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ECOLOGICAL RISK PREDICTION IN RELATION TO THE POTENTIAL DETRIMENTAL CONSEQUENCES AT DISPOSAL OF DIFFERENT INDUSTRIAL WASTES

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Abstract

The ecological risk related to the wastes disposal is that attached to functioning, closure and the post-closure phases of an ecological landfill lyfe cycle. The prediction of ecological risk in each of those three phases - i.e. the manifestation and evolution of possible negative consequences of different severities for different environmental targets - is an endeavor that organizations that possess and operate those ecological landfills should consider in order to ensure the maximum protection for environment and human health. However, it should be noted that there are not too many user friendly methods that an organization can use to estimate the evolution of the adverse effects arising during life time of a waste ecological landfill based on monitoring available data. Therefore, in present article we propose such a methodological instrument that can meet the new environmental management requirements standard EN ISO 14001:2015, related to the necessity that each organization, having in place a certified environmental management system should be able to determine the possible environment risk brought by its operations in order to take adequately management actions.

Key words: assessment, multi-criteria, prediction, risk, waste

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1. Introduction

The legislation in last decades became more and more demanding in relation to the waste management including waste disposal. The past practice of using waste landfilling without taking any measures for the environmental protection is well known. Such practices were generators of highly contaminated leachates producing historical pollution in many regions around the globe. Nowadays, the situation has been changed due to increase of societal awareness towards this phenomenon (Deegan, 2003; Rusu et al., 2017; Sullivan and Wyndham, 2001; Tinsley and Pillai, 2006, cited in Phan and Baird, 2015). In this respect, new environmental laws have been adopted establishing the frame for strict regulation of the design and construction requirements for wastes disposal in order to preserve environment from contamination. One example of contamination from waste is related to leachate infiltration. The leachate pollutants can be toxic for different species of the ecosystem. They can have "possible synergic and additive effects affecting organisms in particular, fish. As fish are the highest level of the aquatic food chain, this can lead to serious intoxication of other animals and humans eating fish" (Baderna et al., 2011). Therefore, prediction of the ecological risk is a very important goal for any organization that manages wastes disposal. There is a plethora of methods/techniques to analyze and characterize/assess the risk in different fields such as engineering, medicine, chemistry, biology, including environment.

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Those methods have been classified (Marhavilas et al., 2011) as follows:

a) *qualitative techniques* - e.g. checklists, what if analysis, safety audits, task analysis, Hazard and Operability study (HAZOP),

b) *quantitative techniques* - e.g. The Proportional Risk Assessment Techniques (PRAT), The Decision Matrix Risk Assessment Techniques (DMRA), Quantitative Risk Assessment (QRA), Predictive, Epistemic Approach Method (PEA) and

c) *hybrid techniques* - e.g. Human Factor Error Analysis (HEAT), Human Factor Event Analysis (HFEA), Fault Tree Analysis (FTA).

The purpose of this work is to introduce an easy to use methodology for organizations that manage waste landfills, including industrial ones to assess and predict the ecological risk based on on-site monitoring available data and information.

2. Materials and methods

The present proposed risk predictive multi-criteria tool can be classified under DMRA type technique. As Marhavilas et al. (Marhavilas et al., 2011) say mentioning the literature in the field (Ayyub, 2003; Haimes, 2009; Henselwood and Phillips, 2006; Marhavilas and Koulouriotis, 2005; Reniers et al., 2005; Woodruff, 2005, 2008), DMRA type of technique is a quantitative "systematic approach for estimating risks, which is consisting of measuring and categorizing risks on an informed judgment basis as to both probability and consequence and as to relative importance". *Risk, according to Varnes ((Varnes, 1984) cited in Darbra, 2008)) "is generally defined as the combination of hazard and vulnerability; hazard represent the probability that a potentially detrimental event of given characteristics occurs in a given area, for a time period; vulnerability is the degree for intrinsic weakness of the system. Risk can be measured by pairing the probability of occurrence of an event, and the outcomes or consequences associated with that occurrence. This pairing is not a mathematical operation, a scalar or vector quantity, but a matching of the probability of the event occurring with the expected consequences*."

For the purpose of this proposed method we use the following explanation for the used concepts:

a) **Hazard**: a substance or situation or a combination of both having dangerous characteristics capable to determine in certain circumstances damages of certain severity for different environment and human health targets;

b) **Vulnerability:** target's characteristics exhibited/occurring in the moment of hazard manifestation facilitating or/and amplifying/magnifying the produced negative consequences of the hazard manifestation.

Any prediction involves uncertainty. Uncertainty might be due to random variability of phenomena or lack of knowledge. Klir (cited in Bernardini and Tonon, 2004) defines randomness as "the disagreement resulting from the attempt to classify an element of a given universal set into two or more disjoint subsets of interest under total or partial ignorance regarding relevant characteristics of the element" and imprecision as "the variety of alternatives that in a given situation are left unspecified". "Often, the word uncertainty has been equated with random variability, and it has been claimed that the classical probability theory will be sufficient for each situation (Ferson and Ginzburg, 1996; Zimmermann, 2000). Lindley (1982) even argued that it is actually the only reasonable description of uncertainty" (Kangas and Kangas, 2004). From this perspective, uncertainty can be expressed by using the two well-known conventional probabilities based approaches namely:" the objective probability" when the probability is expressed as a frequency of an event and "the subjective probability" when the probability is expressed as an estimated frequency of an event in an evaluator's opinion, belief. However, in the latest decades "the use of probability theory as the most adequate framework for describing epistemic uncertainty has been challenged" (Colyvan, 2008, Helton and Oberkampf, 2004a). The main brought criticism is that there are situations where "insufficient knowledge is available to specify a precise probability distribution" (Reichert et al., 2015).

In this respect, literature in the field (Kangas and Kangas, 2004) mentions that, "several other methodologies and theories have been developed to deal with situations for which the classical or Bayesian probability theory was deemed too normative". Some examples of such methods and theories are: interval analysis, possibility theory, certainty theory, evidence theory and fuzzy set theory. They are "especially suitable in cases where human opinions, judgments and decisions are involved" ((Zimmermann, 1985; Dubois and Prade, 1988) cited in Kangas and Kangas, 2004)). As Bernardini and Tonon (2004) comment, those methods and theories "especially those based on fuzzy sets theory that embodies the original Zadeh's idea of vagueness (Zadeh, 2008), i.e. the lack of precise or sharp distinction of boundaries", are useful for human judgments and decisions expressed with concepts containing words like "big", "high", "small", "low", called gradual predicates. Such language terms are pervaded by vagueness and imprecision. Environmental concepts expressed in natural language are a relevant example in this idea. What determines an evaluator to use such terms is lack of specific knowledge, incomplete data/information about the assessed situation. Even more, when the assessed situation is a future event, the evaluator can often make vague characterizations such as "there is a great probability" or "there is a small probability" using again words as "big", "high", "small", "low". Dempster-Shafer theory using subjective probabilities is a good basis for expressing uncertainty arising in environmental risk assessments where vague concepts expressed with gradual predicates are often used (Arama, 2007a, 2007b, 2009a, 2010a, 2010b; Dempster, 2008; Gheorghe et al., 2010; Yager, 2009;

Shaffer, 1990). Subjective probability is more close to real life situations when, with reference to the evaluators' knowledge and information at a certain moment of evaluation, there is the possibility of not knowing to respond to some very challenging questions expressed in ambiguous defined concepts and in vague terms and this is what is usually called epistemic uncertainty. Epistemic uncertainty (Arama and Nicolau, 2009a) reflects actually the doubt of a person/evaluator that certain concepts, data and information can be applied to a certain situation. This doubt is due to missing knowledge, data and information and might have different causes (Rolf, 2007). It might be due to the complex nature of pollution for example when it is known as "structural uncertainty" or due to the development of an unknown future event when it is known as "time uncertainty." "Despite the unquestionable appropriateness of risk assessment as a tool to help in the decision-making process, it can be the part of the whole risk-management process that is most difficult and prone to error, mainly because uncertainty in the measurements of hazard and vulnerability is often large. Insight about risks is limited to the randomness, inherent in nature and the lack of sufficient information about the chances of a risk occurring and the potential consequences of such an occurrence. As a result, uncertainty is inherent in risk assessment" (Darbra, 2008). Unfortunately, despite the standardization efforts made in the environmental field (Pascu, 2015a, 2015b), examples of poor quality data are very often encountered. When statistical data are missing or are too costly, using subjective probability and assessment with linguistic attributes can be successfully used. Those assessments help evaluators to express much easier the results of a risk assessment to the interested parties although it is impossible not to introduce also vagueness and imprecision. If the evaluators are not given some general guidance or methodological orientation for how they should appreciate a "low probability of occurrence" or a "high probability of occurrence" with reference to certain type of phenomena (e.g. modification of wastes composition and behavior during a life time span of approximately 30 years for a wastes ecological landfill) their reasoning might be difficult to be followed up.

To make such an assessment using linguistic characterization terms such as "low risk" or "high risk" less vague /imprecise, a score scale maintaining an appropriate measurement unit with respect to the entire used score scale can be used. The assessors should be instructed how to use it. If the entire scale, for example starting from "small something" and reaching to "big something" is one hundred points and three types of lexical attributes are applied such as: "small", "average" and "big" then, for each evaluator "small something" should be somewhere in the range of (0 -33] score points , "average something" should be somewhere in the range of (33-67] score points and "big something" should be somewhere in the range of (67-100] score points.

A risk score evaluated with 32 score points might be seen in some evaluators perception as not being "small" , neither "average" but rather" small towards average" or otherwise saying "rather average than small". In the classical set theory, there are sharp boundaries between defined classes of objects. Namely, in the above-mentioned examples, between "small" and "average" classes of objects the sharp boundary might be set at 33 score points. Between "average" and "big" classes of objects the sharp boundary might be set at 67 score points. Consequently, an object gathering 32 score points can be classified according to classical set theory as being in one and only one class of objects, namely in the "small" class of objects with certitude i.e. the grade of truth 1. In the fuzzy set theory approach, the same object gathering 32 score points can be mapped to more than one single class of objects. Namely it can be mapped to the class of "small" objects and to the class of "average" objects but with different grades of truth because in a fuzzy set theory, by definition, boundaries of classes share ranges of values between them, so one score points can be mapped to more than one single class of objects. For example the score of 32 points can be mapped let's say with 0.15 grade of truth to the "small" class of objects–defined with score between (0-33) points –and let's say with 0.5 grade of truth to the "average" class of objects -defined with a score between (30-67). That is because the two classes, namely "small class" and "average class" share a common range of values between 30 and 33 points by definition. If a finer evaluation is needed using also linguistic terms one can define also what does mean "very small", or "very, very small" etc., using appropriate score points for definition, understanding that objects characterized with "very small" or "very big" attribute share more properties that are characteristic for the typical objects characterized with the "small" or "big" attribute and classified under the "small" or "big" class of objects. If a "big" object (for e.g. a "big" vulnerability) can typical gather 90 score points, a "very big" object (for e.g. "a very big" vulnerability) should gather more than 90 score points. For example, a 93 score points can be gathered by a "very big object" which is an object from the "big" class of objects, which in the fuzzy set approach has the grade of truth "very", 96 score points can be gathered by a "very, very, big object' which is an object from the class of "big" objects which has the grade of truth "very, very" and a 100 score points can be gathered by an object from " the big class of objects" which has the grade of truth "very, very, very". If we want to classify the vulnerability of a target that can be assessed with about 93 points, we can say that the vulnerability is actually "big' towards "very big". The same approach is valid when we want to classify the vulnerability "average" towards "big".

In the Table 1 the attributes low, average, and high have been used instead of small, average, and big presented in the above-mentioned examples. Next, the proposed method is applied to a specific case study.

3. Experimental (Case study)

We have chosen industrial waste landfills type as example for the method practical implementation because industrial wastes are generators of a large diversity of wastes with potential dangerous effects for the environment but the method can be applied at any type of wastes. According to EUROSTAT in 2012 the totally amount of waste generated only by processing industry, in Romnia, was about 2% from the total generated amount in EU-28. Although the amount of dangerous industrial wastes that have been eliminated is smaller than the non-dangerous industrial ones, they are given due attention in the management for their ecological dangerous potential. In 2016, in Romania, eight of ten ecological landfills were managed by organizations that produced them and that is precisely why those organizations need such a methodology. In Romania, those ecological landfills are all over the Romanian territory. In Romania if the industrial wastes from extractive industry is excluded representing 42 %, the main categories of dangerous wastes are in decreasing ranking order considering their amounts: wastes from refining and coal industry, wastes from mechanical metal and plastic material processing industry and from the thermal processing plants. (OPAC 2014-20120-NPPWG, 2017). Specifically, we applied the proposed method to an ecological landfill with wastes coming from bearings producing industry that was considered to be relevant for the industrial type of wastes being finally disposed.

The method has been conceived to be used with any type of on-site existing monitoring data/information as required by current legislation and from this point of view the instrument is a very flexible one. The monitoring data and information that have been used cover four years of monitoring of operating parameters of the waste landfill receiving hazardous waste including the quality of environmental segments monitoring such as: soil, ground waters and surface water with frequency required by their environmental permits including the integrated environmental authorization. The current legislation requires the characterization, classification and assignation of a waste code from the harmonized European waste list in order to adequate manage them for the environment protection of water bodies (Arama and Nicolau, 2009b, 2009c; Arama et al., 2017; Kim et al., 2018) atmosphere and human health. These provisions are presented in the updated Romanian Legislation 211/2011 (L, 2011). In our case study, organization classified and assigned codes to the produced wastes and then accordingly collected, temporarily stored and finally disposed them. All current legally monitoring requirements for the wastes management activity are found in organization's regular monitoring data registries. The quality of the soil, ground waters and surface waters are checked against the organization's discharge permits limits. With those data, the proposed environmental risk prediction method has been used. The proposed method is a multi-criteria instrument able to synthesize the most important criteria of interest to characterize possible future pollution. Three types of criteria are presented next. They have been chosen for their large degree of generality being applicable to a wide variety of industrial wastes ecological landfills.

C1. – denotes the criterion linked to the integrity of the collection gas/leachate system influencing the probability of penetration of protective barriers. To this general criterion specific sub-criteria can be also attached depending on wastes' type ecological landfills.

C2. – denotes the criterion linked to the target permeability (and its components) to the pollutants (due to leachate infiltration or gas emissions) influencing the magnitude of the detrimental pollutant(s) actions. To this general criterion specific sub-criteria can be also attached depending on wastes type ecological landfills.

C3. – denotes the criterion linked to the dangerousness of the leachate or gas composition and their possible detrimental actions upon the reached targets after penetration of protective barriers. To this general criterion specific sub-criteria can be also attached depending on wastes type ecological landfills.

With those types of criteria, the conceptual model for environmental risk prediction that has been conceived had as guidance essential aspects found in the specialty literature. Extended monitoring studies have been carried out for all kind of pollutants including the organic polar compounds and they have shown patterns of migration at different distances according to the local geological, climate and meteorological conditions and to the pollutants' types. For example, some results from the investigations of landfill plumes "*have* shown that the majority of xenobiotic organic compounds could not be detected at distances exceeding 60 m from the landfills ((Rugge et al.,1995 cited in Baderna et al., 2011)) and at distances greater than 100 m the toxicity towards bacteria or freshwater algae was comparable to that of unpolluted reference samples " ((Baun et al., 2000) cited in Baderna et al., 2011). For the aromatic hydrocarbons, the studies' results showed that they "degrade readily in aerobic environments but can be recalcitrant under reducing conditions resulting in long-term toxicity ((Christensen et al., 2001) cited in Baderna et al., 2011). As for heavy metals, they can be in a variety of more or less dissolved forms: colloidal forms, complex compounds with different solubility/stability constants and less than 10 % of metal concentrations as free metal ions. Because their fate can be strongly influenced by the forms in which they exist, Baun and Christensen (2004 cited in Baderna et al., 2016) mention that they suffer "strong attenuation by sorption and precipitation processes" and that is beneficial for ground water pollution protection.

The important factors to be considered when it comes to the phenomena causing the penetration of the man build safety barrier are: a) *barrier penetrability characteristics and the used safety barrier materials,* *b) waste nature c) leachate nature and long term leachate behavior in deposit, taking into account the meteorological conditions d) the way the deposit is operated*. The probability of subjacent structures pollution, i.e. "detrimental/negative environmental impact" type of event depends on the target vulnerabilities to the magnitude of pollutants discharges when infiltrations occur. The hazardous/dangerous event is considered the barrier penetration with pollutants infiltrations. It should be noted that the penetration (the brake of the membrane) from the physical – chemical point of view is a complex phenomenon. Geo-membranes should be protected against biological factors both in the ecological landfill construction phase but also during the operation phase" (MO, 2004). It should be noted that, the consequences' severity i.e. the different magnitudes of targets' pollution damages when pollution spreads at long distances, after the barrier penetration, depends on permeability of subjacent structures and on the distance up to first aquifer/ground waters. Those might be considered as vulnerabilities of the considered target. The proposed environmental risk prediction method is a multi-criteria instrument using the chosen type of those proposed criteria that uses a score scale with linguistic terms to allow evaluation of environmental risk magnitude based on a combination between the estimated probability of occurrence of possible hazardous event and the severity of its consequences, both characterized by factors given in Table 1.

It is a decision support for "decision making process that guides an individual or group through a series of tasks from problem identification and analysis to design alternatives and selection of an alternative" (Mintzberg et al., 1976 cited in Alamgir, 2016).

4. Results and discussion

The proposed method uses guidance in Table 1 with examples in Table 2. Examples are given in Table 2 in order to guide the evaluator how to make combinations and to use the score from Table 1. The possible targets that might be affected by the waste ecological landfills pollution products (i.e. by lechate and ecological landfills gases) are presented in Table 2.

Table 1. The factors characterizing the probability of penetrating first protection barrier and the target's vulnerabilities in the moment when hazard occurs i.e. when pollution reaches target as a measure of pollution consequences' severity

e.g. R =4 x 4 =16 (very high) (vulnerability very big=4)x(probability very big=4)			***Factors charcterizing target(s) vulnerabilities as a measure of pollution consequences severity during the hazardous occurrence – when pollution reaches the target;targets can be represented by different environmental compartments: soil, subsoil, aquifer, surface water and their ecosystems***			
			Vulnerability very big	***Vulnerability big***	***Vulnerability average***	***Vulnerability small***
			4	**3**	**2**	**1**
Factors characterizing the probability of penetrating first safety barrier of the target and generating pollution (targets can be represented by different environmental compartments: soil, sub-soil, aquifer , ground water, surface water and their ecosystems)	**very big probability**	**4**	Risk = very high (16)	Risk=high (12)	Risk = average (8)	Risk = low (4)
	Diference from succesive risk magnitude in the same class of vulnerability		Δ =4	Δ =3	Δ =2	Δ =1
	big probability	**3**	Risk = high (12)	Risk=average→high or rather high than average (9)	Risk= low→average or rather average than low(6)	Risk = very low (3)
	Diference from succesive risk magnitude in the same class of vulnerability		Δ =4	Δ =3	Δ =2	Δ =1
	average probability	**2**	Risk=average (8)	Risk= low→average or rather average than low (6)	Risk=low (4)	Risk=very, very low (2)
	Diference from succesive risk magnitude in the same class of vulnerability		Δ =4	Δ =3	Δ =2	Δ =1
	small probability in the same class of vulnerability	**1**	Risk = low (4)	Risk = very low (3)	Risk= very, very low (2)	Risk = very, very, very low (1)

Table 2. Characterization criteria for 1) probability of the pollution discharge and 2) target vulnerabilities and its components

Score for risk characterization **R = col (3) x col (5)**	*Criteria for characterization of pollution produced by waste ecological landfill products (leachate infiltration, deposit gases emissions) probability* ***C1**- the integrity of the collection system (of the pollutants leachate (nature, concentrations) or ecological landfill gases)* ***C3**- the dangerousness of the pollutants leachate or deposit gases* *e.g. When to assess with the factor (score) from column (3)*	*Formal characterization score for target protective barrier penetration probability*	*Criteria for characterization of target vulnerabilities and its components (soil, sub-soil, aquifer, surface water atmosphere, human health)* ***C2** - the target permeability to the detrimental action of the pollution from different (leachate or ecological landfill gases)* *e.g. When to assess with the factor (score) from column (5)*	*Formal characterization-on score for target vulnerability and its components*
(1)	***(2)***	***(3)***	***(4)***	***(5)***
very, very, very low risk R=1, (R=1x1)	***When:*** • *Target is represented by adjacent geological structure (soil, sub-soil, aquifer etc.)* • *There are evidences for: -1) incipient deterioration of the leachate drainage/collection system; -2) deterioration of very, very, very small surface (without direct evidence of penetrating protection barrier) when the concentration of leachate regulated components is not exceeding A.T. (English acronym for Alert Threshold), established for each of them in relation to the intended use of the environmental compartment – e.g. the adjacent area of the deposit when a protective distance from the target is considered according to the European Legislation).*	**1**	***When:*** • *Target is represented by geological adjacent structures (soil, aquifer etc.)* • *There are evidences for: -1) the fact that permeability of the adjacent geological structures (soil/sub-soil) is small according to technical literature (z_1) 2) the fact that the first aquifer is situated at distance greater than a certain contextual significant value(y_1).*	**1**
very, very, very low risk R=1,(R=1x1)	***When*** • *Target is represented by surface water and its ecosystem* • *There are evidences of the existence of very efficient measures to mitigate the impact of the collected leachate composition, its values being within the legal approved discharge limits.*	**1**	***When*** • *Target is represented by surface water and its ecosystem and* • *There are evidences for: -1) no pollutants availability/ bioavailability in the surface water (e.g. in the corresponding area, the water body state is good and very good "according to the Directive nr. 60 /2000 (WFD, 2000); - 2) the fact that water body flow is big enough in the area having no significant seasonal variations; -no existing environmental protected Nature 2000 areas or species etc.*	**1**
very, very, very low risk R=1, (R=1x1)	***When*** • *Target is represented by: atmosphere or operation deposit staff health (affected by greenhouse gases emissions having mixture composition explosive damage limits CH_4 < 30 %, O_2>3 % , the composition's values for closing gas feed system: CH_4 <25 %, O_2>6 % according to the Ministerial Order No 757/2004 (MO, 2004))* • *There are evidences for: -1) a functional closed collecting gas system, perfectly isolated from the outside surroundings and from the leachate drainage/evacuation system; -2) in the "Deposit Status Quo Plan "there is only one record for the*	**1**	***When*** • *Target is represented by: atmosphere or human health (affected by greenhouse gases emissions having mixture composition explosive damage limits CH_4 < 30 %, O_2>3 %, the composition's values for closing gas feed system: CH_4 <25 %, O_2>6 % according to the Ministerial Order No 757/2004 (MO, 2004))* • *There is evidences for: -1) no other industrial organizations that generate greenhouse gases in the*	**1**

	malfunctioning of the control and monitoring system and this malfunctioning event has been already fixed according to registration of the existent "Intervention Plan" kept by the organization at the moment of assessment.		*proximity of the ecological landfill;* *-2) all protective technological designed barriers are functional but incidents are not excluded.*	
very, very low risk R=2, (R=1x2)	*Same targets as in above examples, same conditions*	**1**	*Same targets as in above examples but different conditions*	**2**
very, very low risk R=2, (R=2x1)	*Same targets as in above examples but different conditions*	**2**	*Same targets as in above examples same conditions*	**1**
very low risk R=3, (R=1x3)	*Same targets as in above examples, same conditions*	**1**	*Same targets as in above examples but different conditions*	**3**
very low risk R=3, (R=3x1)	*Same targets as in above examples but different conditions*	**3**	*Same targets as in above examples, same conditions*	**1**
low risk R=4, (R=1x4)	*Same targets as in above examples, same conditions*	**1**	*Same targets as in above examples but different conditions*	**4**
low risk R=4, (R=2x2)	*Same targets as in above examples but different conditions*	**2**	*Same targets as in above examples but different conditions*	**2**
low risk R=4, (R=4x1)	*Same targets as in above examples but different conditions*	**4**	*Same targets as in above examples, same conditions*	**1**
low towards average risk R=6, (R=2x3)	*Same targets as in above examples but different conditions*	**2**	*Same targets as in above examples but different conditions*	**3**
low towards average risk, R=6, (R=3x2)	*Same targets as in above examples but different conditions*	**3**	*Same targets as in above examples but different conditions*	**2**
average risk R=8, (R=2x4)	*Same targets as in above examples but different conditions*	**2**	*Same targets as in above examples but different conditions*	**4**
average risk R=8, (R=4x2)	*Same targets as in above examples but different conditions*	**4**	*Same targets as in above examples but different conditions*	**2**
average towards high risk R=9, (R=3x3)	*Same targets as in above examples but different conditions*	**3**	*Same targets as in above examples but different conditions*	**3**
high risk R=12, (R=3x4)	*Same targets as in above examples but different conditions*	**3**	*Same targets as in above examples but different conditions*	**4**
high risk R=12, (R=4x3)	*Same targets as in above examples but different conditions*	**4**	*Same targets as in above examples but different conditions*	**3**
very high risk R=16, (R=4x4)	***When*** • *Target is represented by: adjacent geological structures (soil, sub-soil, aquifer etc.)* • *There are:* *-1) evidences for advanced deterioration with the maximum possibility/probability of protective barrier penetration;* *-2) direct evidences of increased pollutants concentrations measured in the control drilling wells at the small distance from the landfill edge;* *-3) evidences that this contamination cannot be linked to other source and at least 10 % of the regulated leachate components exceed the legally established A.T., for each of them, for the intended use of the environmental compartment (e.g. the adjacent area to the deposit) considering a protective target distance according to the European Law.*	**4**	***When*** • *Target is represented by: adjacent geological structures (soil, aquifer etc.)* • *There are evidences of:* *- 1)the fact that permeability of adjacent geological structures (soil/sub-soil) is very big (z_4)* *- 2)first aquifer is situated at the very small distances (<y_4)*	**4**
very high risk (R=4x4) R=16	***When*** • *Target is represented by surface water and its ecosystem*	**4**	***When*** • *Target is represented by surface water and its ecosystem*	**4**

	• *There are evidences about the possibility of collected leachate accidental discharges occurrence with a frequency (significant for the leachate volume in the regional pollution context) and with pollutants composition presenting exceeding of the current legal regulatory limits.*		• *There are evidences related to the availability/bioavailability of the pollutants in the target ecosystem (in this case the target is the surface water body) that are well correlated with the well-known vulnerabilities of the target and its components; (e.g. existence of Nature 2000 protective areas with unique world species that trend to disappear downstream of the water body in which the leachate is discharged; there is an average water body flow in the leachate discharge area and the local climatic conditions are poor in precipitations).*	
very high risk (R=4x4) R=16	***When*** • *Target is represented by: atmosphere or operation deposit staff health (affected by greenhouse gases emissions having mixture composition explosive damage limits CH_4 < 30 %, O_2>3 %, the composition's values for closing gas feed system: CH_4 <25 %, O_2>6 % according to the Ministerial Order No 757/2004 (MO, 2004))* • *There are evidences for: -1) the existence of a perfectly sealed collection gas system isolated from precipitation waters, leachate drainage and discharge system; -2) that the deposit functionality is not affected in any way and there are not records for being affected in the past; -3) a monitoring system in place for gas concentrations; however, the monitored values are closed to the safety thresholds due to the conjugated causes regarding the modification of the deposit gases composition and to some drawbacks recorded to the exhaustion system.*	**4**	***When*** • *Target is represented by: atmosphere or operation deposit staff health (affected by greenhouse gases emissions having mixture composition explosive damage limits CH_4 < 30 %, O_2>3 %, the composition's values for closing gas feed system: CH_4 <25 %, O_2>6 % according to the Ministerial Order No 757/2004 (MO, 2004))* • *-There are evidences for: -1) the existence of other industrial organization that can generate greenhouse gases in the proximity of the landfill; -2) the existence of a functional protective technological barrier; -3) there are only some malfunctioning/incidents that have been already fixed in due time that are registered within the "Functional Journal" but other similar incidents are not excluded in the future.*	**4**

Those targets might be *1) geological subjacent structures of the deposit and its components (soil, sub-soil, aquifer, underground water); 2) surface water; 3) atmosphere and the human health.* According to the current legislation, (MO, 1997) the risk computation/quantification is based on a simplified system of classification where probability and severity of an event are classified being assigned a random score as follows for: 1) classification of probability as: a) big = 3, b) average = 2, c) small = 1 and for 2) classification of severity as: a) major = 3, b) average = 2, c) minor = 1. The recommendation is that "the risk can be then computed by multiplying the factor of probability with that of severity, in order to obtain a comparative number as for example 2 (big) x 3(serious) =6. The law mentions that this will allow to make comparison between different risks. As results would be greater and greater the assigned priority to control the risk would be bigger and bigger. This technique can be developed to allow more in depth analyses by increasing the range of score classification and including more advanced definition of what should be considered as major gravity and big probability etc." (MO, 1997). Our proposed method shows in Table 2 how to assess the probability and the severity of the consequences of different hazardous events based on those recommendations giving more detailed example to help evaluators to make appropriate combinations in their own perception/opinion/belief. It can be applied by any organization that manages waste' ecological landfills.

In September 2015 the EN ISO 14001 standard (ISO, 2015) for environmental management systems has been reviewed. The new recommendations are that, any organization having an implemented and a certified environmental management system, to be able to assess the environmental risk arising from its operation activities, in this case, the operations being related to the waste deposits management in any life phases of the deposit in order to improve the environmental and health protection. The proposed following Tables 1 and 2 are components of the proposed method.

We conceptually compared our methods with similar methods for risk assessment (PRAT-Proportionall Risk Assessment Techniques) presented in the literature (Ayyub, 2003; Fine and Kinney, 1971; Marhavilas and Koulouriotis, 2007, 2008) that use proportional formula for calculating the quantified risk due to hazard. (Marhavilas et al., 2011) in order to demonstrates its advantages presented next.

1) It allows to integrate any type of monitoring data/information.

2) It uses general applicable criteria allowing addition of contextually conceived sub-criteria against which proves and evidences can be assessed in order to sustain the type of predicted risk.

3) It is conceived with a user friendly linguistic scale expressed in natural language terms -Table 1- easy to communicate the results.

4) It can be applied by producer/holder organization local staff that daily manage the waste landfill due to Table 2 that is incorporated in the method offering detailed guidance for the evaluation.

5) Anyone can review the assessment based on the proposed criteria.

4. Conclusions

The present method represents a flexible instrument for analysis/assessment/decision able to meet the new requirements of the EN ISO 14001:2015 (ISO, 2015) allowing the organization that has such ecological landfill to predict the environmental risk and to take adequate measures in due time to diminish and reduce the environmental risk.

When applied to a specific case study from bearings processing industry, the method was able to predict based on available monitoring data and information the magnitude of risk for two considered targets namely surface waters and soil. According the general type of presented criteria C1, C2, and C3 of the proposed method, the risk is within "very, very very low risk" class, R=1, for surface water and its ecosystem and, in the class of average risk, R=8, according to the criteria for soil and its ecosystem.

More work is needed in the future to apply the method for more landfills with different types of wastes in order to show its versatility/capability to predict, in specific case studies, the increase/decrease of the severity of environmental consequences depending on target vulnerabilities.

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