Journal of Hazardous Materials 209–210 (2012) 308–317

Contents lists available at SciVerse ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Vulnerability assessment using hazard potency for regions generating industrial hazardous waste

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ARTICLE INFO

Article history:
Received 17 November 2011
Received in revised form 9 January 2012
Accepted 9 January 2012
Available online 16 January 2012

Keywords:
Composite index
Aggregation methods
Hazardous waste index
Hazard potency
Vulnerability assessment
Pareto optimality

ABSTRACT

This study proposes a methodology that would measure the hazardous characteristics of industrial waste based on its physical and chemical properties. A composite hazardous waste index (HWI) is framed using a new aggregation operator proposed in this study. However, HWI alone cannot be used to compare the hazardous characteristics of different wastes. The concept of hazard potency (HP) is introduced in this study in order to address this problem. HP can be calculated not only for a single waste stream but also for multiple industrial processes in an industry. Thus the hazardous wastes generated from two industries can be directly compared using this methodology. The vulnerability arising out of an industrial unit has been evaluated using HP values of the unit and the population residing within its impact area. The industries in a region are prioritized based on the vulnerability of the adjoining population using the non-dominated sorting algorithm. Solutions are ordered into various levels of domination depending on their HP and population values. A case study of Kolkata Metropolitan Area is provided to substantiate the methodology.

1. Introduction

Urban areas in developing countries like India have immense pressure on its land resources. High population density in all the major cities is a common phenomenon. Sporadic and organic growth of these cities along with unplanned allocation of industries has worsened the situation. Occurrence of industrial facilities, warehousing and storage facilities are common in the core of these cities or their peripheral areas. These fixed facilities not only handle hazardous chemicals but also generate substantial amount of hazardous waste. The risk of spillage or fire in such facilities cannot be ruled out and their impact on the adjoining population may have catastrophic results. In this light, a mechanism to assess the hazardous potential of all such facilities in a region is necessary.

Researches on impact of hazardous chemicals and industrial solid waste from specific industrial sites have been conducted in the past, where emphasis was on waste characterization and identification of treatment methodologies. Yang [1] emphasized on research pertaining to waste characterization in the industrial processes in a region for an effective waste management. Pollutants found in wastewater of palm oil industry and semi-conductor industries were analyzed. Mbuligwe and Kaseva [2] have conducted a study on the type and quantity of industrial solid waste generated in the city of Dar-es-Salaam. The wastes generated were characterized according to the nature of generating industrial units. A SWOT analysis was carried out on the existing hazardous waste management of the city.

Similar studies were also conducted on specific industries. Mendez et al. [3] had worked on the characterization of waste from eight different paper mills. Abreu and Toffoli [4] had worked on the characterization of chromium waste from tanneries. Fiore et al. [5] had conducted waste characterization studies on waste generated from aluminium foundry. The composition of different type of waste generated e.g. Policast mud, furnace slag, etc. were studied and treatment methods were also suggested.

Khan and Abbasi [6] designed accident hazard index (AHI) to rate potential accidents in industries based on direct impact (heat load, overpressure load and toxic load) and indirect impact (on environment based on Delphi method). The attributes were aggregated using the root sum power addition operator (for exponent value equal to 2). Khan et al. [7], in continuation with the previous research, had proposed a safety weighted hazard index which accounted for the potential damage as well as the preparedness (in terms of safety measures) of the industries. Zabeo et al. [8] had designed a framework based on multi-criteria decision analysis

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0304-3894/$ – see front matter
doi:10.1016/j.jhazmat.2012.01.025

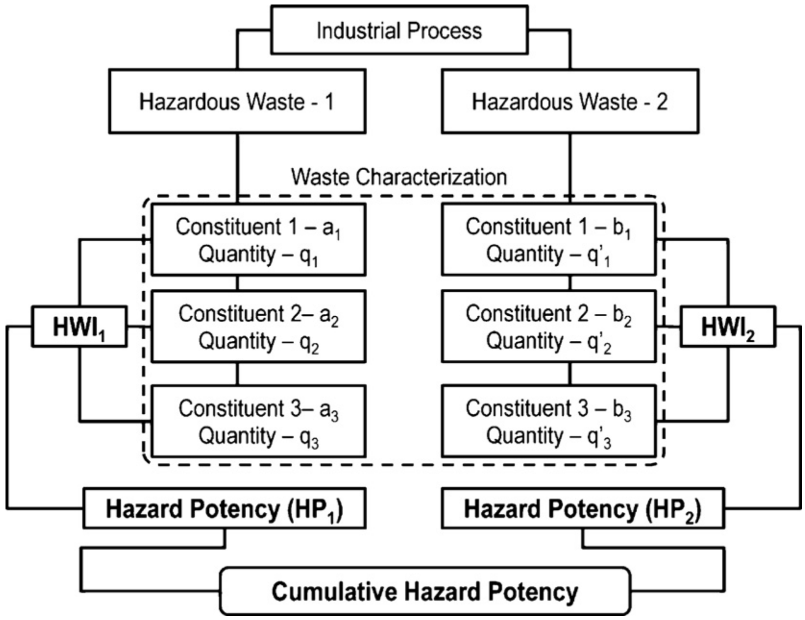

Fig. 1. Proposed methodology for computing cumulative hazard potency of an industrial waste generating unit.

(MCDA) to assess vulnerability of a region due to soil contamination from different sources. This involved four major attributes which consisted of several sub-attributes with a normalized score. The aggregation of attributes was done using the Choquet integral operator. Sebos et al. [9] had designed a methodology to guide landuse planning in a region having polluting industries. Vulnerability of the existing landuse was evaluated based on ten criteria (such as population sensitivity, population density, landuse classification and distribution, etc.). The proposed landuse was decided after overlapping the vulnerability data with the damage zoning.

The knowledge of waste characterization from individual industry has not been transferred to policy makers and implementing agencies and a gap exists between the acquired knowledge and various guidelines, schemes or policies for regional waste management.

This study attempts at meeting the gap between the existing research on waste characterization and vulnerability assessment. A methodology is proposed for measuring the hazard potency of various waste generating units in a region and determining their vulnerability for a better regional hazardous waste management.

The following section will explain the methodology of the proposed model and discuss the principal components of the model.

2. Methodology

The first step for determining the hazard potency of a region is to identify all the industrial processes in the region, the types of hazardous waste produced and their quantities. Next, the hazardous wastes generated by each industrial process have to be characterized. The characterization of waste depends upon its physical and chemical properties which can be attributed to either the raw materials that go into the industrial process or, the compounds that result from production. The methodology adopted in this study has been represented in Fig. 1.

In the present study, hazardous wastes generated by various industrial units in a region were taken into account. The waste characterization was done based on Hazardous Waste (Management and Handling) Amendment Rules, 2003. The waste from each unit was further characterized using secondary data from relevant literature studies and a unique composite index or the hazardous waste index (HWI) was calculated for each waste stream. This composite index was calculated based on an aggregation method. HWI values are independent of the quantity of hazardous waste and are dependent on its chemical composition. Therefore, to compare waste streams from two different industrial processes, the concept of hazard potency (HP) was introduced.

The hazard potency (HP_i) of any industrial process is calculated using Eqs. (1) and (2).

$$HP_i = HWI_i \times Q_i \tag{1}$$

$$HP_{Total} = \sum_i HWI_i \times Q_i \tag{2}$$

where Q_i is the amount of hazardous waste 'i' generated in a given industrial unit, HWI_i is the hazardous waste index of ith waste stream and HP_{Total} is the cumulative hazard potency of an industrial unit.

Section 3 elaborates the calculation of HWI using aggregation method. The efficacy of the composite HWI lies in its computation simplicity. The computations are based on National Fire Protection Association (NFPA) ratings which can be procured from Material Safety Data Sheet (MSDS) of the industrial chemicals and wastes. A working solution based on the above stated methodology and its application is also provided in this study. The Kolkata Metropolitan Area was selected for the above mentioned purpose.

The methodology has introduced new concepts like HWI and HP_{Total} which would be further explained in the following sections.

3. Calculation of hazardous waste index (HWI)

Hazardous wastes are composite wastes consisting of more than one hazard prone constituent, which makes it difficult to measure the hazard potency for a given hazardous waste. The existing research on the framework for comparison of two hazardous waste samples is not very extensive.

The framework for designing environmental indices constitutes of three major steps as proposed by Ott [10]. The first step is to identify attributes for the composite index (e.g. inflammability, toxicity, etc.) and calculate their index values. The second step constitutes of calculating the sub-index values of individual attributes based on the distribution characteristics of the attributes (i.e. whether