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Computer simulation of impacts of a chlorine tanker truck accident

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ABSTRACT

The aim of the study was to present the author's original modelling programs of pollution dispersion in an urban environment. The programs outlined herein are based on a diagnostic model of air velocity field and Langrangian particle model. In both modelling programs author's elements of mathematical modelling were applied. The models have been validated and verified. Geographic Information System (GIS) Idrisi Andes was applied in the pre-processing stage.

The development of author's original computer program and stages of hazardous material propagation modelling were discussed.

The results of computations and analysis of pollution dispersion caused by a chlorine tanker truck collision and chlorine release into atmosphere were presented. It was simulated that the accident took place in the city of Bielsko-Biała, on a bypass in a built-up area causing leakage of 10 t of chlorine. The computer simulations conducted for two wind direction scenarios allow to conclude that the total area affected by the pollutant cloud with concentrations above threshold levels could be over 2 km^2, with 5000 lethally exposed people.

Introduction

Modelling propagation of hazardous substances released in road accidents is an important element in the evaluation of threats related to the use of road transport for the transportation of chemicals. Assessment of probable impacts of a tanker truck collision resulting in spillage is possible thanks to such hazard assessment programs as ALOHA or H-PAC which, however, do not take into account many factors, area topography being one of them.

In the paper there are presented possible applications of author's original software for modelling of pollution dispersion in an urban environment. The software programs used are based on a diagnostic model of air velocity field and Lagrangian model of particles. In both models, some elements of mathematical modelling were applied. The models were validated and verified (Brzozowska, 2013, 2014). Additionally, the Idrisi Andes geographic information system was used in the pre-processing stage.

In the paper it is analysed dispersion of pollutants released in a road accident, involving a chlorine tanker truck, followed by chlorine spillage. It was simulated that the accident took place in Bielsko-Biała (Poland), on a bypass within a built-up area.

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Road transport safety

According to data from Eurostat, the European Commission statistical data resources, in the period of 2009–2013 from 77 000 to 88 000 mln t km of hazardous goods were transported by road within the European Union. Also in Poland the volume of transportation of hazardous goods is constantly increasing in volume and according to the same source, from 5697 in 2009 it rose to 7024 mln t km in 2013, accounting for circa 3% of the total road freight transport volume.

Safety of road transport is governed by, *inter alia*, the provisions of the European Agreement concerning International Carriage of Dangerous Goods by Road (ADR). It is a commonly applied standard, constantly revised by the UN European Economic Commission. Under Polish law, the transportation of dangerous goods is also governed by the Act on the transport of dangerous goods of 19 August 2011 (Journal of Laws, 2011, No. 227 item 1367).

As demonstrated by the analyses conducted by the Polish Supreme Audit Office (2012) per 50 345 audited (within the period of 2009 – 1st quarter of 2011) vehicles/transport systems carrying dangerous substances, irregularities and non-compliances were identified in case of 2585 vehicles/transport systems, which is equal to about 5%.

The audit conducted by Polish Supreme Audit Office revealed that:

- every tenth vehicle did not obtain its technical tests certificate from specialist testing stations,
- about 4% of controlled vehicles (including tanker trucks) did not have permissions to operate as dangerous goods' carriers,
- 60% vehicles were not equipped with fire protection means,
- 17% vehicles were not equipped with environmental protection equipment,
- 16% vehicles were not properly marked,
- 4% drivers did not undergo trainings required by law.

Such irregularities may be the cause of road accidents, failures and disasters threatening the life and health of people and having long-lasting detrimental impact on the environment.

The issue of transportation of hazardous goods has been tackled by many authors. In a study by Oggero et al. (2006), 1932 accidents which occurred during transportation of hazardous substances by road and rail since the beginning of 20th century till July 2004 in Great Britain were analysed. The results showed an increase in the frequency of major accidents over time. More than half of them happened on roads (63%). Majority of these accidents were releases: 78%, followed by fires: 28%, explosions: 14% and gas clouds: 6%. The various causes of accidents, the type of substance involved and the consequences for the population (number of people killed, injured or evacuated) were also analysed in the study.

In the United States (Erkut et al., 2007), most accidents that occurred involved flammable materials: over 42%, caustic materials: 37.5%, toxic: over 5%, oxidants: 3% and mixed materials: almost 4%. As it comes to the remaining accidents, over 8% involved hazardous materials. Approximately 40% of hazmat accidents were caused by human fault and the same amount was due to road accidents, whereas almost 20% were related to containers' failure.

On the other hand, according to Welles et al. (2004) and based on a survey conducted in New York, 21% of hazmat accidents can be attributed to transportation, 39% to faulty equipment and 33% to human fault.

According to annual reports of the Chief Inspector of Environmental Protection on incidents with attributes of major accidents in the years 2009–2013 in Poland, the total number of such accidents was 64 (Report, 2009, 2010, 2012, 2013). Most of these majority accidents were caused by collision or crash of hazmat-carrying trucks, mainly liquid products of oil refining and chemicals. In few cases the transported substance caught fire.

Modelling of impacts of major accidents in road transportation

The occurrence of incidents involving release of chemicals into atmosphere and often causing fatalities, forced environment protection and government organizations to develop real-time response systems based on accurate predictions and computer simulations. The impact of accidental toxic chemicals release may be minimised by provision of accurate information and adequate management of major incident response teams (Alhajraf et al., 2005). A system that is capable of predicting air dispersion of hazardous chemicals is a key tool in supporting decision makers in their planning of preparatory and rescue operations in case of accident occurrence. It must, above all, enable quick evaluation of the impact range of emitted hazardous substances (Quaranta et al., 2002). ARAC (Atmospheric Release and Advisory Capability) developed by Lawrence Livermore National Laboratory (LLNL) would be a good example of such a system (Ermak et al., 2002).

In another study (Zhao et al., 2012) a decision support system in cases of sudden hazardous substance release was proposed. The system is based on Bayes network model. Results of research and simulations show that the most important factors behind the occurrence of major hazmat accidents are: the human factor, transportation vehicle and its markings, as well as the vehicle's loading and unloading.

Methodology used to determine the demographic composition of a population affected by release of toxic materials is an important element in the evaluation of impacts of serious accidents. Such methodology was put forward by Chakraborty and Armstrong (1995) and applied, *inter alia*, by Fisher et al. (2001). It describes the Geographic Plume Analysis (GPA) approach in which data provided by the chemical dispersion model are superimposed on a demographic database. The model utilises also the Geographic Information System (GIS) and a database regarding possible sources of pollution.