



< Green Chemistry >

Moving Towards Safer Chemicals: Introduction



IAMC Toolkit

Innovative approaches for the Sound Management of Chemicals
and Chemical Waste



Introduction

Manufacturers and industrial users of chemicals require chemicals with properties to fulfill certain functions. At the same time, chemicals have intrinsic hazardous properties which can cause serious damage to physical equipment, the environment or human health (acute or chronic effects).

This presentation provides step-by-step guidance on how to compare chemicals with respect to their risks and substitute with safer alternatives.

Specifically, the presentations shows how to assess the intrinsic hazards of chemicals, compare different chemicals on the basis of their chemical hazards, as well as functional and economic performance.

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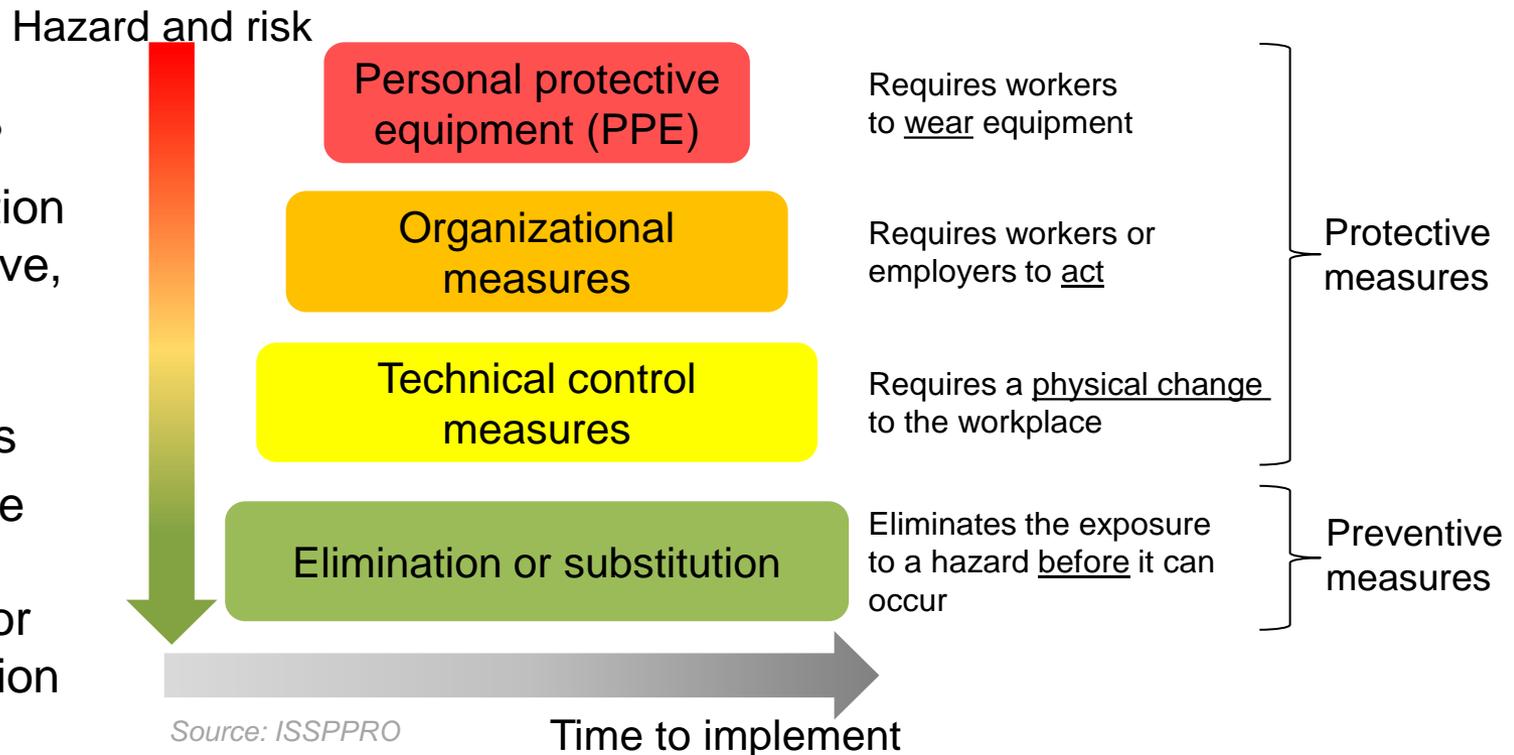
Motivation

Substitution: The First Step in Risk Reduction

Chemicals have intrinsic hazardous properties which can cause serious damage to physical equipment, the environment or human health (acute or chronic effects). If elimination is not a possibility, substitution of a hazardous chemical should be the first step to reduce risk to human health environment.

What is substitution?

- The transition to alternative, safer chemical substances
- An effective preventive measure for risk reduction



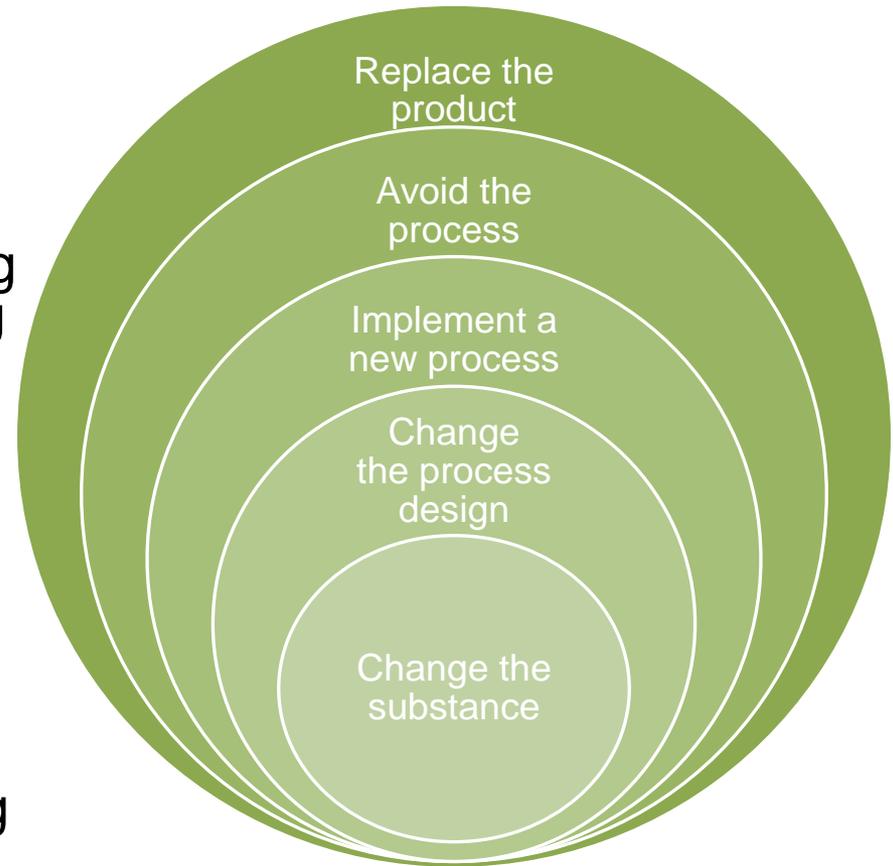
Source: ISSPPRO

Why Substitute?

- **Improve health and safety:** Substitution of hazardous chemicals is a key preventive measure to reduce risks to the environment, workers, consumers and public health as well as to minimize the risk of major accidents.
- **Comply with laws, regulations and value chain requirements:** International regulations and value chains require companies to disclose more information about chemical products in the supply chain, avoid certain chemicals and use safer alternatives.
- **Improve market acceptance of products:** Innovation and proactive elimination of hazardous chemicals can differentiate products and add value for customers.
- **Reduce costs:** Substitution can eliminate exposure to hazardous chemicals, thereby reducing the risks of chemical accidents, the costs of technical control measures and the costs for storage and disposal.

Elimination and Substitution at Different Levels

- **Replace the product** by an alternative which is produced with lower amounts of hazardous substances or none at all.
- **Avoid the process**, e.g. by changing the design of a product and making certain steps redundant.
- **Implement a new process**, e.g. by replacing chemical processes by mechanical ones.
- **Change the design of the process**, e.g. by using closed systems to reduce exposure and emissions.
- **Change the substance** by replacing the hazardous chemical by a less harmful alternative.
⇒ **Chemical substitution**



Source: ISSPPRO

Key Terminology

GHS (Globally Harmonized System of Classification and Labelling of Chemicals)

- Standardized international system created by the United Nations to harmonize the classification and hazard communication of chemical substances and mixtures

Hazard classification

- The GHS comprises three major hazard groups:
 - Physical hazards, health hazards and environmental hazards
- Each hazard group consists of classes and categories (sub-sections of classes).

The safety data sheet (SDS) includes:

- Hazard classification and hazard statements which are the starting point for risk assessments
- Information on the safe storage, handling, transportation and final disposal of the chemical

Refer to [TRP 2](#), [D11_1](#) and [D11_2](#) for more information on GHS classification and labelling as well as on safety data sheets.



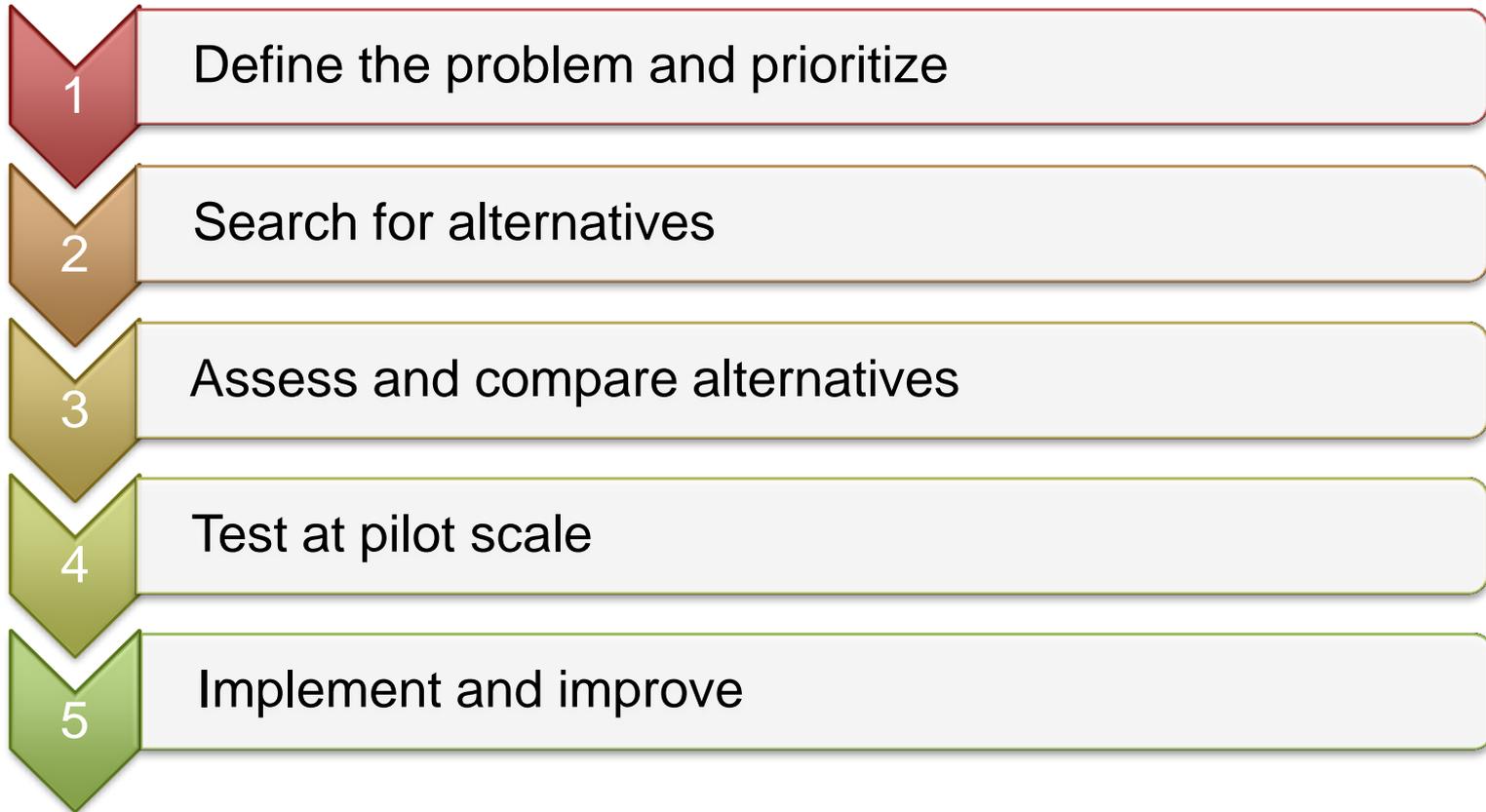
[D11_1 Chemical classification and labelling](#)



[D11_2 SDS](#)

Steps for Moving Towards Safer Chemicals

Steps for Moving Towards Safer Chemicals



Step 1: Define the Problem and Prioritize

Identify and prioritize chemicals to be substituted based on the following activities:

- Ensure that an up-to-date inventory of chemicals is available.
- Describe hazards arising from the chemicals, the functions they perform and how their use might harm workers, public health and the environment.
- Identify chemicals impacted by existing or potential regulations. Regulated chemicals can be found at:
[SUBSPORT List of Lists Database](#)
- Identify chemicals with high risks used in the company and consider substitution as an option for risk reduction.
⇒ The Responsible Production Toolkit has a risk matrix tool that can be used for this purpose.
- Possible criteria for prioritizing include risk level, hazard, regulation potential and marketability of the product.

Step 2: Search for Alternatives

This step provides an overview of possible alternatives based on the following activities:

- Search for alternatives within your company.
- Ask your supplier to formulate safer alternatives.
- Contact authorities, professional associations, NCPCs, NGOs, trade unions, suppliers, manufacturers, universities or consultancies.
- Consider material or process changes to eliminate hazardous chemicals.
- Search for relevant case studies targeting similar applications on knowledge repositories (e.g. [OECD SAA Toolbox](#), [SUBSPORT](#), [IFCS](#)).
- Consider collaborating with companies facing similar challenges.
- Partner with value chain actors to develop a new product for undeveloped and uncontested markets.

Step 3: Assess and Compare Alternatives

- Take an informed decision on possible alternatives by considering:
 - The technical, functional and performance requirements of the chemical
 - The fixed and operating costs as well as revenues expected from the substitution
 - The risk to the safety and health of workers in the supply chain, society and the environment
- Assess and compare the hazards using any of the tools (e.g. the [GHS Column Model](#)) presented in the following section. A description of many useful tools can be found in the [OECD SAA Toolbox](#).
- Compare the alternatives based on their technical, economic and safety performance (e.g. by using the German [TRGS 600](#) summary table).
- Select the best option according to safety (workers and consumers), environmental impact, technical performance as well as costs and revenues. Refer to the Methodology 'Select Options' for guidance on selecting the best option for the company.



[B14_1_Select options](#)

Step 4: Test at Pilot Scale

Before switching over completely to an alternative, consider testing the alternative on a smaller pilot scale first.

- Identify how the risks change. Evaluate required changes in protective measures.
- Specify how the alternative will affect functional performance. Ensure that the alternative is cost-effective and its supply is stable and secure.
- Identify any technical or organizational changes required.
- Identify and address the training needs of workers and other stakeholders to use the alternative safely and effectively.
- Actively integrate workers and other stakeholders in implementing and assessing the tests of the alternative.
- Define how success will be evaluated in terms of functional performance, economic feasibility and impact on the environment, workers and consumers.
- Be prepared to monitor unforeseen consequences.

Step 5: Implement and Improve

Implement the alternative at the commercial level, record the impacts and continuously improve the goal of substitution.

- Develop a plan for commercial implementation incorporating lessons learned from pilot testing. Identify additional measures.
- Communicate changes to workers and other stakeholders, such as suppliers, downstream users and consumers.
- Continuously collect feedback from stakeholders to improve the substitution process.
- Monitor and improve the performance of the implemented alternative with respect to economic, technical, environmental and health and safety impacts.
- Promote and disseminate the results and establish links to national and international initiatives, ecolabels or sustainability certificates.

Refer to 'Methodology' for additional guidance on implementing and continuously improving innovation activities.



[B1 Methodology](#)

Tools for Selecting Alternatives

Tools for Selecting Safer Chemicals (1)

GHS Column Model

- + Free, easy to use as it is based on SDSs
- + Includes chemical and process hazards
- Relies on GHS classification provided in SDSs (which could be incorrect)

[GHS Column Model](#)

Green Screen for Safer Chemicals

- + Focus on hazard reduction
- ± Many parameters and indicators used
- Expert knowledge and training required

[Green Screen software](#)

Tools for Selecting Safer Chemicals (2)

Pollution Prevention Options Analysis System (P2OASys)

- + Chemicals, processes or technologies can be compared
- + Facilitates a more comprehensive and systematic approach to potential hazards (chemical, environment, health)
- Expertise and dedication required

[TURI P2OASys](#)

Priority-Setting Guide (PRIO)

- ± Web-based
- + Provides guidance for decision-making and a database
- Based on R-phrases and covers only the 7,000 chemicals classified in the EC CLP regulations

[Kemi PRIO](#)

GHS Column Model

GHS Column Model

The GHS Column Model:

- Compares the hazards of different substances and mixtures under specific process conditions
- Uses the classification of chemicals according to GHS and uses **hazard statements** and **process conditions** as input
- Is especially suitable for small and medium-sized enterprises (SMEs)
- Drawbacks:
 - Relies on correct safety data sheets
 - Mixtures are not assessed based on their components but on their overall classification.

Note: The GHS Column Model can be used to select less hazardous chemicals to formulate safer mixtures.

GHS Column Model Methodology: Example of Classification Criteria

	Hazards			Hazards becoming effective		
1 Risk	2a Acute health hazards (single exposure)	2b Chronic health hazards (repeated exposure)	3 Environmental hazards	4 Physico-chemical hazards (fire, explosion, corrosion)	5 Hazards from release behaviour	6 Process-related hazards
Very high	Acutely toxic, Cat. 1 and 2. (H300, H310, H330)	Carcinogenic substances/mixtures, Cat. 1A/1B (AGS: K1, K2, H350, H350i)	Substances/mixtures acutely hazardous to the aquatic environment, Cat. 1 (H400)	Unstable explosive substances/mixtures (H200)	Liquids with a vapour pressure of > 250 hPa (mbar) (e.g. dichloromethane)	Open processing
High	Acutely toxic substances/mixtures, Cat. 3 (H301, H311, H331)	Carcinogenic substances/mixtures, Cat. 2 (AGS: K3, H351)	Substances hazardous to the ozone layer (H420)	Flammable aerosols, Cat. 1 (H222)	Liquids with a vapour pressure of 50-250 hPa (mbar) (e.g. methanol)	Partially open design, process related opening with simple extraction, open with simple extraction
Medium	Acutely toxic substances/mixtures, Cat. 4 (H302, H312, H332)	Substances/mixtures toxic to reproduction, Cat. 2 (AGS: R ₃ , R ₃ , H361, H361f, H361d, H361fd)	Substances/mixtures chronically hazardous to the aquatic environment, Cat. 3 (H412)	Flammable aerosols, Cat. 2 (H223)	Liquids with a vapour pressure of 10-50 hPa (mbar), with the exception of water (e.g. toluene)	Closed processing with possibilities of exposure, e.g. during filling, sampling or cleaning
Low	Skin-irritant substances/mixtures (H315)	Substances chronically harmful in other ways (no H-phrase, but still a hazardous substance!)	Substances/mixtures chronically hazardous to the aquatic environment, Cat. 4 (H413)	Self-reactive substances/mixtures, Type G (no H-phrase)	Liquids with a vapour pressure of 2-10 hPa (mbar) (e.g. xylene)	Closed design, tightness ensured, partially closed design with integrated extraction, etc
Negligible	Safe substances based on experience (e.g. water, paraffin, etc.)		Substances/mixtures not hazardous to the aquatic environment	Non-combustible or only not at all readily flammable substances/mixtures (flash point of liquids > 100 °C, no H-phrase)	Liquids with a vapour pressure of < 2 hPa (mbar) (e.g. ethylene glycol)	Process index 0,25 according to TRGS 500

How to Use the GHS Column Model

1. Make a copy of the table for:
 - Every hazardous substance
 - Every potential alternative
2. Collect information about the substances and products (see safety data sheets).
3. Mark the relevant information, including process-specific data, in the table.
4. Compare the columns (not the rows).
 - *Note:* Acute health hazards and chronic health hazards are to be treated as a single column.
5. Prioritize the hazards according to process-specific exposure scenarios.

Interpreting the Results

The objective is to reduce risks, not just to eliminate the hazard source. The result is obvious if the alternative rates better in all five columns.

⇒ This does not happen often!

Often alternatives will have better ratings in some columns and worse in others. Consider the following in order to evaluate the overall risk:

- Assess which hazards are more important for your situation, for example:
 - If ignition sources cannot be excluded in a process, the fire and explosion hazards (column 4) together with exposure potential (columns 5-6) will become more important.
 - If significant amounts of waste chemicals are generated, the environmental hazards will become more important.
- Assess the hazards (columns 2-4) and the hazards becoming effective (columns 5-6) together
 - Example: A potential alternative may have a lower hazard in one category. However, if the alternative has a hazard with a high probability of becoming effective in this situation (according to columns 5-6), the alternative could increase the overall risk.

⇒ The alternative should result in significant improvements to the environment, human health and safety.

Data Sources for the GHS Column Model

The information required for the GHS Column Model can be found in the safety data sheet of a substance. To ensure the validity and accuracy of the data contained in the SDS:

- Request GHS compliant SDSs from the suppliers and ensure they are up-to-date.
- Extended SDSs (E-SDSs) are available for some chemicals and provide additional data on exposure scenarios and risk management measures.
- Confirm the classification contained in the SDS by cross-referencing with competent authorities:
ECHA – [Information on Chemicals](#)

Example: Solvent Use in an Open Process with Simple Extraction (1)

Current situation: Benzene is currently being used as a solvent in a partially open process with simple extraction. Xylene is being considered as an alternative.

The following selected hazard data is collected from the SDS:

Benzene (Signal word = Danger)		Xylene (Signal word = Warning)	
Hazard class	Hazard statement	Hazard class	Hazard statement
Flam. Liq. 2	H225 (highly flammable liquid and vapour)	Flam. Liq. 2	H226 (flammable liquid and vapour)
Asp. Tox. 1	H304 (may be fatal if swallowed and enters airways)	Acute Tox. 4	H312 (harmful in contact with skin) H332 (harmful if inhaled)
Muta. 1B	H340 (may cause genetic defects)	Skin Irrit. 2	H315 (causes skin irritation)
Carc. 1A	H350 (may cause cancer)		
STOT RE 1	H372 (causes damage to organs through prolonged or repeated exposure)		

Example: Solvent Use in an Open Process with Simple Extraction (2)

Hazard category	Benzene (Signal word = Danger)		Xylene (Signal word = Warning)	
	H-Statement	Risk level	H-Statement	Risk level
Acute health	H304, H315, H319	Low	H312, H332	Medium
Chronic health	H340 and H350	Very high	Not classified	Low
Environmental	(H412)	Medium	WKG2	Medium
Physio-chemical	H225	High	H226	Medium
Release behaviour	Vapour pressure 50-250 hPa, between 0 °C and 40 °C	High	Liquids with a vapour pressure of 2-10 hPa	Low
Process related	Partially open process with simple extraction	High	Partially open process with simple extraction	High

Example: Benzene Used in a Partially Open Process

1 Risk	2a Acute health hazards (single exposure)	2b Chronic health hazards (repeated exposure)	3 Environmental hazards ¹⁾	4 Physico-chemical hazards (fire, explosion, corrosion et al.) ²⁾ H-phrases marked in blue occur several times.	5 Hazards from release behaviour	6 Process-related hazards
very high	<ul style="list-style-type: none"> Acutely toxic substances/mixtures, Cat. 1 and 2 (H300, H310, H330) Substances/mixtures that in contact with acids liberate highly toxic gases (EUH032) 	<ul style="list-style-type: none"> Carcinogenic substances/mixtures, Cat. 1A/1B (AGS: K1, K2, H350, H350I) Carcinogenic activities or processes according to TRGS 906 Substances/mixtures mutagenic to germ cells, Cat. 1A or 1B (AGS: M1, M2, H340) 	<ul style="list-style-type: none"> Substances/mixtures acutely hazardous to the aquatic environment, Cat. 1 (H400) Substances/mixtures chronically hazardous to the aquatic environment, Cat. 1 (H410) Substances/mixtures of German Water Hazard Class WGK 3 PBT substances vPvB substances 	<ul style="list-style-type: none"> Unstable explosive substances/mixtures (H200) Explosive substances/mixtures/products, divisions 1.1 (H201), 1.2 (H202), 1.3 (H203), 1.4 (H204), 1.5 (H205) and 1.6 (without H-phrase) Flammable gases, Cat. 1 (H220) and Cat. 2 (H221) Flammable liquids, Cat. 1 (H224) Self-reactive substances/mixtures, Types A (H240) and B (H241) Organic peroxides, Types A (H240) and B (H241) Pyrophoric liquids or solids, Cat. 1 (H250) Substances/mixtures which in contact with water emit flammable gases, Cat. 1 (H260) Oxidising liquids or solids, Cat. 1 (H271) 	<ul style="list-style-type: none"> Gases Liquids with a vapour pressure > 250 hPa (mbar) (e.g. dichloromethane) Dust-generating solids Aerosols 	<ul style="list-style-type: none"> Open processing Possibility of direct skin contact Large-area application Process index 4 according to TRGS 500 (open design or partially open design, natural ventilation)
high	<ul style="list-style-type: none"> Acutely toxic substances/mixtures, Cat. 3 (H301, H311, H331) Substances/mixtures toxic in contact with eyes (EUH070) Substances/mixtures that in contact with water or acids liberate toxic gases (EUH029, EUH031) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 1: Organ damage (H370) Skin sensitising substances/mixtures (H317, Sh) Substances/mixtures that sensitise the respiratory organs (H334, Sa) Substances/mixtures corrosive to the skin, Cat. 1A (H314) 	<ul style="list-style-type: none"> Substances/mixtures toxic to reproduction, Cat. 1A or 1B (AGS: R₁, R₁, R₂, R₂, H360, H360F, H360D, H360FD, H360Fd, H360Df) Carcinogenic substances/mixtures, Cat. 2 (AGS: K3, H351) Substances/mixtures mutagenic to germ cells, Cat. 2 (AGS: M3, H341) Substances/mixtures with specific target organ toxicity (repeated exposure), Cat. 1: Organ damage (H372) 	<ul style="list-style-type: none"> Substances/mixtures chronically hazardous to the aquatic environment, Cat. 2 (H411) Substances hazardous to the ozone layer (H420) 	<ul style="list-style-type: none"> Flammable aerosols, Cat. 1 (H222) Flammable liquids, Cat. 2 (H225) Flammable solids, Cat. 1 (H228) Self-reactive substances/mixtures, Types C and D (H242) Organic peroxides Types C and D (H242) Self-heating substances/mixtures Cat. 1 (H251) Substances/mixtures which in contact with water emit flammable gases, Cat. 2 (H261) Oxidising gases, Cat. 1 (H270) Oxidising liquids or solids, Cat. 2 (H272) Substances/mixtures with certain properties (EUH001, EUH006, EUH014, EUH018, EUH019, EUH044) 	<ul style="list-style-type: none"> Liquids with a vapour pressure 50... 250 hPa (mbar) (e.g. methanol) 	<ul style="list-style-type: none"> Process index 2 according to TRGS 500 (partially open design, process-related opening with simple extraction, open with simple extraction)
medium	<ul style="list-style-type: none"> Acutely toxic substances/mixtures, Cat. 4 (H302, H312, H332) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 2: Possible organ damage (H371) Substances/mixtures corrosive to the skin, Cat. 1B, 1C (H314, pH ≥ 11,5, pH ≤ 2) Eye-damaging substances/mixtures (H318) Substances/mixtures with corrosive effect on respiratory organs (EUH071) Nontoxic gases that can cause suffocation by displacing air (e.g. nitrogen) 	<ul style="list-style-type: none"> Substances/mixtures toxic to reproduction, Cat. 2 (AGS: R₃, R₃, H361, H361f, H361d, H361fd) Substances/mixtures with specific target organ toxicity (repeated exposure), Cat. 2: Possible organ damage (H373) Substances/mixtures that can harm babies via their mothers' milk (H362) 	<ul style="list-style-type: none"> Substances/mixtures chronically hazardous to the aquatic environment, Cat. 3 (H412) Substances/mixtures of German Water Hazard Class WGK 2 	<ul style="list-style-type: none"> Flammable aerosols, Cat. 2 (H223) Flammable liquids, Cat. 3 (H226) Flammable solids, Cat. 2 (H228) Self-reactive substances/mixtures, Types E and F (H242) Organic peroxides, Types E and F (H242) Self-heating substances/mixtures, Cat. 2 (H252) Substances/mixtures which in contact with water emit flammable gases, Cat. 3 (H261) Oxidising liquids or solids, Cat. 3 (H272) Gases under pressure (H280, H281) Substances/mixtures corrosive to metals (H290) 	<ul style="list-style-type: none"> Liquids with a vapour pressure 10... 50 hPa (mbar), with the exception of water (e.g. toluene) 	<ul style="list-style-type: none"> Closed processing with possibilities of exposure, e.g. during filling, sampling or cleaning Process index 1 according to TRGS 500 (closed design, tightness not ensured, partially open design with effective extraction)
low	<ul style="list-style-type: none"> Skin-irritant substances/mixtures (H315) Eye-irritant substances/mixtures (H319) Skin damage when working in moisture Substances/mixtures with a risk of aspiration (H304) Skin-damaging substances/mixtures (EUH066) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 3: irritation of the respiratory organs (H335) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 3: drowsiness, dizziness (H336) 	<ul style="list-style-type: none"> Substances chronically harmful in other ways (no H-phrases, but still a hazardous substance) 	<ul style="list-style-type: none"> Substances/mixtures chronically hazardous to the aquatic environment, Cat. 4 (H413) Substances/mixtures of German Water Hazard Class WGK 1 	<ul style="list-style-type: none"> Not readily flammable substances/mixtures (flash point: 60... 100 °C, no H-phrases) Self-reactive substances/mixtures, Type G (no H-phrases) Organic peroxides, Type G (no H-phrases) 	<ul style="list-style-type: none"> Liquids with a vapour pressure 2... 10 hPa (mbar) (e.g. xylene) 	<ul style="list-style-type: none"> Process index 0,5 according to TRGS 500 (closed design, tightness ensured, partially closed design with integrated extraction, partially open design with highly effective extraction)
negligible	<ul style="list-style-type: none"> Safe substances on the basis of experience (e.g. water, paraffin and the like) 		<ul style="list-style-type: none"> Substances/mixtures not hazardous to the aquatic environment (NWG, former WGK 0) 	<ul style="list-style-type: none"> Non-combustible or only not at all readily flammable substances/mixtures (flash point of liquids > 100 °C, no H-phrases) 	<ul style="list-style-type: none"> Liquids with a vapour pressure < 2 hPa (mbar) (e.g. ethylene glycol) Non-dust-generating solids 	<ul style="list-style-type: none"> Process index 0,25 according to TRGS 500

Example: Xylene Used in a Partially Open Process

1 Risk	2a Acute health hazards (single exposure)	2b Chronic health hazards (repeated exposure)	3 Environmental hazards ¹⁾	4 Physico-chemical hazards (fire, explosion, corrosion et al.) ²⁾ H-phrases marked in blue occur several times.	5 Hazards from release behaviour	6 Process-related hazards
very high	<ul style="list-style-type: none"> Acutely toxic substances/mixtures, Cat. 1 and 2 (H300, H310, H330) Substances/mixtures that in contact with acids liberate highly toxic gases (EUH032) 	<ul style="list-style-type: none"> Carcinogenic substances/mixtures, Cat. 1A/1B (AGS: K1, K2, H350, H350f) Carcinogenic activities or processes according to TRGS 906 Substances/mixtures mutagenic to germ cells, Cat. 1A or 1B (AGS: M1, M2, H340) 	<ul style="list-style-type: none"> Substances/mixtures acutely hazardous to the aquatic environment, Cat. 1 (H400) Substances/mixtures chronically hazardous to the aquatic environment, Cat. 1 (H410) Substances/mixtures of German Water Hazard Class WGK 3 PBT substances vPvB substances 	<ul style="list-style-type: none"> Unstable explosive substances/mixtures (H200) Explosive substances/mixtures/products, divisions 1.1 (H201), 1.2 (H202), 1.3 (H203), 1.4 (H204), 1.5 (H205) and 1.6 (without H-phrases) Flammable gases, Cat. 1 (H220) and Cat. 2 (H221) Flammable liquids, Cat. 1 (H224) Self-reactive substances/mixtures, Types A (H240) and B (H241) Organic peroxides, Types A (H240) and B (H241) Pyrophoric liquids or solids, Cat. 1 (H250) Substances/mixtures which in contact with water emit flammable gases, Cat. 1 (H260) Oxidising liquids or solids, Cat. 1 (H271) 	<ul style="list-style-type: none"> Gases Liquids with a vapour pressure > 250 hPa (mbar) (e.g. dichloromethane) Dust-generating solids Aerosols 	<ul style="list-style-type: none"> Open processing Possibility of direct skin contact Large-area application Process index 4 according to TRGS 500 (open design or partially open design, natural ventilation)
high	<ul style="list-style-type: none"> Acutely toxic substances/mixtures, Cat. 3 (H301, H311, H331) Substances/mixtures toxic in contact with eyes (EUH070) Substances/mixtures that in contact with water or acids liberate toxic gases (EUH029, EUH031) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 1: Organ damage (H370) Skin sensitising substances/mixtures (H317, H318) Substances/mixtures that sensitise the respiratory organs (H334, H335) Eye-damaging substances/mixtures (H318) 	<ul style="list-style-type: none"> Substances/mixtures toxic to reproduction, Cat. 1A or 1B (AGS: R1, R1, R2, R2, H360, H360F, H360FD, H360Fd, H360Df) Carcinogenic substances/mixtures, Cat. 2 (AGS: K3, H351) Substances/mixtures mutagenic to germ cells, Cat. 2 (AGS: M3, H341) Substances/mixtures with specific target organ toxicity (repeated exposure), Cat. 1: Organ damage (H372) 	<ul style="list-style-type: none"> Substances/mixtures chronically hazardous to the aquatic environment, Cat. 2 (H411) Substances hazardous to the ozone layer (H420) 	<ul style="list-style-type: none"> Flammable aerosols, Cat. 1 (H222) Flammable liquids, Cat. 2 (H225) Flammable solids, Cat. 1 (H228) Self-reactive substances/mixtures, Types C and D (H242) Organic peroxides Types C and D (H242) Self-heating substances/mixtures Cat. 1 (H251) Substances/mixtures which in contact with water emit flammable gases, Cat. 2 (H261) Oxidising gases, Cat. 1 (H270) Oxidising liquids or solids, Cat. 2 (H272) Substances/mixtures with certain properties (EUH001, EUH006, EUH014, EUH018, EUH019, EUH044) 	<ul style="list-style-type: none"> Liquids with a vapour pressure 50 ... 250 hPa (mbar) (e.g. methanol) 	<ul style="list-style-type: none"> Process index 2 according to TRGS 500 (partially open design, process-related opening with simple extraction, open with simple extraction)
medium	<ul style="list-style-type: none"> Acutely toxic substances/mixtures, Cat. 4 (H302, H312, H332) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 2: Possible organ damage (H371) Substances corrosive to the skin (H314, pH < 11.5, pH > 2) Substances/mixtures with corrosive effect on respiratory organs (EUH071) Non-toxic gases that can cause suffocation by displacing air (e.g. nitrogen) 	<ul style="list-style-type: none"> Substances/mixtures toxic to reproduction, Cat. 2 (AGS: R3, R3, H361, H361f, H361d, H361fd) Substances/mixtures with specific target organ toxicity (repeated exposure), Cat. 2: Possible organ damage (H373) Substances/mixtures that can harm babies via their mothers' milk (H362) 	<ul style="list-style-type: none"> Substances/mixtures chronically hazardous to the aquatic environment, Cat. 3 (H412) Substances/mixtures of German Water Hazard Class WGK 2 	<ul style="list-style-type: none"> Flammable aerosols, Cat. 2 (H223) Flammable liquids, Cat. 2 (H225) Flammable solids, Cat. 2 (H228) Self-reactive substances/mixtures, Types E and F (H242) Organic peroxides, Types E and F (H242) Self-heating substances/mixtures, Cat. 2 (H252) Substances/mixtures which in contact with water emit flammable gases, Cat. 3 (H261) Oxidising liquids or solids, Cat. 3 (H272) Gases under pressure (H280, H281) Substances/mixtures corrosive to metals (H290) 	<ul style="list-style-type: none"> Liquids with a vapour pressure 10 ... 50 hPa (mbar), with the exception of water (e.g. toluene) 	<ul style="list-style-type: none"> Closed processing with possibilities of exposure, e.g. during filling, sampling or cleaning Process index 1 according to TRGS 500 (closed design, tightness not ensured, partially open design with effective extraction)
low	<ul style="list-style-type: none"> Skin-irritant substances/mixtures (H315) Eye-irritant substances/mixtures (H319) Skin damage when working in moisture Substances/mixtures with a risk of aspiration (H304) Skin-damaging substances/mixtures (EUH066) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 3: Irritation of the respiratory organs (H335) Substances/mixtures with specific target organ toxicity (single exposure), Cat. 3: drowsiness, dizziness (H336) 	<ul style="list-style-type: none"> Substances chronically harmful in other ways (no H-phrases, but still a hazardous substance!) 	<ul style="list-style-type: none"> Substances/mixtures chronically hazardous to the aquatic environment, Cat. 4 (H413) Substances/mixtures of German Water Hazard Class WGK 1 	<ul style="list-style-type: none"> Not readily flammable substances/mixtures (flash point > 60 ... 100 °C, no H-phrases) Self-reactive substances/mixtures, Type G (no H-phrases) Organic peroxides, Type G (no H-phrases) 	<ul style="list-style-type: none"> Liquids with a vapour pressure 2 ... 10 hPa (mbar) (e.g. xylene) 	<ul style="list-style-type: none"> Process index 0,5 according to TRGS 500 (closed design, tightness ensured, partially closed design with integrated extraction, partially open design with highly effective extraction)
negligible	<ul style="list-style-type: none"> Safe substances on the basis of experience (e.g. water, paraffin and the like) 		<ul style="list-style-type: none"> Substances/mixtures not hazardous to the aquatic environment (NWG, former WGK 0) 	<ul style="list-style-type: none"> Non-combustible or only not at all readily flammable substances/mixtures (flash point of liquids > 100 °C, no H-phrases) 	<ul style="list-style-type: none"> Liquids with a vapour pressure < 2 hPa (mbar) (e.g. ethylene glycol) Non-dust-generating solids 	<ul style="list-style-type: none"> Process index 0,25 according to TRGS 500

Example: Solvent Use in an Open Process with Simple Extraction (3)

Comparison of inherent hazards:

- Health hazard: benzene has a very high risk level
- Environmental: both chemicals have medium risk levels
- Physico-chemical: benzene has a high fire and explosion risk

Hazards becoming effective:

- Benzene has a high exposure potential under the current process conditions

Result:

- Substituting benzene with xylene in this open process with simple extraction significantly reduces the risk to workers' health and safety.

Key Messages

- Manufacturers and industrial users of chemicals require chemicals with properties to fulfill certain functions.
- Chemicals have intrinsic hazardous properties which can cause serious damage to physical equipment, the environment or human health (acute or chronic effects)
- Motivation for substitution include improving health & safety, complying with regulations and value chain requirements and accessing new markets
- There are many tools of differing complexity and user-friendliness to support in selecting safer chemicals, e.g. GreenScreen, GHS Column Model
- Companies will likely face trade-offs in health, safety, costs, and functionality when manufacturing or applying chemicals

Where to Find More Information

- The OECD Substitution and Alternatives Assessment Toolbox for tools and resources to support chemical substitution
<http://www.oecdsaatoolbox.org>
- Substitution Support Portal list of links to search for alternative chemical substances
http://www.subsport.eu/links#hazard_identification
- IFA guidance on The GHS Column Model 2014 to assist with substitute assessment
http://www.dguv.de/medien/ifa/en/praghs_spaltenmodell/ghs_column_model.pdf
- ECHA Information on Chemicals portal to provide information on the chemicals manufactured and imported in Europe, covering their hazardous properties, classification, labelling and safe use
<http://echa.europa.eu/information-on-chemicals>

Sources

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- OSHA (2003), Factsheet 34: Elimination and substitution of dangerous substances, <https://osha.europa.eu/en/tools-and-publications/publications/factsheets/34/viewSoerensen>
- SUBSPORT (Substitution Support Portal), Moving towards safer alternatives
 - Case study database: www.subsport.eu/case-stories-database
 - Tools: <http://www.subsport.eu/substitution-tools>
- US Department of Labor, Occupational Safety & Health Administration, Transitioning to Safer Chemicals: A Toolkit for Employers and Workers:
https://www.osha.gov/dsg/safer_chemicals/index.html

Images

- ISSPPRO GmbH, Germany, 2015

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