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A new risk evaluation method for oil storage tank zones based on the theory of two types of hazards

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ABSTRACT

Oil storage tank zones possessing large amounts of harmful substances and energy with great probability of accidental release, can pose risks to personnel, equipment facilities and environment. With risks becoming more complex and diverse, risk evaluation approaches are required to quickly identify hazards, effectively assess safety performances. This paper presents a new risk evaluation model for oil storage tank zones based on the theory of two types of hazards. Firstly, the two types of hazards (inherent hazards, controllable hazards) in oil tank zones are identified, analyzed and classified. Secondly, inherent hazards of oil storage tank zones are quantitatively evaluated by the major hazards method (flammable, explosive and toxic), which conducted on the possibility and severity of accidents. Thirdly, (i) using Fault Tree Analysis (FTA), the risk factors that can lead to the emergence of controllable hazards are identified. These risk factors are screened by structural importance degree to next analysis step as the evaluation factors. (ii) The Analytic Hierarchy Process (AHP) is applied to determine the weight of each index. (iii) After the construction of the multi-factor fuzzy evaluation matrix, fuzzy comprehensive evaluation mode for controllable hazards is established. Finally, the comprehensive risk rank of oil storage tank zones, constituted by the coupling effect of inherent hazards and controllable hazards, is assessed by the developed risk matrix, which provides related standards for risk classification. The proposed method is validated to be more practicality and orderliness by the example.

1. Introduction

Oil storage tanks contain large volumes of flammable, explosive, corrosive and toxic materials. A small accident could have serious consequences (Chang & Lin, 2006). According to accident statistics from 2000 to 2010 by International Association of Oil & Gas Producers (OGP), fire and explosion were considered the most common accidents in oil storage tank zones, and the loss is huge. Thus, dozens of risk evaluating methods have been developed, such as Dow F&E index method, relative risk index, ICI/MOND method, Fault Tree Analysis (FTA) method (Leur & Sayed, 2002; Misra & Weber, 1989; Rahman, Heikkilä, & Hurme, 2005). However, each method has its own feature and application scope, and the evaluation results might be unrealistic without choosing appropriate methods.

Accident occurs frequently in oil storage tank zones in petroleum industries because of complex processing technologies and failure modes of equipment. Meanwhile, poor quality of operators and safety management defects are leading causes of the accidents (Drogaris, 1993). A single risk evaluation approach may not sufficiently meet objective and accurate demands for evaluating the comprehensive performance. Such as Dow F&E index method, it doesn't consider the interaction effect among hazardous substances, processes and safety guarantee system, just adds or multiplies the impact factors together, neglects the weight of each impact index. Similarly, most conventional methods have limitations in flexibility and sensibility when analyzing system hazards. Because various indices are evaluated only by the fixed basis, in other words, if the evaluating units contain the same types and quantities of hazardous substances, with similar spatial distributions, but in reality states of safety performance differ significantly, those methods may get a similar evaluation results for each unit. To evaluate major hazards precisely, it is important to comprehensively identify and classify the hazardous factors of the whole

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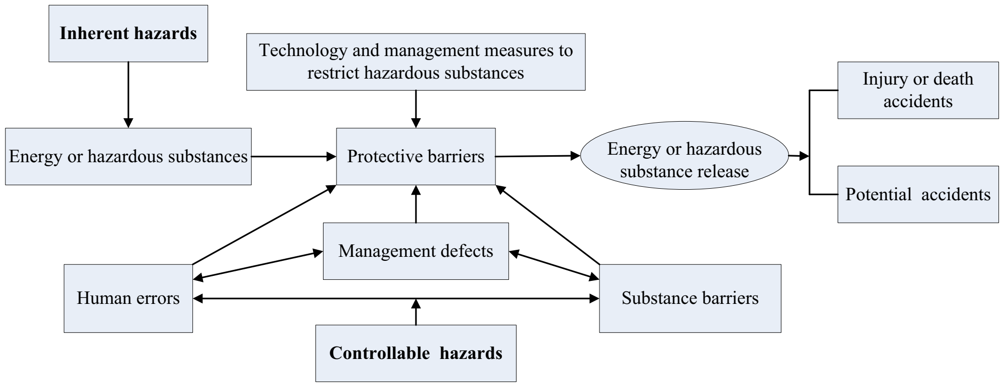

Fig. 1. The event chain that can lead to accidents caused by two types of hazards.

evaluation unit, which can provide more targeted preventive measures to reduce the systemic risk (Yajing, Shanjun, Jiming, & Ruidong, 2007; Yan & Hongwei, 2004).

Oil storage tank zones pose serious environmental hazards since they usually contain a large quantity of hazardous chemicals (Baybutt, 2003). The experiences of accident prevention show that it is necessary to construct a system for major hazards control in order to effectively prevent accidents and reduce the damages. The theory of two types of hazards (inherent hazards and controllable hazards) has an innovative understanding of the essence and characteristics of hazards compared with traditional approaches regarding how to identify and classify hazards. It can also provide a basis for risk assessment and risk control strategy (Ericson, 2005; Slovic, 1991).

Based on unexpected release theory and hazards with different effects on accident developments, hazards resources can be categorized into two types: inherent hazards and controllable hazards. They play different roles in the process of accident occurring and developing (Chung, 2010). Inherent hazards (the first type of hazards), including unexpected release of energy or hazardous substances that can result in personal injuries and property losses, are the fundamental factors leading to accidents. It determines the consequence severity. Controllable hazards (the second type of hazards) are various unsafe factors which may lead to the hazardous energy release unconventionally. The probability of accidents depends on the likelihood that the controllable hazards would occur (Cohen, Lampson, & Bowers, 1996; Leveson, 2004; Zhang & Bracken, 1996).

To evaluate the risk of the system, initially, calculate the consequence severity via the first type of hazards. Then, determine the probability of accidents based on the risk evaluation of the second type of hazards. Finally, the comprehensive evaluation

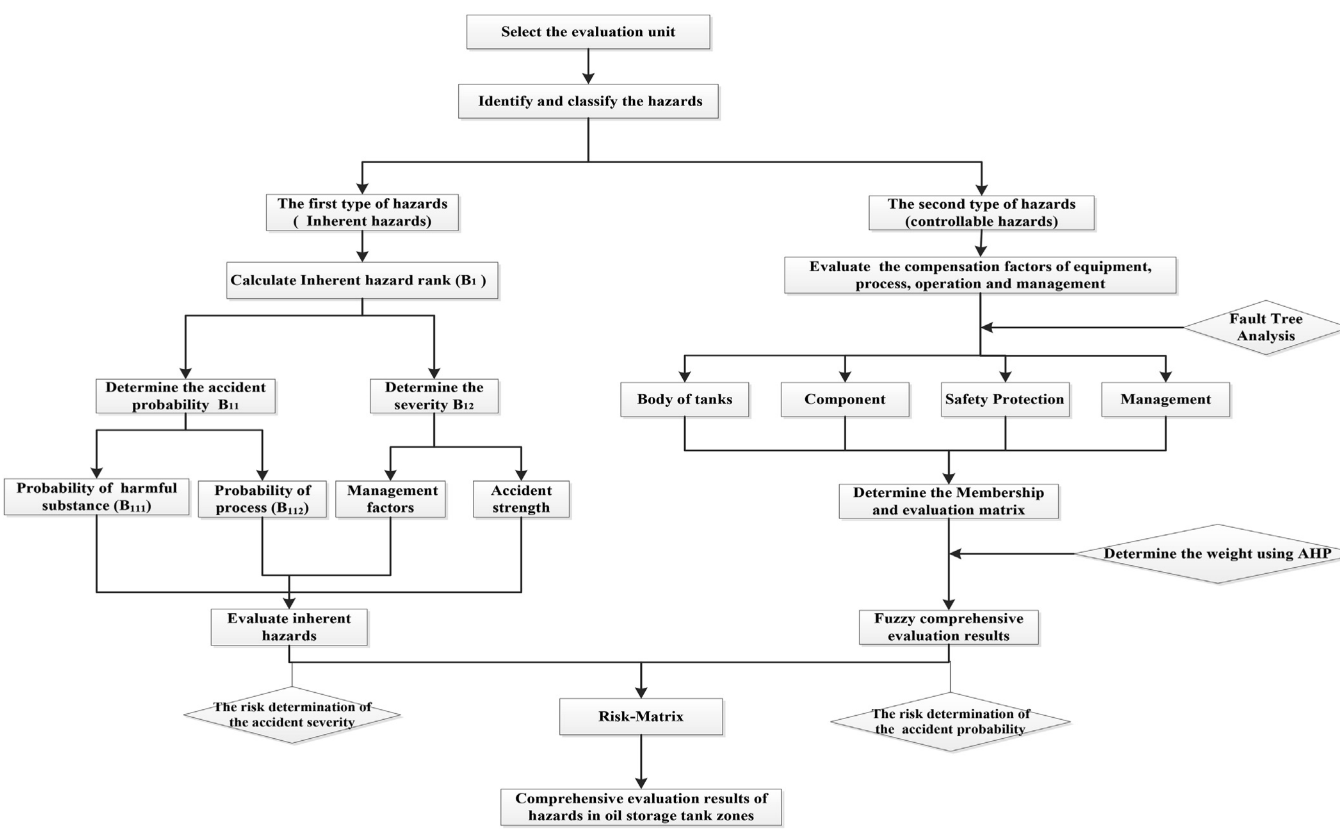

Fig. 2. Framework map of the evaluation process based on two types of hazards theory.