REPORT CHEMICAL SECTOR

NATURVÅRDSVERKET, SWEDISH ENVIRONMENTAL PROTECTION AGENCY

Determination of potential BAT candidates, Chemical sector

PROJECT NUMBER 13010306

INITIAL REVIEW

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SWECO ENVIRONMENT

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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 "Polymer" 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 BAT 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 is the delivery of the assignment covering the chemical sector.

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.

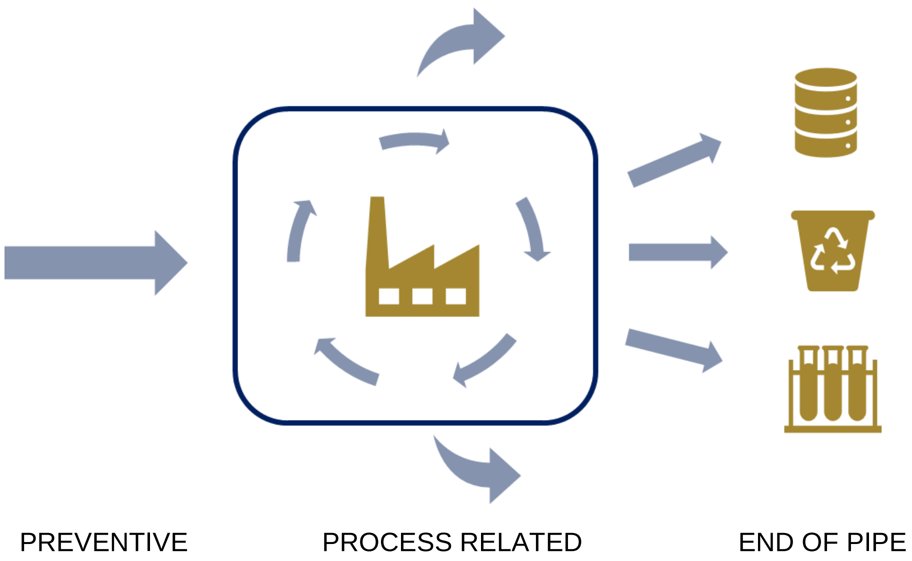


Figure 1 Illustration of different types of measures related to the chemical handling

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 and
- 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, No1
Case study Estonia, No2
Case study Sweden, No3
Case study Finland, No4

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

Contacts with a polymer producer resulted in a few suggestions for BAT. The approaches to one of the producers of inorganic fertilizers were positive but did not result in additional information to the case-study by SYKE. Approaches to other manufactures where not successful mainly due to hesitance to share classified information on their process or production.

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

4 Best Practice Chemical Management and BAT-candidates

A developed and integrated chemical management is a key tool for a chemical producer to reduce its emissions of hazardous and other environmentally harmful substances. Through a systematically approach involving all parts of the industry from daily activities in production to development of the planning of new or existing processes and installations. 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:

- Which 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

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

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 bases 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.

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, there is a need to ensure control over where these substances end up so that they minimise 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.

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 and when possible or necessary revised. To achieve this a long-term systematic approach focusing on hazardous substances could be introduced and maintained.

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 4.1.6.1.3.). 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).

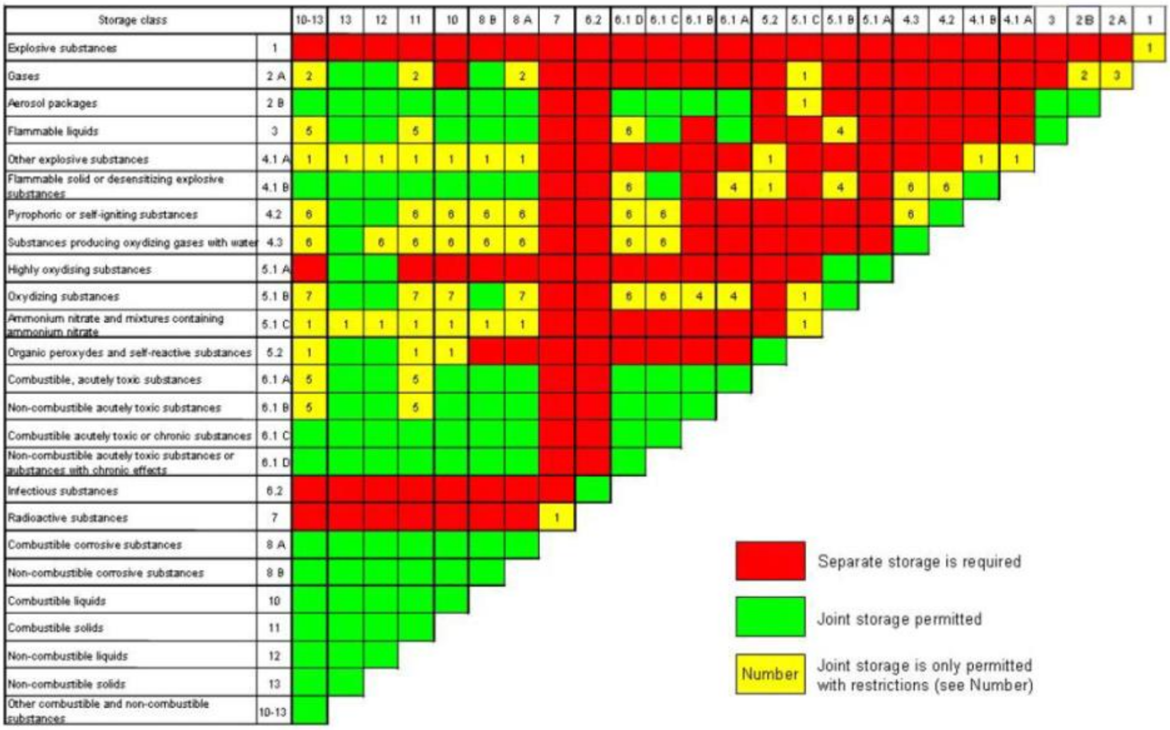


Figure 2. Storage-class-combability check containing a list of storage classes and if they should be stored joint or separately (Source: Technical rules for hazardous substances, TRGS 510)

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 the Case study No1 and its production of polyethylene. The process is based on the operation of loop and gas-phase reactors in series. The output from the second loop is a polymer powder containing residual hydrocarbons that have the potential for material recovery.

In a separation step the residual hydrocarbons are separated from the powder by nitrogen purging and fed to distillation columns where light and heavy compounds are separated. Various hydrocarbon fractions are separated in several distillation units for different purposes. Oligomers are used for energy production; light hydrocarbons are recycled to another process for olefin production as feedstock and unreacted hydrocarbons are recycled back to the loop and gas-phase reactors as an input to the process.

A closed cycle will result in environmental benefits such as decreased emissions to air due to efficient use of hydrocarbons, a minimised use of hazardous chemicals and hence reduced emissions of hazardous substances to the environment.

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.

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 5.

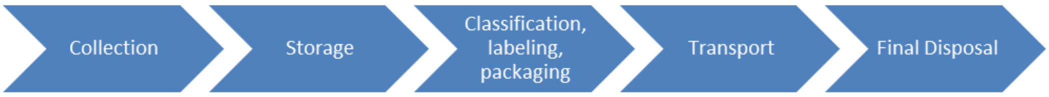
4.4 END OF PIPE MEASURES

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:



Routines for collection

- To separate hazardous waste from other 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 use of necessary Personal Protective Equipment (PPE).

Routines for storage

- 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.

Routines for classification, labelling, packaging

- 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.

Routines for transport and final disposal

- 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 6.

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 chemical industry, 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, Se figure 3 below.

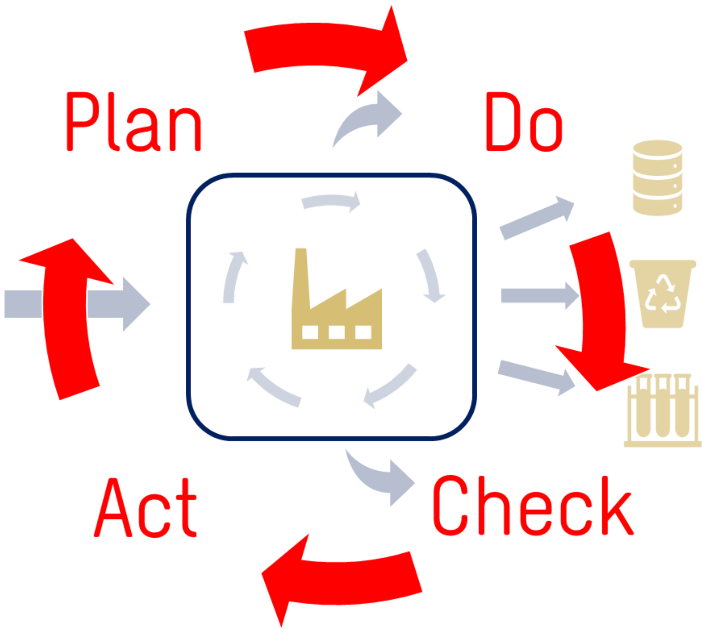


Figure 3 The PDCA-cycle related to chemical management

<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?
-Compliance with relevant legislation?
-How shall reduction of hazardous substances be reached?
-How many non-wanted chemicals can be substituted?

To make things happen it is important with a statement from the top management in the company, like a chemical policy. There is also necessary to set short- 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 chemical 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.
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

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 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 being 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

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 1 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 1 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 1 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 negative impact on human health and/or Environmental aspects. 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.

Table 1 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
		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]
	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			
	vPvB	Persistent: Half-life >60 d sea water or freshwater >180 d marine sediment or freshwater sediment or soil Bioack: BCF>5000, logKow>3			
	Particularly hazardous metals:	Mercury, cadmium, lead and compounds with these metals			
Grupp 5					Substances with permits in REACH[6] RoHS

[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

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.
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 2 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 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 the Case Study No1 and the production of polyethylene. The process consists of the steps pre-treatment, loop and gas-phase reactors in series, gas recycling and processing.

The output from the loop reactors is a polymer powder that is lead through a flash tank where residual unreacted hydrocarbons that have the potential for material recovery are separated. The residual hydrocarbons are separated from the powder by nitrogen purging and fed to distillation columns where light and heavy compounds are separated. Various hydrocarbon fractions are separated in several distillation units for different purposes. Oligomers are used for energy production; light hydrocarbons are recycled to another process for olefin production as feedstock and unreacted hydrocarbons are recycled back to the loop and gas-phase reactors as an input to the process.

A closed cycle will result in environmental benefits such as decreased emissions to air due to efficient use of hydrocarbons, a minimised use of hazardous chemicals and hence reduced emissions of hazardous substances to the environment.

The technique can be used in different types of polymer production where monomer recycling is possible. However, there might be a need for modifications in the recycling process.

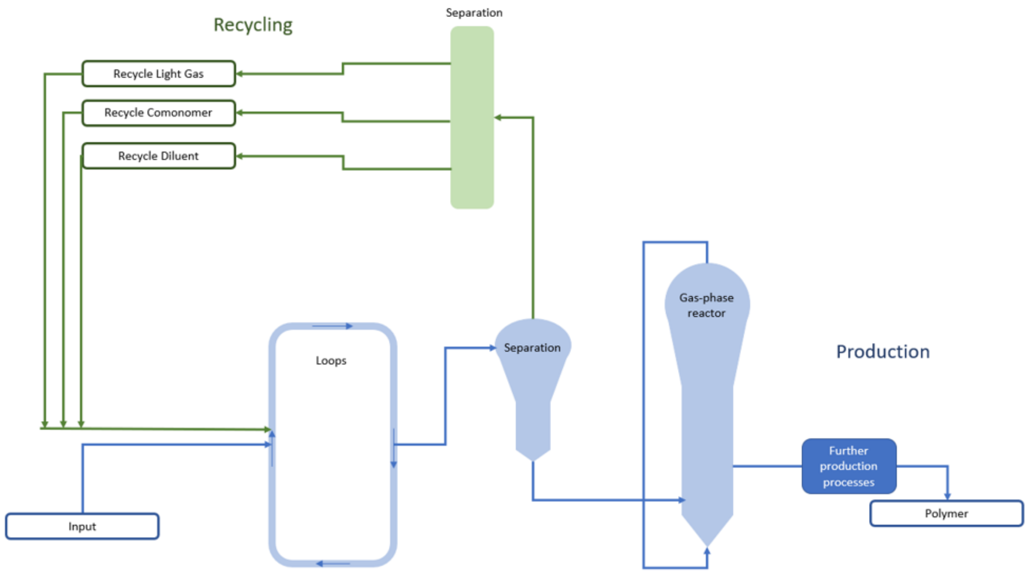


Figure 4. Simplification of process steps in the polymer production.

For each technique	**Task/content**
Description of the technique	The polymer powder contains still a lot of hydrocarbon gases before pelletizing. The hydrocarbon gases have to be cleaned from the powder prior pelletizing to eliminate the risk of explosion. Hydrocarbons can be recycled if they are cleaned and separated.
Technical description	Optimization of intermediate gas flows through automatic process control (APC system, advanced process control) to enhance material recovery and to minimize flaring. Residual hydrocarbons are separated from polymer powder by nitrogen purging. Hydrocarbons are fed to the distillation columns where light and heavy compounds are first separated. Oligomers are removed and used for energy production. Various hydrocarbon fractions are separated in several distillation units. Unreacted hydrocarbons are fed back to the loop and gas phase reactors. Light hydrocarbon fractions are recycled to the olefin production as feedstock.
Achieved environmental benefits	Emissions to air are minimized due to the efficient use of hydrocarbons. The use of nitrogen is optimized and the use of additional/booster fuel for the flare is minimized.
Environmental performance with regard to hazardous substances and operational data	With efficient process control, good chemical management and process integrated techniques, a good level of environmental performance is achieved without end-of-pipe abatement techniques.
	This also minimizes the use of hazardous chemicals and reduces the emissions of hazardous substances into the environment.
Cross-media effects	Efficient use of raw materials Energy efficiency The known trade-offs of the process exist between the use of nitrogen and use of fuel: too much nitrogen will cause dilution of flare gas stream possibly causing incomplete combustion and flame out of the flare, too little will not remove all hydrocarbons. The used amount of nitrogen also affects the NO_x emissions. The optimal use of nitrogen is enough to **replace** all hydrocarbons but is not too much to cause excessive NO_x emissions and excessive use of fuel in the flare.
Technical considerations relevant to applicability	Automatic process control system is required A receiving facility is needed for the return gases. Preferably the gases shall end up in material recovery, secondly in energy recovery. In Kilpilahti the return gases are fed to steam cracker as feedstock.
Economics	After investment, savings in raw material, energy and CO2-emission allowance costs.

Driving force for implementation	Economic reasons, minimized flaring and CO_2-emissions.
Example plants	Case Study No1 (and 2 other sites in Europe)
Reference literature	Case Study No1

Appendix 5 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 5 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 potentially 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	-

Appendix 6 Wastewater Treatment

Specific to one of the interviewed plants a newly installed drum filter is an added technique for wastewater treatment to prevent pollutions of plastic particles form a LD/HD-production plant (Sweden). This added wastewater treatment is part of the plant's project "Zero pellets lost". The filter is a technical solution that can be added in wastewater treatment of all polymer producing plastic pellets.

For each technique	**Additional treatment step in wastewater treatment plant**
Description of the technique	As part of the plants work program for zero pellets lost, the plant has installed an additional treatment step with removal of micro particles down to 10 µm in water leaving the site. Treat both for process water and storm water in separate flows.
Technical description	Drum filter with removal of particles down to 10 µm. Capacity to treat water flows up to 250 m^3/h. The process water filter is placed after oil separation and before final equalisation pond. The storm water filter is placed before the equalization pond.
Achieved environmental benefits	Reduce plastic particles down to 10 µm in water discharged from the production unit, even rainwater is filtrated. The water is finally discharged to the Sea.
Cross-media effects	No cross-media effects are expected from this implementation.
Technical considerations relevant to applicability	This technique is applicable in facilities producing polymer pellets. The example plant has operational issues with dewatering the reject from back flushing of the drum filter treating the storm water. Project on-going for finding solutions for these issues.
Economics	The example plant has not provided information on the economics for this installation.
Driving force for implementation	As a plastic producer the example plant are doing all they can to minimize the risk for plastic particles ending up outside of the production plant - "zero pellet loss". They identified three risk areas for spreading of pellets; via transports, water effluents and snow. Therefore, they have implemented measures to all these risks and the filtration of all water flows is one of them.
Example plants	LD/HD-production plant (Sweden)