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Differences in the risk profiles and risk perception of flammable liquid hazards in San Luis Potosi, Mexico

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ABSTRACT

The pace of urbanization and industrialization in developing countries is rapidly increasing. Unfortunately, regulatory and private-sector control of hazards has not always kept pace. This work identifies the level of emergency preparedness in chemical industries and evaluates the spatial distribution of hazards using a worst-case release scenario. Consequently, we identified potentially exposed urban communities and evaluated the social perception of a hazard. This research characterizes risk scenarios in a case study of the industrial area in San Luis Potosi, Mexico. Intervention zones of major concern are recognized when deficiencies in emergency preparedness join a poor social perception of hazards in communities that are potentially exposed. The worst-case scenario radii of flammable chemicals range from 425 m to 733 m. Potentially exposed communities have a limited perception of chemical risk and no training in emergency response. Proximity to an industrial area influences communities towards a better recognition of hazards. However, communities far from the industrial area have higher exposure to low preparedness worst-case scenarios for flammable chemicals and have a larger level of vulnerability because of their lack of risk perception.

Introduction

The use and storage of hazardous materials in the industrial sector represents a threat from the occurrence of major chemical hazards, which include fire, explosions, and release of toxic substances with negative consequences to human health and the environment. A chemical hazard becomes a risk whenever a potentially exposed human system is present. In this situation, the characteristics of the hazards and the system define the degree of danger, exposure, and vulnerability.

Major accidents in developing countries that involved hazardous materials have shown that vulnerability can magnify the severity of chemical accidents, depending on the organizational level, the emergency response agencies and the level of social perception and preparedness. Vulnerability is determined by physical, social, economic, and environmental factors. Therefore, vulnerability increases the susceptibility of a community to the impact of hazards [1]. Risk perception and the willingness to adapt play an important role in adaptive risk strategy implementation [2]. The social risk level is related to community development and its capability to modify risk factors [3]. It is notable that three of the most serious major

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chemical accidents, in terms of the number of fatalities, occurred in marginalized communities of Mexico, Brazil and India, all in 1984 [4].

This paper focuses on a flammable liquids hazard assessment, taking into consideration that fire accidents are one of the most common and serious threats to public safety and have an accelerating rate in developing countries [5].

Risk assessment

Flammable liquids hazard assessment

The storage of combustible liquids in the industrial sector is potentially hazardous because they can be ignited under almost all ambient temperature conditions; these flammable liquids can also produce a hazardous atmosphere [6].

The consequence-based approach consists of evaluating accidents, calculating the distance to which the physical and/or human health impacts reach for a given exposure period, and establishing a threshold value [7]. The worst-case scenario is used as a reference in this approach; criticisms of this approach focus on the ignorance of the accident frequency [8].

This research is based on the worst-case analysis described in the US EPA's Risk Management Program Guidance for Offsite Consequence Analysis. According to this guide, the worst-case scenario for combustible liquids is a vapor cloud explosion, and the consequences are set using the TNT equivalence method [9]. It is the simplest and most widely used method for modeling vapor cloud explosions [10] and tends to be better for estimating widespread damage [11].

Land-use planning and vulnerability in risk assessment

The objective of land-use planning is the protection of the community from severe outcomes by setting minimum safety distances [12]. There are different approaches and criteria for the establishment of these safety distances, such as: generic separation and consequence-based and risk-based approaches [13–16].

A key in land-use planning is the identification of threat intensity areas for potential accidents and the level of vulnerability of nearby areas [7]. In his work, Johansson based land-use planning decisions on an assessment of benefits, costs, and consequences; these assessments were categorized in three broad areas: environment, social, and risk factors [17]. Salvi and Debray's, risk assessment was performed by considering a scenario's severity as well as the vulnerability of the surroundings [18], while Cutter et al. [19] suggested that the overlap of hazard zones and social vulnerability produces a spatial variation in overall vulnerability of the community. Social vulnerability analysis can be based on expert judgment, hierarchical structures [20], multi-criterial analysis [16] and census block statistics [19]. It is important to mention that a vulnerability assessment can be useful to prepare emergency procedures, as well as preparing risk communication materials for potential health risks [21].

An important variable in vulnerability is the social perception of risk because perceptions of risk and risk-related behaviors may amplify the social, political, and economic impacts of disasters well beyond their direct consequences [22]. Risk perception is a social construct and is culturally determined [23]; the result of the social and behavioral context in which risk is experienced and described [24].

Materials and methods

Hazard characterization

This study classifies chemical hazard internal controls by identifying the degree of fulfillment of the security aspects, followed by the international regulation of hazardous materials locations. The data used in this legislation to classify the level of risk include: accident history, potential threat to public receptors, and effectiveness of emergency response programs and risk management systems.

Deficiencies in developing countries regarding industrial regulations put every industry in a certain level of threat due to their internal hazard management. This threat can be quantified through the level of emergency preparedness, which was constructed as shown in Table 1 in this paper.

Potential exposure assessment

Potential exposure assessment is evaluated using the US EPA's Risk Management Program Guidance for Offsite Consequence Analysis following the worst-case methodology for a flammable substance [9].

The radii obtained are applied to construct circular buffers around the industrial location. Subsequently, the obtained buffer is linked to the emergency preparedness level.