REPORT STM SECTOR

NATURVÅRDSVERKET, SWEDISH ENVIRONMENTAL PROTECTION AGENCY

Determination of potential BAT candidates, Surface Treatment of Metal and Plastics

PROJECT NUMBER 13010306

INITIAL REVIEW

20 APRIL 2020

SWECO ENVIRONMENT

repo001.docx 2015-10-05

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Appendix

1 BAT candidate Chemical Management System
Chemical management and safe use of chemicals (Finland)

2 BAT candidate Chemical and raw material inventory
Handling and storage of chemicals (Finland)

3 BAT candidate Management of new chemicals, approval process

4 BAT candidate Closed cycle
Retardation plant for recycling of Al-Anodizing process solution (Finland)
Recirculation of treated wastewater back to process (Finland)

5 BAT candidate Substitution
Utilization of installation specific substitution scenarios (Estonia)

6 BAT candidate Process mapping of hazardous substances
Utilization of installation specific exposure scenarios (Estonia)

7 BAT candidate Waste Water Treatment
Closed process (Sweden)

1 Background

The EU funded INTERREG-project “Hazardous industrial chemicals in the IED BREFs (HAZBREF)” (2017–2020) has the objective to increase the knowledge of the industrial sources and measures to reduce the release of hazardous chemicals. The aim is to improve or complement how these substances are addressed in IED BREFs by inter alia making better and more systematic use of data from various EU regulatory frameworks (namely REACH, Water Framework Directive). This will contribute to reducing the use of hazardous substances in industrial installations and diminish the emissions to the environment. (https://www.syke.fi/projects/hazbref)

To increase the knowledge on the management of hazardous chemicals in industries case studies were and is carried out in three different sectors: Textile (TXT), Surface Treatment of Metals and Plastics (STM) and Chemical (CHEM). The case studies in the chemical sector covers production of Inorganic Fertilizers and production of Polymers. The aim of the case studies was to analyse current best practices of environmental permitting and chemical management and to identify options for prevention and reduction of emissions.

The Swedish Environmental Protection Agency participate in the international cooperation called HAZBREF (Hazardous industrial chemicals in the IED BREFs) concerning the Baltic Sea. To support that work, the Swedish Environmental Protection Agency has initiated a project to identify potential BAT candidates for prevention or reduction of hazardous substances emissions within the industrial areas “Surface Treatment of Metals and Plastics”, “Large Volume Inorganic chemicals (fertilisers)” and “Production of Polymers”.

1.1 The assignment

On behalf of The Swedish Environmental Protection Agency, Sweco was assigned to the project to identify potential BAT candidates for prevention or reduction of hazardous substances emissions within the industrial areas “Surface Treatment of Metals and Plastics”, “Large Volume Inorganic chemicals (fertilisers)” and “Production of Polymers” according to the agreement quoted below.

“*The supplier shall provide consultancy support for chemical and engineering consultants in the industrial sectors Surface Treatment of Metals and Plastics (STM) and Large Volume Inorganic chemicals (fertilizers), Polymers (CHEM).*

The assignment consists of identifying and proposing BAT candidates with regard to used substances with negative health and environmental characteristics in each of the industrial sectors.

Necessary information must primarily be obtained from case studies carried out at facilities.

Other information can, for example, be obtained from other parts of the Hazbref project, from existing documents concerning current BATs and other literature.

The result shall be presented in the form of a report for each of the industrial sectors (STM and CHEM). The assignment means that cooperation with actors with different interests can occur."

This report covers the Surface treatment industries.

2 Concepts and definitions

To avoid or reduce emissions of hazardous substances a number of approaches should be used. These approaches cover the choice of production process with raw materials and chemicals, measures within an existing production process, to the end of pipe abatement techniques.

In this report we group these approaches within three main categories described below.

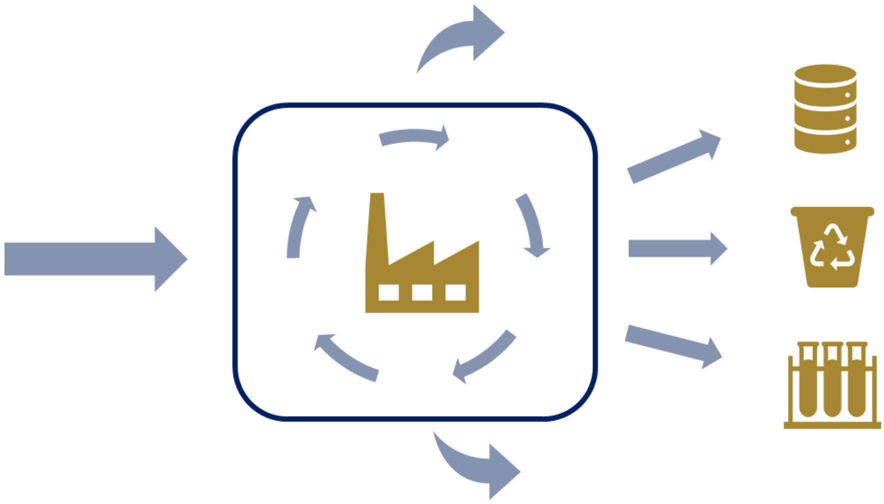


Figure 1 Illustration of different types of measures related to the chemical handling

Examples of important measures related to the chemical handling are named below and described in chapter 4.

PREVENTIVE
Preventive measures address new processes, chemicals or raw materials to be introduced at the facility.

The aim is (1) to avoid usage or production of hazardous substances within the production process or at the industrial facility (2) to limit the usage or production of hazardous substances and (3) to enable efficient preventive measures to avoid or reduce emissions.

To achieve this, it is necessary to obtain and keep enough relevant knowledge and capacity covering:

- development of new products and production processes
- the relevant hazardous substances, approval and management of new chemicals

- chemical and raw material inventory,
- control systems,

PROCESS RELATED

Process related measures mainly relates to improve an existing production process, with support systems, within the facility. Some of these process related measures could also be used as preventive measures as described above.

Examples of process related measures are:
- process mapping of hazardous substances;
- improvements in the existing process;
- substitution chemical storage and transportation and
- closed cycle processes.

END OF PIPE

End of pipe measures are the last option in avoiding emissions of hazardous substances.

Examples of end-of-pipe measures are waste stream management, waste and hazardous waste management, pre-treatment of waste streams, gas and water treatment and emergency preparedness.

3 Method

The approach to gather information and descriptions of best available practise and best available techniques was to utilize:
- The case-studies produced within the HazBREF project available at the time;
- Approaching the industries and organisations;
- SWECO's expertise and experiences;
- List of hazardous substances relevant for the sectors chemicals and
- information available in the current BREF-documents and other descriptions of BAT available.

- The following Case Studies were available;
- Case study Finland, No5
- Case study Estonia, No6
- Case studies Poland, No7, No8
- Case study (part of) Germany, No9

The information in the available case-studies were used and summarised in the report.

The general approaches to the chemical management as well as detailed descriptions of parts thereof described in this report is based on SWECO's experience from several industries, many within the chemical sectors, together with information from the HazBREF case studies. This is also applicable to the STM sector.

4 Best Practice Chemical Management and BAT-candidates

A developed and integrated chemical management is a key tool for a chemical user to reduce its emissions of hazardous and other environmentally harmful substances. Through a systematically approach involving all parts of the industry. The main focus is on the operation of surface treatment plants. But the issue is also important in the development of new processes and in the construction of new plants. It will result in reduced emissions as well as costs for abatement through end-of-pipe solutions or waste management, at and upstream and downstream the installations.

Chemical management could and should address all relevant chemicals and substances. However, the description below is addressing specifically hazardous substances.

In this chapter the concepts described in chapter 2 is addressed.

4.1 Chemical Management System

A systematic approach regarding chemicals and substances covering several integrated administrative and practical measures is, when fully implemented, a Chemical Management System (CMS). The purpose of the CMS is to get good control of chemicals and hazardous substances at the site, increase the knowledge of the characteristics, risks and impact and improve the processes to reduce emissions of hazardous substances.

A general Chemical Management System follows the classical PDCA-cycle[1] as any management system: Plan, Do, Check, Act.

It is important to have an established Plan for the Chemical work to answer the following questions:

- What chemicals or substances are ok/not ok to use on the site?
- Compliance with relevant legislation
- How shall reduction of hazardous substances be reached?
- How many non-wanted chemicals can be substituted?

When objectives and plans are established <<plan>>, the planed measures are taken <<do>>. These measures could cover update of routines, improvements of knowledge of substances and their use and flow within the production process, monitoring of emissions etc.

The outcomes of the measures are then <<checked and studied>>, to be a base for identifying the actions needed <<act>> to improve the process when returning to a new planning phase.

The Chemical Management System is described more in detail as a BAT-candidate in Appendix 1.

[1] Sometimes called PDSA-cycle where S denotes *study*. Also see the Deming and Shewhart cycles and “Lean production”

4.2 PREVENTIVE MEASURES

Preventive measures address new processes, chemicals or raw materials to be introduced at the facility.

The aim is (1) to avoid usage or production of hazardous substances within the production process or at the industrial facility (2) to limit the usage or production of hazardous substances and (3) to enable efficient preventive measures to avoid or reduce emissions.

In order to carry out the systematic approach with an aim of reducing emissions of hazardous substances, a good knowledge of the used or produced chemicals and hazardous substances are needed to set up guidelines and measures to reduce emissions of hazardous substances.

In sections 4.2.1- 4.2.3 below the main components of prevention is described.

4.2.1 Chemical and raw material inventory and Chemical handling system

In order to know which hazardous substances are present at the site, a chemical inventory is needed. It is important to include all types of chemicals and raw materials used in all processes and activities at the site. That is to include chemicals used for example in maintenance, cleaning, firefighting in all parts at the site including chemicals used by contractors and others conducting activities at the site.

In a chemical inventory, there must be information regarding product name, information on ingredients, CAS numbers, hazard statement, quantity stored and where the chemical is stored. The information in the chemical list needs to be searchable and there must be routines in place to update the information in the chemical list regularly.

Main part of the information needed is addressed from the material safety data sheet (MSDS). Good routines to handle new and updated MSDS is crucial to have an up to date and reliable Chemical database. These routines should involve on-site handling and update, communication with suppliers on how MSDS are delivered. The simplest scenario is distribution by paper along with the physical product. Manual handling and large risks of information lost on site and never reaching the right responsible person comes with paper distribution. A more efficient way is through established automatically processed digital distribution of MSDSs connected to the sales/purchase systems.

An example of a Chemical and raw material inventory is described more in detail as a BAT-candidate in Appendix 2.

4.2.2 Management of new chemicals

Hazardous substances may be present in chemical products used in the manufacturing process itself, such as raw materials or process and additive chemicals. The hazardous substance could be an active component or as an unintentional contamination. There could also be hazardous substances in chemical products and raw materials used in supporting activities within the industrial installation, such as maintenance, cleaning, laboratories, firefighting and fire-protection, etc.

Development of new production processes

Most companies have processes for introducing new products with focus on the financial and/or quality aspects of the new product, so called NPI-process, New Product Introduction.

When developing new products or new production processes there is a great opportunity to also improve the product and the process from an environmental perspective, eco design. A key aim of eco design is to reduce to a minimum the overall environmental impact of a product. It refers to innovative design solutions that consider the entire lifecycle – from the extraction of raw materials to production, distribution and use – all the way to recycling, “reparability”, and disposal.

In the NPI-process there can be an objective to improve the handling of chemicals and reduce the emissions of hazardous substances. If there are hazardous substances in the chemical products or possibly formed in the new product or process, you need to ensure that you have control over where these substances end up to minimize uncontrolled emissions to air, water or soil.

If hazardous substances are included or formed in the new process, one must acquire knowledge of the hazardous substances, how they react and where they end up. In a mass balance with focus on hazardous substances for the new product or production process the distribution of the hazardous substance in the products, waste, wastewater, emissions to air etcetera, should be calculated. Transformation of hazardous substances to other substances or formation of new hazardous substances should be considered in the mass balance. This work needs a lot of deep knowledge of chemistry and chemical reactions.

Management of new chemicals, approval process

Chemical products can include regulated hazardous substances and there is a comprehensive regulatory framework that must be known to ensure that substances are not handled without permission. An approval process must be established to secure that the restrictions on chemicals and substances set up in a Chemical policy or in Chemical guidelines are followed. Therefore, routines to review and approve the purchase of new chemicals should be established.

For certain hazardous substances, there may be a total ban on purchases and for other substances, an exemption may be required which also specifies handling regulations to ensure that handling will not contribute to unintended exposure or emissions.

Another issue could be that hazardous chemicals are part of mixtures in such a low concentration that they do not have to be listed but due to high usage, they may end up in the environment in considerable amounts.

An effective purchase routine also involves communication with suppliers of these bans and restrictions to prevent occurrence of forbidden or restricted substances in the production steps were a change is harder to force. One way to establish this is through use of ban- and restriction lists as a part of the business agreements and long-term relationship declarations, involving the suppliers of chemical products to confirm absence of listed substances in their products.

An example of an approval process is described more in detail as a BAT-candidate in Appendix 3.

4.2.3 Training

To increase awareness of chemical management and hazardous substances among employees within the company, training is required. Through increased knowledge and awareness of the risks and consequences of chemicals and hazardous substances, one can improve management and the will to follow routines and regulations, get employees to contribute with improvement suggestions for better management and thus reduce the risks.

It is very important that the employees that are handling chemical products receive a specific training focusing on knowledge and management of chemical products to minimize risks.
The employees that are handling chemical products need at least:

- To know the characteristics of the workplace chemicals, harmful ingredients, safety labels and safety data sheets;
- Knowledge of hazardous chemicals could cause harm to their safety and health and the environment in the course of their work;
- Training, including prevention, control, and emergency treatment or emergency measures and
- Compliance with the national labor protection regulations and environmental regulations.

Additionally, all employees need some form of basic training regarding chemical risks at the site.

The training needs to be repetitive or include follow-up to ensure knowledge of new or updated information and new regulations.

4.3 PROCESS RELATED MEASURES

Improvements of existing production processes are at least as important as preventive measures in development of new production processes.

Many production processes were developed when the environmental and health consequences of many substances were not known or were not considered as hazardous as today. The volumes of production as well as the usages and accumulated emissions of the hazardous substances were fractions of today. Therefore, phasing out of hazardous substances as well as measures to prevent or reduce emissions in existing processes is essential to reduce the emissions of those hazardous substances.

Since knowledge of hazardous and potentially hazardous substances constantly is increasing together with the opportunities to avoid or reduce usages and emissions of those substances, any production and activity should continually be evaluated by the plant operator and other stakeholders such as chemical producers and plant designers and when possible or necessary revised. To achieve this a long-term systematic approach focusing on hazardous substances could be introduced and maintained. It is important that chemical suppliers and those who design and construct new surface treatment plants are involved. It is usually not possible to replace individual chemicals and hence the entire surface treatment process must be reviewed.

The systematic approach should include an overall policy on use, purchase and handling of chemicals and raw materials. Both long-term and short-term goals should be set together with relevant activities and action plans.

In order to follow up on the work, it is good to develop key performance indicators. These should be used to evaluate if overall goals are met and to improve and develop new measures, activities and goals to avoid or limit emissions of hazardous substances. This is in practise a classic management system adapted to and addressing the reduction or elimination of emissions of hazardous substances.

There are many steps linked to the existing process. Below are some of the more important measures to reduce emissions of hazardous substances;

- Chemical Storage and transportation;
- Closed cycle processes;
- Substitution and
- Process mapping of hazardous substances

4.3.1 Chemical storage and transportation

Regarding chemical storage there are several measures to reduce the environmental impact. Many examples are found in IPPC’s Reference Document on Best Available Techniques on Emissions from Storage (BREF document). Some measures in the BREF document are more suitable for storage of hazardous substances and they will be discussed in the following paragraphs.

Storage in tanks

The first example is double-walled tanks (see BREF document 4.1.6.1.13.). A double-walled tank can have different designs. The double wall can be placed on the outside of the tank with a distance to the inner wall, adjacent to the inner wall or inside the tank. The double wall is normally applied in combination with a double tank bottom and leak detection for the storage of flammable substances or substances hazardous in contact with water.

Single-walled tanks is another option if they are combined with tank bunds (see BREF document Section 4.1.6.1.14.). The tank bund shall be designed for large spills and must contain the volume of the tank in case of e.g. shell rupture or a large overfill. The bund consists of a wall around the outside of the tank (or tanks) to contain any product in the event of a spill. The bund is typically constructed of well compacted earth or reinforced concrete.

All IBC’s, small tanks and drums should be placed on a secondary containment (see BREF document Section 3.1.13.1.). Secondary containment refers to additional protection against storage tank releases over and above the inherent protection provided by the tank container itself.

Storage based on the substance

For storage of hazardous substances, it is important to consider the physio-chemical properties. For instance, hazardous materials that could react with other substances which could lead to dangerous gases or fumes, should be stored separately. Storage cells is one option for separate storage (see BREF document Section 3.1.13.1.). In Figure 2, there is one example of a storage-class-compatibility check used in Germany containing a list of storage classes and how they should be stored (joint or separate).

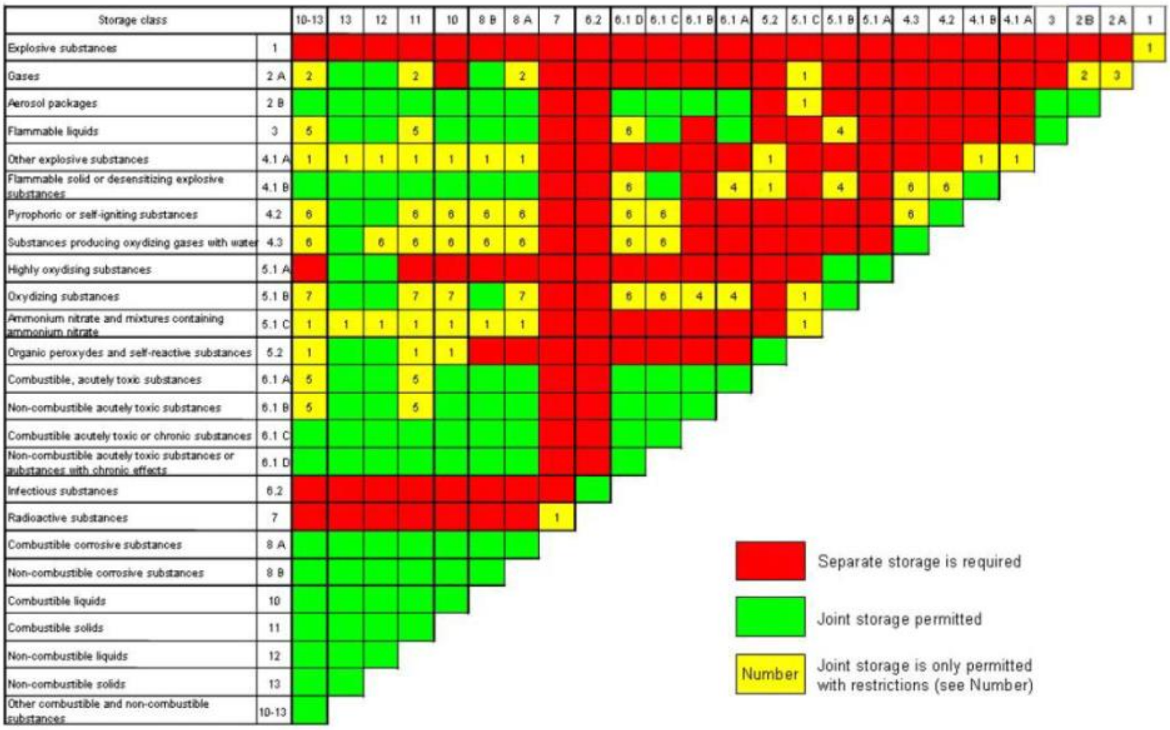


Figure 2. Storage-class-compability check containing a list of storage classes and if they should be stored joint or separately (Source: Technical rules for hazardous substances, TRGS 510)

There could also be dedicated systems for tanks and equipment where these are only used for one group of products. This makes it possible to install and use technologies specifically tailored to the products stored (and handled), thereby preventing and abating emissions efficiently and effectively (see BREF document Section 4.1.4.4.).

Transfer

The transfer of hazardous substances is another potential environmental issue where emissions can occur. To reduce the emissions and the risk of leakage, there should be risk-based inspection plans and proactive maintenance plans as well as leak detections and repair programmes. For new situations, aboveground closed piping should be used for transfer. For valves, fit diaphragm, bellows or double-walled valves should be used (see BREF document Section 4.2.9.).

Additionally, there should be a dedicated unloading area for trucks with precautionary measures in case of spills. These precautionary measures could be for instance a valve or a tank underground to catch accidental releases of chemicals during unloading.

4.3.2 Closed cycle

Establishing a closed cycle in one process step could lead to big savings in resource use as smaller amounts of new materials have to be added in the process. By recirculating chemicals that are not needed in the final product and that would otherwise go to waste, both the chemical input and the unwanted output could be reduced.

One example of a recirculating process step is from case study 5 with their “Recycling of Al-Anodization process solution”. The second example describes recirculation of treated wastewater back to the process.

A closed cycle will result in environmental benefits such as decreased water and a minimised use of hazardous chemicals and hence reduced emissions of hazardous substances to the environment as well as less waste.

An example of a closed cycle process is described more in detail as a BAT-candidate in Appendix 4.

4.3.3 Substitution

A successful substitution work can be performed in four stages;
Stage 1: Identification of Hazardous substances
Stage 2: Screening for possible alternatives
Stage 3: Evaluation and choice of alternatives
Stage 4: Development of new alternatives

1. Identification of Hazardous substances: Strategical decisions on what to screen for and creating a control over the products used in the production processes. An effective tool to manage the identification is to use a structured inventory for all chemicals as mentioned in section 4.2.1. Such a system can help to identify hazardous substances and some of them also have screening methods for substances that are structurally similar to the identified hazardous substance.

2. Screening for possible alternatives: The screening process starts with the understanding of the function of the identified hazardous substance with help of three main questions:

- Why are this product/substance used?
- What is the function of the identified hazardous substance?
- Is that function needed? If yes, can the function be achieved through a substitute?

When the function of the identified hazardous substance and the actual need for the product/process is established the screening process can focus on finding solutions with an equivalent function. This means searching for chemicals or non-chemical alternatives, materials or other technical solutions.

3. Evaluation and choice of alternatives: This process requires both chemical and toxicological knowledge combined with knowledge regarding the production were the substitute is going to be used. Key considerations are the hazardous properties of the substitute, relative exposure (compare the difference in total exposure between the current substance and the substitute), technical performance, and cost.

4. Development of new alternatives: The fourth step of the substitution process involves developing new sustainable substances or techniques. In the absence of available alternatives, new innovations and/or techniques may be necessary.

It is of interest that the needs of certain functions are communicated within the supply chain all the way from the manufacturers down to the end users. Depending of the role of the production facility in the supply chain this step involves different tasks. Transparency in the supply chain is one of the key issues for a successful development.

An example of a substitution process is described more in detail as a BAT-candidate in Appendix 5.

4.3.4 Process mapping of hazardous substances

To be able to take actions for reducing emissions of hazardous substances, good knowledge of the production processes is needed. One example of how to do this is a way of working with process mapping of hazardous substances. The purpose of the project was to reduce the emissions of hazardous substances to the process wastewater and finally to the recipient instead of investing in a very complex and expensive process and treatment plant for wastewater treatment that would have been the alternative.

The process mapping of hazardous substances includes different steps; identification, mass balances, sampling and analysis, implementation of actions and verification and is described more in detail as a BAT-candidate in Appendix 6.

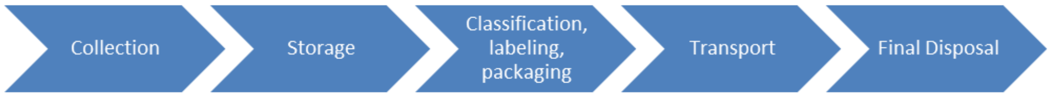
4.4 END OF PIPE MEASURES

All manufacturing processes cause some kind of waste streams such as emissions to air, emissions to water, waste and emergency accidents that can result in emissions to air, water and soil.

Examples of measures to reduce the discharge of hazardous substances via waste streams may be collection of sub-streams for further waste management, pre-treatment of sub-streams, treatment of waste gas, wastewater streams and emergency management. These measures are briefly described below.

4.4.1 Management of hazardous waste

Hazardous waste management can pose a risk when it comes to the discharge of hazardous substances. The following aspects are important to manage by implementing routines for safe handling, training for employees and contractors and environmental requirements on waste transporters and waste vendors in order to get a safe and secure handling of the hazardous waste from the production site and until the waste is finally disposed. Below are examples of routines to have in place for Collection, Storage, Classification-labelling-packaging, transport and final disposal:



<u>Routines for collection</u>

- To separate hazardous waste from other waste (including other hazardous waste) and
- Training for employees handling hazardous waste, with focus on the different types of hazardous waste, the characteristics and risk with different hazardous waste fractions, how to handle them and necessary Personal Protective Equipment (PPE).

<u>Routines for storage</u>

- Hazardous wastes should be stored protected from precipitation and on a surface impermeable to water;
- Liquide hazardous waste should be stored in a secondary containment;
- Acids, bases, solvents and other chemicals should be stored separated from each other and
- Regular inspections of the storage area.

<u>Routines for classification, labelling, packaging</u>

- Classification, packaging and labelling must be performed by a trained waste chemist and
- Documentation of hazardous waste fraction (type, amounts, classification) in a transport document that will follow the transport of the waste to the final disposal.

<u>Routines for transport and final disposal</u>

- According to national and local regulations;
- Requirements on contracted waste vendors and
- Regular auditing of waste vendors to check compliance with requirements.

4.4.2 Waste gas and wastewater treatment

An example of a wastewater treatment process is described more in detail as a BAT-candidate in Appendix 7.

4.4.3 Emergency preparedness

In case of an emergency involving chemicals, the consequences when it comes to emissions of hazardous substances can be severe. Actions taken within the initial minutes of an emergency can largely dictate the severity of consequences. Therefore, it is important to have an action plan to follow when emergencies strike in order to minimize damages.

An emergency response plan (ERP) is something that companies use to address many different types of emergency situations.

The priorities for any ERP are, in this order:

1. Protection and safe conduct;
2. Mitigation/stabilization of the dangerous condition; and
3. Clean-up after spillage

An ERP needs to include who to contact, how to act, and resources to use. In more detail, this means that each chapter should have a list of people to contact, in order, with contact numbers;

- The list of contact people might be organized by their response category, such as Fire Contacts, Municipal Wastewater treatment, remediation contractor etc.
- The safety duties and responsibilities of each role in the company for a given emergency, such as safety manager responsibilities, environmental manager etc.;
- Actions required to maintain safety;
- Actions required to mitigate the incident;
- Actions required due to spillage, if applicable; and
- What resources are best used to mitigate the emergency?

The emergency response plan can be a physical document or one documented on a server.

Appendix 1, Chemical Management System

With focus on reduction of emissions of hazardous substances.

In order to reduce emissions of hazardous substances in the surface treatment industries, it is important to introduce a systematic approach for handling chemicals. It is possible to start by implementing individual actions and sub-measures and when it is fully implemented it can be called a Chemical Management System (CMS).

The purpose of the CMS is to get good control of chemicals and hazardous substances at the site, increase the knowledge of the characteristics, risks and impact and improve the processes to reduce emissions of hazardous substances, in a systematic way.

A general Chemical Management System follows the classical PDCA-cycle as any management system Plan, Do, Check, Act, See Figure 3 below.

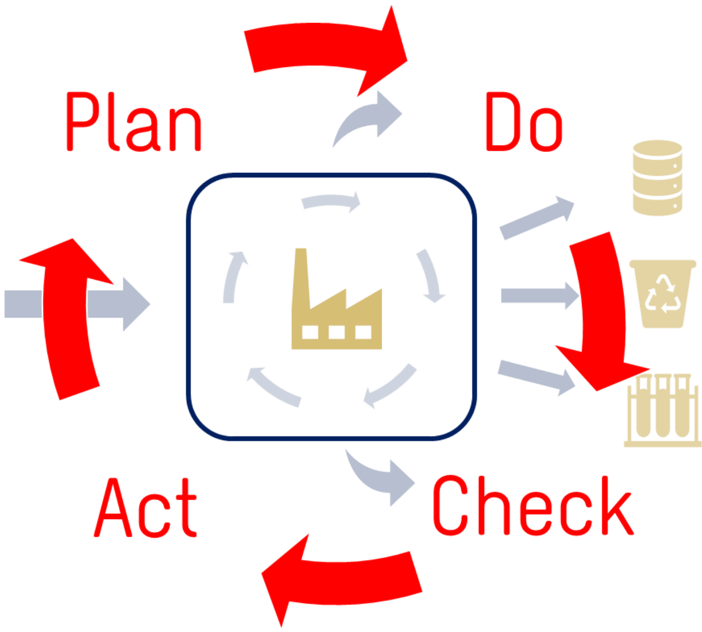


Figure 3 The PDCA-cycle related to chemical management

<u>Plan</u>
It is important to have an established plan for the Chemical Management:
-What Chemicals or substances are ok/not ok to use on the site?
-How shall reduction of hazardous substances be reached?
-How many non-wanted chemicals can be substituted?

To make things happen there needs to be a statement from the top management in the company, like a chemical policy. There is also necessary to set short-term and long-term goals and objectives. These objectives must be measurable to be able to follow up the continuous improvements.

Do
Actions are taken according to the plan. For example, improvement of chemical and raw material inventory, conduct training to raise awareness, changing production procedures etc.

Check
The result of the actions and implementation work are evaluated and analysed. The result must be reported to current decision makers to be able to go to the next step;

Act
Decisions on new changes for improvements, which then go into the planning phase again.

For each technique	**Task/content**
Description of the technique	See the description above. Chemical Management System (CMS) is a way of working that will affect the organization in many ways. There is a need for commitment from the management and communication that these issues are of high importance for the company.
Technical description	A CMS is not a technical solution, more an organizational solution that demands leadership, communication, routines and systematic approach.
Achieved environmental benefits	With an implemented CMS in place there are prerequisites to set the right focus on chemical handling and work with continuous improvements. The aim of the CMS is to achieve an improved handling of chemicals with a reduced risk of discharging hazardous substances to the environment. Targets are set by management and the resources allocated by the management.
Environmental performance with regard to hazardous substances and operational data	N/A
Cross-media effects	No cross-media effects are expected from this implementation.
Technical considerations relevant to applicability	A CMS can be implemented within the whole STM sector and it can be adapted to each type of industry with the focus needed.
Economics	Above all, it is about appointing an organization with a team that can lead the changes. First, in the form of a project, but when the appointed actions are in place and implemented in the operations it will be a natural part in the ordinary procedures at the site.

Driving force for implementation	Costumer specific requirements, requirements from insurance companies can be triggers.
Example plants	Chemical industry in Sweden working with production of organic chemicals (polymers) used in pharmaceutical industries. Also applicable to STM industries.
Reference literature	Framework and certification from internationally recognized management systems such as ISO 9001 or ISO 140001 may be referenced and/or utilized in developing a chemicals management system. https://www.iso.org/standards.html

Below describes an example from surface treatment industry about Chemical management and safe use of chemicals

General management of chemicals is already minimizing the use of hazardous chemicals and releases of hazardous substances and continuous development of the management is one of the key issues in assessing the most suitable BAT applications which are e.g. chemical inventory and the utilization of the MSDS. In the BAT description 'Chemical management and safe use of chemicals' the aim is to give tools for chemical inventory. This BAT is general applicable.

The example below gives examples of this from Finnish plants

Name of the technique	**Chemical management and safe use of chemicals**
Description of the technique	The chemical products have to be selected not only with respect to their performance but also regarding their intrinsic properties (acute, chronic and sub-chronic human and aquatic toxicity, biodegradability) as well as assessed for specific handling and control requirements.
Technical description	The relevant data for all the products used are entered in an operator's database from which tailored compilation of information can be generated. The main sources of data used for the different chemical products are the MSDS and e.g. the Technical Instruction Sheets. The operator should have a MSDS for each chemical product used. The MSDSs should be up-to-date and include all the relevant parameters. Specific safety info cards could be made based on the info in the MSDS. The data base provides information for chemical management needs such as: - List of all chemical products used (see example in Table 1). - Identification of chemical products with high acute aquatic toxicity - Identification of all combustible/flammable products and those which can decompose (thermally or by reaction with other chemicals) - Compilation of relevant data required for planning and implementing adequate storage and handling of chemicals - Assessing compatibility of chemicals and preparing storage layout plan and allowable storage volumes - Compilation of data relevant for communication, reporting and/or certification purposes such as for authorities or customers - Cross-referencing with manufacturing restricted substances lists (e.g. ECHA authorized and restricted substances) or specific customer's substance lists For each hazardous chemical, an estimation on the emissions to the environment should be made.
Achieved environmental benefits	The chemical inventory derived from the data base, combined with different filtering and evaluation options allows systematically identifying substances with undesirable environmental and toxicological (adverse) properties. This is turn facilitates the systematic monitoring of relevant hazardous substances. This also helps in selection of chemical products in terms of elimination/avoidance of hazardous substances. Among others, this also

<table>
<tr><td></td><td>helps to streamline the coordination with chemical suppliers asking for products with less hazardous environmental properties.</td></tr>
<tr><td>Environmental performance with regard to hazardous substances and operational data</td><td>The data from the 8 sections of the respective MSDS (as per European CLP/GHS) is inserted into the data base:

- Location information (line and bath number)
- Identification of the substance/mixture and the manufacturer/importer of the chemical
- Composition/information on ingredients
- CAS number
- Hazards identification
- Hazard statements
- Amounts used and stored
- Chemical categories and maximum amounts in factory based on the classification of the chemical

Table 1 shows an exemplary outline of a chemical inventory containing relevant environmental data of chemical products.

Table 1: Example for compilation of data extracted from a data base

<table><tr><td>Commercial name</td><td>Producer</td><td>Chemical characterisation</td><td>CAS number</td><td>Cont. haz. substances in [weight-%] for indiv. subst.</td><td>GHS hazard</td><td>SDS date</td><td>Annual consumption</td><td>Max quantity stored</td><td>Biolog. degradation/elimination in [%] and test duration [d] and testing method</td><td>COD/BOD value</td><td>Toxicity to daphnia</td><td>Toxicity to bacteria</td><td>Toxicity to fish</td><td>Toxicity to algae</td><td>Released to air [%]</td><td>Released to water [%]</td><td>Ends up to waste [%]</td><td>Bound to the product [%]</td><td>Reacts (Intermediate use)[%]</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td>Cross-media effects</td><td>No cross-media effects expected.</td></tr>
<tr><td>Technical considerations relevant to applicability</td><td>This technique is applicable to any industry as part of chemical Good Housekeeping and basic chemicals management. The necessary software application for the establishment and implementation of such a data base and respective evaluation tools can be either obtained by a range of providers available on the market (as part of an integrated business or stand-alone application) or developed in-house.</td></tr>
<tr><td>Economics</td><td>The investment and operating costs for a chemical data base depend on the level of sophistication intended. Savings usually arise from being able to streamline stocks, manage surplus chemicals, simplify or automate the procedures/process (e.g. by using chemical inventory software) as well as</td></tr>
</table>

	indirectly from reducing environmental management costs by gradually eliminating the use of hazardous chemicals.
Driving force for implementation	Elimination of hazardous substances Companies may be required by law to maintain a chemical inventory, for example a chemical inventory is required in the environmental permit application in Finland. A chemical database promotes continuous improvement in the selection of less hazardous chemical products.
Example plants	Many plants in Finland
Reference literature	GIZ Practical Chemical Management Toolkit, 2017 Supplier Handbook Chemical Management – Section: Documentation (Inventory/MSDS) www.tchibo.com/servlet/cb/1199382/data/-/TrainingshandbuchChemikalienmanagement.pdf KemiDigi https://www.kemidigi.fi/ Substances in Preparation in Nordic Countries SPIN: http://spin2000.net/ Finnish law on chemical information notification 553/2008 https://www.finlex.fi/fi/laki/alkup/2008/20080553

Appendix 2, Chemical and raw material inventory

The main purpose with a chemical inventory is to bring control and a good overview of all chemicals, including raw materials/products for production, maintenance- and cleaning products. A structured inventory is a key factor for further actions and work in a successful chemical management system. This type of systems can be built up in different ways and include small or large amount of data that can be used for screening of hazardous substances used on a specific site. Depending on the size of the company and the amount and variation of chemicals/products that are used different datasets should be included in the system. The ground information beside the product names are some type of material identification if available the CAS or EC numbers should be added to the inventory.

This type of basic inventory can be built up in a simple Excel list with the ability to evolve and stretch out the added information along the work process. Basic information extracted from a MSDS should be included in the inventory:

- Product name
- Producer
- Type of product (Chemical categorization)
- CAS number (Raw material and substances)
- Content of hazardous substances in weight-% for individual substances in mixtures.
- GHS hazards
- MSDS date

The purpose of this basic data is to provide a possibility to track and pinpoint hazardous substances and to identify products in the facilities that contain these substances. The CAS numbers gives an identification commonly used in legislative and customers band and restriction listings. There are no given legal applications on how old an MSDS can be, so the MSDS date is added to evaluate how old the given information is and to monitor the need of a review.

The quality of the MSDS can be a risk factor for false safety information. Since not all classifications are harmonized, different manufacturers can provide contradictory information on the same substance. For monitoring and evaluating information of hazardous chemicals there are many tools on the ECHA webpage and other industry sector NGO´s that can help making a high-quality-risk assessment for substances of concern.

For a more expanded system toxicological, and physical data can be added to the inventory for further advanced evaluations and screenings in the CMS process both for approval evaluations and substitution, but also physical parameters useful for the process mapping of hazardous chemicals and handling and storage processes.

Basic information						Advanced tox data used for evaluation and approvals							Storage		
Commercial	Producer	Process	CAS	GHS hazard	MSDS date	Cont. haz. Substances in [weight-%] for indiv. subst.	Biolog. degradation/ testing method	BOD/COD value	Toxicity to bacteria EC50	Toxicity to algae EC50	Toxicity to daphnia EC50	Toxicity to fish LC50	flashpoint	Annual consumption (kg)	Max quantity stored

Depending on the number of chemicals used at the site, there can be different solutions for a chemical inventory. In the simplest case with handling up to 200 chemicals, an excel file with the setup described above can be suitable.

But if the number of chemicals is greater or used in facilities with different units, a commercial chemical handling system that can be business integrated or as a stand-alone system is preferred. Beside the fact that such a system can handle and structure a larger number of products, these systems also provides good support functions such as; access to material safety data sheets, risk assessment functions, direct contact and update to legislative, classification and labelling changes.

The main advantage with a digital chemical database in the aspect of hazardous substances is the possibility of screening through all products used in a company against various substance lists, governmentally and customer integrated. Keeping the register up to date is crucial for all further work with detecting, monitoring and actions for prevention and reduction of hazardous substances.

Following is a list of important functions to request in a chemical handling tool:

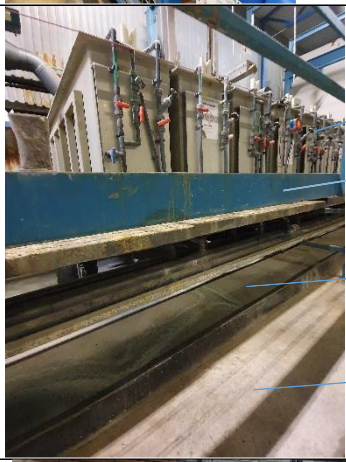
- List of all chemical products used.
- Identification of chemical products with high acute or chronic aquatic toxicity (CLP classification).
- Identification of WFD, PS and SVHC substances.
- Identification of national authority databases ex, Swedish Chemical Agency PRIO-list.
- Identification of chemical products which are non-biodegradable.
- Identification of VOC, and any other environmentally relevant properties, which are not based on CLP hazard classification.
- Identification of all combustible/flammable products and those which can decompose (thermally or by reaction with other chemicals).
- Compilation of relevant data required for planning and implementing adequate storage and handling.
- Assessing compatibility of substances and preparing according storage layout plan and allowable storage volumes.
- Compilation of data relevant for communication, reporting and/or certification purposes such as for authorities or customers.
- Cross-referencing with manufacturing restricted substances lists (e.g. ECHA authorized and restricted substances) or specific customer’s substance lists.

Name of the technique	**Chemical and raw material inventory**
Description of the technique	A Chemical inventory brings structure and a solid handling tool for revue and further preventive and safety work with chemical products. It is the first step for an organized ad structured work and a key to a successful chemical management system.
Technical description	Specific data for all the chemical products used are entered in a database from where targeted information can be searched. The main sources of information used for the different chemical products are the material safety data sheets (MSDS). A commercial inventory can also provide tools for updated substance lists e.g. REACH SVHC and be used for scanning the system for products that contain added substances or targeted classifications.
Achieved environmental benefits	A well-arranged and up to date chemical inventory is the key tool for further preventive work with reduction of hazardous substances. Combined with different filtering and evaluation methods the system helps identifying substances with undesired characteristics.
Environmental performance with regard to hazardous substances and operational data	A procedure on how to bring in new chemicals aligned with an approval process can ensure that all chemicals get evaluated and brought into the inventory. Besides this approval process that can ensure the registration of a new product, a good maintenance system has to be implemented to ensure the information in the system is up to date. Communication and good routines should be implemented with the suppliers.
	MSDS quality and not harmonized information can be an issue. Different suppliers can give contractually data on the same substance.
Cross-media effects	No cross-media effects are expected from this implementation.
Technical considerations relevant to applicability	This technique is applicable to any industry as a key part of a chemicals management system. The necessary software application for the establishment of such an inventory and search and evaluation tools can either be obtained by a range of commercial software systems available on the market (as part of an integrated business system or stand-alone application) or developed in-house.
Economics	The investment and operating costs for a chemical data base depend on the intended use and need of advanced searching systems and integrations with other systems. Commercial software is available as plain lists up to

	advanced systems that can be integrated into other business systems. Savings usually arise from being able to streamline stocks, manage surplus chemicals, simplify or automate the procedures/process as well as indirectly from reducing environmental management costs.
Driving force for implementation	Companies may be required by law to maintain a chemical inventory, for example: German Hazardous Substances Ordinance (GefStoffV), Finnish national chemical register (KemiDigi) and Swedish chemical agency product register on chemical products and biotechnical organisms (products register). A chemical inventory is also required in the environmental permit application in Finland, Estonia and Sweden. The minimum requested information meets the example on base set information given above.
Example plants	Example plants from relevant case studies where chemical inventories are described, both from Polymer, STM and Textile sector. Example on commercial systems for chemical inventories: Ichemistry https://intersolia.com/en/ichemistry/ EcoOnline https://www.ecoonline.com/ Yordas https://www.yordasgroup.com/hive/software Sphera https://sphera.com/spheracloud/
Reference literature	**SCIP: S**ubstances of **C**oncern **I**n articles as such or in complex objects (**P**roducts) https://echa.europa.eu/sv/scip-database Swedish law: Regulation (2008:245) on chemical products and biotechnological organisms. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-2008245-om-kemiska-produkter-och_sfs-2008-245 https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-1998901-om-verksamhetsutovares_sfs-1998-901 Finnish law on chemical information notification 553/2008 https://www.finlex.fi/fi/laki/alkup/2008/20080553

Below is a BAT candidate described from a plant in Finland that describes the handling and storage of chemicals. This is generally applicable to different types of plants.

Name of the technique	**Handling and storage of chemicals**
Description	Electrolytical coating industries use various chemical products in significant quantities. In order to avoid hazards and accidents, including accidental release of chemicals into the environment, threshold values have been developed which concern the quantities stored and specify respective protective measures to be taken. Chemical products, exceeding these quantitative threshold values are required to be stored properly and handled safely as part of general good chemical management practices.
Technical description	In order to prevent any unintended release (accidental release) of chemicals certain precautionary measures are to be taken. Intermediate bulk containers and drums are to be stored at collection points where the minimum volume of the catchment facility determines the volume of the largest container or drum. When storing chemicals, it is of particular importance to check for their respective storage compatibilities as certain chemicals cannot be stored together utilizing the reaction matrix, figure 1. In order to identify potential storage incompatibilities of chemicals, chemical segregation charts are available. Examples for chemicals with special storage requirements are hydrogen peroxide which shall be stored separately in a dedicated catchment facility. Chemical segregation charts should be used together with information gathered from the corresponding Material Safety Data Sheets (MSDS). In addition to the measures described above, the following general measures should also be implemented: • Any production and storage facility should be tight, bearing, robust and thermally and chemically resistant • Any leakage should be fast and reliably detectable • Catchment facilities should not have any drain • Storage facilities should be equipped with sufficient lighting and ventilation • All chemical products should be clearly and unambiguously labelled • The entire staff should regularly receive competent training Emergency exits and escape routes shall be provided
Achieved environmental benefits	Proper unloading, storage and handling of chemicals, combined with a general staff awareness of hazards and a high level of precaution, can significantly reduce the likelihood of accidental release of chemical products used in surface treatment of metals and plastics.

Environmental performance wit h regard to hazardous substances and operational data	The following table outlines exemplary measures (common good chemicals management practices) for the proper discharge, storage and handling of chemical products:	
	Chemical containers are stored in the area with safety pools. Containers have automatic surface level sensors and automatic pumps.	
	Chemicals which are harmful to human health are stored in a locked space with only authorized access. Chemicals which react with another are stored separately. All containers have safety pools.	
	All tanks are built with materials enduring different chemicals. Pools are supported by steel structures to prevent collapse. All pools have safety pools.	
	All IBCs, small tanks and drums are placed on catchment facilities (secondary containments) (secondary containment units should be able contain 10% of the total volume of all containers or 100% of the largest container;	

	holding capacity ideally 110% of the maximum capacity of the largest tank or drum)	

Substance	Zinc (Zn)	Iron (Fe)	Hydrogen chloride (HCl)	Hydrogen peroxide (H_2O_2)	Sodium peroxide (NaOH)	Ammonium chloride (NH_4Cl)	Zinc chloride ($ZnCl_2$)	Di-ethanolamine ($(CH_2CH_2OH)_2NH$)	Water (H_2O)
Iron (Fe)									
Hydrogen chloride (HCl)	GF	GF							
Hydrogen peroxide (H_2O_2)									
Sodium peroxide (NaOH)	GF	GF	H						
Ammonium chloride (NH_4Cl)				H GT	H GT				
Zinc chloride ($ZnCl_2$)			H GT	H GT					
Di-ethanolamine ($(CH_2CH_2OH)_2NH$)			H GT	H F GT	H GT				
Water (H_2O)					H		H GT		

Figure 1: Reaction matrix

Cross-media effects	
Technical considerations relevant to applicability	There are no technical restrictions known for the applicability of the measures described.
Economics	There are no precise figures available for the different measures described. Potential savings arise from reduce risks of uncontrolled reactions and connected costs (losses, damages).
Driving force for implementation	Proper unloading, storage and handling of chemicals is a common compliance requirement for many companies adhering to environmental management systems. In addition, the measures described above facilitate the receipt of insurance benefits and help to meet the necessary requirements of the competent authorities.
Example Plants	Many chemical handlings and storing factories in Europe apply the measures described above, at least part of them.
Reference literature	

Appendix 3, Management of new chemicals, approval process

The purpose of having an independent chemical review of all products before they are brought on site is to prevent incorrect and unnecessary use of hazardous chemicals. The review should end up in a classification of chemicals/chemical products that controls what type of chemicals that are used at the plant area and a tool for substitution of chemicals used in the company.

The classification is based on the inherent properties of the substance/product and may give rise to special conditions for use.

Example of categorization and general criteria's (harmonized with REACH and the SVHC criteria):

Group 1 – Product without restrictions

- The product and its components have no hazardous classifications

Group 2 – Product with restriction for classification

- The product contains no substances priority for substitution
- The product is classified according to the classification in Table 2 below.

Group 3 – Product with restriction for substances with strategic supervisions

- The product contains substances for substitution (Risk-reduction Substances)
- The product is on the SIN list
- The product is classified according to the classification in Table 2 below.

Group 4 – Product with restriction for substances on SVHC or permits for use

- The product contains substances priority for substitution (Phase-out Substances)
- The product is on the SIN list
- The product is PBT or vPvB
- The product is CMR classified
- The product is on the SVHC list
- The use is restricted buy handling permits
- The product is classified according to the classification in Table 2 below.

Group 5 – The product is not approved for onsite use

- The product contains substances that demands permit according to the REACH legislation
- The product contains substances listed in Annex XVII of REACH has a restriction on the given use

Terms of use
The Terms of use is conducted from the risk connected to the different classes. Products in sewer class will trigger need of documents motivating the use of the chemical and higher precautions to secure a safe use of the chemical/chemical product.

Group 1 – Product without restrictions
The product does not require any special conditions. Measures that may be required to minimize the risks of handling may be taken when used.

Group 2 – Product with restriction for classification
Personal protective equipment and/or technical protective equipment may be required to minimize the risks of handling/use.

Group 3 – Product with restriction for substances with strategic supervisions
The product contains substances that are classified and can have impact on human health and/or the environment. Products containing substances in this category may become subject to a permit or may incur large costs in the form of investments.

- Acquisition of products in this class must be motivated by documented needs
- Personal protective equipment and/or technical protective equipment may be required to minimize the risks of handling/use.
- Risks of environmental damage in case of emissions, Preventive actions/constructions may be needed.
- Any need for a health examination
- Specific training or knowledge of specific legislation is required
- The substance or mixture is a so-called process safety regulated substance/mixture

Group 4 – Product with restriction for substances on SVHC or permits for use
The product contains substances priority for substitution (Phase-out Substances) and may be candidate for permitted use or incur large costs in the form of investments

- Acquisition of a product in this class must be motivated by a documented investigation of no other existing better alternatives.
- Personal protective equipment and/or technical protective equipment may be required to minimize the risks of handling/use.
- Risks of environmental damage in case of emissions, Preventive actions/constructions may be needed.
- Any need for a health examination
- Specific training or knowledge of specific legislation is required
- The substance or mixture is a so-called process safety regulated substance/mixture and requires permission to be managed

Group 5 – The product is not approved for use
- Products in this group are not permitted for use.

Appendix 3, Management of new chemicals, approval process

Table 2 Example of Assessment Matrix

	Environmental Hazards		Work environment and fire	Process safety regulations	Laws and regulations
Group 1	No hazardous substances				
Group 2	Hazardous statement	H400, H411, H412	H301, H311, H331 H315, H318, H319, H335, H226, H221		
Group 3	Hazardous statement	H410, H413	H330, H310, H300, H370, H334, H317, H314, H372, H341, H240, H250, H252, H251, H270	H220, H221, H250, H260, H271, H241, H242	PRIO Risk-reduction Substances[2] SIN list
Group 3		logKow>3 L(E)C50<0,1 mg/l LD50<2000 mg/kg Persistent: Not readily biodegradable			
Group 4	Hazardous statement	EUH059 H420	CMR (H340, H350, H360)	GHS class 2.1 (H200, H201, H202, H203, H204, H205), H240- Organic peroxides type A	PRIO Phase-out[3] Substances SIN list[4] SVHC list[5]
Group 4	PBT	Persistent: Half-life >60d sea water >40d freshwater >180d marine sediment >120d freshwater sediment Bioack: BCF>2000 log Pow>3 Chronic NOEC <0,01 mg/l or <30 mg/kg			
Group 4	vPvB	Persistent: Half-life >60 d sea water or freshwater >180 d marine sediment or freshwater sediment or soil Bioack: BCF>5000, logKow>3			
Group 4	Particularly hazardous metals:	Mercury, cadmium, lead and compounds with these metals			
Group 5					Substances with permits in REACH[6] RoHS

Name of the technique	**Management of new chemicals, approval process**
Description of the technique	New chemicals are assessed in detail before taking them into use in the installation. This assessment is based on the products hazardous potential and categorizes the products in to predetermined classes with different demands and permits attached to the specific class.

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[2] Swedish Chemicals Agency PRIO Criteria
[3] Swedish Chemicals Agency PRIO Criteria
[4] Chemsec SINlist
[5] Annex XV to REACH https://www.echa.europa.eu/sv/web/guest/registry-of-svhc-intentions
[6] Annex XVII to REACH https://www.echa.europa.eu/sv/substances-restricted-under-reach

Technical description	The classification is based on the inherent properties of the product and may give rise to special conditions for use. Grades and terms can vary depending of the type of production plant. Table 3 Assessment Matrix gives one example of how the grouping and classifications can be designed.
Achieved environmental benefits	All chemical products will be reviewed not only on their technical performance but also on the hazardous potential. Preventing use of unwanted substances.
Environmental performance with regard to hazardous substances and operational data	An approval process for chemical substances helps preventing use of unwanted hazardous substances. In addition, the work method highlights technical and handling measures of hazardous substances in an early development phase.
Cross-media effects	No cross-media effects are expected from this implementation.
Technical considerations relevant to applicability	This technique is applicable to any industry as a part of a chemicals management system.
Economics	This process can be applied with small economically investments and can be a part of a process bringing new substances into a chemical inventory. The biggest investment is the time needed to review and the extra time added in the implementation process.
Driving force for implementation	This process is general applicable in all chemical handling plants. Requirements on knowledge of not only chemical products but also on content of hazardous substances in end products drives the work with chemical control in an early stage of the production process. An early evaluation on chemicals can facilitate compliance with requirements in REACH and national legislation with information of hazardous substances in products.
Example plants	-
Reference literature	Swedish Chemicals Agency PRIO https://www.kemi.se/en/prio-start Annex XV to REACH https://www.echa.europa.eu/sv/web/guest/registry-of-svhc-intentions

	Annex XVII to REACH https://www.echa.europa.eu/sv/substances-restricted-under-reach Chemsec SINlist https://chemsec.org/business-tool/sin-list/

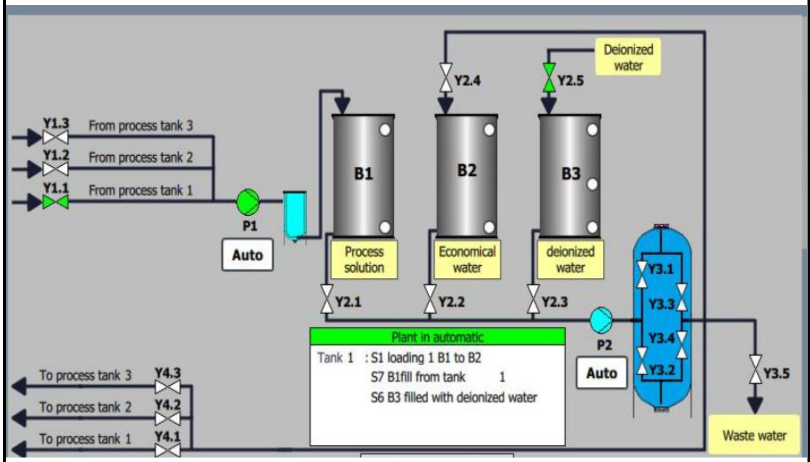
Appendix 4, Closed cycle

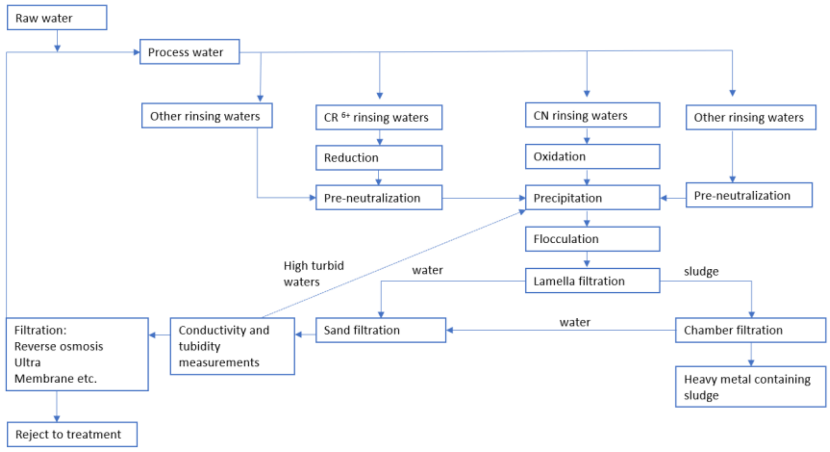
Establishing a closed cycle in one process or process step could lead to big savings in resource use as smaller amounts of new materials have to be added in the process. By recirculating chemicals that are not needed in the final product and that would otherwise go to waste, both the chemical input and the unwanted output could be reduced. The following describes different example on closed systems or recycling.

Retardation plant for recycling of Al-Anodizing process solution reduces the consumption of sulphuric acid considerably. This technique also improves working conditions and occupational health and reduces the amount of waste solutions and aluminum precipitate formation. The technique also cuts down operational costs.

Recirculation of treated wastewater back to process reduces the consumption of water and the amount of wastewater generated and eventually reduces releases of hazardous substances. This also reduces the operational costs.

Name of the technique	**Retardation plant for recycling of Al-Anodizing process solution**
Description	Through the retardation-method aluminium, as acidic aluminium sulphate solution, can be separated from the rest of the acid. The regenerated acid is used again in the anodizing process.
Technical description	The retardation method is based on the adsorption effect of special ion-exchange resins. During this process free and non-dissociated acids are tied on cationic, exchange-active groups, while mineral salts pass the ion exchanger. During the first step of this process, the ion exchanger pillar gets coated with an acid including mineral salt. Usually the stream in the ion exchanger is flowing upward and the metal containing solution (including a bit of acid), is flowing downward. If the exchange capacity has been used, de-ionised water is regenerating the pillar shortly before the concentration of the acid is on its highest level. The resulting eluate, which is full of acid, can be reused in the process.
Achieved environmental benefits	With the regenerating method of GS –electrolytes, acid savings of 85 to 90 % are possible. Reducing waste solutions reduces wastewater treatment costs, wastewater discharges and aluminium-precipitate formation.
Environmental performance with regard to hazardous	Dilution of acid is not required which cuts down the use of acids and improves occupational safety. The technique enables the continuous processes. The volume of sulphuric acid has been cut down to 55%.

substances and operational data	
Cross-media effects	No cross-media effects expected.
Technical considerations relevant to applicability	Figure 1 shows by example the regeneration plant.  A retardation unit can be installed in any existing anodising plant. Space needed for the unit depends on the amount of acid solution to be regenerated. The unit requires deionized water, pressurized air, emergency pools and electricity.
Economics	Investment 33 000 €, operational costs less than 3 200 € annually. Annual savings up to 10 000 € without estimation on the savings in wastewater treatment.
Driving force for implementation	Minimization of waste generation (metal sludge) and energy consumption. Economic reasons: savings in chemical costs and better work efficiency. Improvement of occupational safety.
Example Plants	Case Study No5, Finland
Reference literature	bi.bra Abwassertechnik GmbH, operation manual

Name of the technique	**Recirculation of treated wastewater back to process**
Description	The rinsing water is pre-neutralized and precipitated and flocculated. Cr VI rinsing waters are reduced and cyanide rinsing waters are oxidized before precipitation. After flocculation the water is lamella filtered and sludge is separated. The lamella filtered water is filtered again through sand. After this the conductivity and turbidity are measured prior to third filtration. If the turbidity is too high, the waters are steered back to the precipitation phase. The third filtration includes membrane or ultra filtration and reverse osmosis. Reject waters are discharged to treatment and the purified water is circulated back to the process.
Technical description	
Achieved environmental benefits	Reduction in raw water consumption and in wastewater discharge to the municipal wastewater-treatment plant. Overall reduction of releases of hazardous substances to the environment.
Environmental performance wit h regard to hazardous substances and operational data	The consumption of raw water can be significantly reduced in a continuous surface-treatment plant.
Cross-media effects	No cross-media effects expected.
Technical considerations relevant to applicability	This technique is applicable to any industry as part of wastewater treatment. Space limitations might restrict applicability of this technique in existing installations.

	In addition, the residues of the used chemicals (sugars, salt, lime) might affect the possibility to recirculate water. The treatment requirements and concentration of rejects must be taken into account when designing the treatment process. The salinity of the reject waters may limit the recirculation and affect the operation of the downstream wastewater-treatment plant. The system must be equipped with a continuous flow measurement. The used filtration technique must be selected based on the salinity of the water.
Economics	The savings depend on the price of raw water and wastewater-treatment costs. When the consumption of raw water was cut to half the cost savings were 30% taking into account the operational costs of the purification system.
Driving force for implementation	Significant cost reductions for raw water and wastewater treatment.
Example plants	Many plants in Finland
References	Case Study No5

Appendix 5, Substitution

The BAT candidate from case study 2 below gives examples of how to implement substitution and what is important to consider. When it comes to surface treatment activities, it is often necessary to substitute the entire system even though there is only a need for substitution of a few substances.

Name of the technique	**Utilization of installation specific substitution scenarios**
Description of the technique	While looking for substitution alternatives in STM, it is often a situation that in need to phase out a single substance (e.g. a substance containing hexavalent chromium), there is need to substitute all the system – other chemicals it contains, and also process parameters, processing conditions. So, the adverse toxic and ecotoxic effects should be compared for a whole system as well, and apart from these adverse effects, any adverse impact on the environment should be addressed. e.g. energy consumption, resource consumption. In principle, ideally there is need to consider all life cycle of these systems, starting from resource extraction and finishing with waste management stage / applicability of circular economy principles, i.e. Life Cycle Assessment (LCA) has to be applied, and comparison performed in all the LCA impact categories. LCA modelling requires quite a lot of inputs and outputs, but data are not available in all impact categories. The more there are uncertainties the more unreliable are the results. Thus, **there is need for setting boundaries, and also clear decision-making criteria for substitution.**
Technical description	The substitution assessment should be done for the hazardous chemicals which are used in the processes: WFD priority substances, SVHC substances. There is need to consider, if substances labelled as hazardous to the environment (GHS hazards H400, H410, H411, H412 and H413) has to be included. There are several LCA models, but they are licensed for use. For the modelling data on inputs and outputs to/from the process are needed.
Achieved environmental benefits	Substitution decisions are based on comparison of properties of all hazardous chemicals involved (ideally all chemicals involved), and other impacts, not only chemical hazards are considered.
Environmental performance with regard to hazardous substances and operational data	See above

Cross-media effects	No cross media effects identified from the BAT candidate (but LCA considers cross-media effects).
Technical considerations relevant to applicability	Comparison of systems – generally applicable. LCA - applicable by using modelling. Modelling requires quite a lot of monitoring data (inputs and outputs), the more there are uncertainties the more unreliable the result is. Another challenge is that often there are data gaps.
Economics	LCA tools are not freely available. Appropriate modelling needs resources, especially ensuring quality of inputs.
Driving force for implementation	Modelling techniques and measures can be used as supportive tools in identifying appropriate substitution scenarios.
Example plants	-
Reference literature	-

Appendix 6, Process mapping of hazardous substances

To be able to take actions for reducing emissions of hazardous substances it is necessary to get a good knowledge of the production processes. One example of how to do this is process mapping of hazardous substances. The process mapping includes six different steps; identification, mass balances, sampling and analysis, implementation of actions and verification. Se the project process in Figure 5 below.

Figure 4 Six steps of process mapping of hazardous substances

1. First step of the process mapping is to go through all the chemicals that are part of the production processes at the site and sort these into the category SOC (Substances of Concern) or as Not SOC.
Furthermore, the SOC category is divided into subcategories based on the inherent properties of the chemicals (such as Harmful to the aquatic environment, toxicity, bioaccumulation, biodegradability etc.). The different subcategories then have different strategies for further investigation.

2. Step two is to begin the mapping work itself, the scope of which depends on the nature of the chemical, i.e. subcategory in the SOC classification. The worst chemicals require in-depth examination with theoretical mass balances, sampling and discussion of possible measures. The goal is for all chemicals to have a minimal negative impact on the recipient.

3. Depending of the results from the theoretical mass balances of each substance it can be necessary with sampling and analysis to verify the theoretical mass balances.

4. Step four is identification of necessary actions and implementations of those actions. The actions depend on the processes but can be, collection of washing residues for waste handling or treatment, changes in the production methods to get a higher yield and minimize the emissions etc.

5. When a new procedure is implemented it is important to verify the result of the action

6. Last step is to follow up the entire process mapping to make sure that the goal with the project has been achieved.

To identify what substances to focus on there is a need to prioritize. In table 2 below is an example of how to prioritize.

Table 2 Example of prioritizing substances of concern (SOC)

SOC/NSOC	Catagory number	Description	Further handling
SOC	1	- Harmful to the aquatic environment, Carcinogenic & organ toxic - PEC/PNEC > 1	Need more detailed investigations and analysis (theoretically & by sample testing). Mitigating actions may be needed.
SOC	2	Metals Solvents	Ensure handling, volumes, etc.
SOC	3	Bioaccumulation, biodegradability	1. Review the concentration of outgoing water 2. Check for binding in sludge
SOC	4	Other chemicals that is not included above but potenitially could have a negative effect on the recipient.	Need of further investigations regarding potential negative effect in recipient.
Micro plastics	MP	Micro plastics	Does not need any investigations at the moment but may need further focus in the future
Not SOC	N/A	Other chemicals with no negative effect on the environment	N/A

For each technique	Task/content
Description of the technique	See the description above. Process mapping of hazardous substances is a type of inventory of the hazardous substances at the site. This can be run as a project or a part of the normal procedures.
Technical description	Process mapping of hazardous substances is not a technical solution. It is a procedure or a project as described above. The output of the process mapping can be different technical measures.
Achieved environmental benefits	The achieved environmental benefits can be many; -high knowledge of chemicals and substances in the processes -higher yield and reduction of used chemicals -substitution of hazardous substances -development of abatement techniques - when working with measures closer to the source, there will be less volumes to be addressed All to reduce the emission of hazardous substances.
Environmental performance with regard to hazardous substances and operational data	The result of the process mapping of hazardous substances is a reduction of the emissions of hazardous substances. Depending on the outcome

Cross-media effects	No cross-media effects are expected from this implementation.
Technical considerations relevant to applicability	A project for process mapping of hazardous substances can be implemented within the whole chemical sector and it can be adapted to each type of industry with focus on relevant substances.
Economics	To achieve the wanted results there is a need of an organization to manage the work. Except for a project leader there need to be representatives from the production department, development department (R&D-function), the environmental department and analytical competence within the organization. Depending on how many substances that are prioritized the project can last for many years.
Driving force for implementation	Instead of a big investment in a new wastewater treatment plant with very complex treatment techniques the solution is to reduce the hazardous substances at the source which is less expensive. In addition, it is more efficient to introduce measures at the source, see comment above regarding volumes.
Example plants	Chemical industry in Sweden working with production of organic chemicals (polymers).
Reference literature	-

Below are BAT candidates from case study No2.

"Utilization of installation specific exposure scenarios" describes how to utilize specific exposure scenarios in the work to assess the relevant emissions to the environment.

	Utilization of installation specific exposure scenarios
Description of the technique	The exposure scenario in the MSDS gives the indication where the substance ends up in various processes. These are made with the EUSES model which gives an estimate whether the PNEC values in environmental compartments might be exceeded. The model uses default values which lead to "worst case scenarios". This means that the exposure scenario gives quite vague risk ratios for a specific industrial process. Due to the numerous different industrial processes it is not possible to calculate accurate risk ratios for all of them. **Therefore, the exposure scenario's risk ratios should be refined and recalculated to the specific process in each installation.**
Technical description	The risk ratio calculation should be done for the hazardous chemicals which are used in the processes: WFD priority substances, SVHC substances, substances labelled as hazardous to the environment (GHS hazards H400, H410, H411, H412 and H413). The risk ratio can be estimated by calculating substance flow over the process to estimate emissions to the environment. For example, available tools are STAN tool and the EUSES model. For the modelling data on inputs and outputs to/from the process are needed.
Achieved environmental benefits	Once the relevant substances are identified monitoring and abatement measures can be focused
Environmental performance with regard to hazardous substances and operational data	-
Cross-media effects	No cross media effects identified
Technical considerations relevant to applicability	Generally applicable. Modeling requires quite a lot of monitoring data (inputs and outputs), the more there are uncertainties the more unreliable the result is. Another challenge is that often these detailed exposure scenarios are missing from the MSDSs. Despite missing exposure scenarios, the modelling exercise should be performed for all necessary chemicals indicated in point "Technical description".
Economics	The modelling tools are freely available. But appropriate modelling needs resources, especially ensuring quality of inputs.
Driving force for implementation	Modelling techniques and measures can be used as supportive tools in identifying relevant emissions to the environment
Example plants	-
Reference literature	STAN tool http://www.stan2web.net/

	EUSES model https://ec.europa.eu/jrc/en/scientific-tool/european-union-system-evaluation-substances

Appendix 7, Wastewater Treatment

Usually the process water is purified in a conventional treatment plant where the purification is carried out by felling and post-adjustment.

In new facilities but also at existing surface treatment plants, it is possible to close the surface treatment process. This is done by installing one or more evaporators.

For each technique	Closed process
Description of the technique	Closed surface treatment plant. No discharge to water from the plant
Technical description	The incoming process water from the surface treatment plant is pH adjusted with sodium hydroxide and sulfuric acid. The process water is then fed to one or more evaporator system. In connection with the purification process, metals and salts are separated from the aqueous phase which is returned to production. The purification may in some cases be supplemented with reverse osmosis and ion exchange
Achieved environmental benefits	The plant has no discharge into water. The purified water can be returned to the process
Environmental performance with regards to hazardous substances and operational data	The raw material and chemical consumption can be reduced. The use of chemicals in the waste treatment plant can be significantly reduced up to 80% Hazardous chemicals end up in the waste by purifying the water with evaporators. No pollution of surface and groundwater contaminants. Recycling of metals (e.g. Ni) in the sludge. This can be done at another facility.
Cross-media effects	Energy consumption is increased compared to conventional plant. Closing the plant so that no process water is released requires more energy than traditional purification technology. Equipment such as evaporators, filters and ion exchangers increase energy consumption.
Technical consideration relevant to applicability	The technology gives higher energy consumption and more transport. No release of hazardous chemicals into water. The technology also requires fewer working hours for the operation of the plant (surface treatment plant).
Economics	Increased energy demand. The cost of process chemicals is significantly reduced. Less need for personnel to operate the plant and costs for analysis.
Driving force for implementation	Requirements in permit decisions. Requirements for reduced load on recipient.

	Reduced use of chemicals and recycling of metals is possible
Example plant	Several facilities in Sweden. Both new and existing facilities.
Reference literature	DEA – an aid for identification of BAT in the inorganic surface treatment industry, TemaNord 2002:525