ΤΑ ΓΣΠ ΩΣ ΕΡΓΑΛΕΙΟ ΛΗΨΗΣ ΑΠΟΦΑΣΕΩΝ ΓΙΑ ΤΟΝ ΚΑΘΟΡΙΣΜΟ ΠΡΟΤΕΡΑΙΟΤΗΤΑΣ ΣΤΗΝ ΑΠΟΚΑΤΑΣΤΑΣΗ ΧΩΡΩΝ ΔΙΑΘΕΣΗΣ ΑΠΟΒΛΗΤΩΝ: ΕΦΑΡΜΟΓΗ ΣΤΟ ΝΟΜΟ ΛΑΚΩΝΙΑΣ

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Περίληψη

Κατά την εργασία γίνεται αποτύπωση της κατάστασης που επικρατεί σήμερα στο Νομό Λακωνίας, όσον αφορά την ανεξέλεγκτη διάθεση των αποβλήτων. Για το σκοπό αυτό, το 2005, το Εργαστήριο Μετάδοσης Θερμότητας και Περιβαλλοντικής Μηχανικής εκπόνησε έρευνα πεδίου για την καταγραφή των Χώρων Ανεξέλεγκτης Διάθεσης Αποβλήτων στη Λακωνία, καθώς και των κυριότερων χαρακτηριστικών τους, όπως είναι η απόστασή τους από κατοικημένες περιοχές, εφαρμογή και συχνότητα ανοιχτής καύσης και/ή χωματοκάλυψης, κ.λπ. Στη συνέχεια τα στοιχεία εισήχθησαν σε γεωγραφική βάση δεδομένων προς περαιτέρω ανάλυση και διενεργήθηκε εκτίμηση της επικινδυνότητας των χώρων, η οποία οδήγησε στην επιλογή της κατάλληλης μεθόδου αποκατάστασής τους. Τέλος εφαρμόστηκε παραγοντική ανάλυση με σκοπό οι χώροι αυτοί να ομαδοποιηθούν σύμφωνα με τα χαρακτηριστικά τους.

APPLICATION OF GIS AS A DECISION-MAKING TOOL FOR PRIORITIZING OPEN DUMP RESTORATION IN THE HELLENIC PREFECTURE OF LACONIA

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Abstract

This paper presents an integrated assessment of the current status of open dumps in the Laconia Prefecture, according to a survey which was conducted in 2005, addressing all related data such as their distance from the inhabited areas, practiced systematic open combustion and/or soil coverage of waste and their frequency etc. A Geographic Information System database was then created and the above parameters were statistically analyzed. Hazard assessment for each site was conducted, which led to the choice of the appropriate restoration works. Finally, following the hazard assessment results for the sites in need restoration works, Principal Component Analysis was implemented in order to group them according to their characteristics.

Λέξεις κλειδιά: Χώροι Ανεξέλεγκτης Διάθεσης Αποβλήτων, Καθορισμός προτεραιότητας στην αποκατάσταση, Διαχείριση στερεών αποβλήτων.

Key words: Open dumps, Restoration prioritization, Solid Waste Management.

1. Introduction

Rehabilitation of existing open dumps is connected with possibilities for both urban and rural development, although the low marketability of these sites and the subsequent reluctance to invest in them inhibits their redevelopment and further re-use. Various studies have been made regarding redevelopment, assessment of open dumps, closure methods and management options. Zender and Tchobanoglous (1996) have developed a manual for restoration of open dumps on Indian reservations, while Boyer et al. (1999) have released a practical, graph-based decision methodology for landfill remediation. Other pertinent studies include key concepts that relate to landfill restoration (Simmons and Coulter, 1997); closure and conversion options of open dumps (Rushbrook and Pugh, 1999); investigation procedures for landfill restoration (Bruyat-Korda et al., 1997) and investigation methodology for open dumps (Mavropoulos and Kalliampakos, 1999).

Some of the above studies concern sanitary landfills as well; still, the standards to be adopted in remediating a closed open dump should be comparable to those applicable to the closure of a better operated engineered landfill in similar hydrogeological conditions (Rushbrook and Pugh, 1999). Restoration methods focused on open dumps in specific areas are also common in literature including the establishment of a Europe-wide guideline for risk assessment of old deposit sites (Allgaier et al., 2001); a project for open dump remediation in South Africa (Ball and Bredenhann, 2003); a case study of open dump rehabilitation in Tunisia (Zairi et al., 2004) and open dump restoration in the Hellenic prefecture of Kozani (Tsatsarelis et al., 2005).

In Greece, almost 91.2% is landfilled while 8.8% of the total generated waste is recycled and Hellenic legislation proposed that all open dumps should have been closed until 2005 (Hellenic Official Gazette, 2003). In a follow-up circular (Hellenic Ministry for the Environment, Physical Planning and Public Works, 2004), the former deadline was reminded, binding the authorities to receive a restoration license for open dumps existing in their boundaries, until June 22, 2005. A second deadline was set afterwards until December 5, 2005. Afterwards, on October 6, 2005, the European Court convicted Greece for the existence of 1,125 open dumps, because according to the European law, all open dumps should had been restored by 1999 (Council Directive 75/442/EEC, 1975). The real number of open dumps in the country is even greater (found to be 2,626), in Peloponnese there are 227 of them and the restoration cost is estimated at 27 million euros (Hellenic Ministry for the Environment, Physical Planning and Public Works, 2005). The region had ensured only 10 million euros until June 2006 (Maroutsis, 2005).

The Ministry of Environment Planning and Public Works decided to construct sanitary landfills for waste disposal. In the region of Pelloponese a sanitary landfill and transfer stations will be constructed in every Prefecture, according to its needs. For the Laconia Prefecture, a sanitary landfill will be constructed either in location "Sari – Katarachi", which is located near the open dump in Agii Tessarakonta, or near the army camp in Faridos Municipality. The exact number and location of transfer stations will be then defined. The average annual capacity for a period of 20 years will be 45,406 Mg, the total investment cost is estimated to be 5,490,000 euros and the annual operational cost 672,010 euros (Frantzis et al., 2003).

According to the study conducted by Frantzis et al. (2003), the total waste production for the Laconia Prefecture in 2001 was 36,455 Mg. The mean annual composition of wastes is 47% food wastes, 16.3% paper, 8.7% cardboard, 7.4% plastics, 0.6% aluminium, 2.8% ferrous metals, 2.1% textiles, 0.6% rubber – leather, 3.7% wood – yard wastes, 5% inert, 2.6% glass and 3% rest. Environmental studies have been conducted in just few of the open dumps of Laconia. More specifically, in the waste disposal site of Skala Municipality, (location "Ampoulas"), a compacted clay liner has been installed and in the Krokees Municipality, (location "Nerakia"), drainage trenches have been constructed. Local authorities are responsible for the collection, transportation and treatment of waste, the organization of the SWM system, employment and training of staff and the procurement of containers, vehicles and the essential machinery.

Nowadays, in the majority of Laconia Municipalities, the wastes collected are transported in just one disposal site per Municipality, although there are numerous other open dumps within the Prefecture, which although should be inactive, however still seem to be receiving wastes. Recycling of wastes is still not significantly practiced in any Municipality. Frantzis et al. (2003), calculated that approximately 2,146,360 euros are spent every year in Laconia Prefecture for MSWM where the most (906,000 euros) are spent by Sparti Municipality (which is the capital of the Prefecture) and the least (2,641 euros) by Karies Community. Figure 2 illustrates the MSWM costs per person and year, gathered in the field survey in which Municipalities are assorted according to their population; Sparti has the biggest and Elafonisos the smallest population.

Figure 1. Prefecture of Laconia and related sites (names of municipalities are indicated in bold and those of open dump sites in italic)

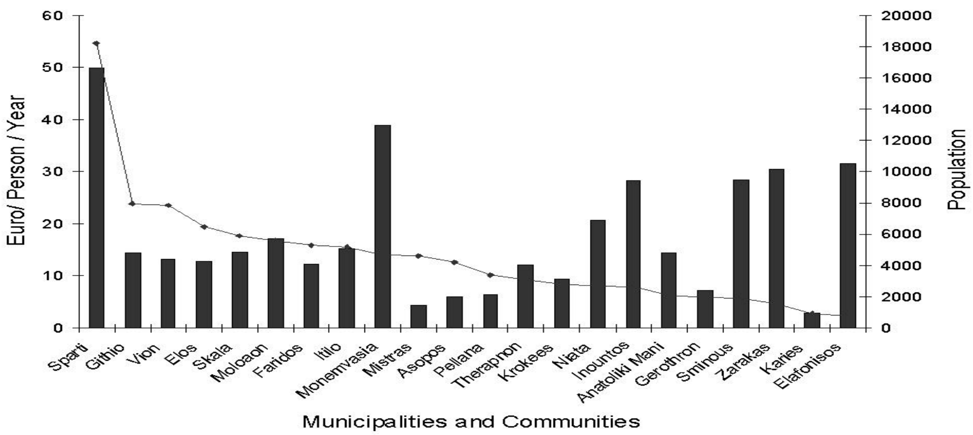

Figure 2. Cost of MSWM per person and year for all municipalities of the Laconia Prefecture; municipalities are listed in a decreasing population scale

2. Materials and methods

2.1 Field survey

A registration of open dumps of the Prefecture was conducted by the Urban Planning Office of the Laconia Prefecture on 2000; therefore, the current study (which was conducted from April until July 2005) validated and supplemented the previous one. The data required were mainly retrieved by the city halls and the local authorities, yet drivers of collection vehicles and local people provided another significant source of information. The fields that were required to be filled in for every open dump concerned:

- Distance from the closest inhabited area.
- Drill existence.
- Site size.
- Estimated depth of waste.
- Estimated volume of waste.
- Compression of waste.
- Estimated type of contained waste.
- Waste dumping around the site.
- Fencing of the dump site boundaries.
- Dumping of sewage and sludge.
- Distance from surface waters – Waste dumping in surface waters.
- Animal breeding in the site or in the close vicinity.
- Incidents of spontaneous combustion.
- Systematic soil coverage of waste.
- Year of the open dump's operation initiation.
- Type and density of vegetation near the site.
- Systematic combustion of waste and its frequency

All the above data were then collected, analysed and supplied a GIS database using the ArcGIS 9® commercial software.

2.2 Analysis of Variance

A single-factor Analysis of Variance (ANOVA) using Microsoft Excel XP® was conducted to identify relationships among the collected characteristics of open dumps. An independent variable is examined in various classes, and in each one of these classes the dependent variable follows a distribution with a specific mean value. By using ANOVA, the equality of the mean values of the dependent variable in the various classes of the independent variable is checked (Tagaras, 2002), and if it is proven that these mean values are not all equal to each other, then the independent variable indeed affects the dependent one.

2.3 Hazard Assessment

A methodology for defining hazard degree has been applied to each open dump according to the official guidelines proposed by the Hellenic Ministry for the Environment, Physical Planning and Public Works (2004). The initial goal of this particular method is to point out the most hazardous open dumps for public health and the environment and to determine the type of measures that should be taken, by calculating a hazard degree ε for each open dump. The implementation of this methodology consists of three steps:

- Step 1 concerns the pollution sources that exist on the site and is conducted by taking into account the quantities, type of waste (household, construction and demolition) and the age of each open dump. Variable μ1max deals with the volume of main type of wastes and μ1min with the volume of the other type of wastes which are disposed of in each open dump. Finally, an intermediate parameter M1 is calculated as follows:
  $M_1 = \mu_1^{max} - \mu_1^{min}$ (1)
- Step 2 concerns the path of pollution dispersion. In this step water permeability of soil and the distance of the aquifer from the deepest point of each site are taken into

account in the context of a provided tabular methodological tool. The distance of the aquifer from the dump site is divided into 4 classes at the aquifer less than 2 m between 2 and 10 m and finally over 10 m and water permeability (Kf) is divided into 3 classes ($K_f<10^{-6}$ m/s, $10^{-4}>K_f>10^{-6}$ m/s, $K_f>10^{-4}$ m/s). By using this tool, another intermediate parameter, M_2, is calculated.

- Finally, step 3 concerns the final receptor of the pollution. In this step, three other parameters (max a, max b, max c) are calculated. These three parameters are determined by consulting a table in which the distance of the site from 3 different categories of water supplies (parameter a), the distance from 6 different categories of land use and inhabited areas (parameter b) and the distance from 3 different categories of protected areas and rivers (parameter c) is divided into 5 classes over 1000 m, between 501 and 1000 m, between 101 and 500 m, less than 100 m and, finally negligible distance. After defining the different values of parameters a, b and c, the values of max a, max b, and max c are calculated. After, using equations (2), (3) and (4), the hazard degree ε results from equation (5).

$$x = M_2 + \max a \quad (2) \qquad y = x + \max b \quad (3) \qquad \zeta = y + \max c \quad (4) \qquad \varepsilon = M_1+\zeta \quad (5)$$

Open dumps are then ranked into 4 categories according to their hazard degree evaluation. The first one ($\varepsilon \geq 90$) includes dumps that should be urgently and extensively restored ('1st priority'), the second one, ($70 \leq \varepsilon \leq 89$) includes sites that should also be restored ('2nd priority'), the third one ($30 \leq \varepsilon \leq 69$) suggests that the included sites should be restored in the future, whereas the last one ($\varepsilon \leq 29$) includes sites that do not need any restoration.

2.4 Principal Component Analysis

Principal Component Analysis (PCA) is amongst the oldest of the multivariate statistical methods of data reduction. Crichton (2000) demonstrated that PCA is a method for producing a small number of constructed components, derived from a larger number of variables originally collected. According to Bernard et al. (1997), PCA's initial goal is the examination of similarities between elements and links between variables. The existence of links between variables leads to a reduction of the number of variables which are then called principal components. The data are illustrated onto Euclidian planes determined by principal components. PCA is usually carried out in two steps. According to Crichton (2001), the first step is to define the components with the biggest contribution to the study (principal components). In order to make the interpretation of the components that are considered relevant, the first step is generally followed by a rotation of the components that were retained (Abdi, 2003). Varimax is the most popular rotation method and for varimax a simple solution means that each component has a small number of large loadings and a large number of zero (or small) loadings. In this work PCA was conducted by using the SPSS 12.0® commercial software.

3. Results

3.1 Characteristics of open dumps

In the current study, 42 open dumps were registered; 28 were found to be active and 14 inactive. The biggest one is located in "Agii Tessarakonta"; it belongs to Sparti Municipality and is also used by three other Municipalities (Inountos, Therapnon, Mistras). From the total number of inactive open dumps, eight still receive any sort of wastes (municipal, debris, agricultural etc.), while the rest are totally abandoned. There is also a restored open dump in Mistras Municipality, which is nowadays an athletic installation and plans for restoration had been prepared for just five open dumps up to July 2005. In 37% of the sites, wastes are covered by soil and while it is not the proper way of waste disposal, this action provides some critical advantages. Soil hinders the rain water from having direct contact to waste, so less water is detained. On the other hand, the danger of waste self-ignition (due to biogas, broken glass, etc) is diminished, odours are detained and rodents find less waste for food. Furthermore, in 15% of the sites, wastes either are combusted in the open, on purpose, mainly for the reduction of their volume, or due to spontaneous self-ignition. Open burning is responsible for generation of toxic byproducts of combustion such as polychlorinated dibenzodioxins and furans (PCDD/F), Polycyclic Aromatic Hydrocarbon (PAH), Volatile Organic Compounds (VOC) and Polychlorinated Biphenyls (PCBs) (Lemieux et al., 2004). Another consequence arises from the danger of fire spreading to surrounding land. On the other hand, in 25% of the sites, both combustion and soil coverage of wastes take place.

According to Martens et al. (1998) in case of uncontrolled waste combustion in open dumps, a crucial distance in which the concentrations of PAH, PCB and heavy metals decline is approximately 1.5 km. In 11 out of 42 open dumps (26%) animal breeding or animal breeding facilities, either at the site or in the close vicinity, was registered. Furthermore, 20 out of the 42 registered open dumps are located in dense vegetation areas and nine sites are located inside Natura 2000 protected regions. According to the Ministry for the Environment, Physical Planning and Public Works (2004), the critical distance of open dumps from protected areas, drillings etc. is about 500 m.

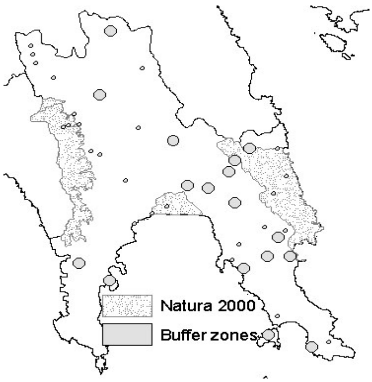

Figure 3. Influence zones of open dumps

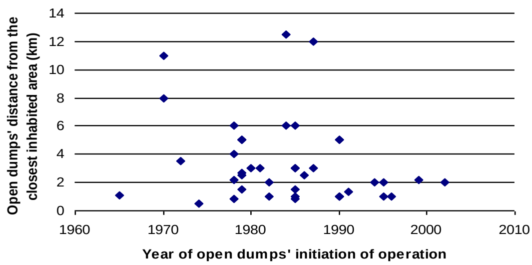

Figure 4. Distance of each open dump from the closest inhabited area, in relation to its initiation date

In Figure 3, the influence buffer zones of all the registered open dumps are illustrated according to open combustion practicing. For the sites that open combustion takes place, the influence buffer zones have 1.5-km radius and for the rest, 500 m. It should be noted that 12 of them affect Natura 2000 areas. For that reason, it is interesting to check the history of open dumps in Laconia Prefecture, regarding their distance from inhabited areas, as illustrated in Figure 4. The distance of each open dump from an inhabited area varies between 500 m and 12.5 km posing serious threats to public health, so the purpose of understanding its history is to find out whether the distance of these sites from inhabited areas depends on their initiation year. This calculation was conducted using the ANOVA tool and resulted that there is no dependence on the year of the dumps' initiation operation and the sites' distance to inhabited areas, meaning that the distance of the site from a settlement is not a factor when the Municipality initiates a new open dump.

3.2 Results of Hazard Assessment

Out of a total of 42 open dumps, not a single one was assigned in the priority-measures-to-be-taken categories (A or B), with the most hazardous site found to be located in Agii Tessarakonta. This overall rating is the result of the small amount of wastes that are disposed in the open dumps, because of the small population of Laconia Prefecture and because of the low level of the aquifer in most dumps (M2 values in many cases are almost zero). Table 1 groups the results of hazard assessment in relation to the measures that should be taken or not (categories C and D) and the estimated costs of restoration (Hellenic Ministry for the Environment, Physical Planning and Public Works, 2004) according to the hazard-degree evaluation. Open dumps of categories C and D are shown in Figure 5.

The methodology used here has been the subject of some criticism and scepticism lately in Greece. One major shortcoming of this methodology is the fact that it only considers locational characteristics of open dumps in the calculation of the hazard degree ε and does not consider any waste management factors such as soil coverage of waste and open burning. Soil coverage may reduce the risks that open dumps pose to the environment and open burning of waste will certainly have a major effect. Also, for estimating the hazard risk to water, only permeability of soil and the distance from the aquifer are taken into account; in case that this distance is more than 10 m, the hazard is considered minor. Leachate might enter the underground water table through cracks in the ground though, regardless of the above. Therefore although this methodology certainly captures some of the risk, the results may not quantify the true risk to the environment and public health posed by some of these sites.

Table 1. Category, priority of measures to be taken, hazard degree, and estimation of restoration costs for all open dumps of Laconia Prefecture (Hellenic Ministry for the Environment, Physical Planning and Public Works, 2004)

Category	C	D
Priority of measures to be taken	Future measures to be taken	No demand for restoration measures
Hazard degree (ε)	30-69	0-29
Number of open dumps	18	20
Restoration cost range (euros / ha)	99,000 – 160,000	34,000 – 78,000

Figure 5. Category C and D open dumps in Laconia Prefecture

3.3 Results of Principal Component Analysis

PCA was conducted for the (categorized as Category-C) open dumps, in order to classify them according to soil coverage, open combustion, fencing, water permeability, initiation date and animal breeding in the site or in the close vicinity. Category-D open dumps are regarded harmless for the environment; thus they were not included in the PCA calculations. Principal goal of PCA was to define the contribution of the above variables and the components that they form in the characteristics of each site, in order to guide the future restoration programs according to the most dominant component and categorize the sites into similar groups which need similar restoration method. The aforementioned variables were considered as the most important ones, so only these were inserted in the PCA model. The implementation of PCA resulted in the derivation of two components, which led to the classification of Category-C open dumps in 5 groups (Figure 6). Component 1 contributes by 33% and component 2 by 28.5% to the classification of open dumps. Common characteristic of group-1 open dumps is the lack of fencing; therefore, a fence should be installed in order to prohibit animals from entering the site and the scattering of wastes. The common characteristics of group-2 open dumps are fencing and open combustion of wastes in sites. It can be concluded that the second and third quadrant (up and bottom left) of Figure 6 are related to the variable of fencing.

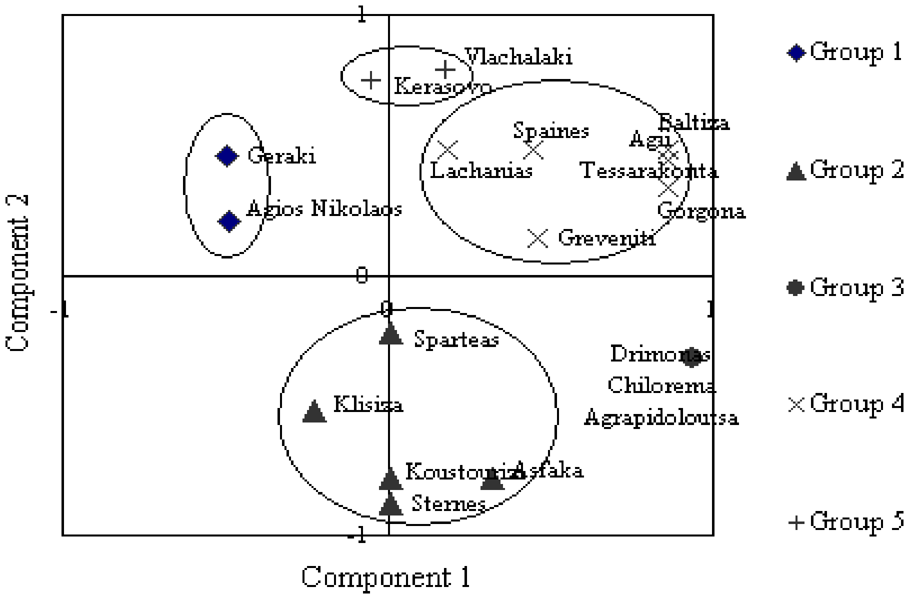

Figure 6. Grouping of Category-C open dumps

Group 3 open dumps, (Drimonas, Chilorema and Agrapidoloutsa), have similar water permeability (10-4>Kf>10-6 m/s) and soil coverage is practiced once per month. By analyzing the above variables, it is concluded that the fourth quadrant (bottom right) is related to soil coverage and open combustion. Group 4 consists of six open dumps where the initiation date (and, therefore, the age of wastes) is the same. However, geological characteristics in Baltiza, Agii Tessarakonta and Gorgona are similar (water permeability 10-4>Kf>10-6 m/s) and that is why these sites share the same point in Figure 6. The main characteristics of Kerasovo and Vlachalaki (Group 5) are low water permeability (Kf<10-6 m/s) and no animal breeding. The above Groups (4 and 5) show that the first quadrant (up right) concerns water permeability and open dumps' initiation date.

4. Conclusions

This study assessed the 2005 status of SWM in Laconia prefecture, which is unfortunately still largely based on open dumping of waste. Forty-two dumps were registered, located relatively close to populated centers, dense vegetation areas and Natura 2000 protected areas. A statistical analysis revealed no evidence that distance from populated centers was taken into account when deciding upon their location. Hazardous materials are disposed of in 85% of them, and open burning of wastes is still practised in 15% of them. On the other hand they are small, between 0.5-1 ha and in 37% of the sites soil coverage of wastes takes place.

The low values of hazard degree ε of open dumps, calculated according to the national guidelines' methodology, are mainly due to the fact that only small amounts of wastes are produced in Laconia prefecture and that most sites underground waters are deeper than 10 m. Although these guidelines comprise a quick and easy to use toolkit for restoration plans, they produce results that may underestimate the hazards of open dumping, since soil coverage of waste and open combustion are not taken into account and contamination of underground water is only calculated by estimation of permeability of soil and distance of waste from the aquifer.

The use of PCA to further categorize the sites subjected to hazard analysis offers a practical methodology for organising the restoration plans for open dumps and it or another suitable factor analysis method could be a useful addition to existing legislation. Use of fuzzy sets for modelling binary variables (compression of waste, animal grazing in the area, etc) might also enhance the analysis, because it would more accurately quantify the contributions of such variables to the impact of open dumps on the environment and public health.

Appendix 1

Abbreviations:

ANOVA	ANalysis Of VAriance	GIS	Geographical Information System
MSWM	Municipal Solid Waste Management	PCB	Polychlorinated Biphenyl
PAH	Polycyclic Aromatic Hydrocarbon	VOC	Volatile Organic Compound
PCA	Principal Component Analysis		

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