Lecture 4, HSE - Planning and Execution of a Biorefinery Investment Project

PROCESS INDUSTRIES DIVISION

28.9.2023

AFRY

Who Am I?

Kaisa Vaskinen
HSE Technology Manager
kaisa.vaskinen@afry.com

SPECIALITY

Chemical safety permitting, authority issues
Risk analyses
Legislation and standards

BACKGROUND

M.Sc. (Tech.), Chemical Engineering (LUT)
01/2023- Afry Finland Oy
2018-01/2023 UPM Biofuels, Lappeenranta biorefinery
2011-2018 Neste Oyj, Porvoo & Naantali refineries

Agenda

- Holistic view of health and safety
  - Regulations, laws, guides and standards
- HSE in projects
- Risk analyses

Safety in projects

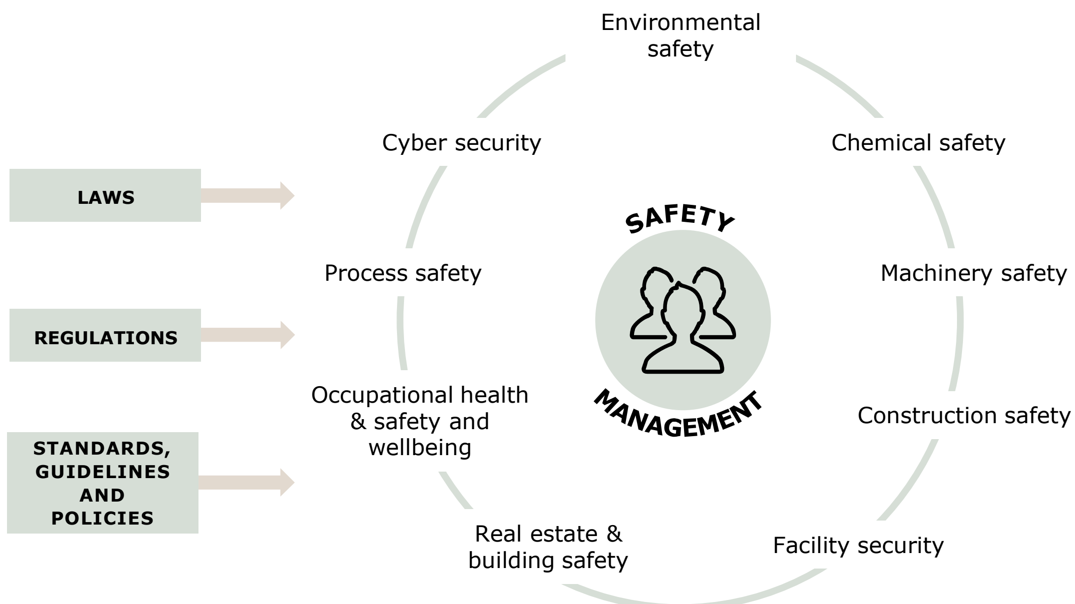
UPM:n Lappeenrannan biojalostamon toiminta katkesi aamulla tulipaloon – taloudelliset vahingot ovat merkittävät

Lappeenrannan UPM:n biojalostamossa aikaisin aamulla syttynyt tulipalo nosti Kaukaan alueelle mustan savupatsaan. Tuotannon katkeamisesta aiheutuu merkittävät vahingot.

UPM:n biojalostamon tulipalosta syntyi sankka savupatsas. Kuva: Maija Rautio

https://yle.fi/a/3-11923357

Holistic view of Health and safety



Regulations

- ATEX Directives 2014/34/EU and 1992/92/EC
- Pressure Equipment Directive (PED) 2014/68/EU
- Machinery Regulation 2023/1230
- Use of Work Equipment Directive 2009/104/Low Voltage Directive 2014/35/EU
- SEVESO III Directive 2012/18/EU
- The Classification, Labelling and Packaging (CLP) Regulation (Regulation (EC) 1272/2008)
- Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) (Regulation (EC) 1907/2006)
- The Biocidal Products Regulation (Regulation (EU) 528/2012)
- Etc.

HSE legislation in Finland

- Chemical safety legislation; Act on the Safe Handling of Dangerous Chemicals and Explosives 390/2005 and Chemical safety Decrees, i.a. 685/2015, 856/2012, 686/2015 and 858/2012
- Government Decree 551/2009 for Safety in the handling of natural gas
- Finnish national ATEX Decrees 1439/2016 and 576/2003
- Decree 848/2017 of the Ministry of the Environment on Fire safety of buildings (848/2017)
- Pressure equipment Directive (PED) 2014/68/EU, Finnish national PED Law 1144/2016 and Decrees 1548/2016, 1550/2016 and 1549/2016
- Act on the Conformity of Certain Technical Devices to Relevant Requirements 1016/2004, and Finnish National Machinery Safety Decree 400/2008 and Government Decree on the Safe Use and Inspection of Work Equipment 403/2008
- All applicable environmental laws and regulations

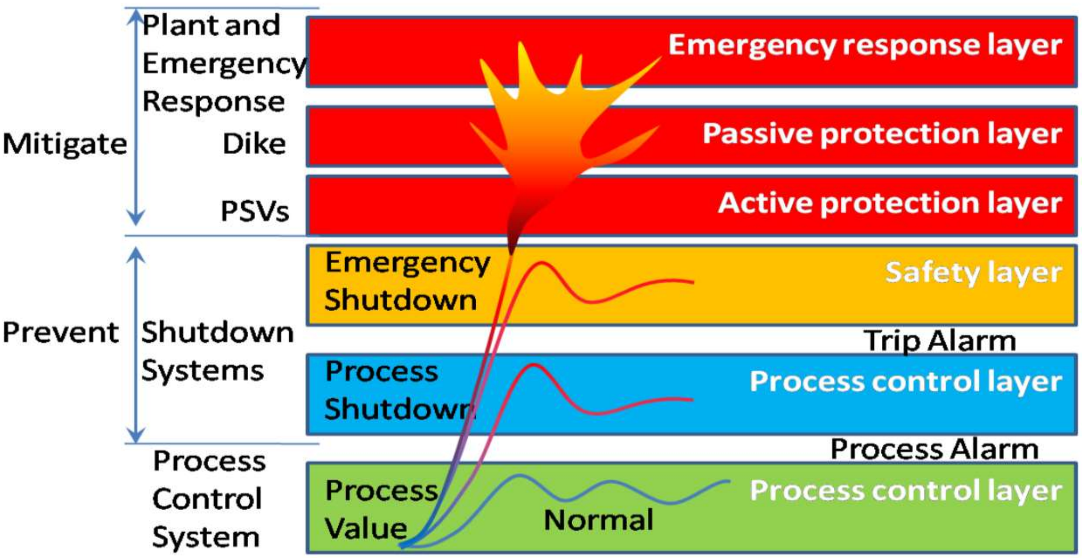
Standards and guidelines

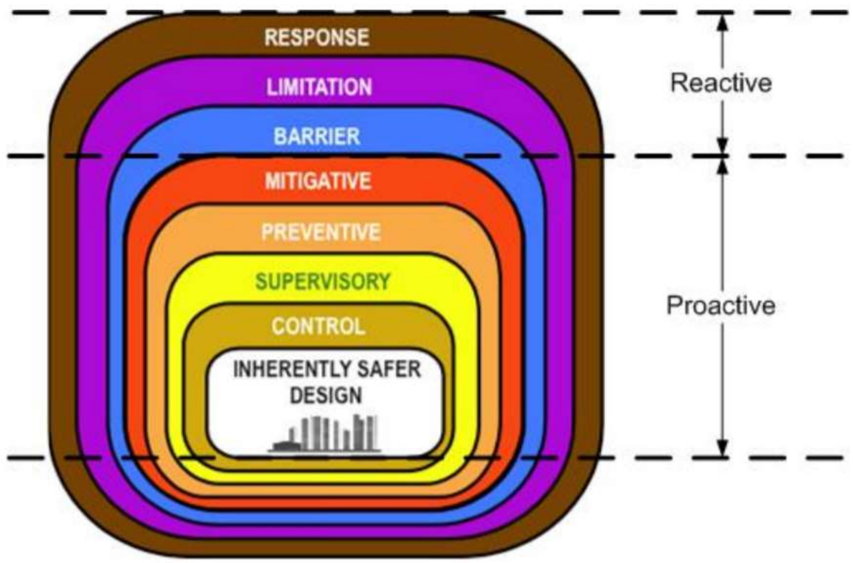
- Tukes guides
  - Dangerous chemicals in industry
  - Guide on good practices at chemical facilities
  - Safety report
  - Plant location
  - Etc.
- The Finnish Standards Association (SFS)
  - Tank storage of flammable and combustible liquids and associated handling facilities, SFS 3350
  - Combustible Chemicals Production Plant, SFS 3353
  - Explosive atmospheres SFS 60079
  - Safety of Machinery SFS-EN ISO 14122
  - Etc.

HSE in projects

PROCESS INDUSTRIES

Inherently safer desing





AFRY

Safety Stepwise™ – Safety within a life cycle of project

1. Step	2. Step	3. Step	4. Step	5. Step	6. Step
Pre-engineering	**Basic Engineering**	**Detailed Engineering**	**Construction and Erection**	**Commissioning and Start-Up**	**Production**
Master action list • HSE criteria/Project specific requirements • Connections to authorities • Principles of Inherent safety • Chemicals and materials • Plant location • Plant structure • Emergency facilities • Empirical accident data in similar plants –Internal –External	• Master action list (update) • Preliminary risk analysis. –Hazardous scenario analysis –Potential problem analysis –Checklists –Etc. • Layout risk analysis –Safety distances (Eg. Standards and Consequence analysis) –Emergency exits/escape routes –Rescue team access –Maintenance –logistics • Fire risk analysis • Pre-ATEX study • Preliminary definition of safety automation • Safety requirements for suppliers • Safety guidelines for engineering • Fire protection classification • Permitting plan	• Master action list (update) • Detailed risk analysis –HAZOP –Human error analysis –What-if -analysis –Failure mode and effect analysis • ATEX Study –Explosion protection document –Hazardous area classification –Equipment classification (Ex) • Design of safety automation –SIL-assessment (risk graph, LOPA, etc. –Safety plan • Fire protection of structures • Process isolation procedures • 3D safety review	• Master action list (update) • Legal safety document • Site HSE plan • HSE organisation and job descriptions • Safety guidelines for contractors • Contractor's commitment for safety and contractors HSE plan • Verification of risk reduction measures • Change management • Operation and maintenance manuals (preparation) • Safety and operation training • Rescue plan • Site safety procedures –Safety instructions –Job safety analysis –Toolbox talks –Personnel equipment –Training –Reporting &investigation –Safety communication –Audits –Work permits, etc • Conformity check • Mechanical completion check	• Master action list (update) • Review of legislation and regulations • Review of safety requirements and practices –Pre-start activities –Operation and maintenance manuals (check) –Acceptance of final documentation –Work permits after mechanical completion • Emergency preparedness	• Master action list (update) • Acceptance of final documentation • Process safety file check • Learning from practical experience • Archiving • Continual improvement
Documentation collected phase by phase into the project's process safety file / system					

Industrial example

Industrial safety within a life cycle of project

Feasibily Study → **Basic Engineering** → **Detailed Engineering** → **Construction** → **Commissioning & Start-up** → **Production**

Procurement

- HSE requirements for vendors
- HSE evaluation of vendors
- HSE incentive plan for vendors

Commissioning & Start-up

- Commissioning risk assessment
- Pre Start-up Safety Review

Process Safety

- HSE philosophy
- Empirical accident study
- Best Available Technology, BAT
- Safety information (hazardous chemicals, materials, etc.)
- Plant layout and siting
- Permitting plan
- Risk acceptability
- Identifying HSE technical authority
- Inherent safety
- Major HSE risks and consequence modelling
- Preliminary PHA
- Detailed PHA
- QRA

Technical Safety

- Plant layout
- Escape and evacuation
- Hazardous areas (ATEX)
- Mechanical integrity
- Detailed risk analyses
- RAGAGEP = Recognized and Generally Accepted Good Engineering Practices (OSHA)
- Pressure Equipment Directive, PED
- Machinery safety
- Process isolations
- Emergency shut-down
- Fire and gas detections
- HSE Design review

Construction Safety / Personal Safety / Behavioural Safety / Process Safety

- Construction safety plan
- HSE site procedures
- Construction risk assessment
- Constructability study
- HSE indicators (leading and lagging)
- HSE statistics
- Incident investigation
- Site security
- Commissioning risk assessment
- Pre Start-up Safety Review

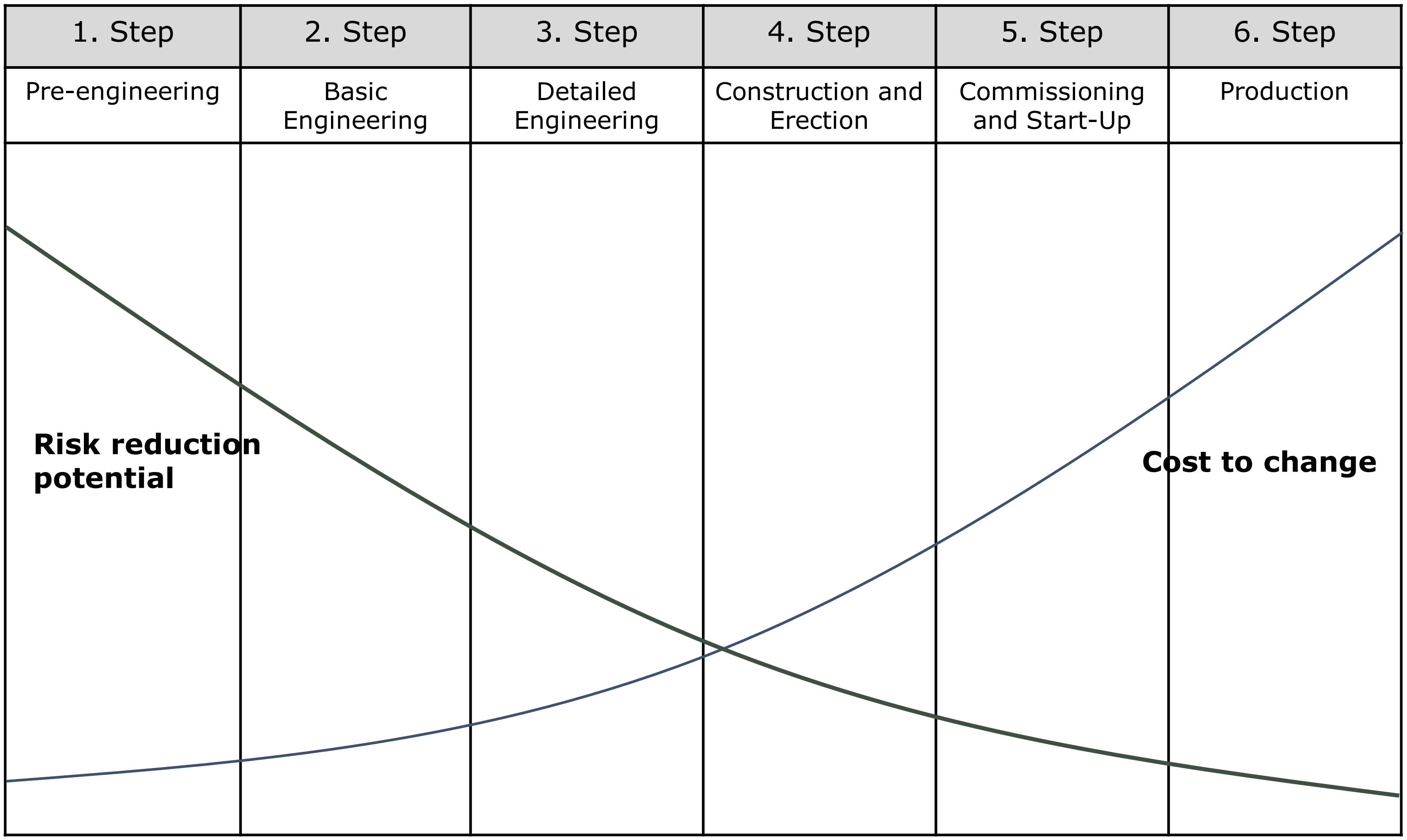
Process Safety

Process Safety / OHS

- Lessons learned
- Risks Analysis updated

PHA = Process Hazard Analysis
QRA = Quantitative Risk Analysis
OHS = Occupational Health and Safety

Safety Stepwise™ –Benefits of risk management throughout the lifecycle of a plant



Risk analyses

Risk analyses

Effective way to

- Identify risks
- Provide safe solutions
- Awareness of process safety and machinery safety related risks not high and correlation and probability of accidents and threats not clear

Risk analysis with several methods

- HAZID, HAZSCAN, HAZOP, SIL (Safety Integrity Level), HEA
- Machinery Safety Risk Analysis
- Consequence analyses and modelling

Benefits

- Risks identified and safe solutions provided
- Information for decision makers
- Requirements set by legislation and authorities fulfilled

Hazard identification study (HAZID) Methodology

— The main purpose of the HAZID is to identify situations capable of leading **major incidents having health, safety and environmental (HSE) impacts and asset losses** and is carried out by a team.

— HAZID is one of the preliminary risk analysis methods
  - The results of preliminary risk assessment are critical in **recognizing the hazardous processes and significant risks.**
  - to **prioritize the identified risks** using their likelihood of occurring and their corresponding consequence.

— The scope and focus of further detailed risk studies, for example the hazard and operability study (HAZOP) or consequence analyses, will be defined on the basis of the HAZID.

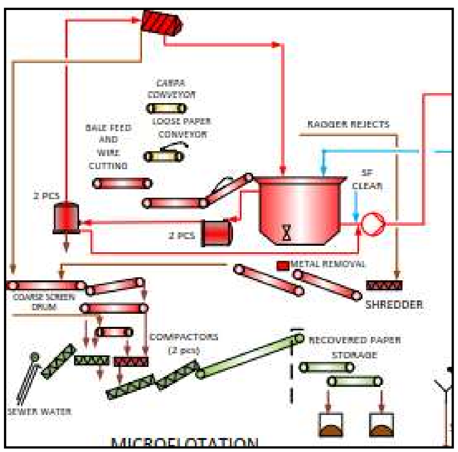
— Implementation of a HAZID study is done using e.g. PHA-Pro software. The software delivers a comprehensive safety management in teamwork oriented analysis.
  - All information becomes recorded reliably ensuring easy and transparent data management.

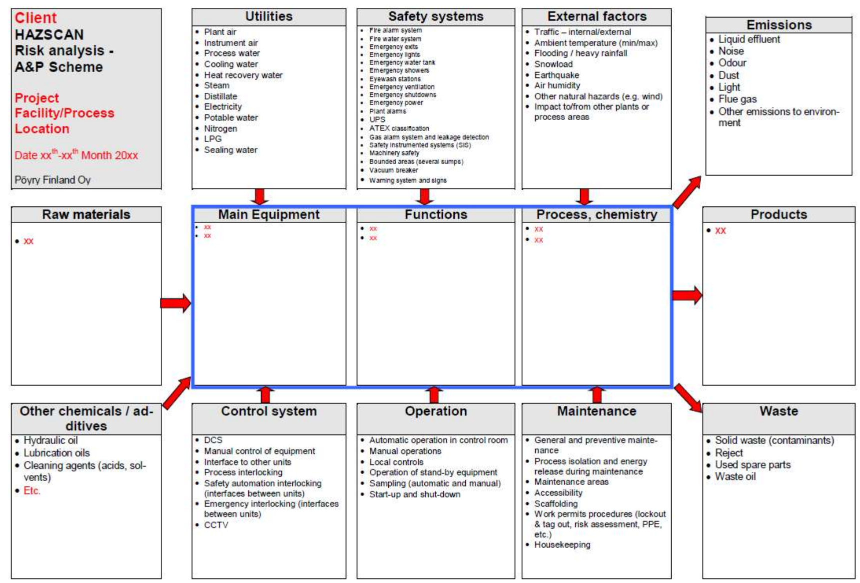
Example -HAZID guidewords

1. Materials and substances (raw materials, chemicals, additives, products, dusts, utilities (electricity, water, steam, nitrogen, pressure-/instrument air))
2. Equipment and machines (malfunctions)
3. Normal operation and working (human errors, dangerous work phases (lifting, confined spaces, ATEX), working alone, physical factors (noise, vibration, temp., lighting))
4. Maintenance (interlocking, isolations, work areas, hazardous work (hot work, confined space, electrical work), deficiencies in maintenance)
5. Processes (malfunctions, instrumentation, fail safe positions, DCS, hazardous reactions (liquids, gases), dusting, safety basins, materials, temperature, pressure)
6. Layout and surrounding facilities (locations, walkways, emergency routes, distances)
7. Environment (relief valves/ventilation openings (emissions to air), emissions to water, waste, extreme weather conditions)
8. Traffic (cars, heavy traffic, work vehicles and pedestrians)
9. Safety systems/solutions (SIS, earthing, safety markings (chemicals, pipelines, noise, Ex, routes), insulations, emergency showers/ eye wash stations, emergency kits, fire extinguishing system, fire water, emergency lighting, ventilation, UPS, working platforms, surface coating/patterns, emergency exits)
10. Accidents (fire (pool/jet), explosions, BLEVE, dispersion of hazardous chemicals, domino effects, heat, smoke, reactions, consequence analysis, escaping)

HAZSCAN (Hazardous scenario Analysis) Methodology

Sub-processes





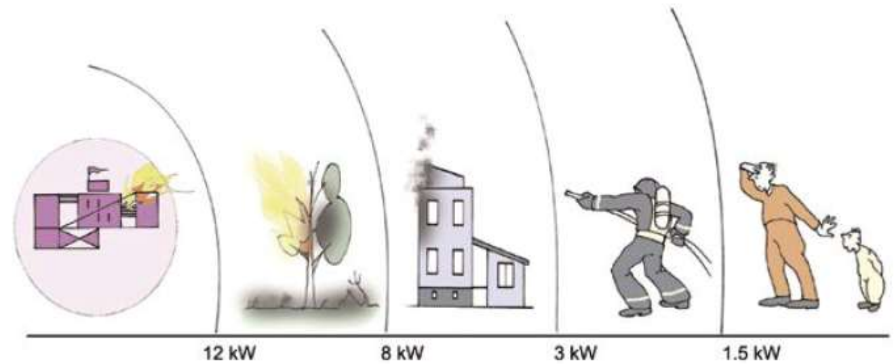
Consequence analysis

- The Seveso Directives are the main EU legislation dealing specifically with the control of on-shore major accident hazards involving dangerous substances
- The Control of Major Accident Hazards (COMAH) Regulations 2015 is implementing the Seveso Directive
- "Take all necessary measures to prevent major accidents involving dangerous Substances and Limit the consequences to people and the environment of any major accidents which do occur" → CONSEQUENCE ANALYSIS
- Consequence analyses consist of major accident scenarios
  - Fire: Heat radiation (kW/m^2) distances, m
  - Explosion: Overpressure effect (kPa) distances, m
  - Dangerous chemical dispersion, m

Heat radiation

— Directions for consequence analysis are according to Tukes guide ”Plant location” (2015)[1]

Heat radiation, kW/m²	Consequences for people and equipment	Basis for design
12	Flora might catch fire	Damage to pressurised steel container's surfaces and process equipment
8	Exposure longer than 20 seconds causes second degree burns, possible death	Limiting value to external constructions. Buildings, equipment and other structures might catch fire
3	Exposure longer than 2 minutes causes permanent injuries	Limiting value for emergency routes
1,5	Long exposure harmless	Safe limit



Tukes Guide Plant location, Appendix 7. Tukes 2015

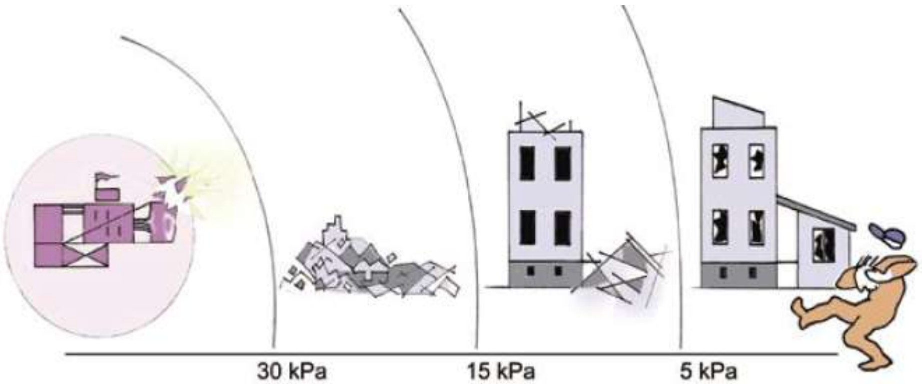
1. https://tukes.fi/documents/5470659/6406815/Tuotantolaitosten+sijoittaminen/ab664564-66f7-49b7-96bb-316dfefe4517/Tuotantolaitosten+sijoittaminen.pdf/Tuotantolaitosten+sijoittaminen.pdf

AFRY

Overpressure wave effect

— Directions for consequence analysis are according to Tukes guide ”Plant location” (2015)[1]

Overpressure wave, kPa	Consequences for people and equipment	Possible structure or building types
30	Collapsing of supporting structures, risk of expansion for the incident	Industrial equipment and structures
15	Partly collapsing of houses, risk of permanent damage	Industrial building and structures, which have been scaled to last a certain amount of overpressure
5	Small damage to structures of houses and risk of an injury	Buildings and areas, where people are normally located



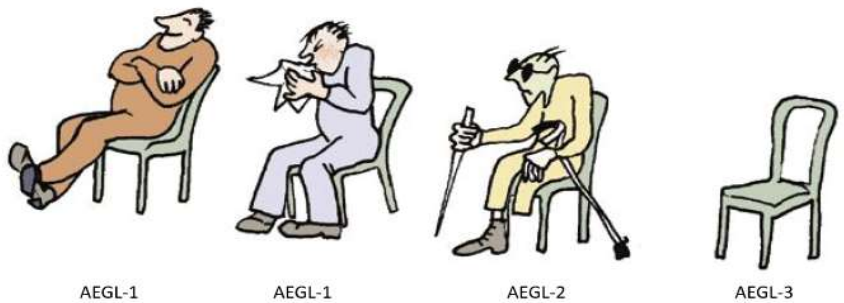
Tukes Guide Plant location, Appendix 7. Tukes 2015

1. https://tukes.fi/documents/5470659/6406815/Tuotantolaitosten+sijoittaminen/ab664564-66f7-49b7-96bb-316dfefe4517/Tuotantolaitosten+sijoittaminen.pdf/Tuotantolaitosten+sijoittaminen.pdf

Health hazards

— Health hazards in consequence modelling are carried out as dispersion models of toxic gases. Consequence modelling is obligated to be executed in the case of a toxic gas spreading outside of the plant's property.

— The chemical concentrations of the impacted areas in the modelled scenario are calculated and compared to limiting values. The possible limiting values are the Acute Emergency Guidance Levels (AEGL).



Tukes Guide Plant location, Appendix 7. Tukes 2015

The Acute Emergency Guidance Levels	Definition
AEGL-1	Causes noticeable discomfort or irritating symptoms. Might also be symptomless.
AEGL-2	Causes unreturnable or other long-term harmful health impacts or weakens the ability to escape.
AEGL-3	Causes deadly consequences or dead.

HAZOP (Hazard and Operability Study)

— HAZOP is a standardized risk analysis method (IEC 61882) that is widely used in the process industry. A method generally accepted by the authorities and insurers.

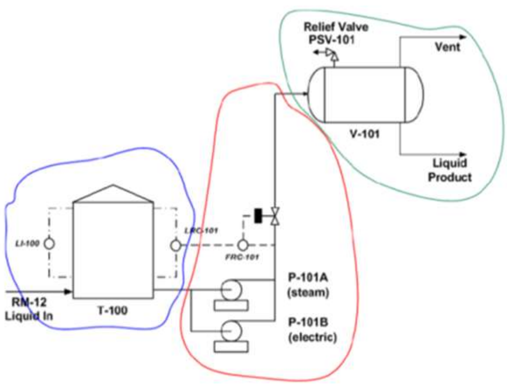
— A systematic method based on the PI diagrams of the process and the division into smaller entities to be processed - **nodes**.

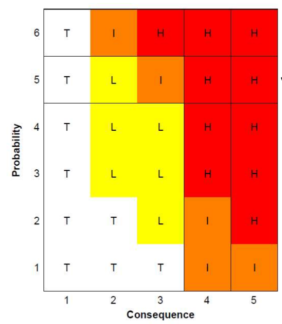
1. Each node is examined individually and any **process deviations (cause)** that occur in them are identified by means of preselected deviations.
2. The identified incidents - **scenarios** - are described as accurately as possible until the final outcome and are classified using a risk matrix.
3. Existing **safeguards** related to the scenario are identified and their adequacy is assessed
4. If necessary, recommendation proposals are recorded to improve the situation

Design Conditions/Parameters:

Deviation	Causes	Consequences	Risk Matrix			Safeguards	Risk Matrix2			Recommendations (HAZOP)					Comment
			S	L	RR		S	L	RR	Recommendations (HAZOP)	Responsibility	Status	Execution	Due Date	
1. High Flow	1. Failure of frequency controller in main conveyor	1. Blockage on biomass feeding point	S1	L3	D	1. Blockage detector in biomass belt conveyor 2. Interlock between the conveyors upstream	S1	L1	D	41. Consider adding 6 blockage detectors before main conveyor, in dropping chutes	nn.				

HAZOP Analysis





Node: 26. HHE - Main Fuel Feeding System
Drawing: abc1; abc2; abc3;
Design Conditions/Parameters:

Deviation	Causes	Consequences	Risk Matrix			Safeguards	Risk Matrix2			Recommendations (HAZOP)					Comment
			S	L	RR		S	L	RR	Recommendations (HAZOP)	Responsibility	Status	Execution	Due Date	
1. High Flow	1. Failure of frequency controller in main conveyor	1. Blockage on biomass feeding point	S1	L3	D	1. Blockage detector in biomass belt conveyor 2. Interlock between the conveyors upstream	S1	L1	D	41. Consider adding 6 blockage detectors before main conveyor, in dropping chutes	nn.				

Node selection
PIDs divided into logical entities (nodes)

Deviation
Deviation from design intend utilizing the guidewords (high flow, no flow, low level, etc.)

Cause of deviation
Cause due to e.g. intrument failure or human error

Consequences
Consequences, e.g. human injuries, environmental hazards, asset losses or reputational consequences

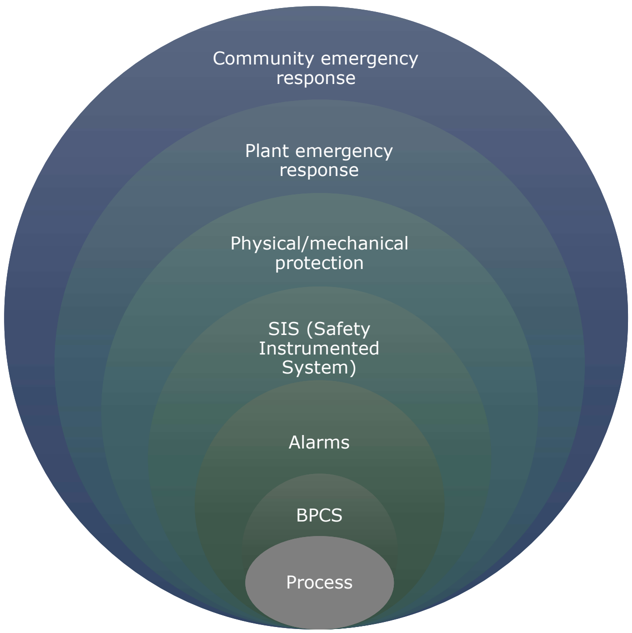
Risk classification 1 (zero risk)
Risk assessed without safeguards

Safeguards
Interlocks and control (DCS) | Alarms, displays | Safety valves | Operating instruction | Safety Instrumented System (SIS) | How much time to act? Etc.

Risk classification 2 (residual risk)
Risk with existing safeguards

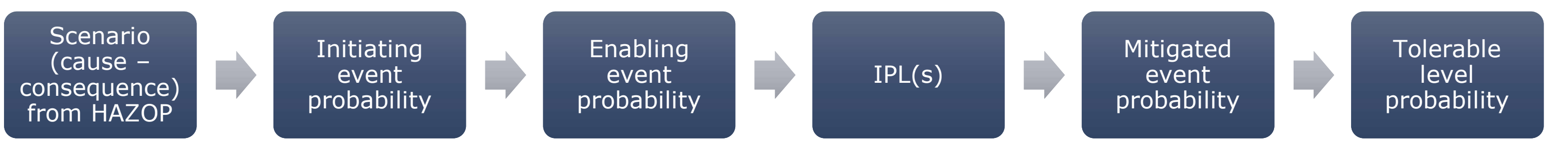
Recommendations
Recommendations for safeguarding of mitigation to lower the risk to an acceptable level

Layer of Protection Analysis (LOPA)



Identification of protection layers that prevent of mitigate hazard

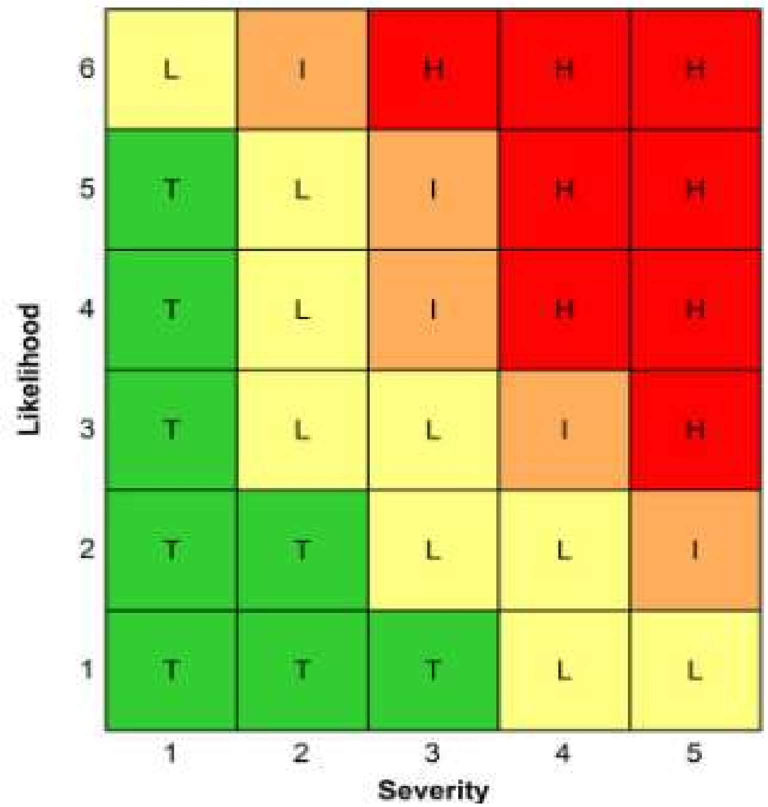
→ Total amount of risk reduction
→ Analyzing of additional risk reduction
→ If SIF (Safety instrumented function), determination of appropriate SIL for SIF



IEC 60300-3-9

Risk matrix example

- The risk is a combination of a severity of consequence and a probability of the event.
- Qualitative analysis and classification of probability is performed according to standard IEC 60300-3-9 which is widely applied in process industry.
- The standard is developed for the risk assessment of technological systems



Risk Ranking	Description
H	High risk. Not acceptable - Immediate actions needed.
I	Intermediate risk. Not acceptable - Actions needed within a reasonable time period.
L	Low risk: Acceptable - Follow-up recommended.
T	Trivial risk. Acceptable - No actions needed.

AFRY

Risk matrix example

Consequence	Description
1	**Negligible** People: First aid injury Assets: No system damage. Environment: No environmental impacts.
2	**Minor** People: Minor injury, minor occupational illness Assets: Minor system damage. Environment: Minor local environmental impacts inside plant area (small leakage can be easily cleaned up).
3	**Severe:** People: Severe injury (Lost-time injury), severe occupational illness Assets: Significant damage to the plant or system. Environment: Hazardous emissions low (temporary local deterioration of water quality, damage to animal and plant species and their habitats inside the plant area)
4	**Major** People: Permanent disability or one fatality Assets: Extensive damage to the plant or system. Environment: Severe local environmental impacts (local fish deaths, damage to animal and plant species and their habitats outside the plant area)
5	**Catastrophic** People: Many fatalities. Assets: Virtually complete loss of plant or system. Environment: Long-term and severe environmental impacts (fish deaths, groundwater pollution, serious damage to animal and plant species and their habitats outside the plant area)

Probability	Description
1	Practically never. Highly Improbable: $< 10^{-6}$
2	Not once in the industrial field. Improbable: 10^{-4} - 10^{-6}
3	Not once during the life cycle of the plant. Remote: 10^{-2} - 10^{-4}
4	Once during the life cycle of the plant. Occasional: 10^{-1} - 10^{-2}
5	More than once during the life cycle of the plant. Probable: 1 - 10^{-1}
6	More than once in a year. Frequent: >1

Other process* risk analysis

- Hazardous areas (ATEX)
  - Explosion hazard identification and assessment
  - Ignition hazard identification and assessment
- Human error analyses (HEA)
- Layout and siting risk assesment
- Chemical compatibility and risk assessments
- Fire risk analysis and simulations
- Etc.

*In addition, multiple work and personnal safety related risk assessment, pre-start up safety reviews, work instructions etc.

Industrial safety consulting core services

COMPLIANCE & PERMITTING

Chemicals

Machinery

Pressure equipment

Environment

Safety audits, HSE DD

Explosion protection (ATEX)

Follow-up services

SAFETY MANAGEMENT

Safety Management Systems

Safety training

Functional safety

HSE Excellence (OE)

Human factors

Safety visualisation

RISK ASSESSMENTS

Process Hazard Analysis, PHA

Machinery safety risk assessment

Environmental risk assessment

Occupational safety evaluation

Food safety, HACCP

Consequence analysis & modelling

RAMS engineering

PROJECT HSE SERVICES

Project Safety Management (Safety Stepwise)

HSE Design review

Construction risk analysis

Site HSE management and supervising

Safety training

AFRY

Questions?

And if any questions later (material or career choices) feel free to contact AFRY's HSE team via Aurora Arkima


Making Future
28.9.2023
AFRY