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A rating system for determination of hazardous wastes

İlhan Talınlı [a,*], Rana Yamantürk [a], Egemen Aydın [a],
Sibel Başakçılardan-Kabakçı [b]

[a] *Istanbul Technical University, Faculty of Civil Engineering, Department of Environmental Engineering, 34469 Maslak, Istanbul, Turkey*
[b] *Istanbul Technical University, Faculty of Chemical and Metallurgical Engineering, Department of Chemical Engineering, 34469 Maslak, Istanbul, Turkey*

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Abstract

Although hazardous waste lists and their classification methodologies are nearly the same in most of the countries, there are some gaps and subjectiveness in determining the waste as hazardous waste. A rating system for the determination of waste as a hazardous waste is presented in this study which aims to overcome the problems resulted from the existing methodologies. Overall rating value (ORV) calculates and quantifies the waste as regular, non-regular or hazardous waste in an "hourglass" scale. "ORV" as a cumulative-linear formulation in proposed model consists of components such as ecological effects of the waste (Ee) in terms of four main hazard criteria: ignitability, reactivity, corrosivity and toxicity; combined potential risk (CPR) including carcinogenic effect, toxic, infectious and persistence characteristics; existing lists and their methodology (L) and decision factor (D) to separate regular and non-regular waste. Physical form (f) and quantity (Q) of the waste are considered as factors of these components. Seventeen waste samples from different sources are evaluated to demonstrate the simulation of the proposed model by using "hourglass" scale. The major benefit of the presented rating system is to ease the works of decision makers in managing the wastes.

Keywords: Hazardous waste determination; Rating system; Hazard criteria; Combined potential risk; Listing

1. Introduction

Hazardous wastes, the main drawbacks of industrialized world, are still keeping their importance because of their potential hazard to human health and environment when improperly treated, stored, transported and/or disposed. These kinds of wastes must be managed and controlled from the point of generation to ultimate disposal.

The legislators of each country should create regulations enforcing the safe management of the hazardous waste. These regulations should appoint the hazardous waste generator as a legal entity who must ensure that the waste is managed in accordance with its regulatory standards [1]. But a generator who will comply a regulatory program demands a far more precise definition of the term "hazardous waste".

The term "hazardous waste", originated from US Environmental Protection Agency, does not have a unique and universally accepted definition but the identification of hazardous waste in each country is based on the four characteristics: (1) ignitability, (2) corrosivity, (3) reactivity and (4) toxicity [2].

Although every country has its own regulatory program, the most common violation of the rules, whether willful or inadvertent, is because of the definition of the waste as hazardous waste [3]. In most of the countries, the board responsible for the hazardous waste management defines the hazardous waste by using two different mechanisms: (1) by listing and (2) by identifying characteristics. These definitions are commonly based on the Subtitle C of Resource Conservation and Recovery Act (RCRA) which is the most extensive study done about hazardous waste management.

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[*] Corresponding author. Tel.: +90 212 285 65 46; fax: +90 212 285 65 87.
E-mail address: italinli@ins.itu.edu.tr (İ. Talınlı).

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Using lists to define hazardous wastes presents certain advantages and disadvantages. The main advantage is that lists make the hazardous waste identification easier for waste producers, but hazardous waste lists simply cannot include all hazardous wastes. Another disadvantage is their lack of flexibility. Lists determine a waste as hazardous, if it falls within a particular category or class. The actual composition of the waste is not considered as long as the waste is listed. Thus, the lists can regulate some wastes that do not pose a significant health threat or a really hazardous waste may not be found in the lists [4].

Designation of hazardous waste by determining the characteristics of the waste is another method which needs proper analyses to define the waste as a hazardous waste. Although phytotoxicity, teratogenicity, bioaccumulation, mutagenicity are the characteristics of the hazardous waste because of the difficulties in testing protocols of these characteristics mentioned above, EPA decided to use four common characteristics to identify the hazardous waste: (1) ignitability, (2) corrosivity, (3) reactivity and (4) toxicity.

Although EPA introduces the test protocols for ignitability, corrosivity, reactivity and toxicity, there are still gaps which enable to determine a hazardous waste as conventional waste. The main gap is seen in toxicity testing, which only 43 of the toxic chemicals are subject to the TCLP test [5]. Thus, if a waste does not bear any of the 43 chemicals, the waste is not considered as hazardous, although in reality it is hazardous. The other example is ignitability which does not have a test method for non-liquid wastes. The gaps for the determination of the hazard potential of hazardous waste mixtures are also noticed and an index is prepared to serve as a guide for people who produce, store, transport, dispose, recycle and/or regulate hazardous waste [6].

Although lists and analyses of characteristics are nearly the same in all countries, the differences in regulations make the determination subjective which creates a serious problem in management of these wastes. In order to eliminate the subjectiveness of lists and characteristics tests, a quantitative determination system is stated in this study. Overall rating value (ORV) calculates and quantifies the waste as regular (conventional) waste, non-regular (solid) waste or hazardous waste by using variables, such as ecological effect (Ee) (ignitability, reactivity, corrosivity, toxicity), combined potential risk (CPR) (carcinogenic effect, toxic characteristics, infectious characteristics, persistency), listing (*L*), physical form (*f*) of the waste and quantity (*Q*) of the waste.

2. Rating system

Conceptual framework of proposed quantitative system in order to determine the waste as hazardous waste is shown in Fig. 1. Mainly, two components take place in this approach: (1) hazard criteria of the hazardous waste in terms of ecological effects and (2) their combined potential risk.

To formulate the rating system, following assumptions are postulated:

1. When the discarded material is defined as a waste, it should be classified if the waste is conventional waste, such as wastewater, municipal solid waste, air emission or not. The term “non-regular waste” has been considered as intermediate waste which is obviously not conventional but probably hazardous. The waste must be determined as hazardous or non-hazardous if it is identified as non-regular waste.
2. In Eq. (1), the component “*D*” represents the boundary of the non-regular waste in the scale. Hospital and radioactive wastes are neglected in this inquiry. Because they have their own control regulations and these wastes have already been identified as non-regular wastes.
3. Listing methodology of the hazardous waste and their lists published in different countries cannot be neglected. Thus, the component “*L*” is added in formulations.
4. Ecological effects (Ee) includes primarily impacts of waste regarding with its hazard characteristics, such as toxicity, ignitability, corrosivity and reactivity. Physical form of the waste is another factor that affects the hazard characteristics.
5. Accumulative and synergistic effects and uncertain potential risks are included in combined potential risk parameter. Components of this parameter are human health toxicity, carcinogenetic effects, infectious risks and persistency associated with biodegradability, solubility and bioaccumulation. Physical forms of the waste and exposure mode are also taken into account during the evaluation of these risks.
6. Four critical components (*D*, *L*, Ee and CPR) are considered as cumulative functions of “overall rating value”. Because higher values of *D*, *L*, Ee and CPR must increase the ORV. Obviously, the amount of the waste (*Q*) is a basic component in this rating system, so it should be a multiplier of the other components.

The formula of the rating system is shown in Eq. (1) which is composed of a cumulative-linear function coupled with eight sub-equations. The values for each parameter in the equations are obtained from ranking tables for each parameter. Mathematical formulations are given below, and the notations are listed in Appendix A.

$$\mathrm{ORV} = D + L + [\mathrm{Ee} + (\mathrm{CPR}) \times f] \times Q \tag{1}$$

$$\mathrm{Ee} = I + C + R + T \tag{2}$$

$$I = i^n \tag{3}$$

$$C = c^n \tag{4}$$

$$R = r^n \tag{5}$$

$$T = t^n \tag{6}$$

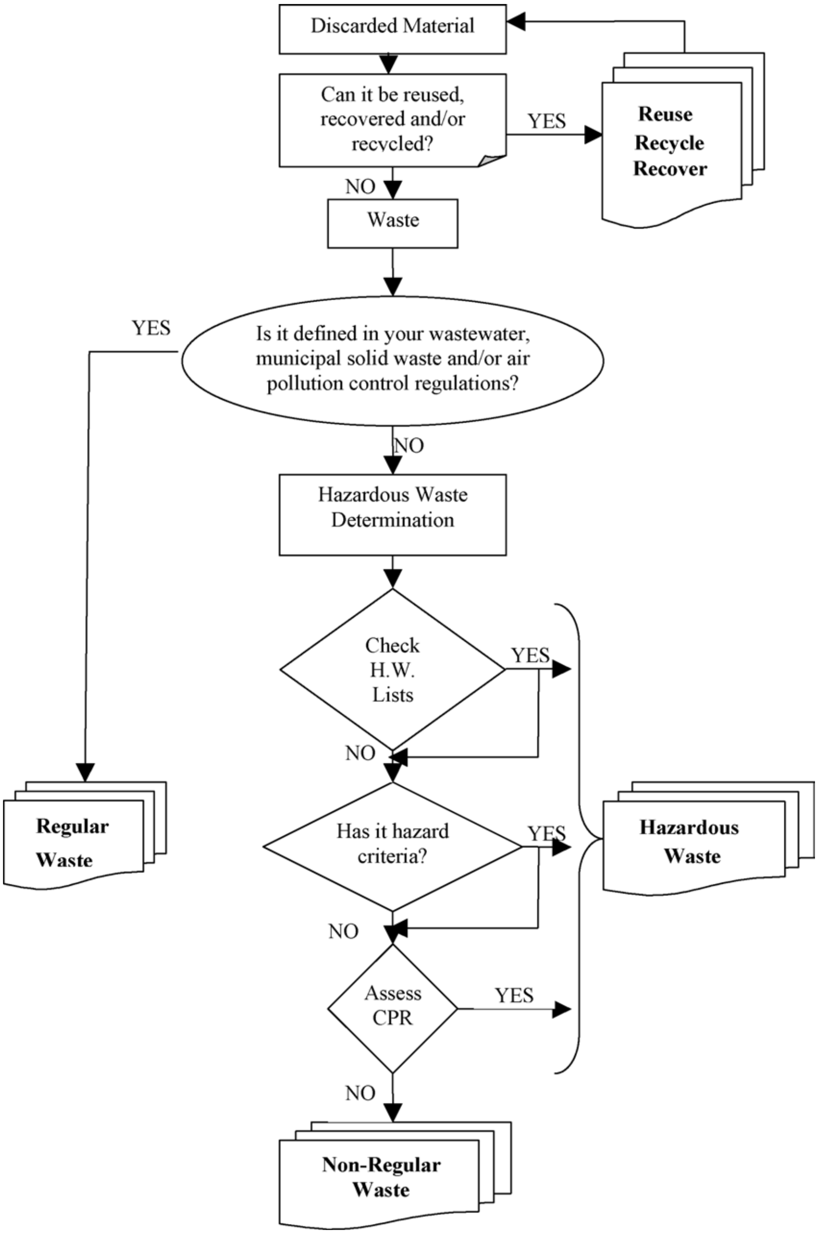

Fig. 1. Conceptual framework of the proposed rating system for hazardous waste determination.

$$\mathrm{CPR} = \mathrm{Cr} + P + \mathrm{In} + \mathrm{Pe} \qquad (7)$$

$$P = p^m \qquad (8)$$

$$\mathrm{Pe} = (\mathrm{Bd})^{\mathrm{Sl}} \times (\mathrm{Bac}) - 1 \qquad (9)$$

The formula quantifies the hazard characteristics which makes the identification of the waste as a hazardous waste easy and understandable. Calculated ORVs from Eq. (1) are matched with range of the “hourglass” scale to point whether the waste is regular, non-regular or hazardous waste. *D* is the decision factor that differentiates the defined regular waste from the undefined wastes. The rating values for decision factor are listed in Table 1.

L defines list value of the rating system. Knowing the source and composition of the waste is an important aspect in determining the hazard characteristics of a waste. USEPA’s lists depend on both hazardous waste from specific source or non-specific source and discarded commercial chemical products. Although, these lists do not consider the amount of the waste, they are taken as a base for rating values which are listed in Table 2.

Table 1
Rating values for decision factor

Regulatory definition of the waste	*D*
Undefined waste in certain regulations	50
Defined waste in certain regulations	0

Table 2
Rating values for hazardous waste lists

List type[a]	List code[a]	*L*
HW from specific sources	K	100
HW from non-specific sources	F	75
Discarded commercial chemical products[b]	P, U	50
Not listed	–	0

[a] Evaluation is based on the EPA's hazardous waste lists.
[b] Forth chemicals deemed toxic (U), therefore hazardous and forth waste identified as acutely hazardous (P).

Eq. (2) expresses the Ee in terms of ignitability (*I*), corrosivity (*C*), reactivity (*R*) and toxicity (*T*). All these terms have different unity which restricts their usage in the same formula. So, all terms are graded in rating value tables in order to have dimensionless values. "*I*" is the corrected ignitability value obtained from Eq. (3) where the dimensionless ignitability value of the rating system is denoted as "*i*". Flash point which is used for grading "*i*" values, is determined using the test method specified in ASTM Standard D-93- 79 or ASTM Standard D-3278 [7–9]. "*C*" is the corrected corrosivity value obtained from Eq. (4) where the dimensionless corrosivity value of the rating system is denoted as "*c*". The test method specified in EPA A600/4-79-020 is used to determine corrosivity value (mm/year). Information on reactive substances which are extremely unstable and have a tendency to undergo violent chemical change or explode during stages of its management is available from descriptive, the prose definition which EPA has publicized. However, a suitable test protocol is unavailable [7,9,10]. Referring to this definition, reactivity is quantified in Eq. (5) where "*r*" is the dimensionless reactivity value of the rating system. It is necessary to include toxicity since the leaching of the toxic constituents (of land disposed wastes) into the groundwater is one of the most significant dangers posed by hazardous wastes [11,12]. Therefore, leaching procedures such as toxicity characteristic leaching procedure (TCLP) and extraction procedure toxicity (EPT) can be used for hazardous waste in solid and sludge form to obtain mobility of the organic and inorganic compounds [13]. Eq. (6) determines the corrected toxicity value "*T*" where "*t*" is the dimensionless toxicity value of the rating system. LC$_{50}$ value obtained from bioassay test is used to grade the toxicity in the rating system. The physical form correction factor "*n*" reflects the effect of the form of the waste on the intensity of the hazard criteria. The rating values of components of ecological effect, which also prevent unit variability, are shown in Table 3.

CPR is formulated as a function of toxicity risks for human health "*P*", carcinogenic effect "Cr", infectious characteristics "In" and persistency "Pe", in Eq. (7).

The quantification of the toxic risk to human is almost similar to the quantification of the environmental risk (LC$_{50}$), and is given by LD$_{50}$ which is the lethal dose to 50% of an exposed population of humans within a given time [14]. LD$_{50}$ for quantifying the toxic characteristics *P* are tabulated in Table 4. It is important to notice that only an individual material shall be considered in the combined potential risk if its existence in the waste is acknowledged. The constant "*m*" defines the effect of exposure mode on the intensity of the toxic characteristics. Main three exposure modes are considered as inhalation, oral intake and skin contact. The risks they pose can be graded, respectively.

The carcinogenity of the hazardous waste cannot be quantified. The classification for the existence is based on the predicted occurrence of cancer, for instance in one person from hundred thousand (10^{-5}) [9,14]. Values used in the rating system for Cr according to this classification are given in Table 4.

The infectious characteristics of a hazardous waste depend on the criteria of being contaminated with relatively high fractions of disease causing material. The infectious risk has to be foreordained with the sources of waste. Infecting property does not have a unity. Dimensionless infectious risk value of the rating system, "In", is involved in rating system and listed in Table 4.

Persistency in Eq. (9) is formulated as a function of biodegradability, bioaccumulation and the solubility characteristics of the waste. The ability of the degradation, "Bd", of a chemical material within the environment or living cell is generally directly proportional to the solubility. This effect is reflected in Eq. (9) where the solubility value "Sl" is the exponential expression. A non-biodegradable material adversely

Table 3
Rating values for components of ecological effects

I		*C*		*R*		*T*		Form of the waste (*n*)	
Flash point[a] (°C)	*i*	Corrosivity[b] (mm/year)	*c*	Reactivity[c]	*r*	LC$_{50}$[d] (mg/l)	*t*		
<60	40	>6.35 or pH < 2 and pH > 12.5	40	Unstable-readily reactive	40	<0.1	40	G	1.4
60–90	30			Reacts with water	30	0.1–10	30	Lq	1.3
90–120	20			Generates cyanide and sulphur gas at pH = 2.0, pH = 12.5	20	10–100	20	S, SL	1.2
120–200	10	<6.35 or 2 < pH < 12.5	0	Explodes with water	10	100–1000	10	SO	1.1
>200	0			Non-reactive	0	>1000	0		

Lq, liquid; G, gas; S, sludge; SL, slurry; SO, solid.
[a] Specified by using the test method defined in ASTM standard D-3278.
[b] Abrasion characteristics at 55 °C specified by using the test specified in NACE (National Association of Corrosion Engineers) Standard TM-O1-69.
[c] There is no a suitable test protocol for measuring reactivity.
[d] Extraction procedure (EP), toxicity characteristics (TC) and toxicity characteristic for leaching procedure (TCLP) methods described by EPA [13].

Table 4
Rating values for combined potential risks Eq. (7)

P[a]		Exposure[e]	*m*	Cr[b]		In[c]		Pe[d]
LD_{50} (mg/kg)	*p*			Risk level	Cr			
0.1	40	I	1.3	$1/10^5$	100	Infectious characteristics except hospital waste	10	Persistency is a function of bioaccumulation, biodegradation and solubility of materials for CPR
0.1–10	30			$1/10^6$	10			
10–100	20	OI, IN	1.2	$1/10^7$	1			
100–1000	10			Non-carcinogenic	0	Non-infectious	0	Eq. (9), Table 5
>1000	0	SC	1.1					

[a] Health based risk specific doses for acutely toxic constituents.

[b] Risk specific levels for carcinogenic constituents as chronic toxicity reference levels.

[c] Animal carcass, animal feces, used sanitary pads, biotic chemical by products.

[d] Bioaccumulation cannot be established experimentally, it may be predicted by its physicochemical properties and stability. Depend on the characteristics of individual substance and situation; biodegradability may be given as percent of its degradation [14].

[e] Exposure modes: I, inhalation; OI, oral intake; IN, ingestion; SC, skin contact.

Table 5
Evaluation of persistency values Eq. (9)

Sl			Bd			Bac	
Solubility	g/100 ml	Sl	Biodegradability	%	Bd	Nature	Bac
Very soluble	>50	0.5	Readily	>90	1	Non-bioaccumulative	1
Soluble	5–10	0.5	Moderately	70–90	3		
Slightly soluble	<5	1	Slightly	>50	5	Bioaccumulative	2
Insoluble		1	Non-biodegradable	<10	10		
Miscible in all proportions		1.5					

affects the human health when it reaches to human body by the food chain or water. The living organisms in water can only degrade soluble materials; otherwise, the prevailing case will be the accumulation of substances. Quantification of bioaccumulation is not possible [14]. Depending on descriptive classification of bioaccumulation characteristic of a matter, dimensionless bioaccumulation value of the rating system Bac, Bd and Sl values are also given in Table 5.

The physical form of the waste should be a function for the evaluation of the CPR, because the fate of the waste in the environment is directly relevant to its physical form. For instance, different risk assessments should be made for a waste which is in solid or gas form. The physical state factor "*f*" is determined and placed in the equation with the rating values summarized in Table 6.

Although different quantities of different wastes may have different effects, the effects must get higher values as the quantity of the same wastes increases. For this reason, the quantity of the waste (*Q*) is the multiplier of effects (Ee and CPR). Selecting the value of "*Q*" from Table 7 is the last step in finding ORV from Eq. (1).

Table 6
Rating values for physical form

Physical form	*f*
Gas	1.4
Liquid	1.3
Sludge–slurry	1.2
Solid	1.1

Table 7
Rating values for quantity

Quantity (kg/month)	*Q*
>10000	1.4
10000–5000	1.3
5000–1000	1.2
<1000	1.1

3. Scaling of rating system

Projection of the ORVs, which are obtained from the model equations for hazardous waste determination, is considered with an "hourglass" scale shown in Fig. 2.

While the upper side of the hourglass above the bottleneck represents the regular wastes, the lower part represents both non-regular and hazardous wastes. The bottleneck represents

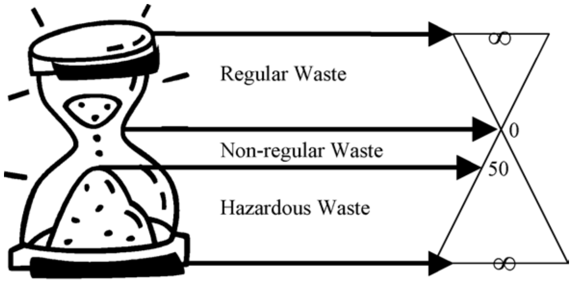

Fig. 2. Hourglass scale for hazardous waste determination.

Table 8
Application of the rating system to the waste samples

	Samples	Waste source	*f*	*Q*	*L*	ORV	Remarks
1	Foundry sand	Foundry, molding process	SO 1.1	1.4 (30 tonnes/day)	0	50	NRW[a]
2	Metal slag	Foundry, melting process	SO 1.1	1.4 (10 tonnes/day)	0	50	NRW
3	Fly ashes	Power station using coal	S 1.2	1.4 (100000 tonnes/day)	0	50	NRW
4	Plastic and rubber	Rubber industry, tooling and vulcanization processes	SO 1.1	1.1 (10 tonnes/month)	0	50	NRW
5	Galvanizing bath bottoms	Foundry, galvanizing process	S 1.2	1.1 (200 kg/month)	0	211	HW[b]
6	Boron oils and lubricants	Foundry, thread-cutting and lubricating	Lq 1.3	1.3 (8 tonnes/month)	P	261	HW
7	Phosphate bath sludge	Automotive industry, phosphatizing process	S 1.2	1.2 (2 tonnes/month)	P	327	HW
8	Wastewater treatment sludge	Leather tanning industry, ww treatment plant	S 1.2	1.4 (2000 tonnes/day)	K057	348	HW
9	Metal finishing bath sludge	Automotive industry, heat treatment and galvanizing	S 1.2	1.2 (2 tonnes/month)	P	416	HW
10	Dying bath bottoms	Foundry, dying process	S 1.2	1.1 (80 kg/month)	P	448	HW
11	Wastewater treatment sludge	Electroplating industry, ww treatment plant	S 1.2	1.1 (200 kg/month)	F006	459	HW
12	Wastewater treatment sludge	Automotive industry, ww treatment plant	S 1.2	1.4 (600 tonnes/day)	F006	494	HW
13	Wastewater treatment sludge	Dye and pigment industry, ww treatment plant	S 1.2	1.2 (60 tonnes/day)	K002-008	500	HW
14	Mineral tailings	Gold mine, gold extraction by cyanide leaching, CIP, CA process	S 1.2	1.4 (1400 tonnes/day)	F014 F015	535	HW
15	Discarded analytical grade chemicals	University laboratories and stores	SO, Lq 1.3	1.1 (100 kg/month)	U, P	654	HW
16	Acrylo-nitrile spills	Acrylo-nitrile storage tank	Lq 1.3	1.4 (6000 tonnes)	U009	805	HW
17	2,4 D acid production wastes	Pesticide industry, reactor cleaning and packaging	Lq 1.3	1.4 (2 tonnes/day)	K099 F003	1025	HW

[a] Non-regular waste.
[b] Hazardous waste.

an ORV zero-level which separates regular from non-regular waste. In Fig. 2, going downwards from zero towards the bottom the level further decreases with increasing ORV. At a value of ORV of 50 the waste becomes designated as hazardous. These levels are interpolated by using minimum and maximum values of terms in Eq. (1). If the waste is non-regular any additional non-zero term of "*L*", "Ee" and "CPR" to this level makes it hazardous. Calculated ORVs with Eq. (1) and their remarks for 17 waste samples are summarized in Table 8.

4. Results and discussion

Seventeen real samples are evaluated by using Eq. (1) and the results are given in Table 8. They can be interpreted as follows:

- Although first four samples have no "Ee" and "CPR" values controlled by referred test methods, neither regular nor hazardous waste lists include these wastes. Thus, they are determined as non-regular waste. Foundry sand and metal slag may be landfilled in situ or on site if they are not reused in other facilities, such as road construction. Huge amount of fly ash sludge should be disposed to a controlled landfill area after solidification. If plastic and rubber scraps cannot be recycled, controlled incineration is recommended because of their high calorific value.
- Samples numbered as 5, 7 and 9 in sludge form are highly toxic and have corrosive characteristics due to TCLP test method results and acidic pH ($pH < 2$). The "Ee" values of these samples are 120, 120 and 167, respectively, and relatively increased "CPR" values cause higher "ORV" values. Controlling the corrosivity is a necessity and the ultimate disposal is recommended after detoxification.
- Sample 6 named boron oils and lubricants from foundry have low "Ee" but high "CPR" values because of its persistency and non-biodegradability. Sample 6 can be assumed as flammable due to high calorific values of organic constituents. Thus, if floatation is not a proper treatment alternative or recovery of the oils is not possible, then incineration should be considered as a solution for its ultimate disposal.
- Samples numbered as 11 and 14 in sludge form have nearly the same "Ee" and "CPR" values with respect to their toxic and reactive hazard criteria because there are cyanide and other reactive materials in their composition. Although they have the same "Ee" and "CPR" values, there is a difference in ORV, which can be explained by the big difference in the quantity of the wastes. Thus, a

careful handling is required in their management series of the processes, such as dewatering, detoxification, solidification/stabilization and ultimate disposal to spent mines or hazardous waste sites are recommended.

- In samples numbered as 8, 10, 12, 13, the common hazard criterion is toxicity (*T*) which is caused by chromium, sulfide, organic and inorganic pigments and solvents concentrated in treatment sludges. High LC_{50} values and toxic characteristics (TC) are determined by TCLP and EPT procedures which are applied to both individual material and leachates. Concentrations of the materials, such as chromium and copper increase the CPR value when they are assessed with threshold limit value (TLV) and time weighted average (TWA) limits. Direct solidification/stabilization or detoxification of the leachate before ultimate disposal can be recommended for these wastes.
- Discarded chemicals from university laboratories (sample 15) show a mixed waste characteristic having all the hazard criteria (*I*, *T*, *C*, *R*). Therefore, it has high "Ee" value. These wastes must be sorted carefully in situ and stored in suitable storage tank prior to transportation to the hazardous waste sites where these wastes are incinerated.
- Acrylonitrile spills during Marmara Earthquake (sample 16) have been assessed as an accident of a hazardous material. Significant amount of this spilled commercial material threats the environment especially soil and water and human health as a hazardous waste. "Ee" and "CPR" values are very high due to its high hazardous characteristics. Soil remediation and clean up procedures should be applied in contaminated area.
- 2,4 D acid production waste (sample 17) contains a lot of hazardous constituents such as cyclohexanone, gasoline, alcohols, 2,4 D and PCBs as liquid form of hazardous waste. Besides, it is published as a hazardous waste in more than one list (USEPA K, F, U). It has also maximum "Ee" and "CPR" values because of its obvious hazardous specifications, such as toxicity and reactivity. Management alternatives for this waste can be considered as chemical treatment by adsorption, extraction and oxidation or its direct incineration in air pollution controlled incinerator on site.
- Breakpoints or determination levels in "hourglass" scale have been obtained with investigation of real wastes and according to their values of hazard criteria. However, neither high nor low ORV classifies the hazardous waste as important, significant or moderate. Instead, the value determines if the waste is regular, non-regular or hazardous. On the other hand, a waste which has a higher ORV than another one requires more attention for its management.

5. Conclusions

The "ORV" and "hourglass" scale presented in this paper is a simple solution of a problem resulting from the definition and determination of the waste as hazardous waste. This rating system is not only designed to determine the type of the waste but also helps to prepare a listing procedure and to decide on management alternatives. For instance, if there is a high "Ee" value caused by toxicity the waste should be detoxified as a management strategy, at first and then it can be disposed. Similarly, incineration should be the first management alternative for an ignitable waste that has a low flash point.

"CPR" depends on estimation of the long term effects. For this reason, this value may be helpful in deciding the risk minimization methodologies for waste producers. Also, the "CPR" value is basically used for the determination of the waste as a hazardous waste.

The proposed rating system is open to modification which eliminates the subjective procedures used in law and regulations.

Appendix A

List of symbols

Bac	dimensionless bioaccumulation value
Bd	dimensionless the ability of degradation value
c	dimensionless corrosivity value
C	corrected corrosivity value
CPR	combined potential risk
Cr	dimensionless carcinogenic effect value
D	decision factor
Ee	ecological effect
EP	extraction procedure
EPT	extraction procedure toxicity
f	physical state factor
G	gaseous
HW	hazardous waste
i	dimensionless ignitibility value
I	corrected ignitibility value
I	inhalation
In	dimensionless infectious characteristics value
IN	ingestion
L	listing value
LC_{50}	lethal concentration to 50% of an exposed population of fishes within a given time
LD_{50}	lethal dose to 50% of an exposed population of humans within a given time
Lq	liquid
m	exposure mode
n	correction factor depend on waste form
NRW	non-regular waste
OI	oral intake
ORV	overall rating value
p	dimensionless toxic risks for human health value
P	corrected toxic risks for human health value
Pe	persistency value
Q	quantity rating value
r	dimensionless reactivity value
R	corrected reactivity value

S	sludge
Sl	dimensionless solubility value
SL	slurry
SO	solid
SC	skin contact
t	dimensionless toxicity value
T	corrected toxicity value
TC	toxic characteristics
TCLP	toxicity characteristic leaching procedure
TLV	threshold limit value
TLW	time weighted average

References

[1] S. Stafford, The effect of punishment on firm compliance with hazardous waste regulations, J. Environ. Econ. Manage. 44 (2002) 290–308.

[2] M.A. Chaaban, Hazardous waste source reduction in materials and processing technologies, J. Mater. Process. Technol. 119 (2001) 336–343.

[3] E.J. Weber, Common RCRA errors and how to avoid them, Metal Finish. 95 (5) (May 1997) 52–54.

[4] Colorado Department of Public Health and Environment, Hazardous Materials and Waste Management Division, Hazardous Waste Identification Guidance Document, first ed., September 1998, http://www.cdphe.state.co.us/hm/hwid.pdf.

[5] United States Environmental Protection Agency – Office of Solid Waste, Hazardous Waste Characteristics Scoping Study, November 15, 1996, http://www.epa.gov/epaoswer/hazwaste/id/char/scopingp.pdf.

[6] J.P. Gupta, B.S. Babu, A new hazardous waste index, J. Hazard. Mater. A67 (1999) 1–7.

[7] United States Environmental Protection Agency, Notification of Regulated Waste Activity, Washington, DC, 1990, pp. 22.

[8] Department of Environmental Protection & Energy, Hazardous Waste Regulations, Hazardous Waste Regulation Program, New Jersey, 1992.

[9] E. Meyer, Chemistry of Hazardous Materials, Prentice-Hall, New Jersey, 1989, pp. 509.

[10] United States Environmental Protection Agency, RCRA Orientation Manual, EPA/530-SW-90-036, Washington, DC, 1990.

[11] H.E. Christensen, Toxic Substances Annual List, National Institute of Occupational Safety and Health Publication DHEW (HSM) 72-10260, US Government Printing Office, 1971.

[12] United States Environmental Protection Agency, Treatability Manual vol. I, EPA-600/2-82-001, Washington, DC, 1981.

[13] M.R. Hall, Jr., R.E. Schwarz, N.S. Bryson, R.C. Davis, B.G. Donouhe, in: Crowell, Moring, (ed.), RCRA Hazardous Waste Handbook, 10th ed., Government Institutes Inc., Maryland, 1993.

[14] The Organization for Economic Cooperation and Development, Control Policies for Specific Pollutants, France, 1982, pp.246.