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Railroad transportation of dangerous goods: Population exposure to airborne toxins

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Abstract

Hazardous materials are potentially harmful to people and environment due to their toxic ingredients. Although a significant portion of dangerous goods transportation is via railroads, prevailing studies on dangerous goods transport focus on highway shipments. We present an analytical framework that incorporates the differentiating features of trains, notably volume and nature of cargo, in the assessment of transport risk. We focus on hazardous materials that are airborne upon an accidental release into the environment. Each railcar is a potential source of release, and hence risk assessment of trains requires representation of multiple release sources in the model. We propose a risk approximation approach, which is not only effective but also robust with regards to the positioning of hazardous cargo in the train. We report on the use of the proposed approach for the assessment of population exposure associated with "Ultra-train" that passes through the city of Montreal everyday.

Keywords: Hazardous materials; Railroad shipments; Risk assessment; Gaussian plume model

1. Introduction

In the wake of the recent catastrophic accidents in Iran and North Korea, risk assessment of railroad transportation of dangerous goods has become a popular concern. United Nations Environment Programme reports 328 fatalities and 460 injuries in Iran, and 161 fatalities and 1300 injuries in North Korea due to explosions [1]. Despite the potentially catastrophic nature of train accidents, an overwhelming

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Table 1
Release incidents involving more than six railcars [8]

Incident year	Number of derailed cars	Number of derailed cars carrying dangerous goods	Number of cars released hazardous cargo
1990	61	19	12
1990	14	13	10
1990	14	14	11
1991	14	14	13
1993	30	23	9
1995	24	17	13
1996	34	16	16
2000	32	18	18
2002	17	17	7
2002	39	15	11
2003	50	19	7

majority of the research on hazardous material (hazmat) transportation focuses on road shipments [2,3]. Although trucks carry a larger share of dangerous goods shipments in many countries, railroad shipments can easily reach comparable levels. In Canada, for example, 48 million tons of hazardous freight was carried via rail while 64 million tons was shipped via trucks in 2000 [4]. There is a need for the development of risk assessment methodologies that incorporate the specific nature of railroad shipments, which we address in this paper.

There are a number of factors that differentiate rail transport from truck shipments. A train usually carries non-hazardous and hazardous cargo together, whereas these two types of cargo are almost never mixed in a truck shipment. Furthermore, a rail tank-car has roughly three times the capacity of a truck-tanker (80 t and 25–30 t, respectively) and the number of hazmat railcars varies significantly among different trains. The resulting variability in the total amount of hazardous cargo needs to be taken into account in assessing the transport risk associated with trains. Also, railroads typically offer much less routing flexibility compared to highway networks.

Another important characteristic of trains, from a risk assessment perspective, is the possibility of incidents that involve multiple railcars. In the United States, there were 11 train derailments during the 1990–2003 period in which more than six railcars were ruptured and released their toxic cargo (see Table 1 for details). Note that this amounts to an average of about one major railroad accident per year. Canada had its share of multiple railcar accidents as well. In December 1999, Canadian National (CN's) Ultratrain (which constitutes our case study in Section 6) released 2.7 million liters of petroleum products due to the derailment of 35 tank cars just outside Montreal. Thirty cars were seriously punctured and had to be demolished at the accident site [5]. Another well-known accident took place near Toronto in 1979, where chlorine leaking from damaged tank cars forced the evacuation of 200,000 people [6]. Thus, train accidents can have more severe consequences than those involving trucks, mainly due to the higher volumes of hazmats being shipped and the interaction between railcars. Fortunately, empirical evidence suggests that trains have lower accident rates than trucks [7].

Traditionally, hazmat transport risk is defined as the *expected* undesirable consequence of the shipment i.e., the probability of a release incident multiplied by its consequence. This risk measure is also called the "technical risk" since it requires a detailed assessment of the accident probabilities across the shipment