Summary
Quantification of the effectivity of self-rescue enhancing measures for accidents with hazardous materials, phase 2

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Summary

Storage and transport of hazardous materials impose risks to surrounding population and structures, both in the urban environment as at (petro-) chemical facilities. Justification of the societal risk is an important part of the Dutch regulatory requirements regarding external safety. The authorities are responsible for the justification of the societal risk. The Safety Regions advise the authorities on the possibilities of crisis management and on safety measures for self-rescue of people. Research has shown that authorities frequently do not follow up on the advises of the Safety Region. One of the reasons is that there is no instrument for the quantification of the gains of self-rescue enhancing measures.

With the purpose of developing an instrument to resolve the above mentioned problem, the Ministry of Security and Justice, in coordination with the former Ministry of Housing, Spatial Planning and the Environment, has started - in 2010 - a project that is executed in phases. Phase 1 was completed by TNO by the end of 2011 and resulted in a set of models allowing the quantification of the severity of sublethal injuries for various risk scenarios relevant for external safety. This concerns accident scenarios involving a fire, explosion or toxic cloud.

This present report is related to phase 2 of the project, in which – using the sublethal injury models from phase 1 – we aim to develop calculation models allowing the determination of the expected gain in safety due to self-rescue enhancing measures. This gain is expressed as a reduction of injuries (numbers and/or severity) compared to the same scenario in which those measures were not taken. The results are based on available data in the (international) scientific literature. No experimental research was performed in this phase.

Given the mathematical formulas of the injury models as developed in phase 1, the positive effect of every self-rescue enhancing measure can be simulated. Such a simulation accounts for the safety measure by applying a shorter exposure time and/or a lower intensity of a physical phenomenon to which a person is exposed. Subsequently a comparison is made between the situations with and without safety measure. The calculated difference between those two situations is the safety gain of the measure, expressed as reduction in number and severity of injuries. With this in mind, the question “what is the quantitative safety gain of a specific measure that enhances self-rescue capabilities” can also be formulated as: “how much shorter does the exposure time become and/or how much lower does the exposure intensity of a physical effect become for a person when this safety measure is taken?”. In this report, the answer to this question has been investigated for the following seven safety measures:

• escape guidance, for example by personnel trained for emergency intervention
• alarm measures, e.g. sirens combined with risk communication for preparedness
• protection measures:
  – ventilation reduction, for example a shutdown of ventilation in an entire building
  – protection against heat radiation, such as heat resistant façades or spill bunds for flammable liquids
• placement of vulnerable groups of people within a building as far away as possible from a risk source
• multiple escape routes
• modification of the layout of a building
• avoiding building functions with populations with reduced mobility
These measures were selected after a consultation on the priorities of experts with experience in the field. For this consultation, use was made of a well-proven interactive method (Group Decision Room; GDR).

The advising committee of the project has specifically requested the researchers to take the effect of emergency trained personnel on self-rescue into account. Based on literature research, a building escape model is proposed including the most relevant parameters for the calculation of the effect of emergency trained personnel on the reduction of preparation and escape time in external safety scenarios. The effectiveness of emergency trained personnel depends on many parameters and is strongly situation dependent. Therefore it is unavoidable that the user of the proposed building escape model must make some estimations of the value of some of those parameters. Where relevant literature values are available, those are provided as indicative values.

The measure “protection” is in fact a measure of technical or constructional nature, which is primarily aimed at shielding individuals from physical effects. Based on literature research we provide two concrete measures with which safety gains in terms of reductions of injuries and injury severities can be calculated:

- ventilation reduction, to protect persons against the penetration of toxic gases
- heat resistant façades or spill bunds for flammable liquids to protect individuals inside a building against heat radiation

**Conclusions**

With the completion of this research project, not all uncertainties about safety gains are eliminated. Nevertheless, the project has provided knowledge — with better justification than before — to make estimations of the safety gain of measures. The role of the advisor remains important: he must make sensible assumptions about scenarios, estimate parameter values etcetera.

In this project, use has been made of ‘best available knowledge’ of prevailing assumptions in the form of quantitative indications derived from (scientific) literature and expert opinions. This does not necessarily mean that this knowledge or these assumptions are beyond discussion.

The effectiveness of specific measures does not have a fixed value, just as the best self-rescue strategy may not be the same in every situation. It depends on the nature, duration and intensity of effects that may occur in relevant scenarios.

Numerous application of the models presented here or new insights resulting from experiments, field data or literature might lead to rules of thumb for the effectivity of measures.

Self-rescue enhancing measures that are primarily aimed at changing the behaviour of people (like an organisation with emergency trained personnel or risk communication for preparedness), are relatively difficult to quantify compared to technical measures. This is due to the fact that actions of people are very diverse and also very dependent on the context of the hazard.

Risk communication for preparedness can be accounted for by modifying the pre-movement time and the chosen self-rescue strategy. This can be quantified by organizing surveys with questionnaires (before and after risk communication) and by additional experimental research. There has hardly been any validated experimental research into the effects of emergency trained personnel on evacuation times. However, there are various sources in the literature that have information about the effect of emergency trained personnel on pre-movement
times, although also in this case the availability of information is unexpectedly small for a measure that is taken frequently. Some (quantitative) indications are given for the time gain that can be made by certain methods of detection or alarm.

Measures that are primarily aimed at shielding people from exposure (like ventilation reduction or constructional modifications) are better suited for quantification of safety gains. Their effectiveness is less dependent on the (complex) behaviour of people.

It is recommended to perform additional research into the quantifiable effect of measures improving self-rescue behaviour of people, i.e. the existence of an organisation for emergency trained personnel and preparedness related risk communication. These measures are frequently advised to the authorities by the Safety Regions, but in the scientific literature there is little 'hard' evidence available about their effectiveness.