

Consequence Modelling of Accidents in Hazardous Substances Transportation



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Introduction

The contribution objective:

- to present results of the modelling using standard models;
- to motivate the importance of the next development stage in the area of transport accident modelling from the point of view:
 - major accidents,
 - terrorist attacks.

Accident History and Statistics

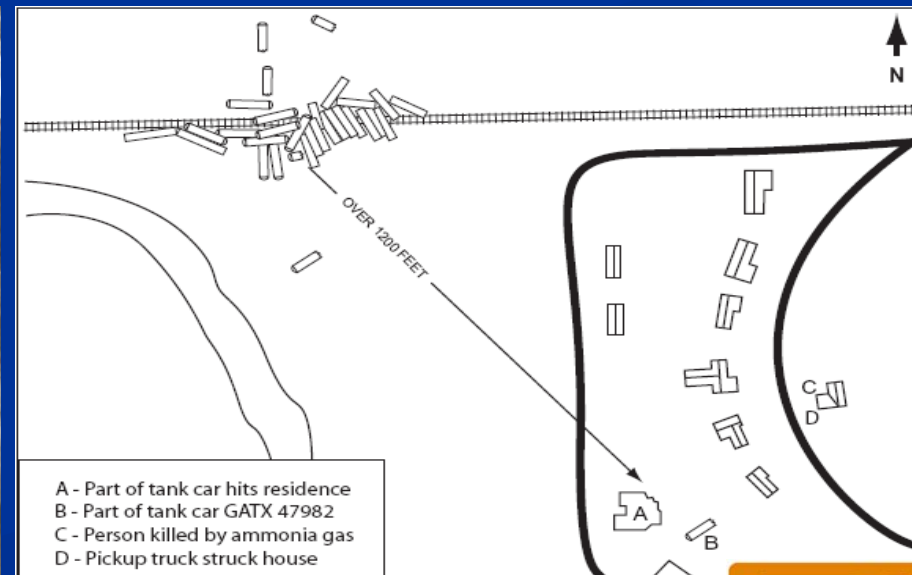
Review of important accidents in hazardous substance transportation

Type of accident	Place	Year	Hazardous materials	Consequences
road	Houston, USA	1976	ammonia release	6 fatalities, 178 injuries
road	San Carlos, Spain	1978	propylene explosion	200 fatalities
rail	Mississauga, Canada	1979	LPG explosion, chlorine release	200 000 people evacuated
rail	Montanas, Mexico	1981	chlorine release	28 fatalities, 1000 injuries

Major Accident Example

Train derailment in Minot, North Dakota, USA, 18.1.2002

- Derailed 31 of its 112 cars, 5 carrying ammonia;
- Release of 350 t ammonia, cloud moves to 5 miles;
- Consequences - 1 fatality, 11 serious injuries, 322 minor injuries.



Transport Information System of the Ministry of Transport (CZ)

Numbers of accidents in dangerous substances transportation in CZ

Year	Road	Rail
2002	4,188	378
2003	5,394	385
2004	5,109	483
2005	5,285	456
Total 1996 - 2007	22,256	3,968

Note: These include very small leakages without consequences (e.g. valve leakage)

Transport Information System of the Ministry of Transport (CZ)

Numbers of accidents caused by selected dangerous substances

Year	Ammonia anhydrous		Gasoline	
	Road	Rail	Road	Rail
2002	36	2	725	49
2003	44	4	820	38
2004	40	9	748	85
2005	35	13	686	36
Total 1996 - 2007	284	83	3,108	2,340

Statistic data in USA

U.S. Department of Transportation (DOT),
PHMSA - the Pipeline and Hazardous Materials
Safety Administration

	2002	2003	2004	2005	2006	Total
Air	15	13	6	19	17	198
Highway	377	399	400	418	389	4,120
Rail	71	58	82	84	75	717
Water	3	2	4	2	1	20
Total	466	472	492	523	482	5,055

Statistic data in USA

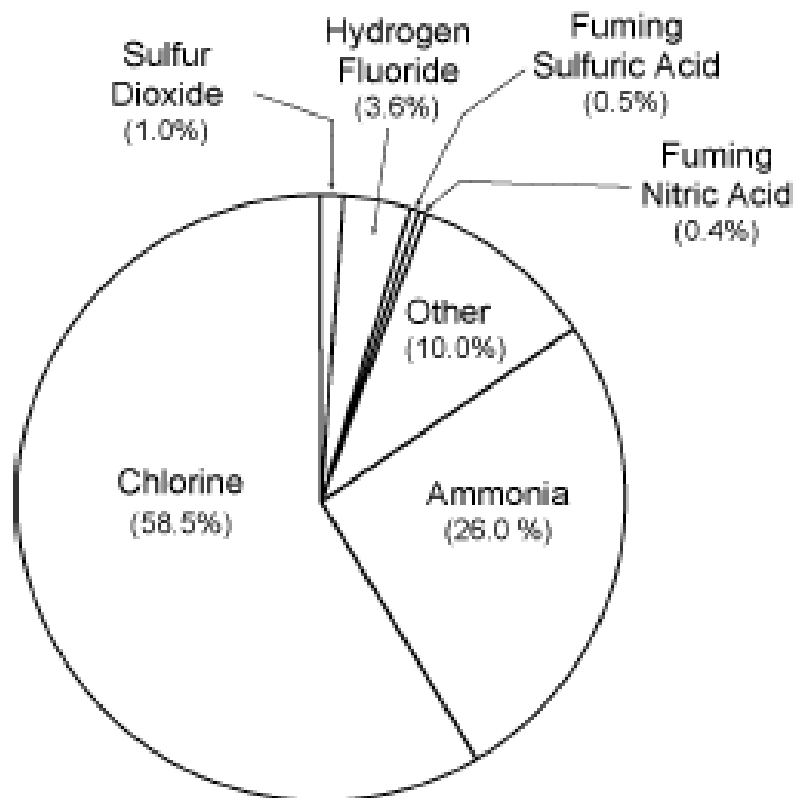
HAZMAT Summary by Result for year 2006

Result	Incidents	INJURIES		Fatalities	Damage
		Hospitalized	Non-Hospitalized		
Vapour (Gas) Dispersion	467	7	31	0	16,948,674
Material Entered Waterway/Sewer	63	2	18	4	9,373,803
Spillage	19,034	22	171	5	59,455,638
Fire	54	6	3	6	8,564,879
Explosion	35	3	3	3	1,948,564
Environmental Damage	85	3	20	3	29,253,693
None	828	0	0	0	5,415,131
Total - 2006	20,566	43	246	21	130,960,382

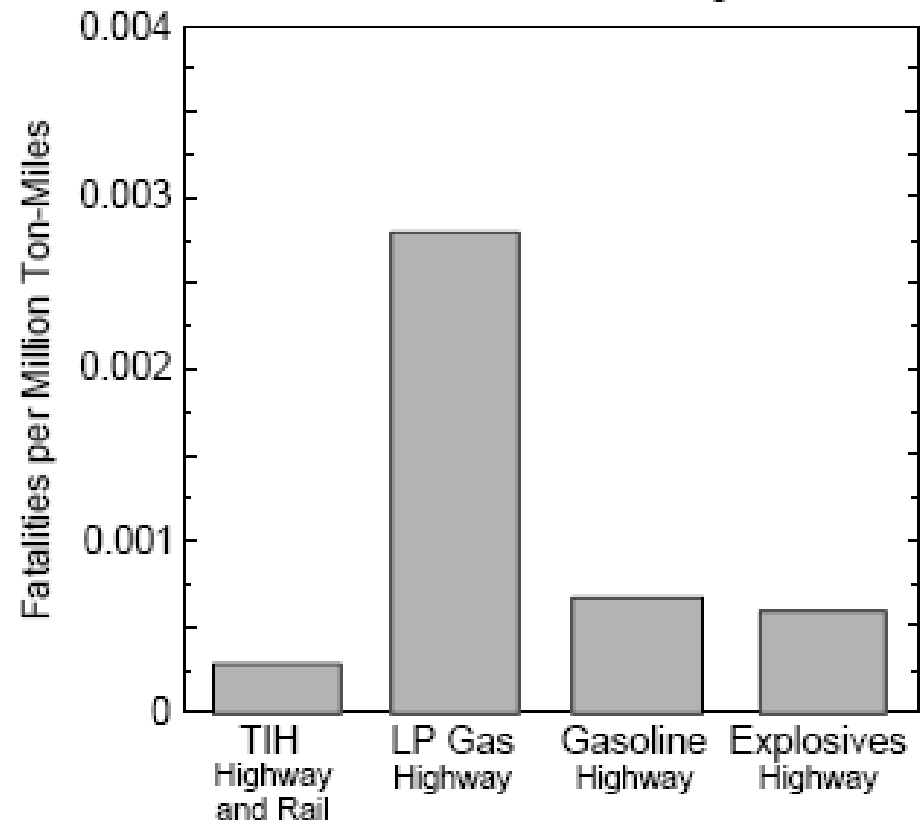
Statistic data in USA

Argonne National Laboratory reports concerning transport risk in the USA

Total Fatality Risk



Normalized Fatality Risk



Description of evaluated scenarios

The following dangerous substances were finally chosen as representative for modelling:

- Anhydrous ammonia – toxic gas lighter than air;
- Chlorine – toxic gas heavier than air;
- Liquefied Petroleum Gas (LPG) – flammable gas;
- Gasoline – flammable liquid.

Strategy for real risk assessment in particular transport routes:

- to treat the most dangerous substances used in local industrial companies,
- the point of view of an eventuality of terrorist attacks.

Description of evaluated scenarios

For hazardous zones modelling the following representative software packages were selected:

- ALOHA 5.4.1. - representative of free-downloaded software from U.S. EPA;
- EFFECTSGIS 5.5. - customary software of the Dutch company TNO;
- TerEx 2.7.8. - commercially available software of the Czech company T-SOFT.

Description of evaluated scenarios

Summary of input data for modelling

Scenario No.* ¹	Dangerous substance	Amount (road/rail) [t]	Type of release	Daytime	Stability class	Wind speed [m/s]	Temperature [°C]	Level of concern [ppm] * ²
1.1 A / B	Ammonia	15 / 50	catastrophic	day	D	5	25	7,700 (50% mort. / 30 min)
1.2 A / B				night	F	1.7	10	
1.3 A / B			continuous	day	D	5	25	
1.4 A / B				night	F	1.7	10	
2.1 A / B	Chlorine	20 / 55	catastrophic	day	D	5	25	380 (50% mort. / 30 min)
2.2 A / B				night	F	1.7	10	
2.3 A / B			continuous	day	D	5	25	
2.4 A / B				night	F	1.7	10	
3.1 A / B	LPG	10 / 24	catastrophic	day	D	5	25	12,600 (60% LEL)
3.2 A / B				night	F	1.7	10	
3.3 A / B			continuous	day	D	5	25	
3.4 A / B				night	F	1.7	10	
4.1 A / B	Gasoline	25 / 58	catastrophic	day	D	5	25	8,400 (60% LEL)
4.2 A / B				night	F	1.7	10	
4.3 A / B			continuous	day	D	5	25	
4.4 A / B				night	F	1.7	10	

Notes: *¹ A for road, B for rail

*² from EFFECTSGIS 5.5 database

RESULTS OF MODELLING

Results of modelling for ammonia

Scenario No.* ¹	ALOHA			EFFECTS			TerEx
	Release rate [kg/s]	Release duration [min]	Fatal zone [m]	Release rate [kg/s]	Release duration [min]	Fatal zone [m]	Evacuation zone [m]
1.1 A	227	1	726	1,391	0.20	681	639
1.2 A	227	1	800	1,065	0.25	280	1,830
1.3 A	13	18	175	38	6	258	647
1.4 A	9	25	236	29	8	244	3,440
1.1 B	756	1	1,300	1,390	0.50	693	1,100
1.2 B	756	1	1,400	1,068	0.75	280	3,160
1.3 B	13	59	175	38	20	258	649
1.4 B	9	60	236	29	27	244	3,450

Notes: *¹ A for road, B for rail

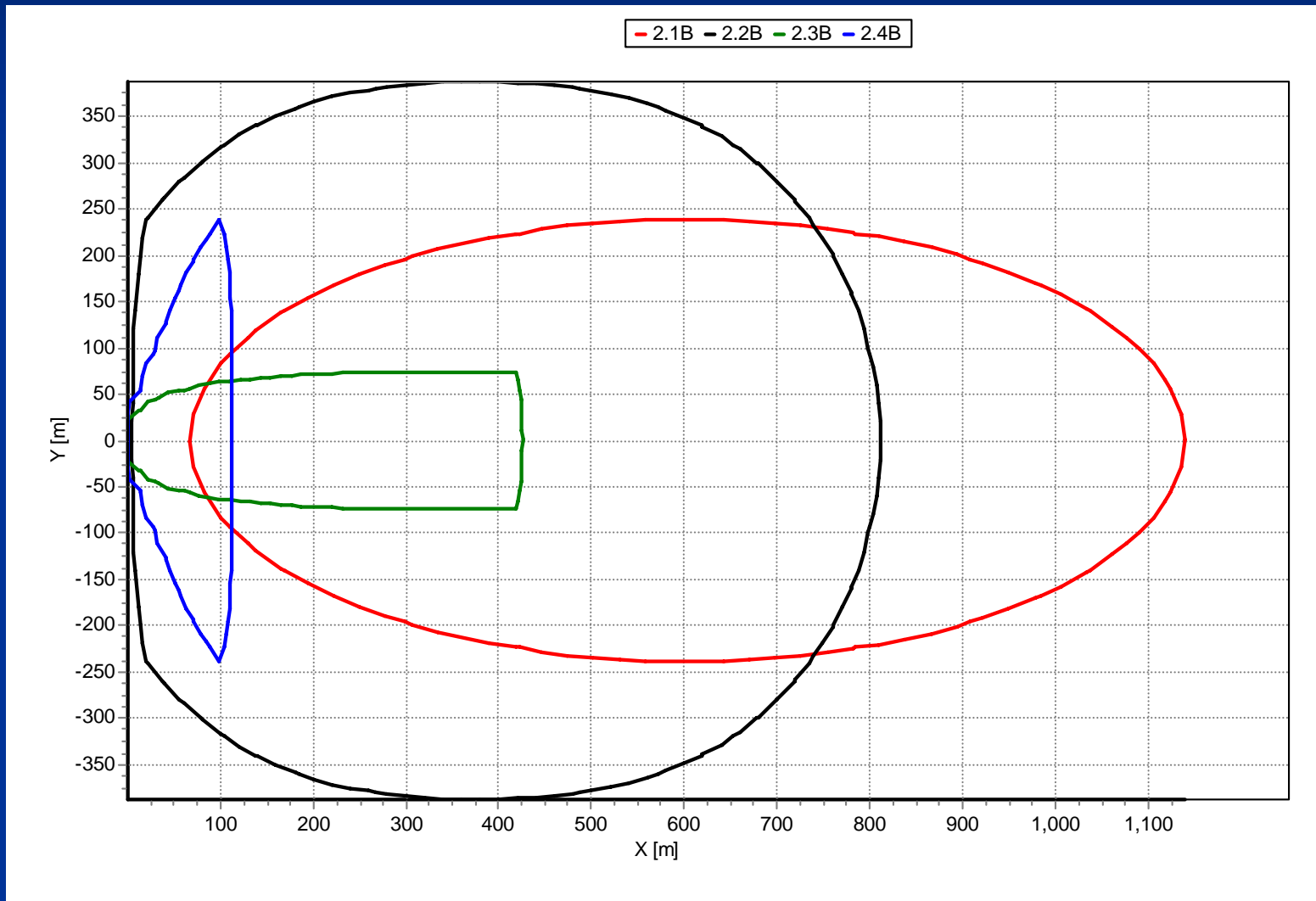
RESULTS OF MODELLING

Results of modelling for chlorine

Scenario No.* ¹	ALOHA			EFFECTS			TerEx
	Release rate [kg/s]	Release duration [min]	Fatal zone [m]	Release rate [kg/s]	Release duration [min]	Fatal zone [m]	Evacuation zone [m]
2.1 A	302	1	1,600	1,790	0.16	1,068	1,710
2.2 A	302	1	1,400	1,410	0.21	647	4,250
2.3 A	21	16	580	49	6	416	1,810
2.4 A	15	21	673	39	8	96	8,480
2.1 B	832	1	2,300	1,790	0.45	1,139	2,600
2.2 B	832	1	2,200	1,410	0.60	810	6,480
2.3 B	21	43	580	49	16	418	1,820
2.4 B	15	58	679	39	22	109	8,510

RESULTS OF MODELLING

Results for tank car chlorine accidents from EFFECTS



RESULTS DISCUSSION

The analysis of the results was made as follows:

- a) comparison of pre-accident and post-accident modelling;
- b) comparison of results from ALOHA and EFFECTS software;
- c) severity of catastrophic versus semi-continuous scenarios;
- d) distances of hazardous zones during two types of conditions weather (the most frequent versus the worst conditions);
- e) general comparison of particular substances results for following risk assessment.

Conclusion

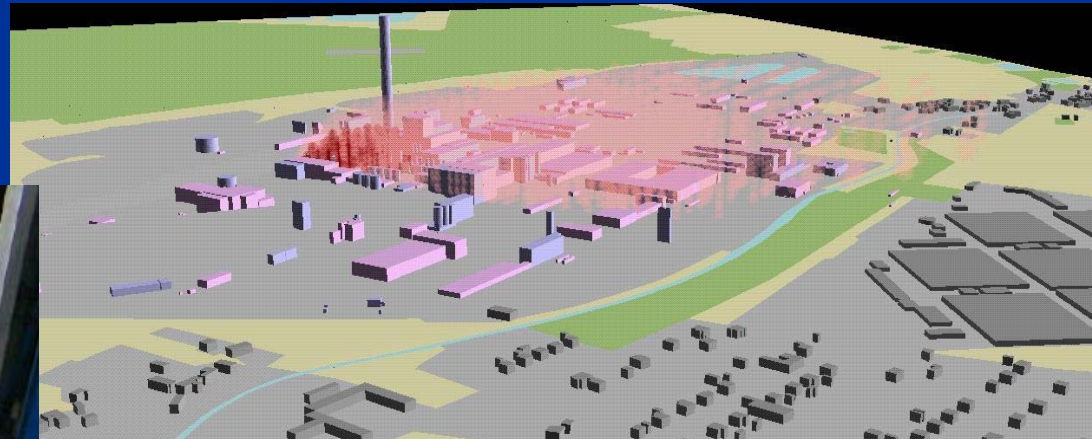
The project results provide practical help in the assessment of risks related to the transport of dangerous substances near inhabited areas.

The results could be useful for various studies – acute and chronic risks and/or environmental risks
example - ventilation intakes in buildings located near a possible accident site.

Conclusion

Future project goals – comparison with:

- computational fluid dynamics modelling,
- wind tunnel experiments.



Acknowledgements

A part of this work was carried out in the framework of the ESF-programme INTROP (Exchange Grant no. 1404)



Thank's for University of Sheffield for possibility of study staying



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