APPENDIX 13

Risk Matrix

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1. Introduction

As explained in the main report, the choice of reference accident scenarios will be based on the position of dangerous phenomena in a risk matrix, depending on their frequency and their class of consequences.

The use of the risk matrix is explained in the main report. This appendix aims to give some information about the figures which have been used to built the risk matrix, because this topic is particularly sensitive. However, this analysis should only be considered as a rough guide.

2. Brief presentation of the risk matrix

2.1 Risk matrix

The **risk matrix** presents the consequence classes on X-axis and the frequency classes (frequencies of dangerous phenomena taking into account the safety barriers) on Y-axis.

Three zones are defined in the risk matrix (see Figure 1):

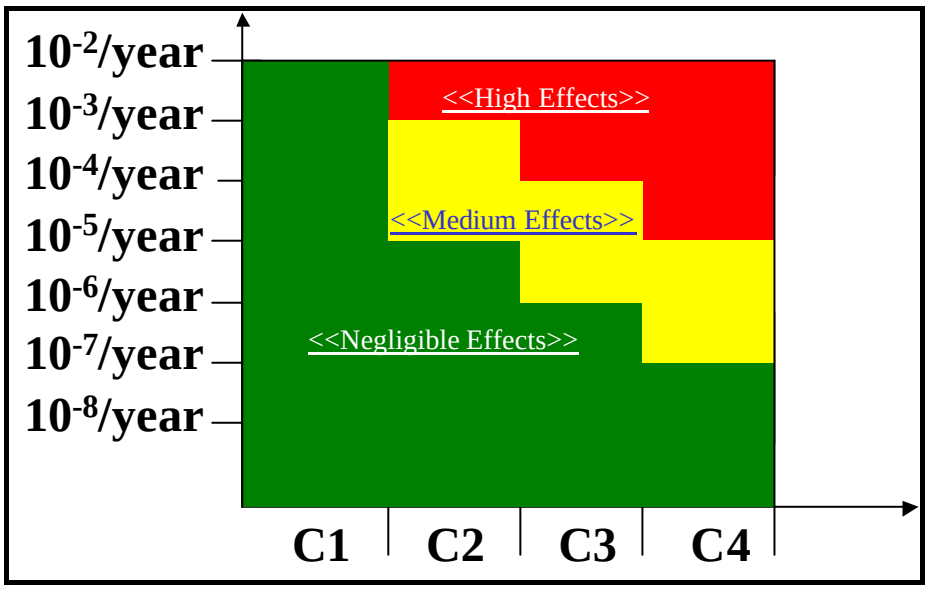

Figure 1: Risk matrix

- ✓ The lower green zone ("Negligible effects" zone) corresponds to dangerous phenomena with a low enough frequency and/or consequences which will probably have no actual effects on the severity.
- ✓ The intermediate yellow zone ("Medium effects" zone) corresponds to dangerous phenomena which will probably have actual effects on the severity and will then be selected to be modelled for the severity calculations. These dangerous phenomena correspond to Reference Accident Scenarios.

- ✓ The upper red zone ("High effects" zone) corresponds to very dangerous phenomena which will surely have actual effects on the severity. Corresponding accident scenarios should be revisited in order to put additional safety systems in place. However, if nothing is changed, these dangerous phenomena shall be selected, in their present state, to be modelled for the severity calculations. Of course, these dangerous phenomena correspond to Reference Accident Scenarios.

It should be reminded that this risk matrix is actually not a guide for the acceptability of risk, but it is only a guidance to select reference accident scenarios which have to be modelled for the calculation of the severity.

2.2 Classes of consequences

Four classes of consequences are defined in Table 1. These consequence classes are defined according to potential consequences in term of domino effects, effects on human targets and effects on the environment.

CONSEQUENCES			**CLASS**
Domino effect	**Effect on human target**	**Effect on environment**	**Ranking**
See note under **Table 1**	No injury or slight injury with no stoppage of work	No action necessary, just watching	C_1
See note under **Table 1**	Injury leading to an hospitalisation > 24 hours	Serious effects on environment, requiring local means of intervention	C_2
See note under **Table 1**	Irreversible injuries or death inside the site, Reversible injuries outside the site	Effects on environment outside the site, requiring national means	C_3
See note under **Table 1**	Irreversible injuries or death outside the site	Irreversible effects on environment outside the site, requiring national means	C_4

Table 1: Class of consequences

Note for domino effects : The Dangerous Phenomenon likely to cause a domino effect is called DP1, and the accident caused by the domino effect is called DP2. It is first necessary to evaluate the class of consequence of DP1 and DP2 only on the basis of potential human and environmental effects. In a second step, if the consequence class of DP2 is higher than the consequence class of DP1, the consequence class of DP1 is increased to the level of the consequence class of DP2. this allows to take into account the possibility of a domino effect, the DP1 causing the accident DP2.

2.3 Frequencies

2.3.1 INTRODUCTION

Many considerations have to be taken into account to explain the choice of the range of frequencies used to defined the three areas of the risk matrix (green, yellow, red) corresponding to the four classes of consequences.

First of all, let us remind that the use of frequency limits in order to define the acceptability of the risk is common in European countries where Quantitative Risk Assessment techniques are used. It is thus interesting to consider here some figures used in these countries.

In the Netherlands [ref. 1], the individual risk of death in the surroundings of the plant must be lower than 1.10^{-6} per year.

In United Kingdom [ref. 2], three risk zones are defined : one corresponding to an unacceptable risk, one corresponding to a tolerable risk and one corresponding to a broadly acceptable risk. Thresholds used in UK are shown in Figure 2.

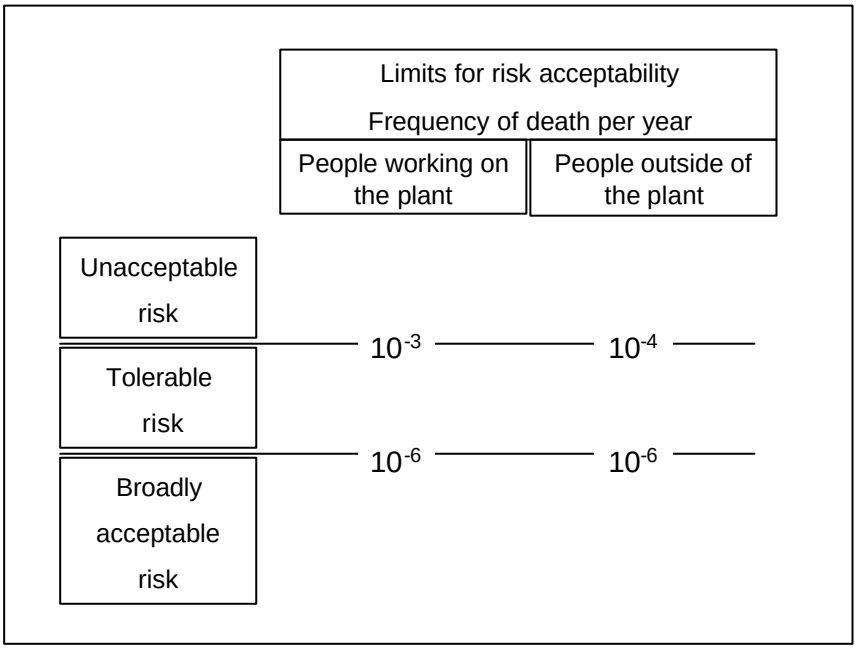

Figure 2: Thresholds used in UK for the acceptability of risk

It should be noted that, in these figures, the frequency of death concerns only the death due to the industrial activities of the plant.

2.3.2 DEFINITION OF THE GREEN, YELLOW AND RED ZONES IN THE RISK MATRIX

Concerning the data shown in the previous paragraph, it should be stressed that these figures are related to **criteria for acceptability of risk**, while the ARAMIS risk matrix concerns **criteria for the selection of reference accident scenarios**. That means that the risk matrix aims to choose,

among the possible scenarios which can arise in the plant, those which are relevant and which will contribute significantly to the "severity mapping" of the plant.

In the ARAMIS method, the acceptability of the risk due to a plant will finally result from the comparison of the severity and vulnerability mappings.

Keeping this in mind, the following principles have guided the choice of the thresholds in the ARAMIS risk matrix:

- **For the scenarios with a C4 class of consequences (risk of death for people outside of the plant),** the lower threshold for the (probably unacceptable) "high effects" zone could have been chosen equal to 10^{-6} per year. However, it should be reminded that the risk matrix concerns **Dangerous Phenomena DP** (for example a toxic cloud), and not **Major Effects ME** (for example the action of the toxic substance on people). Then, the individual risk of death will be lower than the dangerous phenomena frequency (due, for instance, to the probability of the wind blowing in a certain direction, the dilution of the cloud with the distance, the influence of emergency planning, etc). **Therefore, it seems reasonable to increase the lower threshold for the red zone to 10^{-5} per year. The lower threshold for the yellow zone is then chosen equal to one hundredth of the previous value, i.e. 10^{-7} per year.**
- **For the scenarios with a C3 class of consequences (risk of death of workers on the plant),** a comparison has been made with occupational health data. For example, recent figures in UK shows that, depending of the sector of activity in the industry considered, the frequency of death for a worker varies between 10^{-4} and 10^{-5} per year [ref. 2, page 70]. **The higher figure (10^{-4} per year) has been chosen as the lower red zone threshold**, assuming that the frequency of death due to hazardous substances may not be higher than the frequency of death of worker due to other causes in industry. **The lower threshold for the yellow zone is then chosen equal to one hundredth of the previous value, i.e. 10^{-6} per year**.
- As threshold frequencies have been multiplied by 10 between consequence class C4 and C3, the same reasoning was applied in order to obtain threshold frequencies for the **C2 class of consequences**. Thus, in this case, **the lower threshold for the red zone to 10^{-3} per year and the lower threshold for the yellow zone is 10^{-5} per year.**
- **For the scenarios with a C1 class of consequences,** the effects seem to be always acceptable.

Of course, it shall be underlined that these proposals only constitute a rough guide that can be revised if necessary.

3. References

1. Web site of RIVM, NL, pages on external safety (externe veiligheidsrisico's: de kans op een ongeluk; inleiding), www.rivm.nl

2. Health and Safety Executive (HSE), UK, 2001, Reducing risks, protecting people – HSE's decision-making process, downloadable on www.hsebooks.com