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A new Hazardous Waste Index

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Abstract

Hazardous wastes, once generated, have to be stored, transported, treated, disposed off, recycled, depending upon the situation. With laws being tightened, all of the above operations have to be done safely without causing harm to people and environment. Before any operation is carried out, it is vital to know the hazardous characteristics of the waste to be handled. Because waste, generally, is a mixture instead of a pure compound, its hazardous characteristics are difficult to determine and generalize because each waste is specific. A new Hazardous Waste Index (HWI) is proposed in this paper. The index measures hazards related to flammability, reactivity, toxicity and corrosivity as well as the pH value for a hazardous waste. Two examples are given for its use. The index can be modified to include radioactive or mixed waste. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

Hazardous wastes appear to be generated in ever increasing amounts all over the world. Their potential to create acute problems has prompted the public, media, legislators and judiciary to become active in directing industry to manufacture and use these materials more responsibly. Industry has responded well, both by instituting steps to decrease the amounts of the hazardous wastes created and by treating them in various ways to make them non-hazardous and, sometimes, even reusable.

Hazardous wastes, once created, have to be stored, transported and disposed of/re-cycled. In all these activities, the physical and chemical properties of hazardous wastes

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play an important role, especially properties related to fire, corrosion, toxicity, and reactivity. These properties help to determine the hazard potential of wastes, and they are also important in focusing on legislation designed to control these wastes.

Techniques are available to determine the hazard potential of a single chemical compound [1–3]. However, most wastes are mixtures (or solutions) of multiple chemicals. (If they were single chemicals, in most cases they would not be a waste, but usable in an alternate manner.) In certain cases, when the most hazardous chemical also is present in high concentration in comparison to others that are significantly less hazardous and also are present in lower amounts, one cautiously could substitute the properties of the overdominating chemical for those of the mixture. However, such a situation arises only infrequently and assumes that mixtures and intermediates do not create more hazardous characteristics. Most often, the hazardous waste mixture contains multiple compounds in such proportions that properties of several of them must be considered in evaluating the overall characteristics of the wastes. These overall characteristics help to decide the storage, transport, possible recycle, disposal procedures, construction materials of containers, as well as handling of emergencies and antidotes.

While the importance of knowing characteristics of hazardous wastes and predicting the consequences of exposure to them is undisputed, there is a serious lack of work in this direction. Some obvious reasons are too many possible combinations of such wastes and the costs of carrying out research that itself will be full of hazards!

In this paper, we propose a Hazardous Waste Index (HWI) to estimate the characteristics or hazard potential of hazardous waste mixtures. The HWI is intended to serve as a guide to those producing, storing, transporting, disposing, recycling and regulating hazardous wastes.

2. Proposed Hazardous Waste Index (HWI)

The following five principal characteristics are considered in the proposed HWI:

- Flammability hazard
- Reactivity hazard
- Toxicity hazard
- Corrosion or corrosivity hazard
- pH value.

2.1. Flammability and reactivity hazards

The National Fire Protection Association (NFPA) issues hazard ratings for flammability (N_F) and reactivity or instability (N_R) [4,5]. Both of these vary from 0 to 4 in integral steps of one. $N_F = 0$ is for non-combustibles, whereas $N_F = 4$ refers to highly flammable materials with flash point and boiling point both below 37.8°C (100°F). Similarly, $N_R = 0$ is for non-reactive chemicals while $N_R = 4$ is for the most reactive ones. Detailed tables as well as explanation of different N_F and N_R values are in Ref. [4,5]. A comprehensive table from Refs. [4,5] has been reproduced in the DOW Guide [3]. For materials for which N_F and N_R are not tabulated, procedures to derive their values are given in Refs. [3–5].

2.2. Toxicity hazard

While Refs. [3–5] also list a health hazard rating, N_H, it is intended only for personnel operating plants and not for the public that might get exposed. Hence, in HWI, we propose to use the Threshold Limit Value (TLV) because it gives a better measure of the toxic hazard potential for all those handling the hazardous wastes, emergency management personnel and the public-at-large.

2.3. Corrosion or corrosivity hazard

The DOW Guide [3] lists values of corrosion penalty from 0.10 to 0.75 based upon the corrosion rate of the construction material of the containment vessel and pipes due to the material contained in them or the environment they are exposed to on the outside. These rates vary from less than 0.0127 mm/year (< 0.5 mil/year) to over 0.0254 mm/year (> 1.0 mil/year). Corrosion also includes possible defects or breakdowns in any lining used as well the stress corrosion cracking, the last one implying the highest corrosivity hazard: 0.75. Corrosivity hazard as considered here, is between the material and container. This is different from the reactivity hazard, which is the reactivity of the chemical with respect to water at ambient temperature [3].

2.4. The pH value

pH value has been included because it is a measure well known to workers with different backgrounds. The fact that a liquid or sludge with pH = 2 is quite acidic and pH = 11 is quite basic immediately tells workers what kinds of protective measures to use. Whereas, the other measures of fire, reactivity, toxicity and corrosivity are not commonly known, and hence do not illicit an immediate cognitive response. With experience and training, of course, one can learn to respect these rating values as well.

3. Determination of HWI

The following values are required to calculate the HWI:

- Analysis of waste with regard to constituents present and their amounts.
- Flammability and reactivity hazard indices of the constituents.
- TLV values of the constituents.
- Corrosivity of the total waste.
- pH value of the total waste.

Once the waste constituents are known, the flammability and reactivity hazard indices can be known from tables in Refs. [3–5] or calculated by methods given there. The TLV values also can be determined from the literature [6,7]. Corrosivity will have to be determined from accelerated experiments, or from experience with similar wastes or, as a conservative estimate, it may be based upon the most corrosive constituent present. The pH value can be measured easily.

4. Coding mechanism

Different alphabets have been assigned to indicate different hazards:

	Hazard	Code
1	Flammability or fire hazard	F
2	Reactivity hazard	R
3	Toxicity hazard	T
4	Corrosion or corrosivity hazard	C
5	pH	pH

Then, HWI = $[\text{Code i}]_j$, where Code i stands for F, R, T, C and pH and j stands for the numerical value of each, to be determined as given below. This will be followed by two examples.

4.1. Flammability or fire hazard index

A weighted average value for the fire hazard index, F, is calculated as follows:

$$F = \sum x_i N_{Fi} \tag{1}$$

where x_i = mass fraction of waste constituent i, N_{Fi} = flammability or fire index value of component i.

Weighted average is justified on the ground that the constituents with lower N_F values will decrease the propensity to catch fire. The value of F will range between 0 and 4.

4.2. Reactivity hazard index

As for the flammability hazard, a weighted reactivity hazard index, R, is calculated as follows:

$$R = \sum x_i N_{Ri} \tag{2}$$

where N_{Ri} = reactivity index value of component i.

The value of R will range from 0 to 4.

4.3. Toxicity hazard index

For toxicity, the TLV value of individual components is used. Contrary to the cases of flammability and reactivity, where a higher value of N_{Fi} or N_{Ri} means greater hazard, a higher value of TLV_i generally implies that a constituent is relatively less hazardous. Hence, the weighted toxicity hazard index, T, is calculated as follows:

$$T = \sum \frac{x_i}{\text{TLV}_i} \times 100 \tag{3}$$

where TLV_i = threshold limit value for constituent i.

Multiplication by 100 has been used to get T values in the range of 1 to 100 instead of in small decimal numbers. For ease in presentation, values of F, R and T are rounded to the next higher integer value.

4.4. Corrosion or corrosivity index

The corrosivity index is for the total waste. The corrosion rate can be determined experimentally, taken from experience with similar wastes, or from historical data. However, when a highly corrosive substance is present in large quantity compared to other substances of lower corrosivity, one may use the value of the former as a conservative estimate. For the corrosion rate obtained or chosen, a corrosion penalty value should be taken from the DOW Guide [3]. This is the corrosivity index for use here. Because all other indices are in whole integer form for ease of use, it is suggested that the corrosivity index, instead of 0.1 to 0.75 as in the DOW Guide, be taken as 1 to 7 with explanation unchanged.

4.5. pH

The pH value easily can be measured by a pH probe. It should be rounded to the next higher integer if basic or next lower integer if acidic for ease in writing the HWI. This rounding off does not affect handling of the waste.

Example 1

Characteristics of individual constituents of a hypothetical hazardous waste are given in Table 1.

Using the equations given earlier, the above values give, for the total hazardous waste,

the flammability hazard index, $F = 1.6$ (Eq. (1))

the reactivity hazard index, $R = 2.0$ (Eq. (2))

the toxicity hazard index, $T = 4.9$ (Eq. (3)).

For corrosion, based on past experience/accelerated tests, a corrosion rate of over 1 mm/year is taken in this example. This gives a corrosivity index of 0.5 [3] which, as per discussion earlier, is taken as 5.

Table 1
Composition, N_F, N_R and TLV for Example 1

Component	% Composition (mass)	N_F	N_R	TLV (ppm)
A	40	3	3	10
B	20	2	1	25
C	15	0	4	200
D	25	0	0	Non-toxic

The measured value of pH is taken as 11.8. It is rounded up to 12.0 as discussed earlier. Hence, the HWI for this waste is,

$$\mathrm{HWI} = F_2 R_2 T_5 C_5 \mathrm{pH}_{12}.$$

This can be interpreted as follows.

- It is a flammable mixture at relatively high ambient temperature (flammability index value of 2 represents materials that must be moderately heated or exposed to relatively high ambient temperature before ignition can occur [4,5]).
- It is a very reactive material (reactivity index value of 2 represents materials which are themselves unstable and readily undergo violent chemical reaction but do not detonate [4,5]).
- Toxicity index value of 5 is rather high. This should be kept in view when deciding upon further treatment, recycle or disposal by landfill, incineration and/or other methods of the waste. It may be detoxified by selectively reacting, dilution or otherwise. It should be handled very carefully.
- Corrosion factor of 5 is high. The container material should be corrosion resistant and/or have a thicker wall to maintain its integrity for the expected lifetime. It should be cleaned thoroughly after each use, such as triple-rinsing.
- Waste is highly basic in nature with a pH of 12. Hence, it should be handled accordingly.

Example 2

Characteristics of individual components of a hypothetical hazardous waste are given in Table 2.

Using the equations given earlier, the above values give for the total hazardous waste,
the flammability hazard index, $F = 1.0$ (Eq. (1))
the reactivity hazard index, $R = 0.2$ (Eq. (2))
the toxicity hazard index, $T = 5.8$ (Eq. (3)).

The waste has been determined to be able to produce stress corrosion cracking. The corrosion factor for this condition is 0.75 [3], which, as per earlier discussion, is put at 7. The measured value of pH is 3.6 which is rounded down to the next integer 3.

Hence, the HWI for this waste, after rounding off the F, R and T indices to the next higher integers as discussed earlier, is

$$\mathrm{HWI} = F_1 R_1 T_6 C_7 \mathrm{pH}_3$$

This can be interpreted as follows.

- The flammability hazard is very low. The flash point is above 93.3°C (200°F) and boiling point is higher still. It will burn only if heated to above its flash point for sufficient length of time.

Table 2
Composition, N_F, N_R and TLV for Example 2

Component	% Composition (mass)	N_F	N_R	TLV (ppm)
A	10	2	0	2
B	20	4	1	25
C (water)	70	0	0	Non-toxic

- It is a stable material (reactivity index value of 1 represents materials that are themselves stable but may become unstable at elevated temperatures and pressure [4,5]).
- Toxicity index value of 6 is very high. Careful handling is needed. Refer to discussion in Example 1.
- Corrosion factor of 7 is very high. Stress corrosion cracking can happen. Hence, specify the right type of material of construction to minimize it.
- The waste is highly acidic with a pH of 3. Hence, it should be handled accordingly.

The above examples show the process of calculation and interpretation of HWI.

5. Conclusions

The HWI proposed here is a simple means of determining hazards related to flammability, reactivity, toxicity and corrosivity of a hazardous waste. The pH value is given also. This index helps in deciding safe procedures related to handling, storing, transporting, treating and disposing of the hazardous waste. For mixed or radioactive wastes, another term can be added.

This is the first proposal for a HWI. Constructive comments from readers and users with real wastes will demonstrate its utility and probably will result in its modification into a refined version including, probably the procedure to calculate the weighted average values of F, R and T. The need for such an index, however, is not in doubt.

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