Risk Matrix as a Tool for Risk Assessment in the Chemical Process Industry

BASF The Chemical Company

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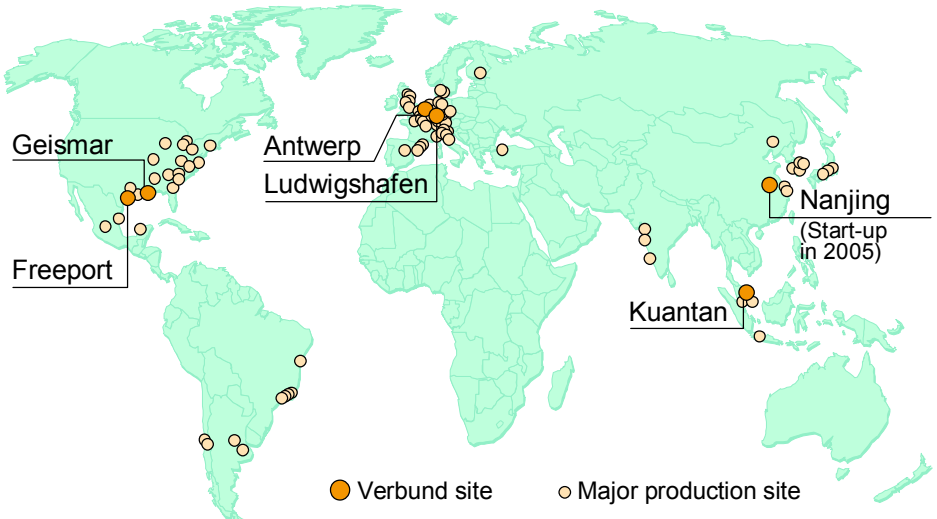
BASF – The Chemical Company

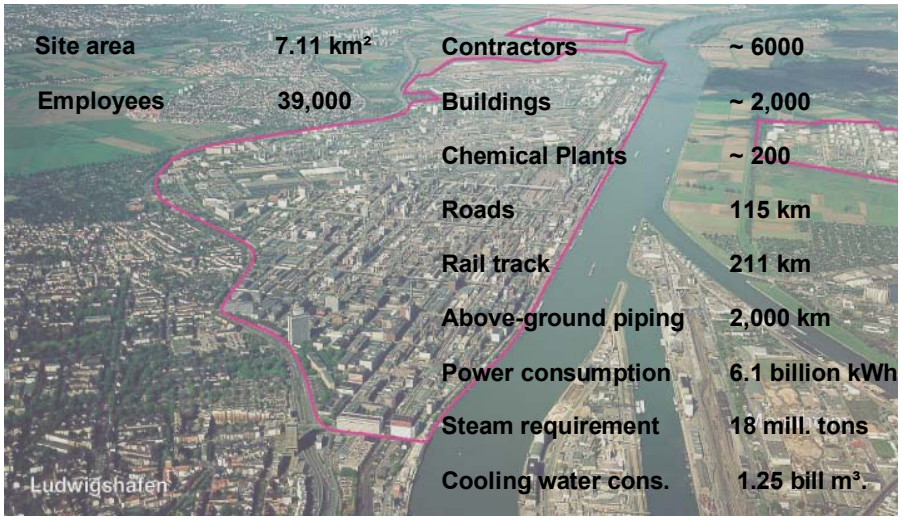
The world's leading chemical company

Global presence

BASF The Chemical Company

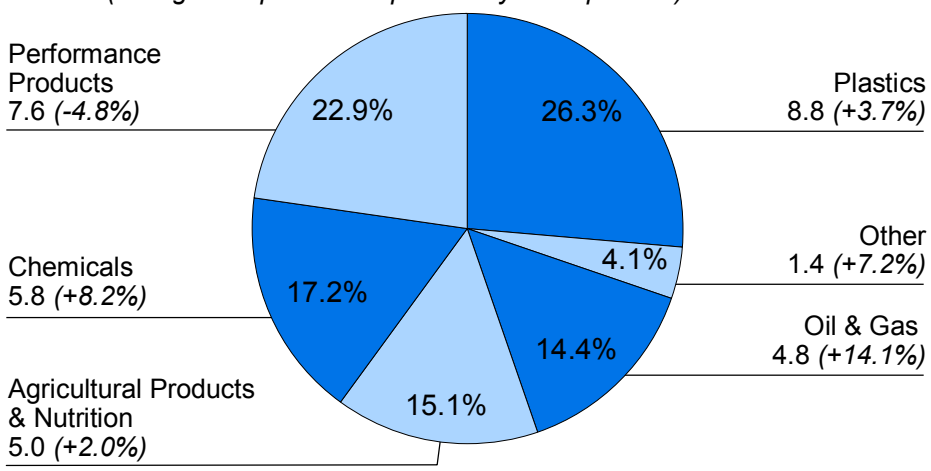


The Ludwigshafen site: The world's largest integrated chemical complex



BASF Group: Sales by segment in 2003

Billion € *(change compared with previous year in percent)*



Ammonium Nitrate Explosion at BASF Lu in 1921

VUE AÉRIENNE DE L'USINE DE LA « BADISCHE ANILIN UND SODA FABRIK », A OPPAU, APRÈS LA FORMIDABLE EXPLOSION DU 21 SEPTEMBRE

What is Process Safety ?

Interdisciplinary effort to prevent fires, explosions and accidental chemical releases

Performance Expectations:

Safety reviews are conducted for existing and new processes/facilities (**BASF Group Directive – SHE)**

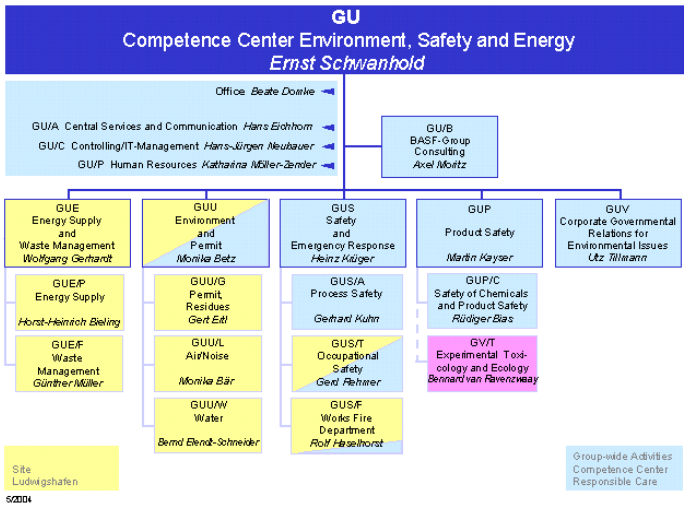
Documented plant safety concept and periodic review

Current, complete documentation is available, e.g. safety relevant parameters, protective devices, P&I diagram, hazardous area-classification, fire protection concept, etc)

Investigation of all incidents and communication of lessons learned

Management of change system is implemented

Organization



Definition of Risk

$$R = P \times S$$

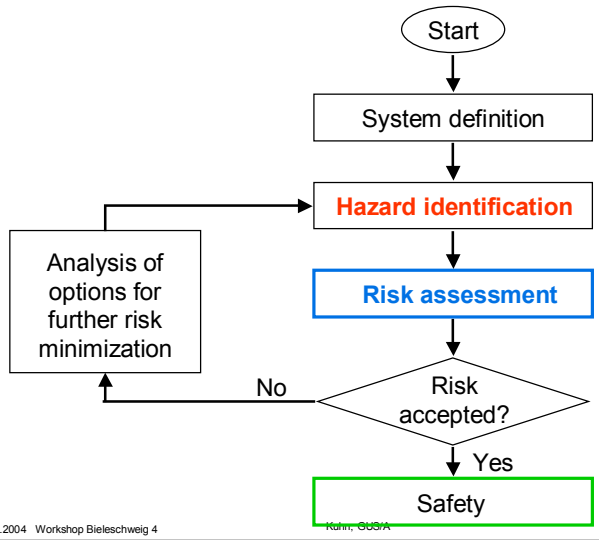
R Risk

P Probability (expressed as frequency)

S Severity

The term risk may be used qualitatively or quantitatively

Risk Assessment as Part of a Safety Review



Qualitative Risk Assessment (1)

in accordance with VDI/VDE guideline 2180

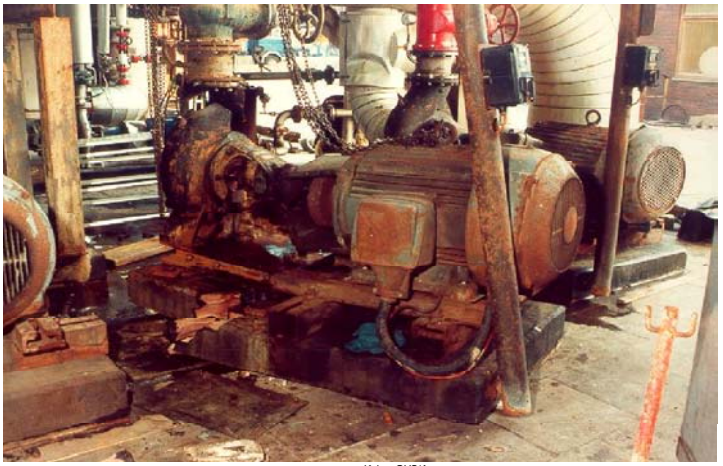
If an incident with severe consequences such as danger to human life or the environment can be triggered by a primary cause, which cannot be reasonably ruled out, the chain of events between the primary cause and incident must be interrupted by a protective measure such as a pressure relief device or a Safety Instrumented System.

Qualitative Risk Assessment (2)

Qualitative estimation of the frequency of occurrence

- **Scenarios requiring more than one independent simultaneous primary fault as initiating event are not taken into account**
- **Only those primary faults are considered which cannot be reasonably ruled out on the basis of operational experience**

Example 1: Rupture of a cooling water pump (continued)



Principles of a risk matrix

A risk matrix

- Is a semi-quantitative tool
- Uses orders of magnitude
- Can be adjusted to company specific acceptance criteria
- Does not require special skills or software
- Is relatively easy to use

BASF Risk Matrix

BASF	Risk Matrix			
	Severity			
Frequency	S 1	S 2	S 3	S 4
P 0	A	B	D	E
P 1	A/B	B	E	E
P 2	B	C	E	F
P 3	C	D	F	F
P 4	E	F	F	F

Elements of the BASF Risk Matrix

Frequency classes

- P_0 Happened a couple of times (once per year or more often)
- P_1 Happened once (Approx. once in 10 years)
- P_2 Almost happened, near miss (Approx. once in 100 years)
- P_3 Never happened, but is thinkable (Approx. once in 1,000 years)
- P_4 Not plausible (less than once per 10,000 years)

Elements of the BASF Risk Matrix

Severity classes

- S_1 On site: Potential for one or more fatalities
- S_2 On site: Potential for one or more serious injuries (irreversible)
- S_3 On site: Potential for one or more lost time injuries
- S_4 On site: Potential for minor injuries, or irritation

Elements of the BASF Risk Matrix

Risk classes and Risk Reducing Measures

Risk Class	Risk Level	Risk Reducing Measures
A	Extreme, totally unacceptable risk	Process or design change preferred
B	Very large, unacceptable risk	Process or design change, or one protective device of SIL 3 (PSV, Class A)
C	Large, unacceptable risk	Process or design change, or one protective device of SIL 2 (PSV, Class A)
D	Medium, acceptable risk, which should be further reduced	One monitoring device of high quality with documented testing or administrative procedure of high quality
E	Small, acceptable risk, which should be further reduced	One monitoring device or administrative procedure
F	Very small, acceptable risk	None

How to use the BASF Risk Matrix

Conventions

- **No credit** is taken **for existing safeguards** when determining the risk class
- **Full credit** is taken for normal reliability of **instrumented control** and **operator control** when determining the frequency of an event
- The **protective devices listed** as risk reduction measures for risk classes B and C are the **minimum requirement**, the implementation of additional monitoring devices is highly recommended (layers of protection)

How to use the BASF Risk Matrix

Determination of frequency

- Use good judgement
- Evaluation by the interdisciplinary process review team (Orders of magnitude)
- Applicable data from literature

How to use the BASF Risk Matrix

Determination of severity

- Use good judgement
- Practical experience
- Quantitative methods such as dispersion calculations.

How to use the BASF Risk Matrix

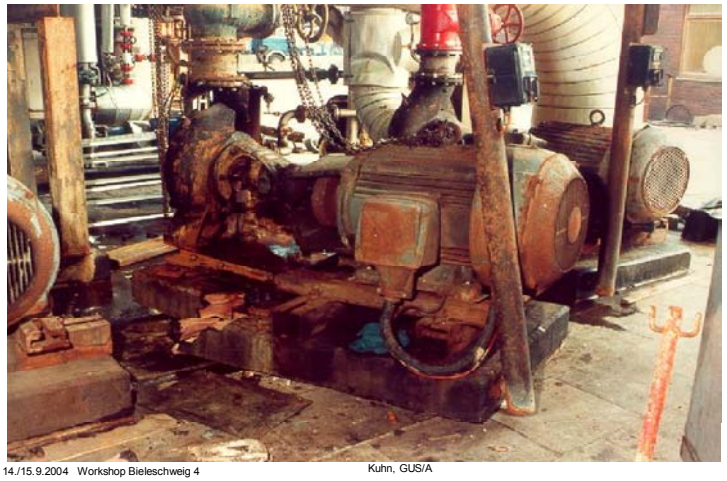
Dealing with less likely consequences

- Form separate pairs of severity and corresponding probability and determine the risk class for each pair
- Use the most severe risk class to represent the scenario
- Combining the frequency of an initiating event with the most severe but unlikely consequence would result in the **wrong risk class**

Example 1: Rupture of a cooling water pump

A 50 kW- cooling water pump made of brittle construction material (e.g. gray cast iron) is inadvertently operated with blocked-in water. Undue overpressure may occur by thermal expansion and cause rupture of the casing. Because of the brittle construction material flying debris is to be expected.
Evaluation of frequency:
The operation takes place 10 times per year.
VDI guideline 4006/2 suggests an error probability of 10^{-3} for a task, which is simple and has often been performed with little stress and with sufficient time available in familiar situations.
Thus a frequency of 10^{-2} per year
or
once in 100 years (P_2) can be inferred.

Example 1: Rupture of a cooling water pump (continued)



Example 1: Rupture of a cooling water pump (continued)

If there is no personnel near the pump, the severity can be classified as S_4 (potential for minor injuries or irritation)
Result: Risk class F (P_2S_4; very small, acceptable risk)

BASF	Risk Matrix			
	Severity			
Frequency	S_1	S_2	S_3	S_4
P_0	A	B	D	E
P_1	A/B	B	E	E
P_2	B	C	E	F
P_3	C	D	F	F
P_4	E	F	F	F

Example 1: Rupture of a cooling water pump (continued)

10% of the time (frequency P_3) personnel is expected to be near enough to that particular pump to sustain a serious injury (severity S_2).
Result: Risk class D (P_3S_2; medium, acceptable risk, which should be further reduced).

BASF	Risk Matrix			
	Severity			
Frequency	S_1	S_2	S_3	S_4
P_0	A	B	D	E
P_1	A/B	B	E	E
P_2	B	C	E	F
P_3	C	D	F	F
P_4	E	F	F	F

Example 1: Rupture of a cooling water pump (continued)

The probability of the injury being fatal is about 10 %. Thus the frequency for somebody being present and fatally hit by debris is P_4.
Result: Risk class E (P_4S_1; small, acceptable risk, which should be further reduced).

BASF	Risk Matrix			
	Severity			
Frequency	S_1	S_2	S_3	S_4
P_0	A	B	D	E
P_1	A/B	B	E	E
P_2	B	C	E	F
P_3	C	D	F	F
P_4	E	F	F	F

Example 1: Rupture of a cooling water pump (continued)

The worst case risk class is D, requiring one monitoring device of high quality, e.g. a high pressure switch, to shut off the pump.

BASF	Risk Matrix			
	Severity			
Frequency	S 1	S 2	S 3	S 4
P 0	A	B	D	E
P 1	A/B	B	E	E
P 2	B	C	E	F
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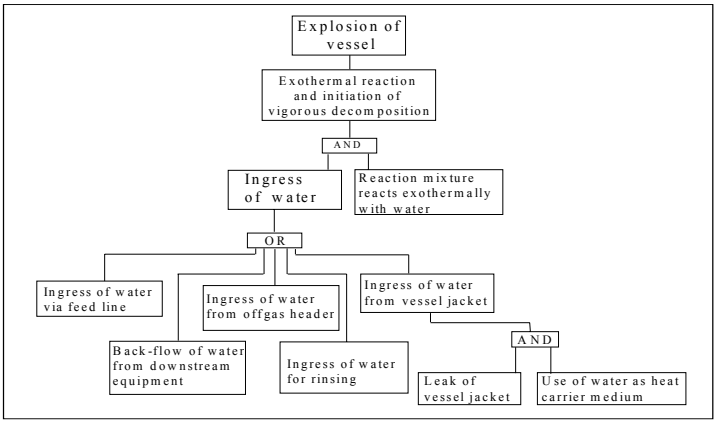
P 4	E	F	F	F

Example 2: Explosion of a stirred reactor

In a stirred reactor containing a heat sensitive reaction mixture, ingress of water would produce a strongly exothermal reaction causing the reaction mixture to decompose explosively.

Example 2: Explosion of a Stirred Reactor caused by Ingress of Water



Example 2: Explosion of a stirred reactor

Example 2: Explosion of a stirred reactor

According to operational experience ingress of water is presumed to occur about once in ten years (P_1, “happened once”).
Even relatively small amounts of water would result in an explosive decomposition causing rupture of the vessel and flying debris with the potential of serious injuries (S_2; combination P_1S_2).
Assuming that the probability of the injuries being fatal is 10 %, a combination of P_2S_1 can be derived.
In both cases the risk class is classified as B.

BASF	Risk Matrix			
	Severity			
Frequency	S_1	S_2	S_3	S_4
P_0	A	B	D	E
P_1	A/B	B	E	E
P_2	B	C	E	F
P_3	C	D	F	F
P_4	E	F	F	F

Example 2: Explosion of a stirred reactor

Since I/E-protective devices would not prevent the scenario from occurring, the risk has to be reduced by design change and organizational protective measures e.g.

- use of non-aqueous heat carrier medium instead of water
- installation of a spool piece at the connection to water supply for rinsing the vessel
- highly reliable visual control for remaining water in the vessel after cleaning operations.

Conclusion

The BASF Risk Matrix is a tool to perform semi-quantitative risk assessments. It reflects BASF's philosophy on maximum acceptable risk and the determination of what additional measures are necessary or not to reduce the risk. It presents a further development of the qualitative risk assessment method.

Analysis of incidents in the BASF Group during recent years shows that most incidents occurred not because of wrong risk assessments but since hazards had not been detected in advance. Emphasis has therefore to be laid on early identification of hazards. Only hazards which are identified can be countered by appropriate safeguards.