THE IMPACT OF EARLY WARNING - MODEL FOR EVALUATION

Ondřej Svoboda
Univerzita Pardubice, Fakulta ekonomicko-správní, Ústav ekonomiky a managementu

Abstract: *This article deals with methods of evaluation of damage which is caused by accidental breakdowns. Industrial accidents are often associated with the possibility of leakage of dangerous substances which may harm human health and ecosystem health in the affected zone. The calculation of damage compensation is based not only on physical knowledge of leaked substance and atmospheric phenomena, but it also needs to be familiar with the existing law. The model, described in this article, can be used for assessment of impact of early warning to the number of saved residents.*

Keywords: *evaluating of damages, risk analysis, breakdowns in industry, legislative adjustment of compensation, simulation of leakage of chlorine, early warning*

1. Introduction

In the case of damage assessment of industrial accidents it is necessary to carry out an analysis of the selected type of risk. This article focuses on leakage of dangerous toxic substances.

Risk analysis can be simply defined as the technology which can enable understanding of different phenomena working in the hazard analysis system [3]. During evaluation of specific threats it is necessary to rely on a team of analysts and to establish a methodological and mathematical approach. This approach could help minimize human errors. Today the information technology development has breathtaking speed. We can distinguish a number of approaches available to risk analysis. There are many possibilities how to obtain input information which is necessary for risk assessment for example databases on the Internet (statistics of accidents in traffic, industrial accidents and other events). Early warning plays a key role in the saved resident number. This article deals with the question what’s the relationship between warning speed and the number of saved people. The evaluation of impacts of early warning was simulated by different variants of leakage of chlorine in defined area by means of author’s model. To simplify it, everyone who has been warned is considered saved.

2. Legislative adjustment of compensation and prevention of serious accidents

Legislative adjustment of compensation is reflected in the Civil Code [2] [3]:

Liability for damage and for unjustified enrichment
Statute 40/1964, Chapter one, Prevention of threatening damages, § 415:
Everyone must act so as to avoid damages to health, property, nature and environment.

Chapter two, Title one, General liability, § 420:

(1) Everyone shall be liable for damage caused by violating a legal duty. (2) The damage shall be considered caused by a legal entity or by an individual also if they were caused in the course of their activity by those who were used in such activity. These persons themselves shall not be liable according to this Act for the damage caused in this way; their liability under labour law regulations shall not be affected by this rule. (3) A person who proves not to have caused the damage shall relieve himself of the liability for them.

§ 420a:

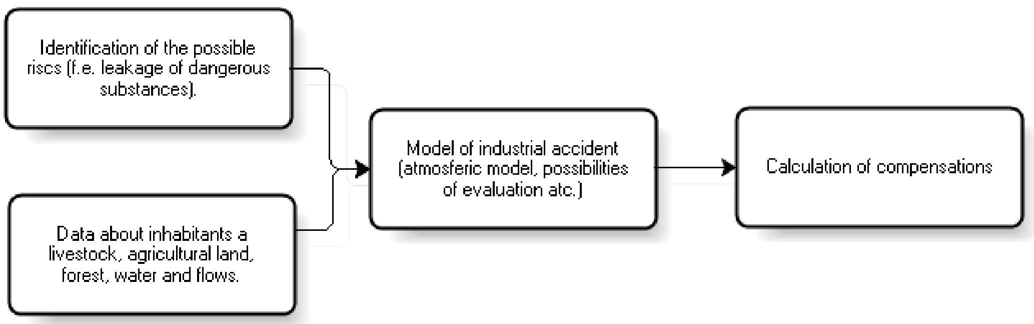
(1) Everyone shall be liable for damage caused to somebody else by operational activities. (2) The damage shall be considered caused by operational activities if they were caused by a) an activity of an operational nature or by a thing used in the course of such activity; b) physical, chemical eventually biological influences of the operation on the surroundings; c) a lawful operation or assurance of works that caused damage to somebody else's real estate property or that essentially aggravated or even prevented such person from using the real estate property. (3) The person who caused the damage shall be relieved thereof only he proves that the damages were caused by an inevitable event not originating in the operation or by the own conduct of the damaged person.

3. Process of evaluation damage in the case of leakage dangerous substance

The process of evaluation damages in the case of leakage dangerous substances contains next point [6]:

- Identification of the possible leakage of dangerous substances.
- Collecting data about inhabitants and about livestock, agricultural land, forest, water and flows.
- Model of industrial accident (selection leakage model, the choice of atmospheric conditions).
- Calculation of compensation (insurance benefits, the cost of treatment, contribution on funeral expenses, compensation for lost profits, compensation for survivors (infant's maintenance).

This process is showed on picture number 1. Detail of process is showed on picture number 2.



Picture No.1: Chart of evaluation of damage in the leakage of dangerous substances, source: author

Evaluation of leakage of hazardous substances includes the collection and processing of data on the distribution of objects with hazardous substances and plotted on the map (chart). This evaluation will take place on the basis of the information about objects that contain hazardous substances, weather conditions and topographical peculiarities of terrain.

<u>Contents of the evaluation of leakage of dangerous substances consist of [1]:</u>

- collecting and processing data on the areas of deployment of objects with hazardous materials and their characteristics (type and the quantity physical-chemical and toxic properties)

- finding and evaluating the weather situation in the area where the object
- determining the depth of contaminated areas

We can distinguish the following zones [4]:

  - **fatal contamination zone** = area where there is in most cases death of people
  - **health wounding contamination zone** = area where concentration of hazard substances don't reach lethal dose for people

- identification and evaluation of the impact of configuration and coverage of field in the direction of the wind
- determination of the estimated minimum period of expansion of the cloud contaminated area

<u>Identifying and evaluating leakage of dangerous substances is important for [6]:</u>

- precautionary measures to protect people
- determination of the volume and extent of work needed to destroy the consequences
- planning other activities in real terms

<u>Survey and evaluation of leakage of dangerous substances takes place in two stages [1]:</u>

1st stage

The aim of this stage is to determine the weather situation now unknown area of fatal and health wounding contamination and thus the potential extent of the expected necessary measures in the event of leakage of dangerous substances. This phase ends with finding where is the object with a dangerous substance and a preliminary evaluation of contamination zones.

2nd stage

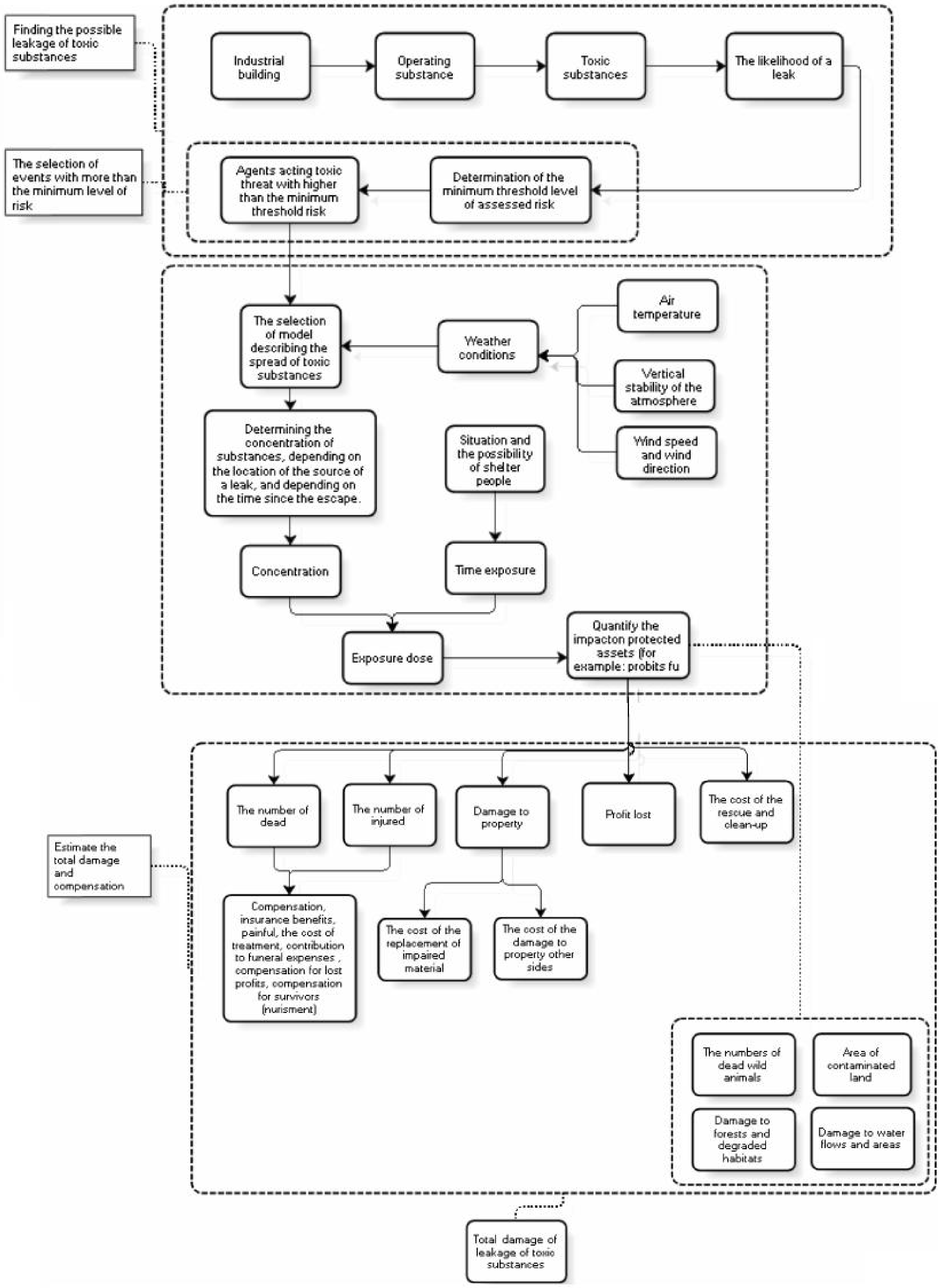
The aim of 2nd stage is to specify the projected area of fatal and health wounding contamination and safety precautions. The second stage begins with assessment of release of the dangerous substance on the basis of the actual weather situation. Stage ends with evaluation of the actual situation after exploration and assessment of resident status.

The main problem is to obtain preliminary information about current weather situation from relevant specialized institution (National Hydrometeorological Institute) which can be specified using information from the IRS (Integrated rescue system). Concerning parameters are [1]:

- wind speed and wind direction,
- air temperature,
- vertical stability of the atmosphere (inversion, isotherm, convection)
- UN code and Kemler's code of the dangerous goods transported.

Procedure for evaluating the impact of leakage of hazard substances assumes the following tasks [1]:

- mapping of place of the incident in the small-scale maps,
- identification and draw zone contamination,
- determination of the time of arrival to the place where the cloud is directly threatening the residents.



Picture No. 2: Chart of evaluation of damage in case of the leakage of dangerous substances, source: author

4. Model of evaluation of the impact of early warning

This model was created by author and this model can be instrumental for evaluation of the impact of the speed of warnings on the number of saved people. The model simulates different variants of leakage of **chlorine** in defined area as well. To simplify it everyone who has been warned is considered as saved.

Realized model comes out from models of calculating damages and compensations of leakage of toxic substances. The main modification is that model calculates only the number of people who are in the fatal and health wounding contamination zones and also the number of people who was warned before affected of chlorine – it doesn't calculate compensations of damage (as it was showed on picture number 2), but only percentage of potentially savable people.

The basic principles of model are:

- each person in fatal and health wounding zone is warned, but some of them is warned after the contact with chlorine (these people are considered as non-saved, residual people in both zones are considered as saved)
- number of people in the fatal and health wounding contamination is taken for 100%
- warning delay (time of warning) is considered as time from event of leakage to event of warning
- the number of people who wasn't saved by warning was calculated on the basis of theoretical number of people in fatal and health wounding contamination zone minus number of people who were warned after the contact with chlorine

Determining the depth of contaminated areas

The depth of the contaminated area, which has implications for damage to the health of the residents is given by [4]**:** $H = 5{,}4 * \sqrt[3]{\frac{M}{D*v*K}} * N$

H……… depth of field of the fatal or health wounding contamination area (it dependents on parameter D) [km]

M………mass of pollutant [t]

D……… hurting exposition dose [$mg*min*l^{-1}$]

N........… temperature-dependent correction factor

v………. wind speed [$m*s^{-1}$]

K……… coefficient of vertical stability of the atmosphere (inversion K=2, isotherm K=3, convection K=4)

Parameter D for chlorine and fatal contamination zone is 6 $mg*min*l^{-1}$ and for health wounding contamination zone is 0,6 $mg*min*l^{-1}$ [4]**.**

The simulated model is based on the following table that serves as a basis for the distribution of residents in different directions and distances from the point of leakage of chlorine.

Table No.1 – Number of residents in modeled area, source: author

	Distance (km), 0 km is the place of accident				
Direction from the place of accident (degrees)	**0 – 5**	**5 – 10**	**10 – 15**	**15 – 20**	**20 – 25**
1 - 30	1650	525	300	263	263
31 - 60	3000	500	500	500	500
61 - 90	1200	5600	400	400	400
91 - 120	8000	8000	2000	1000	1000
121 - 150	40000	40000	10000	5000	5000
151 - 180	4000	4000	1000	500	500
181 - 210	2500	1250	500	375	375
211 - 240	550	175	100	88	88
241 - 270	1800	300	300	300	300
271 - 300	750	3500	250	250	250
301 - 330	1200	200	200	200	200
331 - 360	600	100	100	100	100

The calculation of dept of the fatal and health wounding contamination area was conducted with the following input data, which were in the limits and randomly (uniform distribution was used) inserted into the calculation:

- Wind speed: 1 – 6 $m*s^{-1}$
- Wind direction: 0 - 360°
- Mass of pollutant: 0,5 – 100 t
- Air temperature: 0 – 20 °C
- Coefficient of vertical stability of the atmosphere: one from this state - inversion, isotherm, convection.

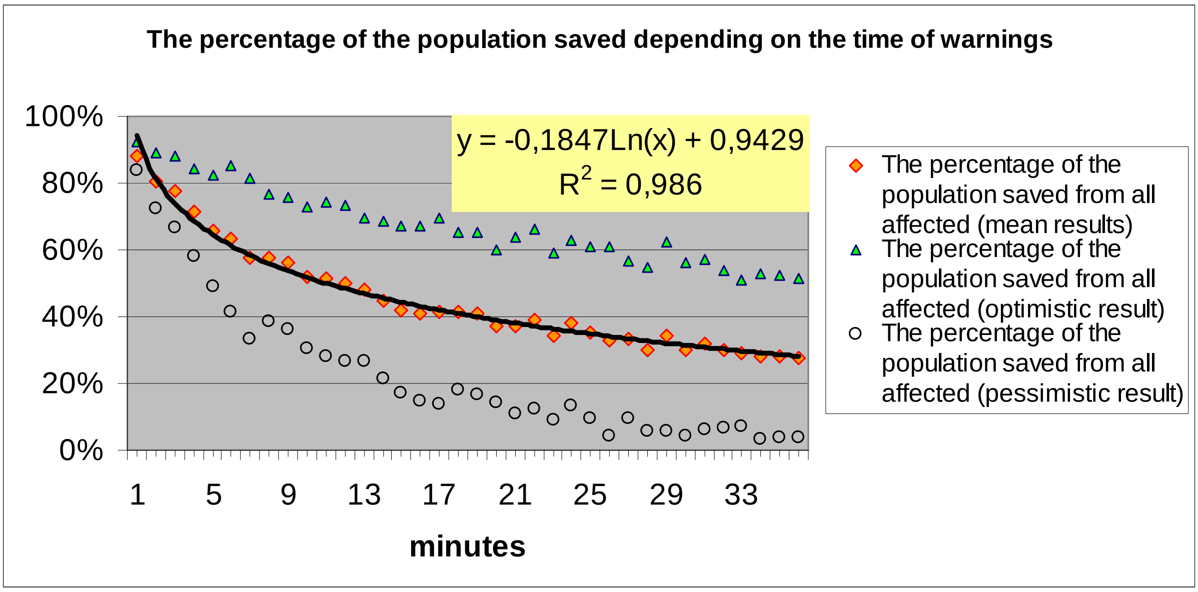
This randomly calculation of dept of the fatal and health wounding contamination area was made with different time of warning delay (time from event of leakage to warning):

- warning delay: 1 – 35 minutes

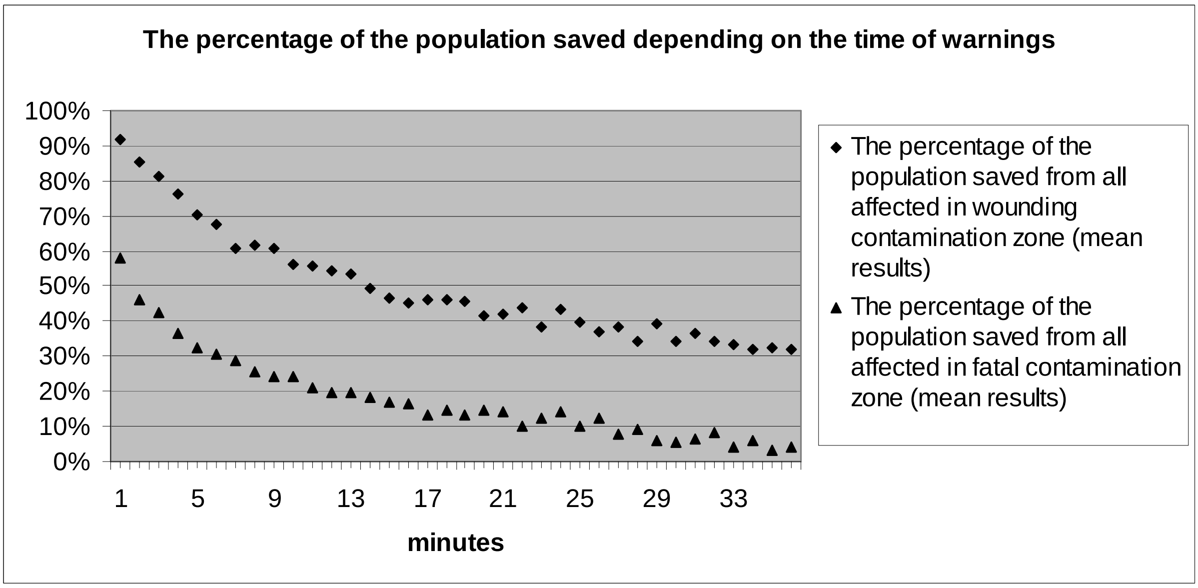
Outputs data of model are:

- The number of residents in fatal contamination zone
- The number of residents in wounded contamination zone
- The total number of residents in both areas
- The distance between the cloud of chlorine and place of accident in the time of warning
- The percentage number of residents, who has been warned from total number of residents in both zones (in three forms: pessimistic/optimistic/mean result – calculated on the basis the minimum/maximum/mean of percentage number produced from different variants of leakage of chlorine)

The simulation for different warning delay was performed 10.000 times and it was established the following chart.



Picture No. 3 Graph of the percentage of the residents saved depending on the time of warning, source: author



Picture No. 4: Graph of the percentage of the residents saved depending on the time of warning – fatal and health wounding contamination zones, source: author

5. Conclusion

The results of simulation of saved people in the case of leakage of chlorine with different time of warning delay show a very close relationship between these two variables. This is a logarithmical relationship with coefficient of determination about 98%.

Warning with delay only 5 minutes leads to a loss of the possibility of saving 44% of total affected residents in the average case (Picture No.3 shows that can be saved only 66% of residents) and also leads to loss of the possibility of saving approximately 70% of affected residents in the fatal contamination zones (Picture No.4 shows that can be saved only 30% of residents in this area) and leads to loss of the possibility of saving approximately 30% of affected residents in the wounded contamination zones (Picture No.4 shows that can be saved 70% of residents in this area).

The results of the simulation also showed decrease of the percentage of potentially savable people from 100% (in time of 0 minutes) to 75% in the case of 4 minutes warning delay. The possibility of saving only 50% of total affected residents is in case of 12 minutes warning delay (in average case). In this time it's possible to save only 55% of residents in health wounding contamination zones and approximately 20% of residents in fatal contamination zones.

Simulation of model confirmed key role of early warning and quantify the relationship within the percentage of the population potentially savable and a warning delay of residents.

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Contact address:

Ing. Ondřej Svoboda
Univerzita Pardubice, Fakulta ekonomicko-správní
Studentská 84, 532 10, Pardubice
Email: ondrej.svoboda.@upce.cz
Tel: +420466036480