	22%	20%	15%
Korištenje tla (MaxB)	22%	20%	15%
Površinske vode (MaxC)	5%	20%	15%
Ukupno	100,00%	100,00%	100,00%

Koristeći maksimalnu težinu kriterija za svaki Scenarij, dolazimo do Tablice 3:

Tablica 3. Najviši rezultati za svaki kriterij u odnosu na različite Scenarije

Kategorije kriterija	**Scenarij A**			**Scenarij B**			**Scenarij C**		
	Max težina (%)	Max rezultat	Težina faktora	Max težina (%)	Max rezultat	Težina faktora	Max težina (%)	Max rezultat	Težina faktora
M1	37%	41	1	20%	22,2	0,54	40%	44,4	1,08
M2	14%	15	1	20%	22,2	1,48	15%	16,6	1,1
MaxA	22%	25	1	20%	22,2	0,89	15%	16,6	0,66
MaxB	22%	25	1	20%	22,2	0,89	15%	16,6	0,66
MaxC	5%	5	1	20%	22,2	4,44	15%	16,6	3,32
Total	100%	111		100%	111		100%	111	

Koristeći 5 kriterija (M1, M2, MaxA, MaxB, and MaxC), te težinu faktora iz Tablice 3, moguće je izračunati opasnost za svako područje pod različitim Scenarijem.

Scenarij A: E_A = M1 + M2 + MaxA + MaxB + MaxC (II)

Scenarij B: E_B = 0,54M1 + 1,48M2 + 0,89MaxA + 0,89MaxB + 4,44MaxC (III)

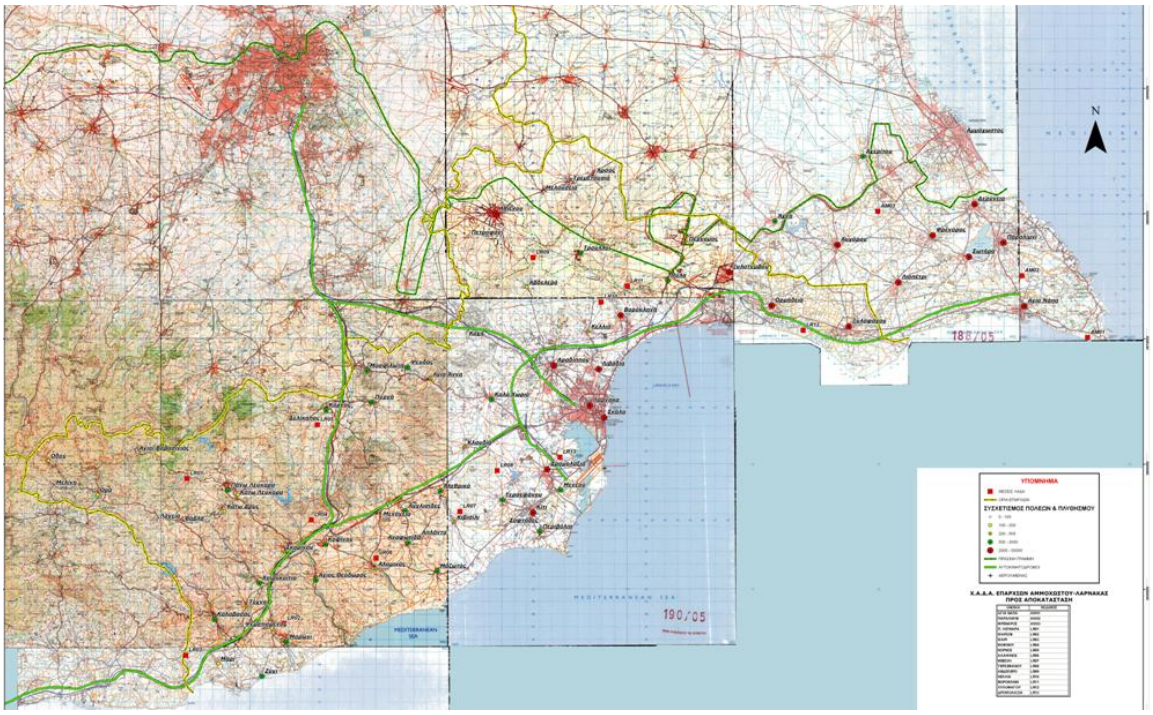
Scenarij C: $E_Г$ = 1,08M1 + 1,1M2 + 0,66MaxA + 0,66MaxB + 3,32MaxC (IV)

Za bolji pregled rezultata, ukupna vriejdnost može se izraziti u skali od 1 do 111.

3. REZULTATI I DISKUSIJA

3.1 Snimljena područja

Iz sakupljenih podataka, odlagališta otpada su kategorizirana na temelju njihova trenutnog statusa rada kao što je prikazano na slici 2. Iz detaljne studije, snimljeno je 15 odlagališta koja predstavljaju potencijalni rizik po okoliš i zdravlje ljudi na Cipru. Nakon dovršetka ovog stupnja, moguće je pristupiti procjeni rizika i konačnoj kategorizaciji područja koja su prioritetni za zatvaranje i sanaciju.



Slika 2: Lokacije odlagališta otpada na Cipru (u crvenim trokutima)

3.2 Procjena opasnosti onečišćenja

Tablica ispod pokazuje konačne promišljene rezultate za svako odlagalište, prema Scenariju uzetom u obzir i rangiranje ovih područja na temelju "strogog numeričkog" rejtinga koji su postigli za svaki Scenarij.

Tablica 4: Ukupni rezultati – serije 15 područja rizika za svaki Scenarij

	SCENARIJ A			SCENARIJ B			SCENARIJ C		
N / A	***Oznaka područja***	***Općina***	***Stupanj***	***Oznaka područja***	***Općina***	***Stupanj***	***Oznaka područja***	***Općina***	***Stupanj***
1	AM01	Agia Napa	80	AM01	Agia Napa	75	AM01	Agia Napa	85
2	AM02	Paralimni	78	LR12	Xylofagou	69	LR12	Xylofagou	79
3	AM03	Frenaros	77	LR08	Tersefanou	66	LR08	Tersefanou	78
4	LR08	Tersefanou	77	AM02	Paralimni	58	AM02	Paralimni	74
5	LR10	Kellia	77	AM03	Frenaros	58	AM03	Frenaros	73
6	LR09	Avdellero	74	LR10	Kellia	58	LR10	Kellia	73
7	LR12	Xylofaogou	68	LR09	Avdellero	56	LR11	Oroklini	70
8	LR04	Kofinou	67	LR11	Oroklini	56	LR09	Avdellero	70
9	LR02	Maroni	60	LR04	Kofinou	52	LR04	Kofinou	62
10	LR11	Ooroklini	58	LR05	Kornos	50	LR03	Mari	60
11	LR03	Mari	57	LR02	Maroni	49	LR05	Kornos	58
12	LR06	Alaminos	50	LR06	Alaminos	45	LR02	Maroni	55
13	LR07	Kivisili	48	LR03	Mari	40	LR06	Alaminos	52
14	LR05	Kornos	47	LR07	Kivisili	39	LR01	Pano Leukara	48

	SCENARIJ A			SCENARIJ B			SCENARIJ C		
N / A	***Oznaka područja***	***Općina***	***Stupanj***	***Oznaka područja***	***Općina***	***Stupanj***	***Oznaka područja***	***Općina***	***Stupanj***
15	LR01	Pano Leukara	46	LR01	Pano Leukara	34	LR07	Kivisili	46

Nakon završetka bodovanja, prikazano je konačno rangiranje odlagališta, koje je u obzir uzelo i opseg i količinu otpada koji je prihvaćan ili se još uvijek prihvaća, dobiven je stupanj rizika, na osnovu kojega je postavljeno konačno rangiranje odlagališta kako je prikazano u tablici ispod.

Tablica 5: Rangiranje odlagališta po potencijalnom riziku

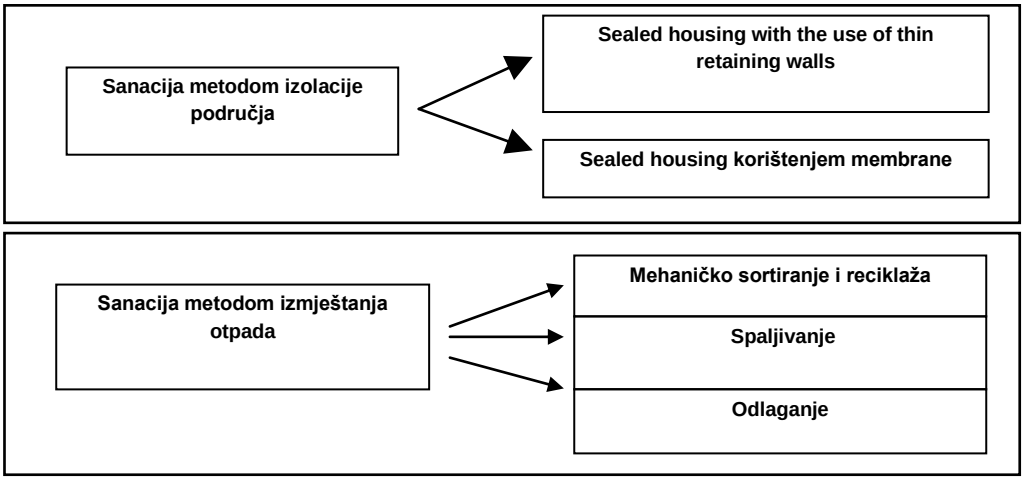
KATEGORIJA	Odlagalište	POTENCIJALNI RIZIK
A.	LR02 Maroni	**ograničen**
	LR7 Kivisili	
	LR05 Kornos	
B.	LR10 kellia	**opravdan**
	LR04 Kofinou	
	LR11 Oroklini	
	LR03 Mari	
	LR06 Alaminos	
	LR01 Pano Lefkara	
C.	AM01 Ayia Napa	**Važan**
	AM02 Paralimni	
	AM03 Frenaros	
	LR08 Tersefanou	
	LR09 Advellero	
	LR12 Xylofagou	

Studija prikazuje iscrpnu analitičku okosnicu za utvrđivanje prioriteta za sanaciju odlagališta na Cipru. MCDA model dao je sistematičan i transparentan pristup koji je Ciparska Vlada koristila za razjašnjavanje procesa donošenja odluka i olakšan je odabir od strane onih koji odlučuju.

Ulazni podaci za kriterij mogu se relativno lagano dobiti. U određenim slučajevima, kako bi se premostio problem kad nije bilo dostupnih pouzdanih podataka za odlagališta, dan je ili maksimalan rezultat, ili su odabrani različiti rejtinzi za dovršenje procesa kategorizacije (predstavljena je analiza osjetljivosti). Međutim, oba rješenja zahtijevaju pažljivu procjenu kako bi se donijela ispravna odluka. Ukoliko je kriterij kritičan da bi se donijela odluka, potrebno je kompletirati sve podatke i mora se napraviti analiza osjetljivosti.

3.3 Metode sanacije

Tehnologije sanacije uključuju većinom tehnologije sprječavanja širenja utjecaja i u nekoliko slučajeva premještanje otpada na moderna odlagališta, kao na Slici 3.



Slika 3: Metode sanacije

Odabir tehnologije ovisi o području i temelji se na potrebnom stupnju propusnosti, mogućnosti monitoringa i održavanju sustava. Monitoring tehnologije uključuju sustave monitoringa podzemnih voda, oborinskih voda, bioplina, procjedne vode, slijeganja tla i pokrovnog sloja. Predloženi sanacijski radovi za 15 područja prikazani su u tablici 6.

Tablica 6: Projekti sanacije 15 odlagališta u Larnaca - Ammochostos

A/A	PROVINCE OZNAKA	OPĆINA	odbaćeno AREA .*	VOLUMEN OTPADA (m^3) **	KLASA OPASNOSTI	PROJECTS REORGANISATION - RECOVERY											
						TRANSPOR-TATION OF WASTE DEPOSITS	SPOT WORKS REORGANISATION - RECOVERY									PROJEKTI KONTROLE OKOLIŠA	NEW USES
							ZAVRŠNI POKROV - OZELENJEVANJE			PROJEKT MANAGEMENT Drenaža		BIOGAS PROJECT MANAGEMENT					
							A	B	C	SAKUPLJANJE – TRANSPOR-TATION	OBRADA	OČEKIVANA PROIZVODNJA BIOPLINA (m3 /h)	RELIEF WINDOWS	Sakupljanje - Spaljivanje	Oporaba energije		
1	AM01	AGIA NAPA	95	451 000	C				√	√	Procjedna voda se sakuplja u kontejenrima i odvodi se periodično tankerima na obradu na postrojenje za obradu procjednih voda u stanicu za obradu otpada Larnaca - Famagusta at "Koshi"	228.88		√		√	√
2	AM02	PARALIMNI	94	300 000	C				√	√		153.65		√		√	
3	AM03	FRENAROS	41	200 000	C				√	√		93.22		√		√	
4	LR01	PANO LEUKARA	15	25.500	B			√		√		11.30	√			√	
5	LR02	MARONI	4.5	5.300	A	√						2.93					
6	LR03	MARI	5	130 000	B			√		√		72.53		√		√	
7	LR04	KOFINOU	9	18.000	B			√		√		9.85	√			√	
8	LR05	KORNOS	15.5	31.100	A		√					14.41	√			√	
9	LR06	ALAMINOS	4	24.200	B			√		√		13.12	√			√	
10	LR07	KIVISILI	6	4130	A	√						2.10	√				
11	LR08	TERSEFANOU	183	1661650	C				√	√		756.16			√	√	√
12	LR09	AVDELLERO	9.5	53.200	C				√	√		25.79	√			√	
13	LR10	KELLIA	73	148 000	B			√		√		78.73		√		√	
14	LR11	OROKLINI	20	76.000	B			√		√		36.51	√			√	
15	LR12	XYLOFAGOU	34.5	100 000	C				√	√		48.47	√			√	

* Opseg otpada dan je u njivama.

** Volumen otpada je identificiran kompjutorski usporedbom topografijom trenutne situacije i topografijom prije odlaganja otpada (1:5000, digitalizirano)

4. Zaključci

Studija prikazuje iscrpnu analitičku okosnicu za utvrđivanje prioriteta za sanaciju odlagališta na Cipru. MCDA model dao je sistematičan i transparentan pristup koji je Ciparska Vlada koristila za razjašnjavanje procesa donošenja odluka i olakšan je odabir od strane onih koji odlučuju.

Ulazni podaci za kriterij mogu se relativno lagano dobiti. U određenim slučajevima, kako bi se premostio problem kad nije bilo dostupnih pouzdanih podataka za odlagališta, dan je ili maksimalan rezultat, ili su odabrani različiti rejtinzi za dovršenje procesa kategorizacije (predstavljena je analiza osjetljivosti). Međutim, oba rješenja zahtijevaju pažljivu procjenu kako bi se donijela ispravna odluka. Ukoliko je kriterij kritičan da bi se donijela odluka, potrebno je kompletirati sve podatke i mora se napraviti analiza osjetljivosti.

MCDA analiza pokazala je da prisutnost 15 odlagališta u Larnaca i Ammochostos regijama na Cipru. Prioritet kod sanacije ostalih područja također će ovisiti o vrsti sanacijskih radova.

Korištenje MCDA metode u sektoru gospodarenja otpadom ima mnoge prednosti, poput:

- Faktori su jasno opisani
- Ako nema dovoljno podataka, potrebno je kompletiranje
- Osjetljivost analize podataka otkriva glavne karakteristike svakog područja
- Metoda se može diferencirati i prilagođavati

Bez obzira na gore navedene prednosti, korisnici metode moraju biti svjesni zaključaka koji krivo navode u slučajevima kad nedostaju kritični podaci i/ili kad je određena kriva težina faktora.

Završetak radova je intervencija koja će značajno poboljšati kvalitetu života društva. U konačnici, ovaj projekt će značajno doprinijeti Cjelovitom sustavu gospodarenja otpadom na Cipru.

Literatura

9. Saaty T.L., 1980. *The Analytic Hierarchy Process.* McGraw-Hill Inc., New York.
10. Linkov I., Vargee S., Jamil S., Seager T.P., Kiker G., Bridges T., 2004. *Multi-criteria decision analysis: a framework for structuring remedial decisions at contaminated sites* (eds. Linkov I. and A. Ramadan).
11. Saaty T.L, 2001. *Decision making with Dependence and Feedback: The Analytic Network Process.* 2nd ed., RWS Publications.
12. Belton V., Stewart T.J., 2002. *Multiple Criteria Decision Analysis: An integrated approach*. Kluwer Academic Publishers, Dordrecht.
13. Thill J. C., 1997. Spatial Multicriteria Decision Making and Analysis: A geographic information system approach. Ashgate Publishing, England.
14. Lolos T., Koullapis G., Lolos G., Paschali-Manou K., Tsobanidis C., Georgiou I. and Panagoulopoulos A., Identification, Evaluation And Categorization Of Uncontrolled Landfill Sites In Cyprus, *Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium*
15. Hellenic Ministry for the Environment, Physical Planning and Public Works, 2005. *Standard technical specifications for the restoration of uncontrolled landfill sites.* Circular 135977/5051.
16. Promentilla, M.A.B. (2006) Development of a multiple criteria decision making method for remedial countermeasures of contaminated sites. PhD thesis. Hokkaido University.