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Risk-based personal emergency response plan under hazardous gas leakage: Optimal information dissemination and regional evacuation in metropolises

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HIGHLIGHTS

- Information spreading models of six media are developed using for disaster.
- In Zhongguancun area, Beijing, 3-D risk distribution for carbon monoxide was drawn.
- Personal risk is calculated in evacuation, staying at home, and optimized response.
- Different response plans are provided based on different situations of residents.
- Sensitivity analysis of four influencing factors helped to make response plan.

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ABSTRACT

Knowledge on the characteristics of regional evacuation based on optimal information dissemination in hazardous gas leakage in metropolises plays a critical role. We established a risk analysis model for residents combining optimal emergency information dissemination and evacuation simulation in order to guide residents to make appropriate personal emergency response plan in hazardous gas leakage. The model was developed considering eight influencing factors, type and flow rate of hazardous gas, location of leakage source, wind speed and direction, information acquirement time, leakage duration, state of window (open/closed), and personal inhalation. Using Beijing as a case study, we calculated the risk of all grids and people and also obtained the three-dimensional special risk distribution. Through the microcosmic personal evacuation simulation in different condition, detailed data were obtained to analyze personal decision-making. We found that residents who stay near to the leakage source had better stay at home because of high concentration of hazardous leakage on their evacuation route. Instead of evacuation, staying at home and adopting optimal stay plan is very efficient if residents can receive the emergency information before the hazardous gas totally dispersed. For people who lived far from leakage source, evacuation is usually a good choice because they have longer time to avoid high-concentration hazardous gas.

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1. Introduction

In recent years, we have seen more hazardous gas leakage due to rapid economic development, an increase in the number of industries, complex traffic conditions, old gas pipes lacking of maintenance, and poor design etc. Hazardous gas is a kind of hazardous gaseous chemical. In China, 1400 gas leakage accidents occurred during 2006 to 2011 [1]. On August 4, 2003, mustard gas (bis (2-chloroethyl) sulfide) leaked in Qiqihar City of China resulting in 36 deaths. These hazardous gas leakage accidents usually affect a great number of people and a large sphere of air and land. Therefore, research on hazardous chemical leakage in urban areas is important to public health.

The accidental severity, death tolls, and property losses, which were caused by hazardous gas leakage, are related with several influencing factors including individual exposure duration [2], governmental pre-warning time [3], population density [4], speed of response of disaster carrier [5], evacuation plan [6], and some other factors. A hazardous gas leakage usually lasts long time because of undeveloped monitoring system, low information dissemination capability, and inefficient governmental emergency response plan. On the evening of April 20th, 2004, it took near two and a half hours to take control of the leakage of chlorine gas in Nanchang, China, and 22 persons influenced by a serious toxic. In addition, communication of emergency information is a key factor in exposure situations. Therefore, learning how to reduce the time it takes residents to obtain during gas leakage emergency is very important to reduce exposure time and ultimately negative health outcomes. In urban area, the risk of hazardous gas leakage is high because of high population density, crowded buildings and complicated urban gas pipelines [7]. The famous gas leakage accident in Bhopal (an Indian city) in 1984 resulted in an unexpected consequence that 520,000 residents exposing in the gas of methyl isocyanate. Because of the ineffective emergency response plan organized by local government, almost 8000 people died during the first week, and more than 100,000 people got permanent injuries [8]. To solve all problems listed above, governments or relevant agencies should reduce information acquirement time and hazardous gas leakage duration, and develop efficient personal emergency response plan based on real time risk assessment for hazardous gas.

At present, there are some models of gas diffusion along with the developed computers and software technology. Pontiggia used previously validated CFD (Computational Fluid Dynamics) model to simulate the hazardous gas releases in an urban area with complex geometries [9]. Benjamin used Lagrangian Integrated Puff model to simulate hazardous chemical dispersion in order to better coordinate the emergency response effort [10]. However, the model introduced above usually has a long simulation time. The Gaussian Dispersion Model, which has been developed to estimate concentrations of inert gaseous pollutants from curved, circular and straight sections of a complex road interchange [11], is usually used to generally simulate gas diffusion [12,13]. Moreover, short simulation time is very important in emergency response. In this paper, we used the Gaussian Diffusion Model to simulate the trajectory of hazardous gas diffusion.

A vast majority of emergency response research focuses on evacuation based on disasters such as earthquake [14], hurricanes [15,16], high-rise fires [17,18], flood [19,20] and some other disasters. However, middle-scale regional evacuation under the condition of hazardous gas leakage is still lacked. Toxic gas also can influence a large area. Based on Gaussian Diffusion Model, with the initial condition of 4000 kg weight of substances released, and 4.4 m/s wind speed, hazardous gas can cover a death zone of 8709 m^2, and influenced zone of 150, 000 m^2 [21]. An efficient response and evacuation also involves efficient information dissemination. In a disaster scenario, less than 50% of people cannot evacuate because of lower information reception coverage [22]. How to use advanced social media to spread information in disaster is very important [23,24].

In this paper, according to the time of residents to require the disaster's information, hazardous gas leakage duration, and atmospheric environment, a risk analysis model is developed and a dynamic real-time personal emergency response plan is provided.

2. Methodology

Fig. 1 shows the procedure of emergency information dissemination and regional evacuation. Hazardous gas leakage can be monitored by governments or relevant agencies. It also might be found by residents directly. When residents received the information of disasters, they may spread the information through social media if they have time (represented by dotted line) (According to the statistical data from questionnaire of one of the most famous Chinese news portal-Sina (http://survey.news.sina.com.cn/result/56729.html), about 75% of information received by residents through oral communication, short message service (SMS), blog, portal, and TV.). Utilizing different social media and interpersonal communication, emergency information can be quickly disseminated. Based on calculated dynamic risk for hazardous gas, estimated leakage duration, and relevant factors, residents will obtain a personal emergency plan by government. The main goal is to reduce the total risk of hazardous gas leakage for every resident.