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New Manual for Risk Calculations in Flanders as the Result of the Project Unification

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In Flanders, Seveso-establishments are obliged to perform a Quantitative Risk Analysis (QRA) in the Safety Reports. The QRA is performed by external experts who are free to choose the software to do these calculations. A few years ago, Flanders determined that the outcome of a risk calculation depends very much on the external expert who does the calculations and on the software used. Therefore, Flanders started the Project Unification to reduce the differences between experts and software. The result of the Project Unification is a new manual for risk calculations. This manual contains all major steps necessary for the calculation of the risk of an establishment. The manual is published in April 2017.

1. Introduction

The Flemish regulations require Seveso-establishments to draw up (1) a safety report to obtain an environmental permit and (2) a safety report in the context of the European Seveso-Directive. These safety reports must contain a Quantitative Risk Analysis (QRA) in which the risk map of the establishment is calculated. The risk map includes the location specific risk as well as the societal risk and they both must meet the applicable risk criteria to get the environmental permit. In Flanders, criteria for the location specific risk are set for the iso risk contours (IRC) of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year. For the societal risk, a fN-curve is calculated by combination of the amount of victims and the cumulative frequency. This curve has to stay beneath the criterion.

The calculations are performed by external and recognised safety experts who have to take into account the existing guidelines on risk calculation. Before publication of the Manual Risk Calculations these guidelines consisted only of the Handbook Failure Frequencies 2009, the guideline on meteo conditions, the guideline on warehouse fires and the guideline on flash and spray fractions. For the moment, the safety experts are free to choose the risk calculation software. Nowadays, 4 different software programs are used (Phast/Safeti developed by DNV GL, Effects/Riskcurves developed by TNO and 2 programs developed by experts).

2. Project Unification

To reduce the differences in the results and to obtain more uniform risk maps, Flanders started the Project Unification. This consisted mainly of the executing of case studies by safety experts. Also, a number of other scientific studies were carried out to get a complete view on the QRA, its models and their parameters. In the following paragraphs, the motivation for the project is described, as well as the general concept of the case studies, a short overview of the other studies and the way towards the manual for risk calculations.

2.1 Motivation

As the risk map of an establishment must meet the criteria for the location specific risk and for the societal risk to obtain an environmental permit, it is important that the risk map is independent of the experts and the software.

However, a few years ago, Flanders determined that the risk map of an establishment differed a lot when remade by another safety expert. A few establishments had the calculations carried out by another expert and

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the result was a much lower risk. Therefore, the establishment could be granted the environmental permit with the most recent calculations, while the permit could not be granted with the earlier calculations, because of the exceeding of the risk criteria.

2.2 Case studies

Three case studies were prepared to have these carried out by four different external safety experts, who all use different software. In a preparatory step the case was discussed between all parties, so everyone started with the same point of view and with the same data. In a first calculation step, the 4 experts were free to do the calculation like they were used to do them. Results were then compared and after discussion about the differences, agreements were made to recalculate in a more uniform way. The agreements are about parameters as well as models. The recalculated risk was compared again. If necessary, additional agreements were made and the risk was again recalculated.
The following fictive cases, with a fictive population matrix, have been studied:

1. Case warehouse fire: calculation of 2 compartments with different characteristics.
2. Case atmospheric liquids: calculation of a tank in a bund with the associated equipment. One situation is with the flammable substance pentane and one with the cryogenic substance LNG.
3. Case liquified gases: calculation of a tank with the associated equipment. One situation is with an above-ground tank and pipeline, once with the flammable substance butadiene and once with the toxic substance chlorine. And one situation is with an underground tank and pipeline, only with the flammable substance.

Important remark: not all experts could apply all of the agreements because of the limitations of the software program used. This means that the risk calculations after recalculation are still not completely the same.

2.3 Other scientific studies

During the Project Unification also some other scientific studies were performed to clarify a few topics. Following items are addressed: (1) modelling of the different steps of a QRA, (2) meteo and environmental conditions, (3) failure modes and frequencies, (4) probit function for overpressure and (5) probit functions for toxic substances.

2.4 Manual for risk calculations

Based on the case studies and the agreements made during the discussions and based on the other scientific studies, Flanders made a concept for the new Handbook Risk Calculations. The concept was proofread by all of the external safety experts. After a few iterations, the Manual Risk Calculations was published.

3. Case studies

The results of the three different case studies are described in the next paragraphs (DNV, 2014) (Sertius, 2014) (SGS, 2014) (M-Tech, 2014).

3.1 Case warehouse fire

For the case warehouse fire, one compartment is discussed in this paper. For the first calculation step, the location specific risk for the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year and the societal risk are shown in Figure 1. The distance from the border of the warehouse to the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year are given in table 1 (left). This demonstrates the big differences between the different experts. For example, expert 1 is exceeding the criterion for the societal risk and expert 4 does not even have a societal risk. This means that the establishment will not get the permit, if the risk is calculated by expert 1. In this case, this can largely be explained by the fact that experts 1, 2 and 3 did the calculation without plume rise and expert 4 did it with plume rise.
After the first calculation, agreements were made on the ventilation rate, the dimensions of the source, plume rise, dispersion, averaging time, influence of the wind, dimensions of the grid for the population matrix, point of release. For this case, it has been decided to calculate the warehouse fire once without (set a) and once with (set b) plume rise, as those are the different original assumptions made by the experts for this parameter and because this seems to be a very influencing parameter. The results of this recalculation are shown in Figure 2. The distance from the border of the warehouse to the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year are also given in Table 1 (right) for the situation without the assumption of plume rise. This demonstrates that the differences between the experts are reduced after making some agreements on the assumptions. It is also very clear that the assumption of plume rise or not is very important, as this determines the risk of the warehouse. The distance to the IRCs is much smaller with plume rise, and there even is no societal risk anymore.

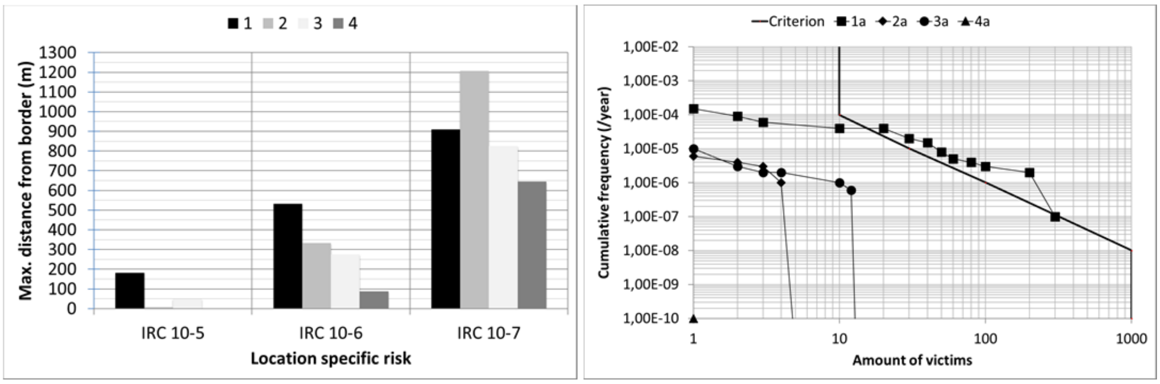

Figure1: Location specific risk (left) and societal risk curves (right) for case warehouse fire after the first calculation

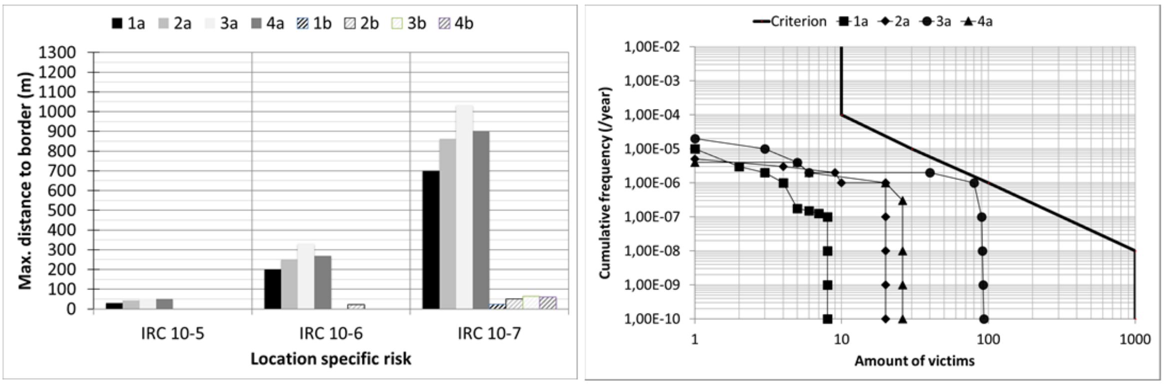

Figure 2: Location specific risk (left) and societal risk curves (right) for case warehouse fire without (a) and with (b) plume rise, after recalculation (for situation b, there is no societal risk)

Table 1: Maximum distance from border (m) for the IRCs of 10^{-5}/y, 10^{-6}/y and 10^{-7}/y for case warehouse fire after the first calculation (left) and after the final calculation (set a, without plume rise) (right)

Distance (m) - step 1	IRC of 10^{-5}/y	IRC of 10^{-6}/y	IRC of 10^{-7}/y	Distance (m) – final	IRC of 10^{-5}/y	IRC of 10^{-6}/y	IRC of 10^{-7}/y
Expert 1	181	532	910	Expert 1	30	200	700
Expert 2	8	333	1207	Expert 2	44	252	863
Expert 3	50	275	825	Expert 3	52	333	1035
Expert 4	0	88	646	Expert 4	50	270	900

For the other compartment, an analogue story can be written.

3.2 Case atmospheric liquids

For the case atmospheric liquids, the tank with the flammable substance pentane is discussed in this paper. For the first calculation step, the location specific risk for the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year and the societal risk are shown in Figure 3. The distance from the border of the tank farm to the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year are also given in Table 2 (left). This demonstrates the big differences between the different experts. For example, expert 1 has a much higher location specific risk and is exceeding the criterion for the societal risk. This means that the establishment will not get the permit, if the risk is calculated by expert 1.

After the first calculation, agreements were made on the calculations for pipes, the modelling of the release, the modelling of the spreading of the pool and the evaporation (with the convective heat flux, the mass transfer coefficient, the conduction heat flux and the radiant heat flux), the modelling of the dispersion, the modelling of the effects of pool fire and vapour cloud explosion. The results of this recalculation are shown in Figure 4.

The distance from the border of the tank farm to the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year are also given in Table 2 (right). This case also shows that the result is very dependent on the assumptions made and that the making of assumptions has a big influence on the result.

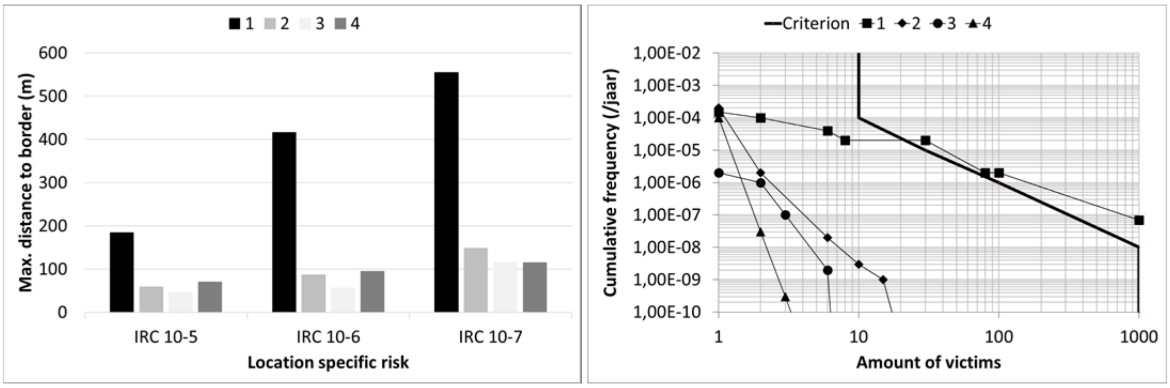

Figure 3: Location specific risk (left) and societal risk curves (right) for case atmospheric liquids after the first calculation

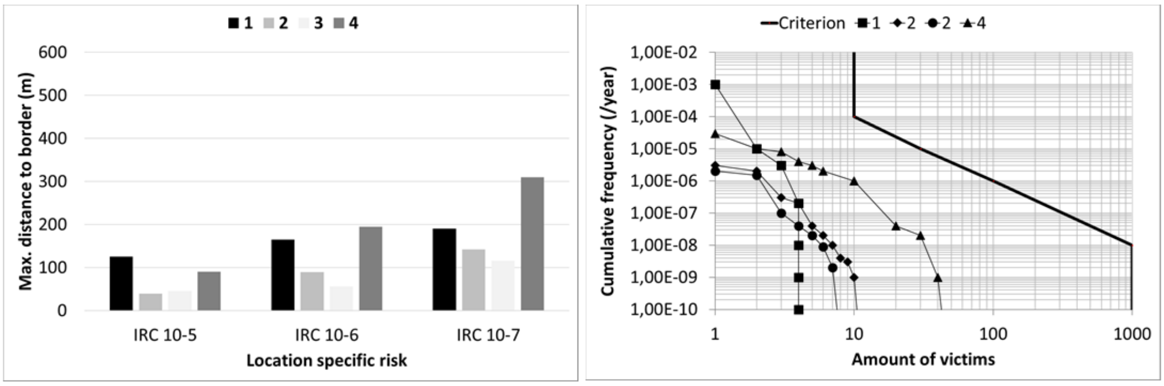

Figure 4: Location specific risk (left) and societal risk curves (right) for case atmospheric liquids after recalculation

Table 2: Maximum distance from border (m) for the IRCs of 10^{-5}/y, 10^{-6}/y and 10^{-7}/y for case atmospheric liquids after the first calculation (left) and after the final calculation (right)

Distance (m) - step 1	IRC of 10^{-5}/y	IRC of 10^{-6}/y	IRC of 10^{-7}/y	Distance (m) – final	IRC of 10^{-5}/y	IRC of 10^{-6}/y	IRC of 10^{-7}/y
Expert 1	184	416	555	Expert 1	125	165	190
Expert 2	59	87	148	Expert 2	39	89	142
Expert 3	45	56	116	Expert 3	45	56	116
Expert 4	70	95	115	Expert 4	90	195	310

For the tank with cryogenic substance LNG, a similar story can be written. However, in this case, the agreements made for the tank with pentane were already taken into account in the first calculation step. Therefore, the differences after the first step were not so big and further agreements did not have a lot of influence anymore.

3.3 Case liquified gases

For the case liquified gases the above-ground tank with the flammable substance butadiene is discussed. The first calculation, in which the agreements of the case tank park were already taken into account, resulted in the risk maps of Figure 5. The distance from the border of the tank farm to the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year are also given in table 3 (left). This demonstrates again the differences between the different experts, although the differences in this case are smaller.

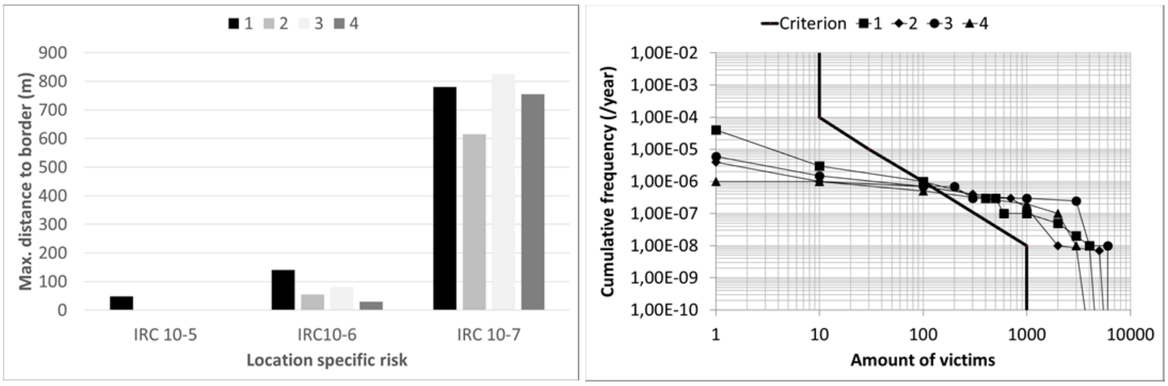

Figure 5: Location specific risk (left) and societal risk curves (right) for case liquified gases after the first calculation

After this first calculation, agreements were made on the modelling of the release and especially the calculation of the flash, spray and rain-out fractions, the modelling of the effects BLEVE, fireball and jet fire, the calculation of the risk. The results of this recalculation are shown in Figure 6. The distance from the border of the tank farm to the IRCs of 10^{-5}/year, 10^{-6}/year and 10^{-7}/year are also given in Table 3 (right). This too shows that the result is very dependent on the assumptions made and that the making of assumptions has an influence on the result, although the differences in this case are smaller than for the other cases.

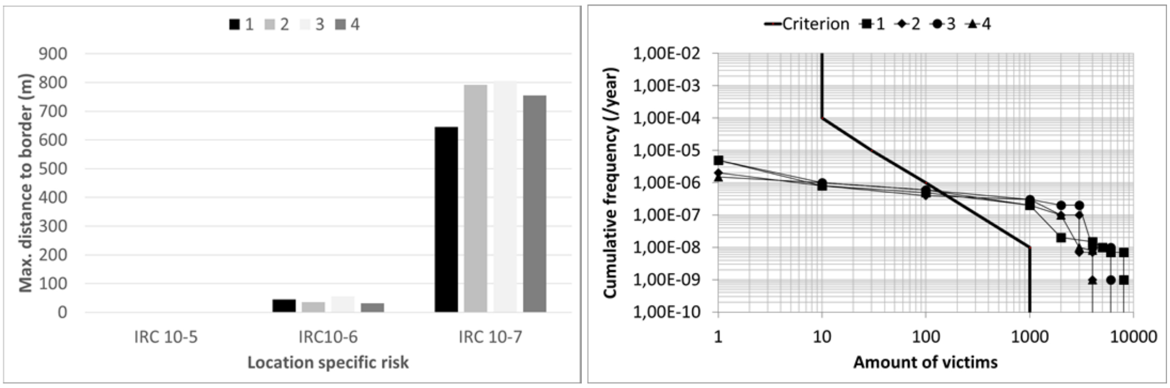

Figure 6: Location specific risk (left) and societal risk curves (right) for case liquified gases after recalculation

Table 3: Maximum distance from border (m) for the IRCs of 10^{-5}/y, 10^{-6}/y and 10^{-7}/y for case liquified gases after the first calculation (left) and after the final calculation (right)

Distance (m) - step 1	IRC of 10^{-5}/y	IRC of 10^{-6}/y	IRC of 10^{-7}/y	Distance (m) – final	IRC of 10^{-5}/y	IRC of 10^{-6}/y	IRC of 10^{-7}/y
Expert 1	48	140	780	Expert 1	0	45	645
Expert 2	0	55	615	Expert 2	0	36	792
Expert 3	0	81	825	Expert 3	0	55	805
Expert 4	0	30	755	Expert 4	0	32	755

For the underground tank and the tank with chlorine, a similar story can be written. In this case, the agreements made for the above-ground tank with butadiene were already taken into account in the first calculation step. Therefore, the differences after the first step were not so big and further agreements did not have a lot of influence anymore.

4. Manual Risk Calculations

The result of the Project Unification was a new manual, called the Manual Risk Calculations. This manual contains all major steps necessary for the calculation of the risk of an establishment, being (1) the

determination of the failure mode and accompanying failure frequencies of common equipment, (2) the determination of the consequential events and probabilities, (3) the determination of the release, (4) the formation and evaporation of the pool, (5) the dispersion and (6) the calculation of the effects.
There are also separate sections for the selection of the relevant dangerous substances, for consequence-limiting measures, for the conditions of the meteo and the environment, for the population matrix, for the determination of indirect risks and for the qualitative risk analysis of the environment.
The Manual Risk Calculations is published on the website of the Department of Environment & Spatial Development in April 2017. For new safety reports in view of obtaining an environmental permit, the manual has to be used from August 2017.

5. Future

In the future, it is planned to add the missing parts in the Manual Risk Calculations, like the preliminary selection method in order to have a relative small set of scenarios to be calculated in the QRA, the set of representative substances and the determination of indirect risks due to external sources of danger. It is also important to realise that the manual is only a first step towards unification and that it is a dynamic and living document. It will be continuously evaluated and modifications will be executed if necessary. However, complete unification is not possible for the moment due to the different software that do not have the same possibilities on the subject of models and parameters and the different safety experts that still want some freedom to use their expert judgement. Also, some specific situations require a specific approach. Not all these situations and approaches can be covered by the handbook.

6. Conclusions

As the risk map of an establishment must meet the criteria for the location specific risk and for the societal risk to obtain an environmental permit, it is important that the risk map is independent of the expert and the software. However, this was not the case. Therefore, Flanders started the Project Unification, which consisted mainly of the executing of case studies by safety experts. In these cases studies agreements about the different steps of the QRA were made between safety experts to reduce the differences in the results and to obtain more uniform risk maps. Due to the limitations of the software, risk maps were not yet totally aligned, but a first step towards unification was made. Together with the results of other scientific studies this lead to the accomplishment of the Manual Risk Calculations. In the future, a continuous evaluation is in order.

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