IAMC Toolkit

Innovative Approaches for the Sound Management of Chemicals and Chemical Waste

Technical Manual

Application of Paints

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Masthead

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Unless otherwise mentioned, all references to sums of money are given in United States dollars. References to “tons” are to metric tons, unless otherwise stated.

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1 Introduction

The United Nations Industrial Development Organization's (UNIDO) overarching objective is to reduce poverty through sustainable industrial development. In response to this global challenge, UNIDO launched the ***Green Industry*** initiative with the aim of fostering the positive role of industry in achieving sustainable economic growth. According to UNIDO's Green Industry vision, the industries' role is to constantly provide creative and innovative solutions and alternatives to countries' economies, focusing on a well-balanced economic, environmental and social impact of industry. Sustainable development has indeed become a core determinant of economic competitiveness and allows industries to decouple their economic growth and revenues from excessive and increasing resource use and pollution by minimizing waste in every form, using renewable resources, taking precautions to avoid harming workers, communities as well as the environment [1].

The joint global ***UNIDO-UNEP Resource Efficient and Cleaner Production (RECP) Programme*** endorses the Green Industry vision. The programme is based on a multi-pronged programmatically and geographically focused approach to scale up and mainstream the application of RECP concepts, methods, techniques, technologies and policies in developing and transition countries in order to improve resource efficiency and environmental performance of enterprises and other organizations, in particular small and medium-sized operators in the manufacturing and associated sectors.

The multi-faceted reliance on chemicals across industries makes chemicals production one of the major and most globalized industrial sectors with a high impact on the overall sustainability performance of supply chains. The essential economic role of chemicals and their contribution to improved living standards needs to be balanced under consideration of all potential costs. An adequate cost analysis thus has to include the ***chemical industry's use of resources,*** such as water and energy, and the potential adverse impacts of chemicals on the environment and human health. The potential severity and complexity of such impacts highlights the fact that sound chemicals management is a key issue for sustainable development [2].

Under this programme, the project entitled ***Innovative Approaches for the Sound Management of Chemicals and Chemical Waste*** aims at providing three groups of industries, namely producers of chemicals, formulators and industrial users of chemical products, with innovative approaches and specific technical solutions to chemicals and chemical waste management. The main target is to achieve a reduction of chemical consumption in both production and application of chemicals. Further targets also address the replacement of hazardous chemicals by chemicals with a lower risk, the reduction of chemical wastes, the safe handling of chemicals and risk reduction related to accidents with chemicals. In each of the five participating countries (as of 2013: Colombia, Egypt, El Salvador, Morocco and Peru) and the three groups of industries concerned by the project, the identification and implementation of innovative alternatives and solutions is made on a subsector basis (i.e. industries in the paint formulation, paint application, textile finishing and polymers domains). Assessments in subsectors in each of the participating countries led to the development of the present ***technical manual***, which aims at triggering innovative ideas, providing cost-effective innovative solutions and at enabling companies in these countries and subsectors to implement environmentally sound management of chemicals and chemical waste with high impact.

Introducción

El principal objetivo de la Organización de las Naciones Unidas para el Desarrollo Industrial (ONUDI) es reducir la pobreza por medio del desarrollo industrial sostenible. En respuesta a este desafío global, ONUDI lanzó la iniciativa ***Industria Verde*** con el objetivo de promover el papel positivo de la industria a la hora de conseguir un crecimiento económico sostenible. Según la visión de la Industria Verde de ONUDI, el papel de las industrias es el de ofrecer constantemente soluciones y alternativas creativas e innovadoras a las economías de los países, centrándose en un impacto social de la industria bien equilibrado, económico y medioambiental. De hecho, el desarrollo sostenible se ha convertido en un factor decisivo central de la competitividad económica y permite a las industrias separar su crecimiento económico y sus ingresos del uso de recursos excesivo y creciente y de la polución, así como minimizando el gasto en todas las formas, usando recursos renovables, tomando precauciones para evitar dañar a los trabajadores, así como a las comunidades y al medioambiente [1].

El ***Programa ONUDI-PNUMA para la Eficiencia en el uso de Recursos y Producción Más Limpia (RECP)*** respalda la visión de la Industria Verde. El programa está basado en una estrategia multidual con enfoque programático y geográfico para aumentar y hacer prevalecer la aplicación de los conceptos, métodos, técnicas, tecnologías y políticas RECP en los países en desarrollo y en transición. El objetivo es de mejorar la eficiencia en el uso de los recursos y el rendimiento medioambiental de las empresas, con especial enfoque a los medianos y pequeños operadores de los sectores manufactureros y asociados.

La interdependencia de las industrias en relación con las sustancias químicas a lo largo de las industrias hace que la producción de sustancias químicas sea uno de los mayores sectores industriales y más globalizados con un alto impacto sobre el rendimiento global de la sostenibilidad de las cadenas de suministro. El papel económico esencial de las sustancias químicas y su contribución a la mejora del nivel de vida debe ser equilibrado considerando todos los costes potenciales. Así, un análisis de costes adecuado debe incluir el **uso de recursos por la industria química** como el agua y la energía, así como los impactos potenciales adversos de las sustancias químicas sobre el medioambiente y la salud humana. Teniendo en cuenta la potencial severidad y complejidad de dichos impactos, subraya el hecho de que la buena gestión de las sustancias químicas constituye un factor clave para el desarrollo sostenible [2].

Bajo este programa, el proyecto titulado ***Enfoques Innovadores para una Buena Gestión de las Sustancias y de los Desechos Químicos*** pretende ofrecer a tres grupos de industrias, en concreto a los productores de sustancias químicas, a los formuladores y a los usuarios industriales de productos químicos, enfoques innovadores y soluciones técnicas específicas a la gestión de sustancias y desechos químicos. El principal objetivo es lograr una reducción del consumo de sustancias químicas tanto en su producción como en su aplicación. Además, se pretende afrontar la sustitución de sustancias químicas peligrosas por sustancias químicas de menor riesgo, la reducción de los desechos químicos y el tratamiento seguro de sustancias químicas y la reducción de riesgos relacionados con los accidentes con sustancias químicas. En cada uno de los 5 países participantes (en 2013: Colombia, Egipto, El Salvador, Marruecos y Perú) y en los tres grupos de industrias interesados en el proyecto, la identificación y la implementación de alternativas y soluciones innovadoras se realiza sobre una base subsectorial (es decir, industrias de formulación y aplicación de pinturas, acabado de textiles y polímeros). Las evaluaciones en subsectores en cada uno de los países participantes condujo al desarrollo del presente ***manual técnico*** que pretende desencadenar ideas innovadoras, ofreciendo soluciones innovadores efectivas a nivel de costes y permitiendo a las empresas y a los subsectores en estos países implementar una buena gestión medioambiental de las sustancias y desechos químicos con un gran impacto.

Introduction

L'objectif prioritaire de l'Organisation des Nations Unies pour le développement industriel (ONUDI) est de réduire la pauvreté à l'aide du développement industriel durable. Pour répondre à ce défi mondial, l'ONUDI a lancé l'initiative en faveur de ***l'industrie verte (Green Industry)*** dans le but de promouvoir le rôle positif de l'industrie dans la croissance économique durable. Selon la vision de l'industrie verte de l'ONUDI, le rôle des industries est de fournir en permanence des solutions et des alternatives créatives et innovantes aux économies des pays, en recherchant un équilibre entre les impacts économiques, environnementaux et sociaux. Le développement durable est en effet devenu un facteur déterminant de la compétitivité économique et permet aux industries d'assurer la croissance économique et les revenus, tout en limitant la pollution et l'utilisation excessive des ressources, en réduisant toutes les formes de déchets, en utilisant des ressources renouvelables et en prenant des précautions pour éviter de nuire aux travailleurs, aux communautés et à l'environnement [11].

Le ***Programme mondial commun de production propre et économe en ressources (PCER) de l'ONUDI-PNUE*** sanctionne la vision de l'industrie verte. Le programme est basé sur une approche à plusieurs volets dont les objectifs (en termes de contenu et de géographie) sont d'étendre et d'intégrer l'application des concepts, méthodes, techniques, technologies et politiques du PCER dans les pays en développement et en transition. Le programme vise à améliorer l'efficacité des ressources et la performance environnementale des entreprises et des autres organisations, en particulier les acteurs de petite et moyenne taille dans les secteurs de la production.

La dépendance multiple des industries vis-à-vis des produits chimiques fait de leur production l'un des secteurs industriels les plus mondialisés, générant un impact important sur la durabilité des chaînes d'approvisionnement. Le rôle économique essentiel des produits chimiques et leur contribution à l'amélioration du niveau de vie doivent être pondérés au regard de l'ensemble des coûts potentiels. Une analyse adéquate des coûts doit donc inclure ***l'utilisation des ressources par l'industrie chimique,*** comme l'eau et l'énergie, ainsi que les impacts négatifs potentiels des produits chimiques sur l'environnement et la santé humaine. Prendre en considération la gravité potentielle et la complexité de ces impacts, met en évidence le fait que la gestion rationnelle des produits chimiques est une question clé pour le développement durable [2].

En vertu de ce programme, le projet intitulé ***Approches novatrices pour la gestion rationnelle des produits chimiques et des déchets chimiques*** vise à fournir à trois groupes d'industries, à savoir, les producteurs de produits chimiques, les formulateurs et les utilisateurs industriels de produits chimiques, des approches novatrices et des solutions techniques spécifiques pour la gestion des produits chimiques et des déchets chimiques. L'objectif principal est de parvenir à une réduction de la consommation de produits chimiques tant dans leur production que leur application. D'autres objectifs portent également sur le remplacement des produits chimiques dangereux par des produits chimiques moins risqués, la réduction des déchets chimiques, la manipulation en toute sécurité des produits chimiques et la réduction des risques liés aux accidents avec des produits chimiques. Dans chacun des cinq pays participants (depuis 2013 : la Colombie, l'Égypte, le Salvador, le Maroc et le Pérou) et des trois groupes d'industries concernés par le projet, l'identification et la mise en œuvre d'alternatives et de solutions innovantes ont été faites pour les sous-secteurs industriels suivants : soit formulation de peinture, application de la peinture, finissage textile et polymères). Les évaluations des sous-secteurs dans chacun des pays participants ont mené à l'élaboration du présent ***manuel technique***, qui vise à susciter des idées novatrices produisant des solutions innovantes et rentables ainsi qu'à permettre aux entreprises de ces pays et aux sous-secteurs de mettre en œuvre une gestion écologiquement rationnelle des produits chimiques et des déchets chimiques à fort impact.

2 General description of the paints & coatings industry

2.1 Main fields of application

Paints and coatings are of considerable economic importance. Many activities are concerned by the industrial application of paints. The BCF (British Coating Federation[1]) considers the following sub-sectors: automotive OEM (original equipment manufacturers) bodies, automotive OEM components (primarily plastic automotive components), vehicle refinishing, marine/offshore, high performance (protective, fire protection, anti-corrosion coatings), rigid metal packaging (food, beer and beverage and general cans), coil coating, drum, furniture/joinery, aerospace, ACE (Agricultural, Construction and similar Equipment), general Industry (trade coaters, industrial equipment, metal furniture, original equipment, heavy engineering, plastics (other than those for automobiles), powder). [3; p. 3] [28; p. 354-359]

The paints and coatings industry in the United States, Western Europe and Japan is mature and generally correlates with the health of the economy, especially housing, construction and transportation. Overall demand from 2012 to 2018 will increase at average annual rates of 2–3% in the United States and 1.5–2.5% in Western Europe. In Japan, however, consumption of paints and coatings will experience relatively slow growth during this period (0.5%), as a result of no growth in major markets such as automotive OEM, machinery and appliances.

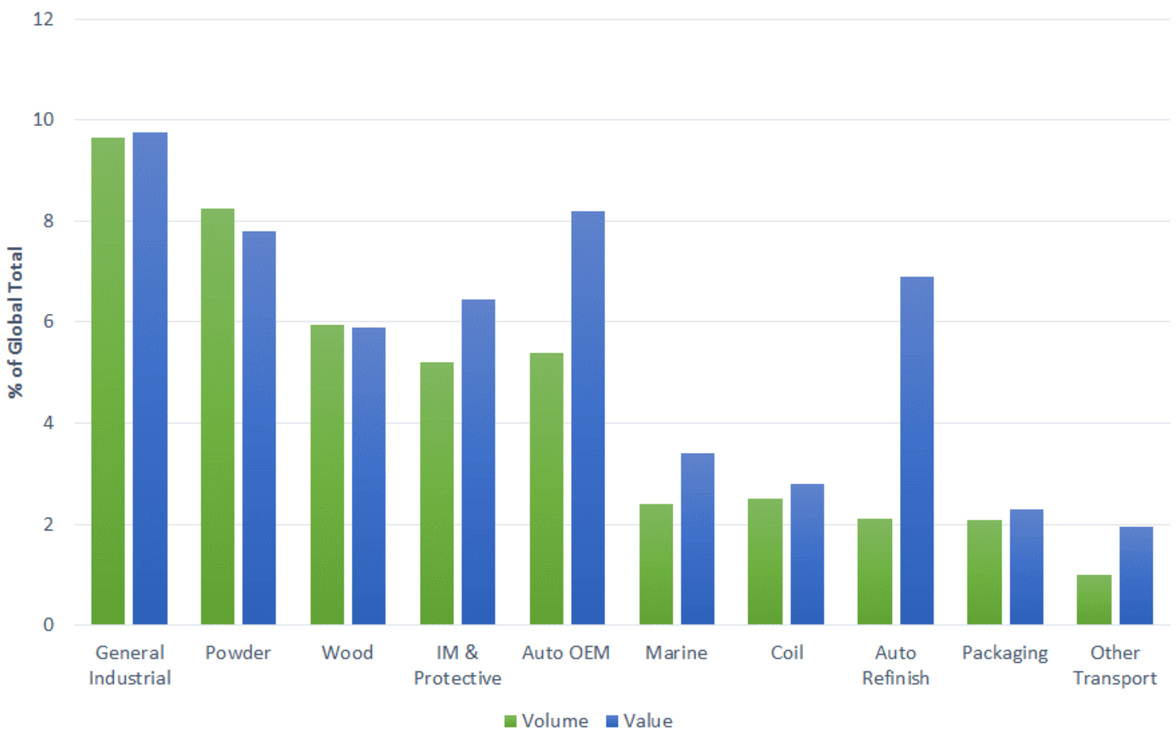


Figure 2-1. Industrial Coating Segments volume and value as part of the Global Coating Market in 2012 [based on 3]

[1] British Coating Federation (BCF): www.bcf.co.uk

The following pie chart shows world consumption of paints and coatings by technology:

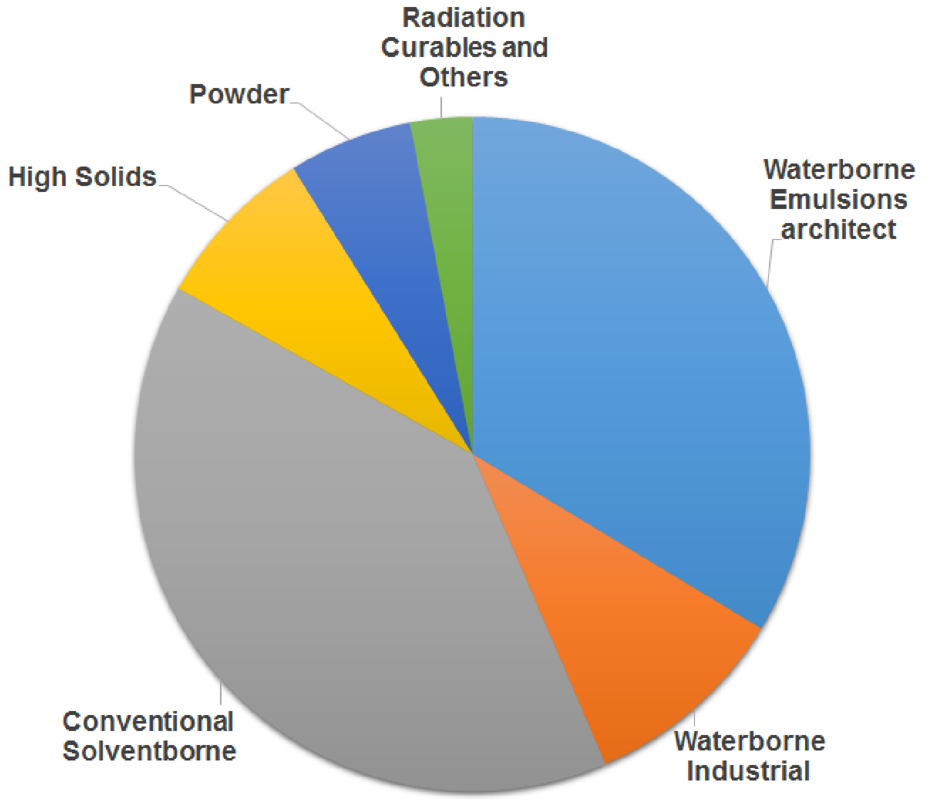


Figure 2-2. World consumption of paints and coatings by technology – 2012 [based on 27]

Most of industrialized European countries and North America consume annually paint coatings more than 20kg per capita and high growth rates can be expected in the less industrialized countries of Eastern Europe, Asia, and South East Asia. The annual utilization of solvent-containing conventional coatings is estimated to be 1 -2 % and, of environmentally friendly coatings (high solids, water-based, powder coatings, etc.), ca. 5 %. The value of the global production of paints and coatings was about 13% higher in 2012 than in 2010. Demand in Asia continues to rise faster than elsewhere in the world, and that region now accounts for nearly 40% of global consumption.

2.2 Common environmental and health issues concerning solvent based paints

Solvents are a major source of environmental concern because at normal temperatures and pressures they can volatilize (i.e., the liquid solvent becomes a vapour). Exposure to these solvent vapours is dangerous for a number of reasons. In the workplace, solvent vapours can result in a number of human health risks. Solvent vapours also can pose fire/explosion hazards, necessitating careful storage and handling procedures. [5; p. 57] Because of their properties and the quantities involved, solvents are the key materials of concern: [6; p. 3]

VOCs react with NOx in the presence of sunlight to form ozone in the troposphere. This usually refers to NMVOC (non-methane volatile organic solvents)

- halogenated solvents, their toxicity and their impact on reducing ozone in the stratosphere
- some solvents are toxic to aquatic organisms
- some solvents are not readily biodegradable, so they have the potential to contaminate soils.

Traditional solvents are not PBT (persistent, bioaccumulative, toxic) and none are vPvB (very persistent, very bioaccumulative). However, solvents can readily spread through soil to groundwater, where there are limited or no mechanisms for their removal or breakdown. There are numerous reports of aquifers used for drinking water being contaminated by solvents (although not necessarily from these industries).

2.3 Paint systems

The following are the some of the properties of paints required for different applications:

Table 2-1 An overview of the ranking[a] of application properties required for different application [based on 21, 22, 24, 25, 26, 28]

Applications / Properties	House-holds	Auto-mobile	Coil coating	Can Coating	Aero-space	Buildings	Naval
Hardness / toughness	++	++	++	+	++	++	++
Durability	++	+++	++	+	+++	++	+++
Abrasion / Adhesion	+	++	++	++	+++	++	+++
Corrosion	+++	+++	+++		+++	++	+++
UV resistance		+++	+++		+++		+++
Appearance (i.e. brightness)	++	+++		++		++	
Low cost	++	++	+	++	++	+++	+
Low weight	+		+	+	+++	++	+
Storage stability	+	+	+	+	+	+	+

[a]*Ranking: +++ : required (75-100%); ++ : required (50-75%); + : required (25-50%)*

The major change that has taken place in the coatings industry during the last forty years has been the adoption of new coating-paint technologies. The new coating technologies include waterborne (thermosetting emulsion, colloidal dispersion, water-soluble) coatings, high-solids coatings, two-component systems, powder coatings and radiation-curable coatings. The operation of a paint system has many variables that affect cost. Effective control of these variables will provide the best quality at the lowest cost. Some cost variables are part of the design, some are part of the operation, and others are related to decisions on how to run to the system. Each cost variable has to be considered to know how much the system costs to operate and how much to charge for painting a part. [17], [18]

- System design
- Quality
- Substrate condition

- Racking
- Rework
- Color change

The major issues facing the coatings industry during 2010–2011 were increased raw material costs in commodities (solvents, resins and others), which were driven by higher hydrocarbon costs. Despite the relatively slow growth in demand anticipated for coatings overall, waterborne and high-solids coatings, powders, UV curables and two-component systems appear to have good growth prospects [20].

2.3.1 Conventional solvent-based paints

The major components of solvent-borne paints and coatings are solvents, binders, pigments, and additives. In paint, the combination of the binder and solvent is referred to as the paint "vehicle." Pigment and additives are dispersed within the vehicle. The amount of each constituent varies with the particular paint, but solvents traditionally make up about 40-50% of the total formulation. Typical solvents include alkenes, aromates, esters and ketones. The share of solvents might vary in a range of 30% - 70% depending on the use and application of the paint.

Binders account for about 30%, pigments and extenders for about 20 %, and additives for 2 to 3%. Environmental issues surrounding paints usually center around solvents and heavy metals used in the pigments. Binders and other additives can also affect the toxicity of the paint depending on the specific characteristics of the paint. [5; p. 2] Solvent-based products are used as first layer/sealers, primers and topcoats, depending on the industry and substrate. [6; p. 435]

2.3.2 Solvent-based high solid paints

Conventional, solvent based paints contain approx. 30 – 70 weight per cent of organic solvents for a regulation of viscosity and film formation. The type of the used solvents mainly depends on the utilised bonding agents. According to the process of film forming, the materials can be subdivided into polycondensation lacquers (e.g. phenol/urea/melamin resin lacquers), polymerization lacquers (e.g. polyesters-, acrylate resin-, alkyd resins), and polyaddition lacquers (e.g. epoxy of PU lacquers).

High-Solids represent an advancement of conventional, solvent based paints. Their solids content amounts usually more than 65 %. The used film forming agents are mainly based on epoxy resins or 2-component polyurethanes1. For paints used for the varnishing of agricultural and construction machines, or household devices, mainly high-solids, based on acrylate and polyester isocyanate are use. [7; p. 48]

2.3.3 Water-based paints

Water-thinnable paints contain water-thinnable or water-dispersible film forming agents.
Mainly alkyd, polyester, acrylate, melamine- and epoxy resin. Also water-thinnable paints often contain 3 – 18 % of organic solvents as solubilizer and for an improvement of the properties of the wet film layer. As preservatives for the storage of the paints, often biocides are part of the formulation. If water-thinnable paints are utilised, some particularities have to be considered:

- **Inflammability:** In general smaller expenditures are necessary for the application, storage and drying of water-thinnable paints, compared to conventional materials.
- **Evaporation of solvents:** Compared to organic solvents, water has a higher evaporation energy. Therefore the energy demand for the drying of water-thinnable paints is generally higher, if the same drying rate as for solvent based paints has to be achieved.
- **Corrosion:** Pipelines of paint application devices have to be made of synthetics or stainless steel.

- **Air humidity:** The drying rate depends on the ambient air humidity. Therefore the application is only possible under suitable or defined air humidity conditions. [7]

2.3.4 Powder coatings

Powder coatings are solvent free materials. Their application does neither generate wastewater nor VOC-emissions. As film forming agents mainly polyester or epoxy resins are used. For the most application a recycling of the overspray is possible.
For drying, the material is heated and thus merges into a film. At present powder coatings are mainly applied via electrostatic assisted spraying on the work pieces (primarily metal but also glass or wood surfaces). In several sectors the application of powders is a well-established technique.
Due to environmental advantages, possibilities for an automation and good profitability due to the possibility of a recycling of the overspray, the use of powder coatings is increasing. [7; p. 49]

2.3.5 Radiation curing paints

Radiation curing paints contain either only low amounts of organic solvents (approx. 2 - 5 %) or consist entirely of solids (e.g. using reactive thinners). In special cases also paints with a solvent content of up to 65weight per cent are utilised. Radiation-curing lacquer consists of reactive resins (e.g. epoxy, acrylates), monomers or oligomers and a photo initiator. In general three different drying techniques are applied:
UV radiation curing and **electron beam hardening** and **Ultrared radiation curing.** The latter is working based on heating up the paint in both other cases radiation causes the chemical reaction.
[7]

2.4 Paint application processes

The application of paint spans a disparate group of industries which differ in size, complexity, and purpose of economic activity. However, the key challenges faced in reducing chemical consumption, substituting hazardous chemicals, and reducing chemical waste in these industries have many common solutions; many of which are outlined in the following text. Generally, paint type and means of application are dependent upon what function the coating must perform. Painting and coating applications typically include the following process steps (see Figure below):

- Procurement of material, storage, and feeding of materials
- Substrate surface preparation
- Application of the coating
- Drying/curing of the coating
- Equipment cleaning

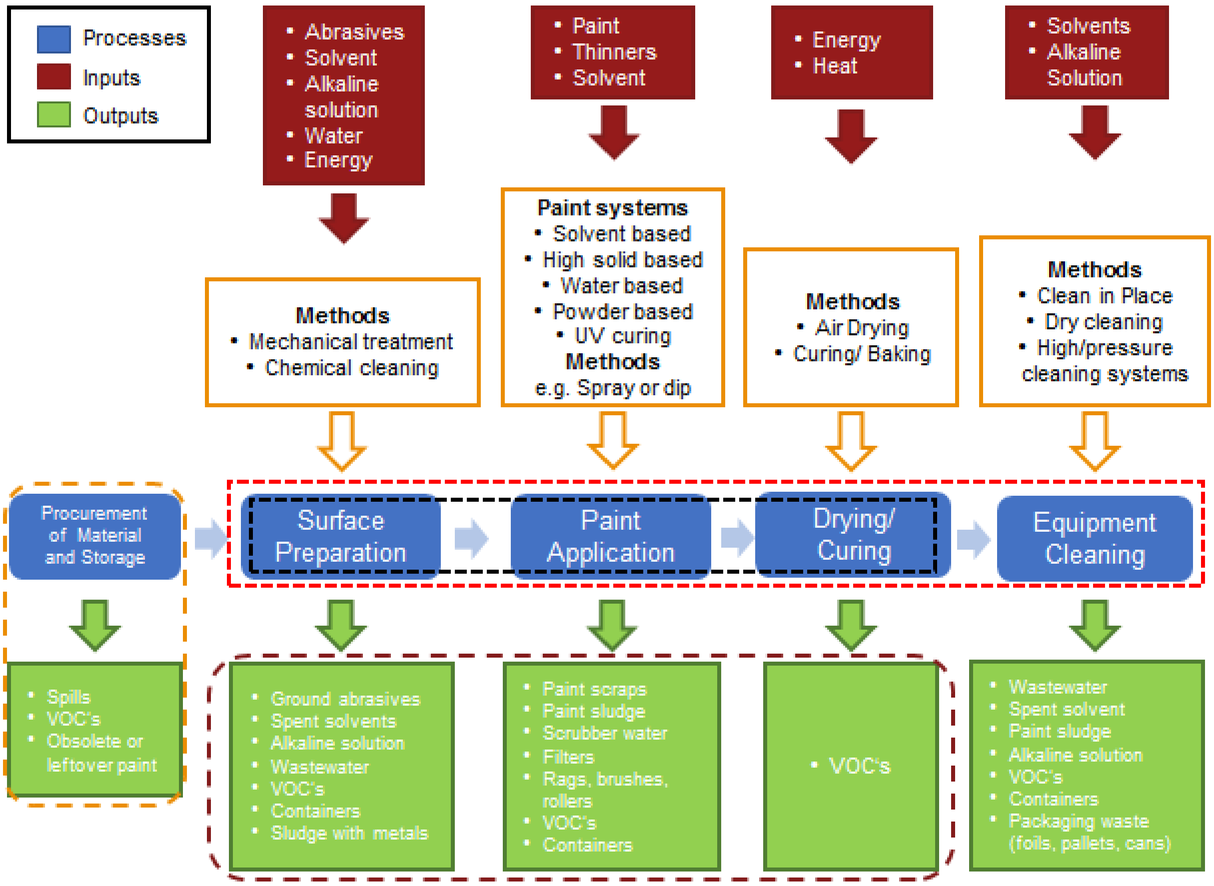


Figure 2-3. General schematic of a paint application process [ISSPPRO]

The performance profile of a coating is initially shaped by the paint and thus by the paint manufacturer, it is the processor who actually generates the finished properties. The industrial scale coating of consumer goods is therefore a joint effort between paint and coatings manufacturers and processors.
Paint manufacturers provide the conditions for successful painting by their permanent technical presence and support. This relates primarily to materials and processes, though includes detailed environmental protection and occupational safety issues. Paint manufacturers offer a package, as it were, in which the material is just one component among many (see Figure 2-4).

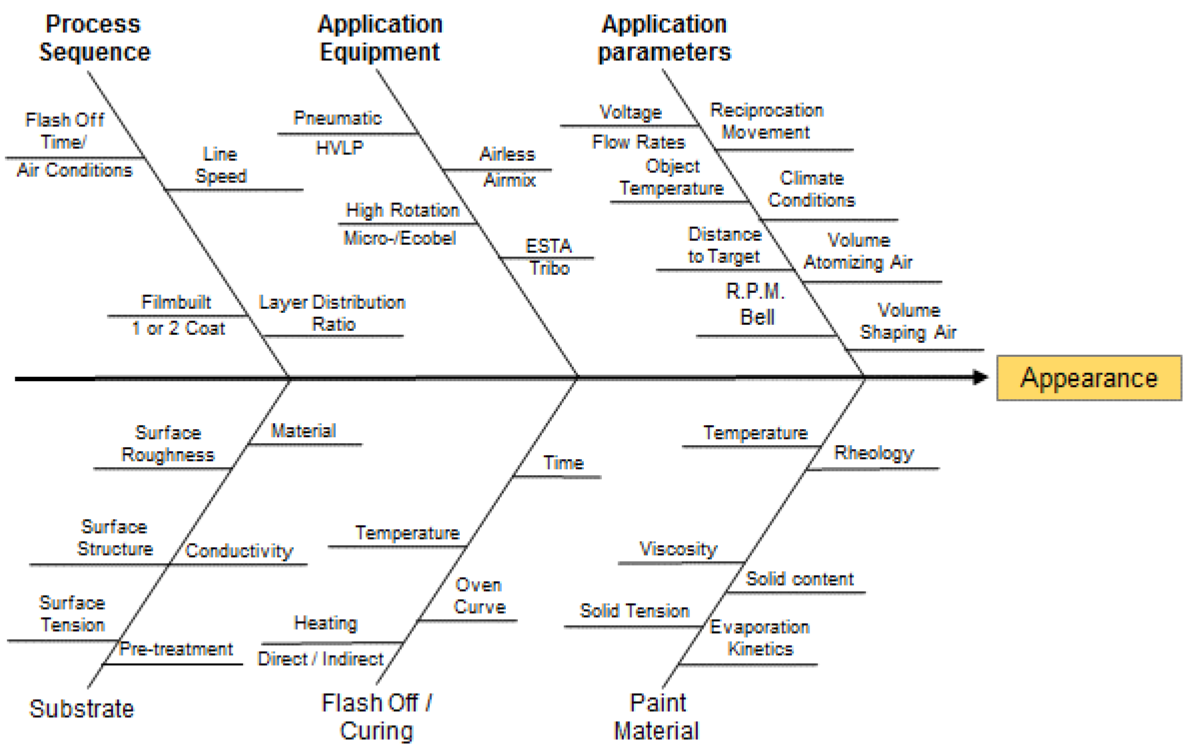
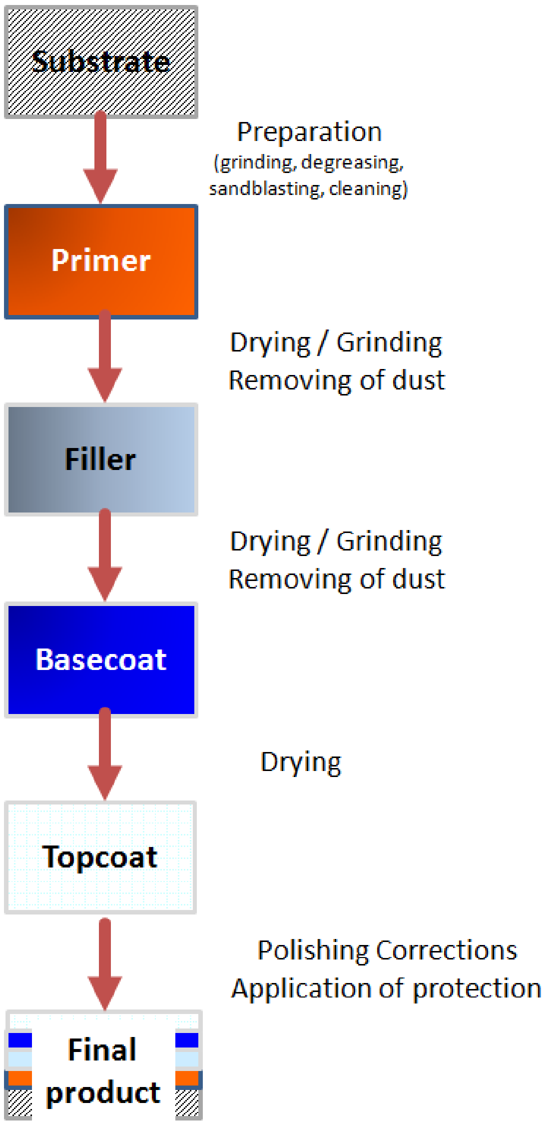


Figure 2-4. Various factors determining the final coating result of the spray application process [based on 22, p.20]

Paint manufacturers are faced with specific problems since they are expected to produce constant material quality and at the same time paints with constant processability. Only this provides the best conditions for achieving a uniform result in the painted article. This means that production paint and coatings entails more than merely manufacturing a product whose composition is identical to a defined standard. Rather, since physical variables can only rarely be applied as criteria for the practical properties of coatings, paint testing of necessity includes simulating the application method used by the processor of these materials. This gives rise to a large number of different test methods because of the very wide range of specification conditions and the different requirements on the coating process resulting from them. Standardising these tests and reducing their overall number is also a priority task for all concerned.



Primer :

- Main function: Bond to substrate, prevention of corrosion
- Thickness of dry film: few µm to > 0.1 mm (max. ~0.2 mm)
- Used technologies: dipping (cataphoretic painting), all kinds of spraying, manual application

Filler :

- Main function: Structural strength, flexibility of coating, equalising of surface
- Thickness of dry film: 0.05 - >0.1 mm (max. ~0.2 mm)
- Used technologies: All kinds of spraying, manual application

Basecoat :

- Main function: Colour
- Thickness of dry film: 0.01 – 0.10mm
- Used technologies: all kinds of spraying (including high speed rotation), flooding, rolling

Topcoat :

- Main function: Gloss, special effects, first barrier against environmental effects (UV, water, salt)
- Thickness of dry film: 0.02 – 0.10 mm
- Used technologies: All kinds of spraying (including high speed rotation)

Figure 5 : Brief overview of application techniques, classified by task and physical type [based on 23]

2.4.1 Substrate surface preparation

Substrate surface preparation can be grouped into two techniques [6; p. 431-432] :

- Solvent-based degreasing: Oil, grease and dirt are removed from metal or plastic substrates with solvents. This is usually by immersion in a vat of solvent or the solvent vapour above the liquid. The vats can be open or closed, and may be used with ultrasonic systems.
- Water-based pretreatments: Water-based pretreatments are applied for three reasons: to remove grease and dirt from previous operations, improve corrosion resistance and to improve adhesion of the subsequent paint layers. The usual pretreatments applied are degreasing, phosphating and chromating. These processes are not applied in the coating of wood and furniture as they are not necessary and they remove oils from the wood.

2.4.2 Application of coating

The following paint applications techniques and their advantages and disadvantages are described in more detail in the following chapter:

- High Volume Low Pressure (HVLP) Spray
- Low Pressure Low Volume (LPLV) Spray
- Airless Spray
- Rotary Atomization
- Electrostatic Spray
- Autodeposition
- Electrodeposition
- Dip, Flow and Curtain Coating
- Pouring
- Rolling

2.4.3 Drying of the coating

Once a coating is applied to the work piece it then undergoes a curing or drying process. While the terms drying or baking are commonly used in the painting industry to refer to curing, there is a distinction between drying (baking) and curing. In curing, the resin must be converted into a new resin, while drying refers to the loss of the solvent so that the resin remains the same. Curing and drying both use the two same methods to harden a coating: air/force dry and baking. [5; p.109]

- **Air Drying**. In air drying, a coating film is formed by the evaporation of solvent, which leaves behind a solid film. The rate of drying is governed by how quickly the solvent evaporates. Moderate heat (below 194°F) can be applied to accelerate evaporation (called force drying), however, the process still basically remains one of air drying.

- **Elevated Temperature Curing/Baking**. Elevated temperature curing uses one of three means: conduction, convection or radiation to apply heat to the coated part

2.4.4 Cleaning of Equipment

This section refers to process equipment cleaning. In all activities, the process equipment will be cleaned. This is consists of two types: 6

- operational or interim cleaning. Cleaning of the application system is necessary at regular intervals, e.g.
  - for colour change and quality reasons. e.g. for spraying cars, after five to ten vehicles and at each colour change
  - cleaning of spray booths is necessary at regular intervals
  - between printing jobs
- maintenance, periodic or in-depth cleaning. It is periodically necessary to clean application equipment thoroughly to remove accumulated deposits and clean parts of equipment that are more difficult to clean quickly. This usually requires some disassembly.

The type of technique used will depend on whether the equipment is cleaned in situ, dismantled completely or in part.

The different cleaning techniques are and their areas of application are shown in the table below.

Table 2-2. Overview of cleaning techniques and their applications [based on [6; p. 565]

Technique	Process equipment		Substrate
	Non-persistent contamination	Persistent contamination	
Minimizing cleaning	Yes	Yes	Yes
Preparation prior to solvent or other types of cleaning	Yes		
Conventional solvent cleaning	Yes*	Yes*	
Solvents with lower evaporation speed	Yes		
Cleaning with powerful solvents		Yes	
Cleaning with solvents with lower ozone forming potential (OFP)**	Yes	Yes	
Water-based cleaning	Yes	Yes	Yes
Cleaning by hand	Yes		Yes
Washing machines using solvents	Yes	Yes	
Cleaning with solvent recovery	Yes		
Cleaning with high pressure water spray		Yes	
Ultrasonic cleaning		Yes	Yes
Dry ice cleaning		Yes	Yes

2.4.5 Typical chemicals used

- Solvents
    - Thinning of paints
    - Cleaning of substrates
    - Cleaning of equipment
- Several inorganic liquid chemicals:
    - Acids (pickling, e.g. Nitric acid – HNO_3, Sulphuric Acid H_2SO_4, Hydrofluoric Acid HF- mostly mixtures are used)
    - Phosphation
    - Chromation (Cr(III) and Cr(VI)
    - Purging agents (washing active chemicals)
- Paint removing chemicals
    - Organic bating agents (chlorinated HC, N-Methyl-pyrrolidone)
    - Brines (Sodium-hydroxide)

3 Innovative solutions

3.1 Reduction of chemicals consumption

The reduction of chemicals consumption in the application of paints can be broken down into the following categories:

- Material procurement & production management
- Storage, preparation, and feeding of materials
- Surface preparation:
    - Eliminate the need for cleaning
    - Best practices in degreasing of surfaces (#voc manual)
- Application of paint that directly results in less chemical consumption
    - Technology: optimizing existing system.
    - Minimize amount of paint being applied (#thickness, overspray reduction, optimum spray properties, etc.)
- Cleaning of equipment:
    - Cleaning machine
    - Cascade cleaning cascade (multiple) rinsing
    - Etc.

3.1.1 Material procurement & production management

Just in time management [6; p. 424]

Applying a just-in-time management system will ensure that the ordered amount of materials, e.g. paint or ink, which are to be used for a specific job, matches the volume that is needed. For example, the ordered amount of paint of a certain colour matches the volume needed for a certain strip to be coated. This applies to external suppliers, and does not include the in-house preparation of batches of inks, paints, etc. Less waste materials will arise and fewer raw materials are used. Use of a paint management system also leads to cost reductions.

Use of pre-coated materials [3; p. 443]

Pre-coated materials can be used in the assembly of products, reducing the number of paint coatings or eliminating the need to paint. In the case of coating substrates of uniform dimensions, such as coil coated metals, wood or fibre boards, etc. coatings can be applied using techniques which are more difficult to apply to the assembled products or part-products, but are more environmentally beneficial.

Significant reduction of VOC emissions dependent on the spraying activities that are replaced by applying coil coated materials. More efficient use of materials, more efficient drying or curing. More efficient collection and destruction of emissions during coil coating, as the application of the coatings and extraction of waste gases for a continuous flat surface is easier and more efficient than for coating formed components and bodies.

Batch painting/colour grouping [6; p. 428]

Batch painting, also called colour grouping or block-to-block painting, means that a series of a specific products is painted in the same colour. This will result in less frequent changes to a different colour.
Benefits include VOC reductions through reduced paint line cleaning/purging. Less paint residues produced. This technique is commonly applied in the automotive industry, in the coating of trucks and commercial vehicles and in the coating of metal packaging.

Sufficient storage space for the products as well as an appropriate logistical planning system have to be available. It also depends on the number of different colours and their relative abundance in the production programme. For the automotive industry, the average colour group length is between two and six units.

There are many other worthwhile measures to consider:

- Use pre-mixed coatings where possible to avoid mixing on-site.
- Thin or mix coatings in a centralised mixing room, or preferably in an enclosed machine. Use trained staff for this task. Where possible, use electronic/computerised equipment.

Do not allow machine/process operators to mix their own coatings at the machine side. Such bucket chemistry' usually leads to significant emissions into the workplace. [14; p.29-30]

3.1.2 Storage, preparation, and feeding of materials

Direct piping of solvents from storage [3; p. 429]

Solvents for viscosity control are piped directly from the storage area to the painting or inking units. For better control, aboveground piping should be carried out as underground pipes for solvents are a known source of serious soil and groundwater pollution. The system is effective if coupled with regular inspection and maintenance. Otherwise, solvent losses from pumps, valves and flanges may add up and become a significant source of VOC emissions.

Piped systems have a number of advantages, which are:

- reducing the risk of spillage through transfer and decanting
- removing the need to uncover tanks and reservoirs, allowing better sealing and reducing the risk of exposure to contaminants
- being able to fit with flow meters to allow accurate auditing.

Supply of paint [14; p. 29], [3; p. 428]

Depending on the job involved, paint can be supplied either remotely of with a paint cup. For small amounts or frequent changes in colour, a paint cup is involved. Remote paint pots are applicable for large quantities and reduce sprayer fatigue. However remote paint pots have to be depressurized, refilled, and re-pressurized; leaving residue and incurring down-time. An alternative are systems equipped with (usually diaphragm-) pumps reducing the changing times because no pressure-changes are needed

Piped systems have a number of advantages, which are:

- reducing the risk of spillage through transfer and decanting
- removing the need to uncover tanks and reservoirs, allowing better sealing and reducing the risk of exposure to contaminants
- being able to fit with flow meters to allow accurate auditing.

Fewer waste paints or inks, fewer containers and fewer materials to clean. For example, the achievable level of residues for heatset plants is <1 % of the purchased ink.

Advanced mixing systems [3; p. 425-426]

When using automated mixing systems, it is strongly recommended but not strictly necessary to use standard colours to mix the required colour. Specific colours can be composed from non-standardised colours by computer-controlled equipment. This, however, requires very sophisticated software and exact knowledge of the non-standardised colours which are to be used for the mixing. For this purpose, these non-standardised colours need to be measured with a photo spectrometer and the result is introduced to the colour-computer.

For example, with an online mixing system for 2-component products such as paints or adhesives, the exact amount needed will be dosed and mixed immediately before usage. The mixing unit is not a part of the paint or adhesive application tool. It is a standalone unit.

It is possible to obtain similar proportional benefits from using programmable scales or computerised Pantone colour matching systems. During manual mixing, losses of 1 or 2 % of solvents can occur. These can account for 15 % of the total VOC emissions. Automated mixing in enclosed machines reduces most of these emissions. Also, less cleaning agent is needed. With an online mixing system for 2-component products, reductions of 10 - 30 % of waste can be achieved.

Online mixing systems for 2-component products are applicable when produced on equipment dedicated to a single product line. There is no restriction in subsequent application techniques.
In the Netherlands, companies are advised to apply this technique when over 2000 litres of
2-components paint needs to be mixed. For adhesives, relatively small amounts are mixed. It is commonly applied in wood and furniture painting. It is also applicable to the coating of trains, e.g. for applying the ground coat and primer/filler.

For online mixing systems for 2-component products, investment costs are EUR 9.000 – 18.000 for a mechanically driven installation used for the mixing of base coat. The costs are EUR 27.000 – 37.000 for an electronically driven installation. The payback time will normally be several years for companies coating small series. However, this depends on the amount of waste prevented, the price of the materials that are mixed and the costs for disposal.

Pig-clearing systems [6; p.430-431]

This method only fills as much paint into the system as necessary for the coating processes. The paint is pressed back from the (flexible) tube into the paint supply by an elastic separation module (pig-clearing) and is re-used. The purged solvents can be recovered and reused.
A special type of purging is called 'soft purging', where lower VOC paint materials, rather than solvent are used to purge guns and lines. The advantages are the lower use of cleaning agents, the reduction of paint and solvent losses as well as the decrease of the manual processes with the colour change.

Only applicable where:

- paints or inks are delivered to machinery through pipes, and
- different colours are sent through the same pipe regularly.

Not applicable where low viscosity products are used as they will run past the module; currently applied in some base coat lines of automotive paint-shops but there is no widespread use of this technology.

3.1.3 Surface preparation

Degreasing of components using organic solvent methods can be a significant source of emissions and wastage. This section describes measures that can reduce the consumption of chemical in the surface degreasing and pretreatment. [14; p. 24]

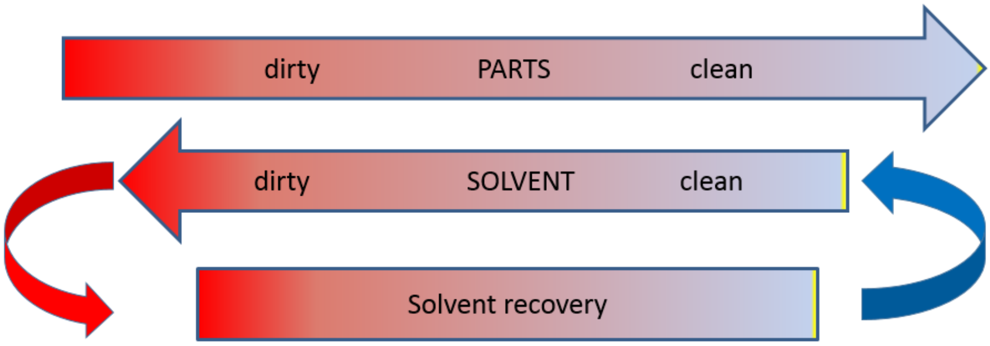


Figure 3-1. Countercurrent cascade confirguration for surface cleaning [based on 23]

Eliminating the need for cleaning

Your first priority should be to eliminate/minimize the need for degreasing operations:

- Keep items well protected (eg using covers and stretch-wrap) and free from contamination between processes. This will reduce the need for grease/oil used as an anti-corrosion measure.
- Spin-off excess oils and/or allow longer drain times between machining and cleaning of components.
- Stack components carefully before cleaning to reduce oil retention.

Good housekeeping for solvent degreasing

Where solvent degreasing has to be used, consider the following points: [14; p.25]

- Where practicable, use modern enclosed degreasing machines, e.g. with appropriate doors/lids, and, ideally, hermetically sealed machines. Open-topped vapour degreasing plant using risk phrase solvents is unlikely to comply with the requirements of the Solvent Emissions Directive (SED)
- Where practicable, fit cooling condenser coils (attached to a closed-loop chiller unit) below the extraction vent inside the machine to allow internal solvent capture and hence minimize vapour losses.
- Open-topped tanks should be retrofitted where possible with a lid - below any rim or other local exhaust ventilation (LEV) extraction system - and interlocks fitted to ensure that extraction occurs only when the vessel is open.
- Organize (i.e. rack or jig) the items so that there are as few solvent traps as possible and that the items drain freely. This will reduce drag-out.
- Where possible, equipment that transports the components through the degreasing process should be integral to the machine and should not allow items to carry solvent out of the machine (e.g. to drip on the floor).
- Turn the work in the freeboard zone to minimise solvent drag-out.
- Where possible, use powered hoists and lifts to ensure that the correct loading and unloading speeds are always used. This will ensure minimum disturbance of the solvent surface and minimum solvent carryover. Use a maximum speed of 3 m/min in the vertical plane and 6 m/min in the horizontal plane.
- When topping up the machine, avoid decanting losses by pumping solvents from the supply tank to the degreasing machine through a pipe system. Alternatively, use sealed drums and a drum pump.

3.1.4 Paint application

Processes with high application efficiency include filling, rolling, casting, dipping, flooding and vacuum coating. These processes generate less overspray than spray applications but are not universally applicable. There are two dipping processes: conventional and electrocoating. Spraying may be with or without electrostatic assistance[2].
For electrostatically assisted spraying, an electric field is generated between the workpiece and the spray gun. Then the following advantages concerning the environment as well as coat effectiveness are reached:

- lower material consumptions, lower emissions, smaller amounts of paint sludge and a reduced soiling of painting areas (less cleaning)
- improved possibilities for automation of painting processes, faster coating and, therefore, a higher productivity
- less air consumption (less energy demand).

Disadvantages of electrostatically assisted spray applications are the risk of edge runners and layer thicknesses which are too deep into cavities and interior edges due to a concentration of paint materials onto these areas. Several electrostatically assisted spray applications are in use, and they are described in the following sections. Also there may be special requirements concerning quality achieved, geometry, paint materials, electrical conductivity (e.g. affecting the ability to recoat surfaces) and workplace safety relating to the high voltages used.

Despite the increasing use of electrostatic application techniques, spraying without electrostatic charge is still widely used for various applications. In comparison to electrostatic processes, the investments are significantly smaller. Also there are no special requirements concerning geometry, paint materials, electrical conductivity and workplace safety. The disadvantages of these application techniques are low efficiencies. Thus, several techniques were developed for a minimisation of the overspray and their efficiency is comparable to electrostatic processes. These techniques are also described in the following sections. However, it should be noted that every spraying technique can be improved by converting it to an electrostatic process.

Overview of paint application options, benefits and limitations

Transfer efficiency is a measure of how well a technology applies a layer of paint, i.e. how much applied paint actually ends up on the job. It is defined as the percentage of coating used that becomes attached to the workpiece, Coating material that is not applied to components being coated is a major source of waste, e.g. overspray caused by the properties of the spray gun and the way the spray gun is used. Overspray can be reduced by good operator practice.

One of the most important aspects to reduce paint consumption is to measure and monitor the applied paint thickness. Only apply the necessary thickness as specified by the paint manufacturer.

[2] More information for this section can be found in the following reference: [6; p. 444-445]

Table 3-1. Transfer Efficiencies of Various Application Technologies [based on 5,p.83 and 7]

Technology	Transfer Efficiency	Operating Cost	Finish Quality	Recess Coverage
Conventional Air Spray	30 to 60%	Low	High	Good
HVLP Spray	40-70%	Low	High	Good
LPLV Spray	40-70%	Low	Unknown	Good
Airless Spray	65 to 80%	Medium/high	Low	Good
Electrostatic Spray	60-90%	Medium/high	Low	Poor
Electrodeposition	90 to 99%	NA	NA	NA
Conventional Dipping	90-95%	Low	Low	Good

Note: Given values are ranges for plane objects.

NA : not applicable

Table 3-2 : Overview of application technologies [based on 5,p.83; 6,p.224-225; 20,p.118]

Technology	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
HVLP Spray	Reduces overspray, increasing transfer efficiency Reduces VOC and HAP emissions Lowers risk of blowback to the worker	Can be used on many surfaces	Is portable and easy to clean Allows operator to vary the air pressure, air volume, paint pressure and spray pattern	Has production rates that are not as high as conventional air spray
LPLV Spray	Has a high transfer efficiency rate Has low operating costs Has moderate capital costs			Is not widely used
Airless Spray	Has a transfer efficiency of 65 to 80% Cuts overspray by more than half, and is cleaner and more economical	Hydraulic atomization used most widely by painting contractors and maintenance painters Heated atomization used by furniture manufacturers and industrial finishers	Is twice as fast as air spray and produces a higher film build; is more portable than air spray	Is limited to painting large areas, requires a different nozzle to change spray patterns; nozzle tends to clog and can be dangerous to use or clean because of the high pressures involved
Air-Assisted Airless Spray	Has higher transfer efficiency and lower chance of blowback	Used by furniture and industrial finishers	Has material savings that are 50% better than air spray Has higher film build per pass than air spray	Has same dangers as airless, but requires more maintenance and operator training, and has a higher initial capital cost
Rotary Atomization	Has excellent efficiency		easy adaptation to different viscosities by adjusting the rotation speed	Requires high degree of cleanliness

Technology	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
Electrostatic Spray	Has high transfer efficiency Produces little overspray and uses relatively little paint	Is good for painting oddly shaped objects Is used by most appliance manufacturers If installed correctly, can also work with waterborne and metallic paints Can be applied to more than one coating	Produces a uniform coat because the paint itself acts as an insulator	Has limited coverage with complicated parts because of Faraday cage effects Can paint only conductive parts Presents a possible shock hazard Is more expensive, slower and has higher maintenance costs than air spray Surface of the object must be extremely clean
Autodeposition	Uses water-borne paints	Is limited to iron, steel, zinc and zinc-alloy plated materials	Is effective for anti-corrosion properties and coverage of the objects Uses no electricity Hollow spaces can be covered	Is limited to dull or low gloss finish; few available colors
Electrodepositi on	Has transfer efficiency of almost 100%	Is limited to metallic or other electrically conductive objects (e.g., autobody coating)	Can accommodate high production rates; production can be automated	Requires that objects be metallic or electrically conductive Is costly and requires a lot of energy Requires that employees receive high level training to use this system Limited useable for hollow spaces
Dip, Flow and Curtain Coating	Has high transfer efficiency	Is well suited for parts that are always the same color and have minimum decorative finish requirements, such as agricultural equipment	Has high production rate Requires relatively little labor	Depends greatly on the viscosity of the paint, which thickens with exposure to air unless carefully managed Is not suitable for objects with hollows or cavaties Has lower quality finish

Technology	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
Roll Coating	Has high transfer efficiency	Is limited to sheet materials (e.g., strip metal and boards); used to decorate cans and other metal objects	Has high production rates	Is limited to flat work

Implementation of electrostatic support[3]

Electrostatic spraying is a subcategory of electrophoretic deposition (uses an electric field to deposit colloidal particles onto a substrate acting as an electrode) which involves atomized paint droplets which are charged at the tip of the spray gun by an electrode. It allows the workpiece to be completely coated with a film of uniform thickness, including normally inaccessible areas.

[3] http://www.globalspec.com/learnmore/materials_chemicals_adhesives/industrial_sealants_coatings/industrial_coatings

Table 3-3 : Basic characteristics of the electrostatic spraying [based on 8]

Requirements	Advantages	Disadvantages
• Conductivity of painted parts • Adjustment of formulation • Investment in spraying equipment	• Spraying efficiency 60 – 90% (instead of 40 – 80%) backside is covered with paint • Production can be automated	• Thickness is higher on the edges • Spraying waterborne paints is more complex • Manually spraying pistols are not easy to handle • No paint in Faraday´s cages

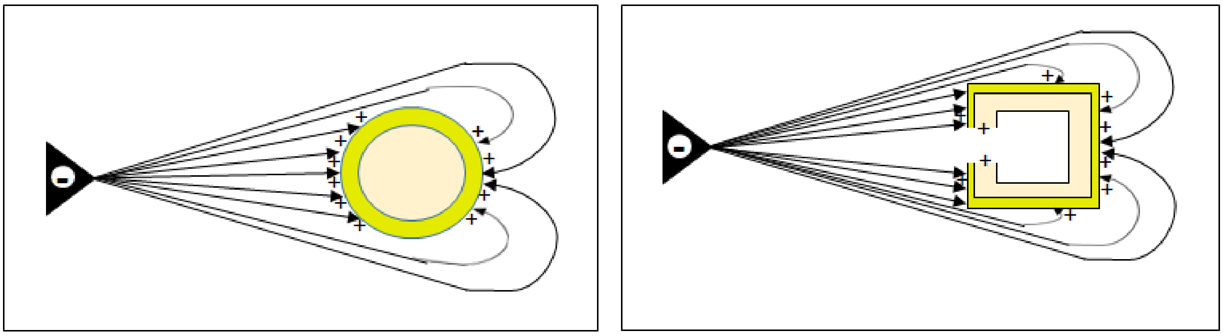


Figure 3-2 Implementation of electrostatic support [based on 8]

Good spray gun techniques [14; p.22-25]

Good practice during setting up and when using spray guns can:

- save money by reducing paint waste;
- save energy costs by reducing the amount of energy used for pumping paint and producing compressed air;
- save time by reducing rework caused by poor quality finishes.

Poor operator practice can produce high rework rates and high material consumption from a good spray gun system. In addition to purchasing new spray application equipment, improving your facilities current spray techniques will also reduce waste volume with little to no capital expense.

Preparation:

- Maintain spray guns properly. Worn parts, e.g. nozzles and needle valves, produce poor atomisation and will result in poor finish quality and the need for rework.
- Assemble the spray gun correctly for the job at hand, according to the paint manufacturer's recommendations. This may include selecting the correct nozzle size to ensure the appropriate application flow rates.
- Test spray before starting on the job to check that the spray pattern is correct for the particular job.
- Use the correct size compressed air hose, according to the spray gun manufacturer's advice.
- Good quality compressed air, at the correct supply volume and pressure, is vital for good quality spraying. Problems with poor air supply should be tackled at source. In addition:
    - Check that the air supply to the spray gun is at the correct pressure and the line can supply the correct air flow rate for the spray gun. Excessive air pressures result in over atomisation, leading to poor finish quality due to dry spray and excessive overspray from increased bounce back

- With HVLP spray guns, use an aircap pressure tester to ensure the air supply is delivering the required pressure at the aircap (according to the spray gun manufacturer's advice). Do not exceed this pressure. A common mistake among sprayers, even with conventional spray guns, is to set the aircap pressure too high.
- Follow the manufacturer's instructions when setting up spray guns that use compressed air. The techniques can be learned.

- Increasing the fluid flow rate in an attempt to increase paint application rates can be counterproductive. Excessive fluid flow rates can lead to poor atomisation, causing finish quality problems and excessive overspray.
- With electrostatic spray systems, ensure that electrical connections are sound and clean.

Operation

Spray guns should be held at right angles to the surface being painted and at the specified distance. This depends on:

- the job at hand;
- the type of spray gun;
- The type of coating being applied.

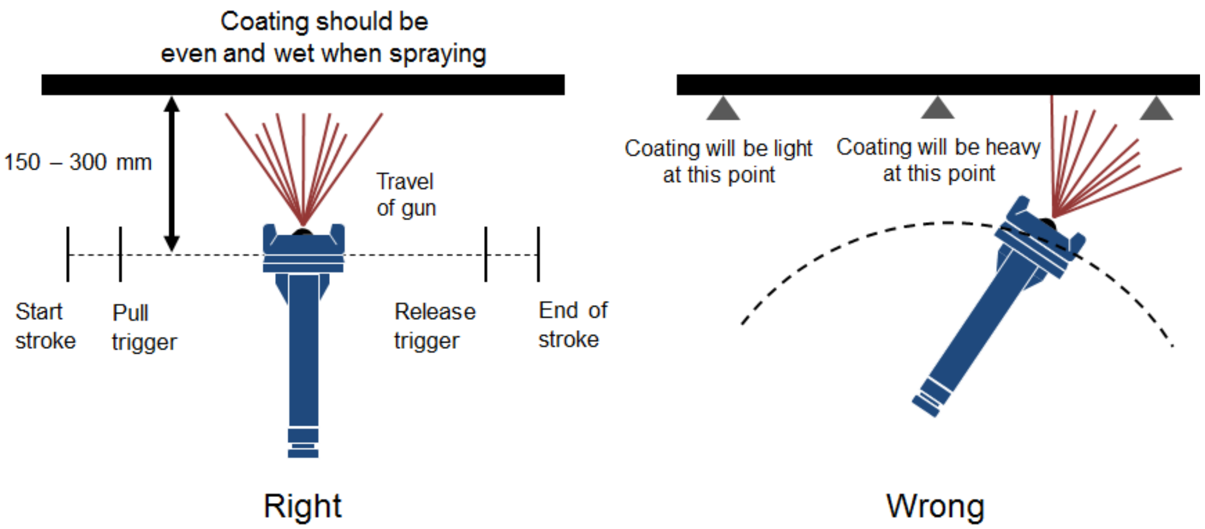


Figure 3-3. Correct spray techniques for all spray guns including HVLP spray guns [based on 14]

The following points should be noted for HVLP spraying:

- If the spray gun is held too far from the workpiece, transfer efficiency is lost due to excessive fog and losses to gravity. Finish quality will also be affected, as too much solvent may evaporate from the spray before it reaches the workpiece, causing common faults such as orange-peel effects and dry spray.
- If the spray gun is too close to the workpiece, the applied coat may be too wet. This can cause sagging and runs that spoil the finish quality.

The painting action should ensure that the spray gun is kept parallel to the surface at all times. Arcing the gun alters the spray gun to workpiece distance throughout the stroke (see

Figure 3-3, leading to patchy finish quality.

- The spray gun should be moved at a speed that gives a full wet coat to the surface. Each stroke should overlap the previous stroke by about 50%.
- At the beginning and end of each stroke, the trigger should be used to feather the applied paint. This prevents sagging from over-application of paint where strokes overlap.
- Edges should be sprayed first. Paint should then be applied working away from the edge to the main area of the workpiece.
- If poor technique is contributing to poor finish quality or high material consumption, then a refresher training course will help to bring operators back to standard.

Minimising overspray

Generally, it is necessary to keep overspray and evaporating solvents under control. Optimisation of equipment settings and proper training can lead to a significant reduction in overspray, less fog, and an improved coating performance.

As shown in **Error! Reference source not found.**, overspray can be substantially reduced by:

- Feathering - or triggering - the spray gun at the end of each stroke. This entails rapidly turning the spray gun off and then on again to start the next stroke. This conserves paint when the spray gun is not pointed at the workpiece and reduces excessive application at edges - the cause of sagging and runs
- Adjusting the spray pattern to match the job at hand. Adjusting the spray to match the smallest of a batch of objects will minimise overspray on all the objects. Using the largest spray pattern to gain speedy application is wasteful.
- In industrial-scale processing the spray equipment is enclosed in booths. In these the evaporated solvents and the overspray are removed by supplying fresh air. This ensures air flow which is as laminar as possible from top to bottom in the booth. [22, p.560]

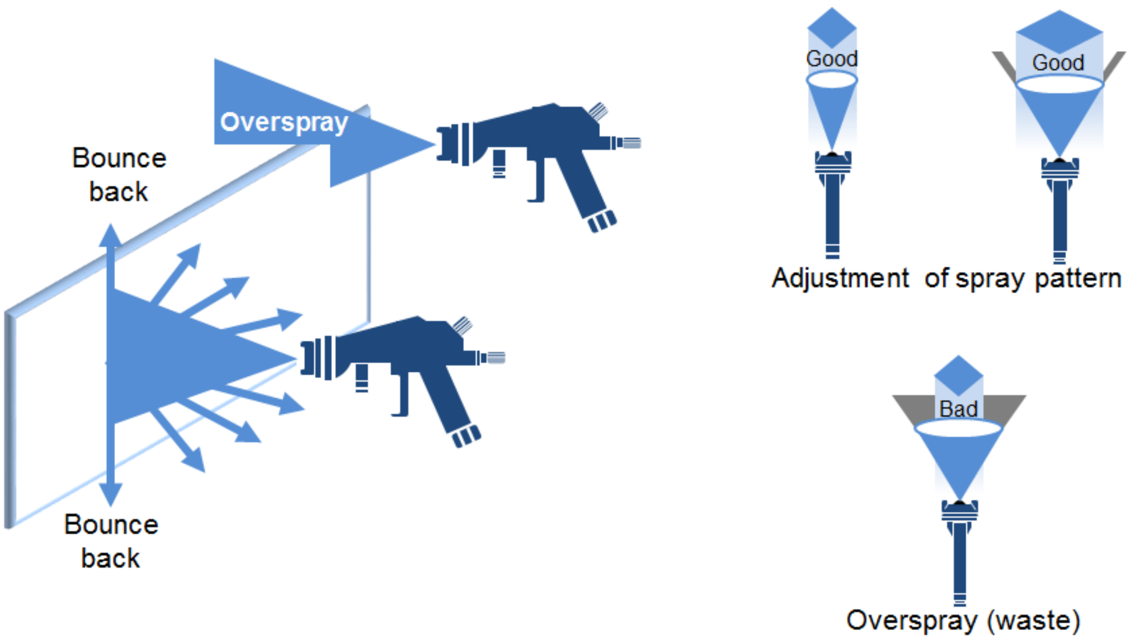


Figure 3-4. Reducing overspray [based on 14]

Highest efficiency in a spray booth is always attained when the capacity, size and other specifications are most suited to the kind of work to be performed. The following factors are important while selecting the most appropriate booth for a specific coating component [11]:

- Size and geometry of the article to be coated.
- Rate of production (i.e. Paint Consumption).
- Product handling method.

There are different types of spray booths such as:

I. Spray Painting Booths; and

II. Powder Coating Booths.

Gravity feed HVLP system

An alternative to the syphon feed HVLP system is the gravity feed HVLP system, using a gravity cup. No paint is wasted in this type of cup, as long as the correct amount of paint is mixed or measured out for each job. When the gun runs out of paint, the only paint left in the cup will be the small amount which adheres to the sides of the cup. Gravity cups tend to be smaller than syphon cups, thus reducing the top-heavy effect disliked by many sprayers. However, this feature - coupled with the fact that gravity feed increases paint delivery rates - has the disadvantage that the cup has to be refilled more often.

Gravity cup spray guns also have the advantage that they weigh less, thus reducing operator fatigue. On average, a gravity cup HVLP spray gun weighs 250 g (8 oz) less than the equivalent syphon cup spray gun. A relatively new development is a plastic-bodied gravity feed HVLP spray gun weighing up to 500 g (1 lb) less than a metal syphon cup HVLP spray gun.

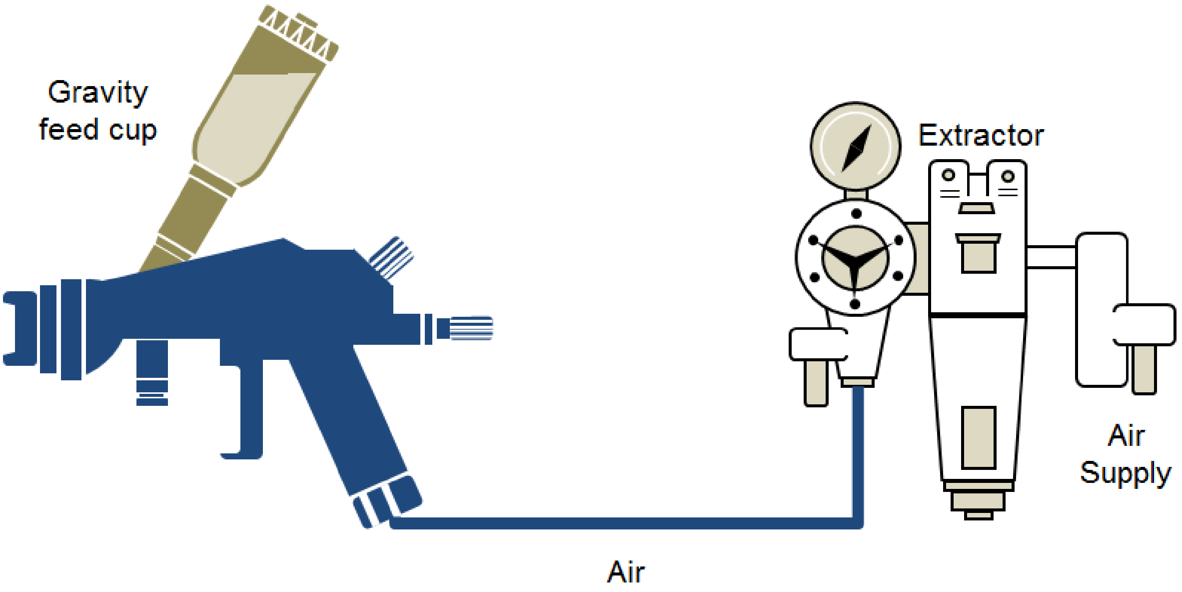


Figure 3-5. Gravity feed HVLP system [based on 14]

Warming of paint with a heating hose [VDI-ZRE; Lack 2012]

Changes in the paintshop temperature throughout the day can lead to changing viscosity and differing spray performance. Some techniques heat the pot to counteract this undesirable effect.

A new technique is to use a heated hose connecting the pot to the spray gun so that the paint arrives at the gun at the desired temperature. This overcomes the previous disadvantages encountered when using a heated pot:

- No reduction in the pot time of 2K paints (2 component paints), and therefore more paint can be used.
- Less temperature required (since do not need to account for temperature decrease in hose)
- Uniform heating and no danger of overheating
- Less energy consumption
- Low capital cost and easy control
- Can be used with any paint application system

Automation of equipment [6; p.414-418] [14; p.35]

Automation of coating can be applied to almost all industrial situations. While this automation is more applicable to medium-to-high volume coating operations, it may also be of interest to companies seeking to increase capacity or looking for ways to achieve closer control of their coating process. 14

Many operations in an installation may be automated, depending on the activity and the industry. Examples include:

- robot spraying:
    - of cars,
    - of trucks
    - of ships
    - of plastics
- automatic mixing systems
    - for printing, applicable to flexible packaging only
- roller coating
- curtain coating
- piped delivery of solvents and solvent-based
- cleaning of equipment

Benefits include the minimization of overspray, reduction of dust, increased materials efficiency, reduced paint waste and less solvents.

3.1.5 Cleaning of equipment

When cleaning spray guns, it is BAT is to minimise the release of solvent by collecting, storing and reclaiming for re-use the purge solvent used to clean coating spray guns and/or lines: 80 to 90 % can be re-used. [3; p. 479]

BAT is to minimise VOC emissions by using non-solvent or low solvent emission cleaning techniques such as one or more of those are described in Table 3-5 and Table 3-6.Conventional solvents should be used in conjunction with techniques to minimize emissions, such as in sealed washing machines venting to waste gas treatment.

<u>Practices for cleaning with solvent:</u>

- Control the use of cleaning solvents by providing operators with a set amount each day/shift. Use triggered spray containers rather than free access to cans.

Solvent Recovery by filtration or distillation: [6; p. 543-545]

Used solvents, e.g. used for cleaning, can be treated for re-use, e.g. by filtration or distillation. Both recovery and re-use can be done on site or off-site. For example, where pig-clearing systems or purge systems are applied, solvents are used on-site to clean the system after each change of color – called the purges. Modern paint supply equipment includes recovery of the purge solvents. Solvents can also be disposed of as hazardous waste to an off-site solvent recovery installation. There, the clean solvents are reused, but not necessarily by the same user.

Filtration

Dirty cleaning solutions, e.g. of HBS or VCA, can be filtered although the majority of recovery process are based on distillation. The solvents can be re-used and the water residue can normally be discharged to the municipal waste water system resulting in less waste water and less use of fresh solvents.

Filtration requires energy and the water residue is discharged Any dissolved HBS or VCA will drastically affect the chemical oxygen demand and biological oxygen demands of the water being discharged to the municipal waste water system.

Distillation

Solvent-based waste such as inks, paints, paints and adhesives can be distilled to recover the solvent and to reduce the amount of hazardous waste. Special purpose distillation equipment exists.

Achieved environmental benefits: The amount of hazardous waste is reduced and the solvent can be re-used, e.g. for cleaning. Distillation requires energy. However, compared to incineration, which creates CO2 and also uses energy, it is likely that distillation and re-use saves energy.

The distillation equipment must be installed and operated with care. Cleaning agents with a high flashpoint generally also have a high boiling point. For these solvents, only vacuum distillation equipment can be applied; in these situations membrane filtration may be used. It is reported that relatively small vacuum distillation units (50 litres) are readily available. Cleaning machines that have distillation equipment attached are available.

Investment costs start at EUR 10,000 for smaller vacuum distillation plants, depending on, e.g. size, tank capacity and automation. There is an additional cost if the existing equipment for the distillation of cleaning agents can be used.

Recovery of Solvents from Wipes [6; p. 547]

The majority of solvents in wipes are removed by draining by gravity, a wringer, or a centrifuge prior to transport.

Note: this technique is an answer to the *bad practice* of using too much solvent and pouring the excess used solvents over the wipes in order not to have to dispose of them separately. The recovered solvents can be used again for cleaning, or if too dirty, distilled and re-used.

3.2 Substitution of hazardous chemicals

3.2.1 Surface preparation

The evaporation speed of solvents determines the amount of solvent that will evaporate during the cleaning activity and the later storage of the contaminated wipes (a standard test is used: DIN 53170). The evaporation speed of traditional solvents, e.g. in printing, toluene and ethyl acetate, is higher than the evaporation speed of solvents with medium and high flashpoints. Consequently, the evaporation during cleaning can be reduced by using the latter. Data on the evaporation speed can be obtained from the supplier, if not provided to the user of the solvent. If this information is not available, the flashpoint of a solvent is a good indication of its evaporation speed, and all lower flashpoints should be indicated on the packaging of the solvent. [16]

Using medium and high flashpoint cleaning agents also has some health and safety advantages, because the exposure of personnel to the evaporated solvents will be reduced. However, as very low OELs sometimes occur, e.g. 1 or 2 ppm versus 150 ppm for ethyl acetate, these advantages occur when the alternative cleaning agent meets the following criteria:

- there is not a substantially lower occupational exposure limit
- the change in solvent does not lead to heating being required
- the solvent is not dried by forced evaporation with HP air.

As the coating is usually most readily soluble or re-suspended in the original solvents, occasional use of traditional low flashpoint cleaning agents will be necessary to assist in difficult cleaning tasks. A small amount of these (e.g. some 5 % of the total) will have to be kept in stock. For example, HBS or other low volatility solvents are not applicable to all printing plants. Inks that are based on volatile solvents, when dry, dissolve easily in the same solvent which they originally contained. Using solvents other than the original solvent is generally counterproductive. One of the reasons is that it is not possible to use existing machinery for in-house distillation and re-use when changing to HBS. In-house filtering systems are under development for HBS. Other examples of the occasions where volatile cleaning agents will need to be used are the following:

- cleaning dampening rollers
- maintenance
- cleaning UV curing inks
- difficult color changes.

Where alternative solvents with lower volatility/higher flashpoint are used for cleaning floors, these solvents do not (by definition) evaporate rapidly, and therefore leave the floor slippery. It is therefore necessary to dry the floors, sometimes with small quantities of volatile solvents.

Water-based cleaning [6; p.431-435, 467-476]

Components and sub-assemblies can be cleaned in vats using water-based cleaning or degreasing techniques based on detergent systems. These systems are also used to clean substrates or workpieces for water-based treatment techniques, e.g. There are a range of chemical systems used, based on combining detergents with alkalis and others substances, depending on the substrates and the materials to be removed. These, and their maintenance options, are discussed in the STM BREF.
There are typically no solvent emissions in water-based cleaning. However, additional heating may be required and subsequent treatment of wastewater is likely. Furthermore, it may take longer to clean components than solvent-based techniques.

Table 3-4 : Alternatives to Chlorinated Solvent Cleaning [based on 5; p. 35]

Contaminant	Possible Alternatives
Corrosion Inhibitors	Alkaline-soluble compounds
Fats and Fatty Oils	Hand wipe or use alkaline cleaners
Fingerprints	Handle all fabricated parts with gloves Use alkaline compounds for had wiping Use alcohols with hand wiping
Ink Marks	Use water-soluble inks and remove ink with water Use labels or tags until final marking is applied
Hydrocarbon Greases and Oils	Institute the use of hand wiping stations to remove enough soil for alkaline cleaning Use water-soluble compounds
Machining (cutting fluids)	Substitute water-soluble fluids for use in machining
Polishing Compounds	Use water-soluble compounds Clean at polishing station

3.2.2 Paint application

The use of less harmful substances (substitution) can be achieved in one of three ways[4]:

- Direct replacement of one substance by a less hazardous one. This is usually limited to simpler systems, for example, replacement of low flashpoint cleaners by high flashpoint ones.
- Replacement by different process chemistries or techniques using less hazardous substances. This is used where there is no direct replacement. Different coating process chemistries give treatments with different properties, even for the same materials. This is the principle route for replacing harmful substances in this sector, and is dealt with in the appropriate activity and industry chapters.
- Eliminating the surface treatment process in the installation and using, for example, precoated materials in production (e.g. for producing white goods or construction panels). This type of substitution may be shown to be environmentally beneficial (e.g. in life cycle studies) and may be considered by an operator to achieve various objectives including reducing VOC emissions. However, the IPPC Directive refers to the installation and the activities used. This type of substitution (in effect, cessation of the process within the installation) is therefore not a technique likely to be considered in determining BAT and is not discussed further in this reference document.

[4] More information for this section can be found in the following reference: [6; p. 484-496]

Table 3-5 : Example of solvent substitutes used in the coating sector

Low solvent coatings	High solids
	2-component (chemically inter reacting
	Water-based
	Powder slurry
Solvent-free coatings	Hot melts
	Powder coating
	Powder polyester coating
	Radiation curable coating

The majority of conventional coatings are solvent borne, traditionally containing about 25 - 50% solids (20-30% binder and 20-30% extender and pigment) with a relatively high organic solvent content. A clear-coat might contain up to 75%. These materials generally have been applied with conventional air spray, which uses compressed air at high pressures to atomize paint, a technique known as low-volume/high-pressure (LVHP).

3.2.3 Alternative Coatings (Low-VOC Paint)

These coating alternatives to solvent-borne coatings can reduce emissions of VOCs and, in so doing, reduce the generation of hazardous wastes and decrease worker exposure to toxic air emissions. [6; p. 435-443]

Table 3-6. Overview of Alternatives to Solvent-Borne Coatings [based on 5;p. 63-64]

Technology	Pollution Prevention Benefits	Reported Application	Operational Benefits	Limitations
High-Solids	Reduces solvent in coatings (low VOC) Has less overspray compared to conventional coatings	Corrosion protection, like Zinc-coated steel doors Miscellaneous metal parts Same as conventional coatings	Can apply thick or thin coat Has easy colour blending or changing Is compatible with conventional and electrostatic equipment	Does not eliminate solvent completely Has shorter pot life than conventional coatings Must be heated in some cases
Waterborne	Eliminates or reduces solvent in coating (little or no VOC) Uses water for cleanup	Wide range Architectural trade finishes Wood furniture Damp concrete Automotive	Can apply thick or thin coat Has easy colour blending or changing Is compatible with conventional and (special-) electrostatic application equipment	Has coating flow properties and drying rates that can change with humidity, affecting coating application Is sensitive to humidity May have poor flow characteristics Needs special equipment for electrostatic application Has water in paint that can cause corrosion of storage tanks and transfer piping, and "flash rusting" of metal substrates
Powder	Eliminates solvent in coating (no VOC) in most cases Reduces solvent in cleanup Reduces need for solid paint waste disposal	Steel Aluminium Zinc and brass castings Wood	Can apply thick coat in one application Requires no mixing or stirring Has efficient material use (i.e.; nearly 100% transfer efficiency)	Requires special handling of heated parts Has electrostatic application systems that must be electrically conductive; complex shapes difficult to coat Needs special equipment or extra effort to make colour changes Is difficult to incorporate metal flake pigments Substrate must be able to handle high temperatures (> 100°C).
Radiation Cured	Eliminates solvent in coating (no VOC) Is 100% reactive liquid	Some metal applications Filler for chipboard Wood, paper "Wet look" finishes	Can apply thin coat Has easy colour blending or changing Has efficient material use (i.e., merely 100% transfer efficiency)	Has styrene volatility Is typically best applied to flat materials Is limited to thin coatings Has high capital coast of equipment Can have yellow colour Colour limited (mostly clear coat despite printing inks

Comparison of Coatings alternatives [7; p. 48-49], [15; p. 19-23]

High-Solids Coatings

Pollution prevention benefits:

- reduces solvent in coatings
- less overspray compared to conventional coatings
- higher transfer efficiencies

Operational benefits:

- can apply thick or thin coat
- easy colour blending or changing
- compatible with conventional and electrostatic application equipment

Energy savings:

- reduced air flow in work spaces (depending on local regulations, only in automatic application)
- and curing ovens (low VOC)
- reduced energy needed for heating makeup air

Applications:

- zinc-coated steel doors
- miscellaneous metal parts same as conventional coatings

Limitations:

- solvent use not completely eliminated
- shorter pot life than conventional coating

Water-Dilutable Paints

Pollution prevention benefits:

- eliminates or reduces solvent in coatings
- reduced VOC emissions and fire hazards
- reduced hazardous waste disposal
- water used for cleanup

Operational benefits:

- can apply thick or thin coat
- easy colour blending or changing
- compatible with conventional and (special-)electrostatic application equipment

Energy savings:

- reduced air flow in work spaces
- (little or no VOC)
- reduced energy needed for heating makeup air but more energy needed for paint drying

Applications:

- wide range (industrial and do-it-yourself)

- architectural trade finishers
- wood furniture
- damp concrete

Limitations:

- coating flow properties and drying rates can change with humidity, affecting coating application
- sensitive to humidity, workplace humidity control required
- may have poor flow characteristics due to high surface tension of water
- special equipment needed for electrostatic application
- water in paint can cause corrosion of storage tanks and transfer piping, and "flash rusting" of metal substrates

Radiation-curing Paints

Pollution prevention benefits:

- eliminates solvent in coating
- allows for increased production rates 100% reactive liquid

Operational benefits:

- can apply thin coats
- easy colour blending or changing
- efficient material use, nearly 100% transfer efficiency

Energy savings:

- little air flow in work spaces (no VOC)
- cure with UV instead of an oven
- little energy needed for heating makeup air

Applications:

- some metal applications
- filler for chipboard
- wood
- paper
- "wet look" finishes

Limitations:

- styrene volatility
- typically best applied to flat materials
- limited to thin coatings
- high capital cost of equipment
- yellow colour
- limited availability of colours (mostly clear coat, despite printing inks)

Powder Coatings

Pollution prevention benefits:

- eliminates solvent in coatings
- little or no VOC emissions
- easier to recycle and reuse overspray

- reduces solvents for cleaning
- reduces need for solid paint
- waste disposal

Operational benefits:

- can apply thick coat in one application
- no mixing or stirring
- efficient material use, possible to achieve nearly 100% transfer efficiency if a reclaim system is used

Energy savings:

- little air flow needed for worker protection (no VOC)
- little energy needed for heating makeup air

Applications:

- steel
- aluminium
- zinc and brass castings

Limitations:

- requires handling of heated parts
- part must be electrically conductive, complex shapes difficult to coat
- difficult to apply thinner coatings
- need special equipment or extra effort to make colour changes
- difficult to incorporate metal flake pigments
- substrate must withstand temperature during melting/curing process (> 100°C)

3.3 Reduction of chemical waste

3.3.1 Overview of waste generated

Waste from Paint application

The general steps for paint application include:

- Surface preparation
- Paint application, and
- Curing or drying

In addition, cleaning the equipment used in each of these steps generates waste.

Wastes generated from industrial paint application processes may be considered hazardous because of the presence of toxic metals and organic solvents. Wastes generated during industrial paint application include the following:

- Scrubber water, paint sludge, and filters from air pollution control
- Equipment cleaning wastes
- Aqueous waste and spent solvents from surface pretreatment
- VOC emissions during paint application, curing, and drying,
- Empty raw material containers, and
- Obsolete or unwanted paint

In addition, residential paint use generates waste from equipment cleaning, VOC emissions, empty containers, and leftover paint.

Table 3-7: Waste Reduction Techniques for Paint Application

Technique	Description	Effects
Use alternative paint	Substitute water-borne, powdered, or high-solids paints for solvent-based paints Use paints that have less toxic pigments	Reduces the toxicity of paint sludge and paint scraps Powdered paints eliminate scrubber water and paint sludges from overspray Reduces need for organic solvents for cleaning or paint thinning Reduces VOC emissions
Reduce quantity of solution used for surface preparation	Reduce solvent evaporation by installing tank lids, increasing freeboard space, and installing freeboard chillers. Extend life of cleaning, solution by removing solids and adding components to increase efficacy, when needed. Redesign rinsing system to reduce rinsewater usage	Reduces quantity of spent solvents, aqueous solutions, and rinse water from surface preparation Reduces use of raw materials
Reduce toxicity of solutions used for surface preparation	Use physical or mechanical methods Use less toxic solvents or aqueous solutions	Reduces toxicity of surface preparation wastes Reduces VOC emissions
Recycle surface preparation wastes	Recover and reuse spent solvents Reuse nonhalogenated solvents as fuel Recover metals from surface preparation solutions	Reduces the quantity of surface cleaning wastes
Increase transfer efficiency	Use of electrostatic spraying to increase transfer efficiency Use flow coating, roller coating, or electrodeposition to increase transfer efficiency Improve operating practices	Reduces paint loss due to overspray Reduces paint sludge, scrubber water, and spent filters from air pollution control
Reduce equipment cleaning efficiency	Revise schedules to reduce switching paints Use dedicated equipment Use proportional mixing	Reduces the quantity of equipment cleaning waste If solvents are used, reduces VOC emissions
Substitute cleaning materials	Use less toxic solvents or high pressure alkaline solutions	Reduces toxicity of cleaning wastes Reduces VOC emissions
Recycle cleaning solution	Remove paint sludge and reuse cleaning solution Recover and reuse spent solvents Reuse nonhalogenated solvents as fuel	Reduces quantity of equipment cleaning waste
Reduce wastes from air pollution control	Improve transfer efficiency Switch from wet to dry paint booth(not always valid) Use screen of bag filters that can be	Reduces the quantity of waste from air pollution control

Technique	Description	Effects
	cleaned and reused Reuse scrubber water Reuse paint sludge as a filter material or as fuel; this solution is dependent on local regulations	
Reduce old or unwanted paints	Implement inventory controls Find a user through a 'drop and swap' or waste exchange Reuse the paint as fuel Return paints to the manufacturer for reblending	Reduces quantity of paint waste Reduces loss of raw materials
Reduce raw material containers	Buy bulk quantities Reuse containers Recover metals from containers	Reduces quantity of container waste

Waste from Paint Removal

Conventional paint removal techniques include scraping, sanding, sand blasting and solvent stripping. Both sand blasting and solvent stripping, although widely used, generate waste that pose environmental and health risks.

Wastes generated during paint removal include the following:

- Large volume of wastewater containing solvent/paint residues
- Sand and other silica-containing materials used in sand blasting are harmful
- Dry paint residue and spent abrasive media are hazardous and may be landfilled or incinerated
- Toxic dust for the workers from abrasive blasting

Table 3-8 : Waste Reduction Techniques for Paint Removal

Technique	Description	Effects
Rinse water reduction	Collect paint and solvent solution Filter and reuse stripper solvent	Reduces the quantity of wastewater from rinsing after solvent paint stripping Reduces the quantity of virgin solvent used
Solvent substitution	Immerse objects in molten salt or hot caustic bath instead of solvent bath	Reduces VOC emissions
Abrasive media substitution	Use plastic media or dry ice as abrasive media Use high-pressure water sprays	Eliminates use of sand and related health risks Eliminates spent media waste (i.e. plastic media are recyclable) Plastic media blasting can be substituted for solvent stripping, eliminating VOCs and spent solvent waste
Substitute pulsed light for abrasive media	Use lasers to heat and loosen paint	Eliminates spent media waste

3.3.2 Surface preparation

Appropriate surface preparation is the precondition for a high quality coating with a long lifespan. Furthermore, the surface condition can influence what type of coating can be applied. Therefore, surface preparation is a key step influencing the sustainability of the total process.

Minimising cleaning of surfaces

Methods for surface preparation vary depending on the material to be painted, the paint to be used and the desired properties of the resulting finish**.** Surface preparation can generate a number of wastes, including spent abrasives, solvents and/or aqueous cleaning baths, and surface treatment baths; air emissions from abrasives and solvents; rinsewaters following aqueous processing steps; and solvent-soaked rags used for wiping parts before painting. Depending on the complexity of the operation and the nature of the chemicals used, the volume and toxicity of wastes generated can vary widely. [5; p. 29]

Principal cleaning techniques [14; p. 24-25]

- ***Mechanical cleaning*** methods such as scraping, brushing, blasting and tumbling/vibration can be useful to remove dirt/grease.
- ***Aqueous cleaning*** systems generally have a wash stage (sometimes ultrasonically assisted), combined with rinse and hot air drying stages. Some use alkaline aqueous solutions and some incorporate a conversion dip (preferably phosphating rather than chromating) to provide extra corrosion protection. Such systems should eliminate the need for any form of manual preparation such as handwiping with organic solvent.
- ***Controlled pyrolysis ovens (organic solvents)*** burn off organic coatings and inks from metal surfaces at temperatures of around 930°C. These systems have been successfully used to clean paint jigs and hangers, body panels and other metal components.

Table 3-9 : Main advantages and disadvantages of principal cleaning techniques [based on 14, p. 10]

Cleaning method	Advantages	Disadvantages
Mechanical	Low cost, particularly if using brushes rather than fully enclosed systems. May avoid the need for solvents. Sandblasting is aa more expensive mechanical cleaning technology.	Only line-of-sight is cleaned. Waste disposal costs may be high. Difficult to re-use media when removing oil or grease. May affect the component surface.
Organic solvent	Effective at dissolving oils and greases. All parts of the component are cleaned. Load is dry on leaving plant.	Risks to health, safety and the environment. Governed by strict legislation. Special waste generated, which is expensive to dispose of. Solvent losses may occur through evaporation. Plant needs to be maintained and cleaned regularly.
Aqueous	Lower operating costs than vapour degreasing. All parts of the component are cleaned. Water can often be re-used or recycled. Less hazardous to human health and the environment than organic solvent cleaning.	Effluent treatment costs may be high. Components may be wet and require drying on completion. This may increase costs. Certain chemicals may corrode machinery and components.
Biological	Low operating temperature means lower operating costs than vapour degreasing. All parts of the component are cleaned. Solution can be disposed of directly to sewer. Biological surfactants, which make use of micro-organisms, do not need replacing. Less hazardous to human health and the environment than organic solvent cleaning.	Only suitable for Hydrocarbon contamination. May take longer than traditional degreasing techniques. Enzyme cleaners require replenishing. Components may be wet and require drying on completion. This may increase costs.

Measures for waste in the surface preparation [5; p. 30-31]

This section covers general methods to improve the efficiency of the surface preparation process and to reduce the pollution generated during the surface preparation processes.

A cost-effective method for reducing these wastes is to minimize the need for surface preparation by

- Improving current operating practices and
- Setting standards for cleaning and stripping. If the need for surface preparation cannot be reduced by these methods, alternative technologies must be assessed.
- Maximizing the cleaning capacity of current methods also can help reduce wastes.

Each of these options is discussed below.

Improve Current Operating Practices

To reduce the need for cleaning, technical assistance providers can help companies examine the sources of workpiece contamination. Technical assistance providers should determine how contaminants such as lubricants from machining, dirt from the manufacturing environment, and finger oil from handling by shop personnel are contaminating the workpieces. Once the contamination sources are identified, technical assistance providers can help determine whether some or all contamination sources can be eliminated by improving current operating practices. For example, proper storage of materials and just-in-time delivery of parts can keep contaminants from becoming a problem. To eliminate finger oil contamination, gloves can be used in areas of parts handling; gloves can be made of lint-free material, or lint can be removed with a dry cloth

In the case of paint stripping, technical assistance providers can help firms examine what causes the need for paint stripping. Possibilities include: inadequate initial part preparation, defects in coating application, improper time/temperature cycle for the curing oven, and equipment problems or coating damage due to improper handling. While no process is perfect, reducing the need for repainting can greatly reduce the volume of waste generated from paint removal

Set Standards for Cleaning and Stripping

Next, companies should determine the cleanliness level or cleanliness standard that is needed. Cleaning requirements are generally based on two factors: process specifications and customer requirements. A system to measure cleanliness should be used to prevent over-cleaning and ensure efficient use of cleaning agents.

In the case of abrasive stripping, standards should be set to avoid blasting a surface longer than necessary, creating excess waste and reducing productivity. Measuring devices can be used to define the level of surface scratching or "profile" desired. Most standards use classifications for surface cleanliness. There are two types of standards available: visual disk and photographic. A surface profiler instrument also can be used.

Pollution prevention approaches tends to favour mechanical or aqueous cleaning methods, but solvent vapor degreasing can be more economical and suitable for certain types of parts (e.g., parts that slide into each other to form a close fit, preventing some surfaces from being exposed). Advanced technologies have made both of these processes more effective and less harmful to the environment.

Maximize Cleaning Capacity of Current Methods

The following practices should be implemented where possible to maximize the cleaning capacity of aqueous or solvent cleaners:

- Use counter current cleaning (i.e., begin with "dirty" cleaner, followed by "clean" cleaner)
- Add an additional rinse
- Recycle cleaning solvent and rinsewater
- For aqueous cleaners, control water temperature and pressure. For example, elevated temperature solutions are more effective for removing greases and oils.

The following sections provide more detail on specific surface preparation processes including solvent vapor degreasing, aqueous cleaning, alternative solvents, phosphatizing, anodizing, stripping, and abrasive blasting.

3.3.3 General Good Housekeeping

Improvements in better operating practices, or "good housekeeping" methods apply to all emissions and waste streams, require minimal capital outlays, and can be very effective in reducing wastes and pollutants. Good housekeeping includes the development of management initiatives to increase employee awareness of the need for, and benefits of pollution prevention; preventative maintenance to reduce the number of leaks and spills; and efficient use of raw materials. The following Table presents a summary of good housekeeping measures.

Table 3-10. Opportunities for Improved Housekeeping in Coating Operations [based on 5; p. 26]

Waste	Method
General	Improve material handling and storage to avoid spills Segregate waste streams Perform preventative maintenance Practice emergency preparedness Charge departments generating waste for costs associated with management and disposal
Paint Waste	Maintain rigid inventory control to reduce thinner use Initiate routine maintenance and training to reduce leaks and spills Mix paint according to need; document use Provide operator training to improve transfer efficiency Schedule jobs to maximize color runs
Solvent Waste	Control inventory to reduce use Substitute coating material for one with low or no solvents Substitute cleaning solution for one with low or no solvents Practice proper equipment cleaning methods Recycle solvents onsite

3.3.4 Prevention of unplanned releases/emissions

BAT is to design, construct and operate an installation to prevent pollution from unplanned emissions by the identification of hazards and pathways, simple ranking of hazard potential and implementing a three-step plan of actions for pollution prevention. This is particularly useful to prevent the contamination of groundwaters and soils, and to assist in site decontamination on cessation of activities. The complexity of the approach will vary according to the size and complexity of the installation and the hazard potential identified. To minimise unplanned releases, the steps should include measures to address all the bullet points below[5]:

Step 1:

- allow sufficient plant dimensions
- contain areas identified as being at risk from any chemical spillage by using appropriate materials to provide impervious barriers, including identifying any possible access to sewers, such as drains and inspection hatches, and sealing them appropriately
- ensure the stability of the process lines and components (including temporary and infrequently used equipment).

Step 2:

- ensure storage tanks used for risk materials are protected by using construction techniques such as double skinned tanks or by situating them within contained areas
- ensure operating tanks in process lines are within a contained area
- where liquids are pumped between tanks, ensure the receiving tanks are of sufficient size for the quantity to be pumped or a fail safe level control system is installed

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[5] More information for this section can be found in the following reference: [6; p. 560-561]

ensure there is either a leak identification system or contained areas are regularly checked as part of the maintenance program.

4 Cross-cutting innovative approaches

This section contains an introduction to cross-cutting innovative approaches for the sound management of chemicals and chemical waste that are valid for all sectors in the chemical product's value chain and not only in the sector which is the focus of this document.

The cross-cutting approaches and technologies include:

- How to use chemical leasing and other innovative business models to improve resource efficiency and safety in the value chain while also increasing competitiveness and enabling differentiation in a competitive market place
- How to understand the basic elements of a safety management system in order to reduce the risk of major accidents in facilities manufacturing or handling chemicals
- How to understand and use the Globally Harmonized System of Classification and Labelling of Chemicals to handle chemicals safely and responsibly
- How to safely store chemicals according to their hazard categories and minimize the risk of accidents
- How to develop a fire protection system, classify chemicals and implement technical risk reduction measures
- How to classify and manage hazardous waste effectively and remain in compliance with relevant regulations
- How to improve energy efficiency at facilities manufacturing or handling chemicals

4.1 Chemical leasing and other innovative business models

Chemical businesses are dependent on innovation and a continuous pipeline of innovative products and applications. This chapter provides an overview of known and successful chemical management business models.

4.1.1 Introduction to innovative business models

Greater spread and application of innovation in business models that reduce resource use has the potential to create multi-billion euro markets in the EU and overseas and achieve very substantial environmental and economic benefits. The actual spread of innovative business models currently covers a very broad range of sectors including industrial production of solid goods, fluids and ingredients as well as transportation, construction and maintenance, agriculture and public services. [3, p. 1]

4.1.2 Innovative chemical management business models

The chemical industry and the many companies that use its products have developed over time a linear business model in which raw materials are used to create valuable substances which are then, in turn, used to produce other products further down the value chain(s). Traditionally, chemicals are sold to customers, who become owners of substances and therefore responsible for their use and disposal. Their suppliers have a clear economic interest in increasing the amount of chemicals sold, which is usually related to negative releases to the environment. However, this is in opposition to the drive for resource efficiency and sustainability where the aim is to minimize resource use whilst maximizing added value.

Innovative service-based business models have the potential to resolve this problem. They aim to optimize the use of chemicals, save energy and encourage the recovery and recycling of chemicals. They also represent a better use of technical expertise and create an alignment of aims and business models and a stronger relationship between the manufacturers of chemicals and those who use them. Besides, they appear able to deliver benefits throughout the supply chain as well as wider benefits for society. [3, p. 3]

Chemical leasing

Chemical leasing (ChL) is a preventive and service-oriented business model that shifts away from high sales volumes of chemicals towards an integrated approach and extended producer responsibility throughout the entire life cycle of a chemical. Compared to conventional approaches, the concept of chemical leasing is much more service-oriented. In this business model, the customer pays for the benefits obtained from the chemical, not for the substance itself. Consequently, the economic success of the supplier is not linked to product turnover anymore. The chemical consumption becomes a cost rather than a revenue factor for the chemicals supplier. Companies will try to optimize the use of chemicals and improve the conditions for recycling in order to reduce the amount consumed, which, in turn, reduces the environmental pollution.

Without the ChL model, the appropriate (safe) use and disposal of chemicals would be the responsibility of the user of the chemicals. In the ChL business model, however, this "classical" role allocation is shifted towards the producer and provider of chemicals and the function performed by these chemicals, respectively. The responsibility of the producer and service provider is extended and may include the management of the entire life cycle.

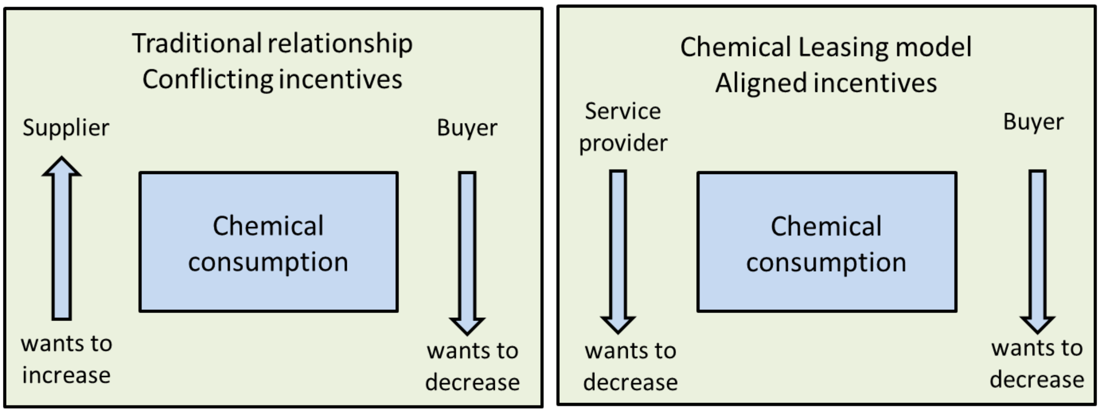

Figure 4-1: Traditional approach vs. chemical leasing model [based on 3, p. 9]

In Europe, the REACH regulation[6] has given a new legislative frame to the production, marketing and usage of chemicals. For certain hazardous chemicals (for example trichloroethylene), it requires authorization processes as a precondition of continued use. In this context, chemical leasing will play an increasingly important role in authorization processes because the business model requires the manufacturers to extend their responsibility and commitment to the safe and optimized use of chemicals. It is expected that in the near future certain chemicals requiring authorization will only be sold under a chemical leasing business model.

The following figure shows how technology and process improvements resulting from intensified collaboration can significantly reduce the consumption of chemicals [31]:

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[6] More information about REACH:
http://ec.europa.eu/enterprise/sectors/chemicals/reach/index_en.htm

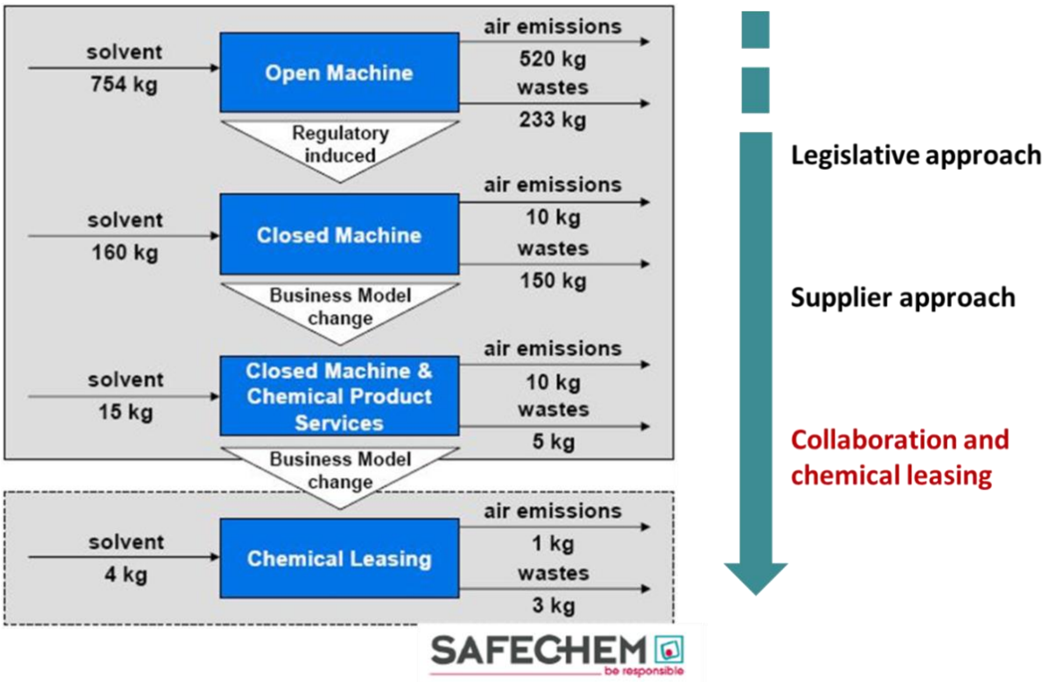

Figure 4-2: Example of consumption and emission reduction by technology and process improvements resulting from intensified collaboration [74 and SAFECHEM Europe GmbH]

The application of ChL models achieves economic advantages for all partners involved, provides specific solutions for efficient chemicals management and ways to reduce negative impacts on the environment. Since chemical products provide a broad variety of services such as “cleaning”, “coating”, “colouring” and “greasing”, the ChL model is applicable in a multitude of industry sectors [32].

Chemical Management Services (CMS)

Chemical Management Services (CMS) is a business model in which a customer purchases chemical services rather than just chemicals. These services can encompass all aspects of the chemical management lifecycle including procurement, delivery/distribution, inventory, use (including chemical substitute research), collection, monitoring/reporting, training, treatment, disposal, information technology and even process efficiency improvements. Each of these services poses its own costs and risks. Under CMS, the service provider is compensated based on the quality and quantity of services provided that reduce lifecycle costs, risks and environmental impacts of a chemical substance, and not on the volume of chemicals sold. Therefore, the service provider has the same objective as the customer: to reduce chemical use and costs. Both partners achieve bottom-line benefits through reduced chemical use, cost and waste. This model is now widely used in the automotive, aerospace and microelectronics sectors, where environmental benefits observed include reduced chemical use, reduced emissions and reduced waste generation, as well as substantial cost savings. A total average cost reduction of 30 per cent has been achieved in the first 5 years [3]. This model differs from ChL in that the unit of payment in ChL is the service provided by the chemical, which will always result in its efficient use, while in CMS the unit of payment is the whole service of chemicals management. This approach depends on the good management of the chemicals by the service supplier.

Closed-loop models

These models take a life cycle approach to materials used in goods and services and furthermore strive to keep materials within the economic system rather than letting them become waste. In the closed loop system, there is effectively no such thing as waste. The application of this approach starts by focusing on what is being delivered to the customer and how it can be achieved more efficiently.

More and more sectors and major businesses are moving towards closed-loop approaches in order to internalize major risks, protect against resource supply disruption, reduce environmental impacts and develop a better value proposition for customers. The benefits of this model are therefore broad and not only environmental in character.

For chemistry-using industries, this approach means not only taking responsibility for minimizing the impacts of the substances produced and sold from raw material sourcing right through to the end of product life, but also taking back the product at the end of its life and restoring it to a condition where it can be reused.

The approach ranges from extending the lifespan of a product (repair and remanufacture) to providing a service based on the effect a substance delivers rather than the substance itself. The latter is typically achieved by full recycling of the material with ownership retained by the provider.

Experience has shown that closed loop models work very well business-to-business but can be harder to implement along complicated supply chains or in business-to-consumer industries [30].

Feedstock foundation

This model focuses on petrochemicals, and typically consists of three to five business units. Feedstock foundation companies produce the essential building blocks for downstream players in the chemical industry and end markets, and concentrate on adding value to feedstock primarily through “smart” locations (advantaged feedstock, growth markets), large-scale facilities and leading process technology [32, p. 4]. Thus, this innovative business model is suitable for limited, large-scale businesses.

Chemicals platform

Chemicals platform companies typically consist of five to ten business units that span the entire chemical value chain. The platform of this model is a sort of “portfolio management company” that concentrates on the businesses, capabilities, markets and products loosely targeted at some of today’s mega trends such as health, energy, transportation, housing and construction. These companies consist of a portfolio of business units operating more or less independently according to the companies’ governance structure and actively managed for growth and synergy [32, p. 4].

Market maker

Market makers typically consist of one to three business units. This model focuses not on chemical end markets, but rather on selected end markets such as life science, agrochemicals, paints and coatings, and related technologies. Market makers focus on driving innovation based on the understanding of product performance and act on pervasive end-market trends, not simply customer input. These players make a significant investment in brand and distribution. They tend to have high growth with products that represent a limited share of customer cost and value chain [32, p. 4].

4.1.3 Additional sources of information

Websites

Chemical leasing website: a one-stop site to learn everything about this business model and to find helpful guidelines and recommendations for its implementation:
http://www.chemicalleasing.org/index.htm

Material on chemical leasing provided by **UNIDO**: http://www.unido.org/chemical-leasing.html

Chemical Strategies Partnership (CSP) website (USA): provides information on CMS and guidelines for its implementation: http://www.chemicalstrategies.org/implement_manualstools.php

Documents

DEFRA, UK: "A guide to chemical services" (2013); provides an easily accessible introduction to the chemical services model.

EU – DG Environment: "Promoting Innovative Business Models with Environmental Benefits" (2008); describes a selection of innovative business models that are economically profitable and also have positive environmental effects.

4.2 Prevention of major accidents

This chapter provides an overview of the state of the art in the prevention of major accidents, relevant for small and medium enterprises.

4.2.1 Importance of preventing major accidents

The advantages of reducing the likelihood and consequences of major accidents – including better protection of human health, the environment and economic resources – are well known [34, p. 6-7]. An example of legislative measures supporting the prevention of major accidents is the Seveso Directive which obliges Member States of the European Union to ensure that operators have a policy in place to safeguard against major accidents [33].

EC Directive 96/82/EC (Seveso II[7]) definitions [33, article 3]:

Major accident: a major emission, fire or explosion, leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside an establishment, involving one or more dangerous substances

Hazard: an intrinsic property of a dangerous substance, with a potential for harm

Dangerous substances: named substances or substances with certain generic hazardous properties, for example flammability

Community

Major accidents can cause death and serious injury to workers and the local population as well as significant long-term health effects. They can harm livestock, crops and water supplies, and cause considerable environmental damage. They may also result in major economic losses for the enterprise involved and the entire community.

Health and environment

Major accidents can have devastating impacts on human health and the environment. For instance, they can cause direct, immediate harm to workers and other persons in the vicinity who are exposed to the harmful chemicals or who are injured by an explosion or fire. Acute exposure to dangerous substances can also cause long-term health effects including chronic diseases and cancer. Additionally, people may suffer harm indirectly through their diet as a result of ingesting contaminated drinking water, agricultural products, fish, livestock and other food items spoiled by polluted air, surface water and soil.

The release of dangerous substances into the air, water and soil can have serious environmental impacts, killing animals and vegetation, poisoning water supplies used for drinking, fishing and irrigation, and rendering soil unfit for agriculture.

[7] The Seveso Directive (currently the Seveso II Directive) will be replaced by the Seveso III Directive on 1 June 2015.

Economic impact

In addition to the potential impact on human health, accidents can cause significant economic harm, both to the enterprise as well as to the community. The costs associated with response, clean-up and recovery, including health services provided such as medical treatment, can be quite significant.

It is obvious that the enterprise where the accident occurred may suffer significant economic losses (from, for instance, property damage, loss of jobs, having to stop operations for an extended period or even bankruptcy). What is less evident are the costs incurred by other industries in the vicinity of the accident. For example, an accident may pollute local water bodies increasing the costs of water used for drinking and agriculture, and causing significant damage to the fishing industry. In addition, suppliers and customers of the enterprise will be impacted.

4.2.2 Main cause of major accidents

The potential for major accidents has become more significant with the increasing production, storage and use of dangerous substances. Inadequate management is often recognized as the main cause of major accidents, specifically:

- Inadequate design;
- Inadequate maintenance and operation procedures;
- Inadequate assessment of the existing hazards and the associated risks in the facility;
- Inadequate staffing or training.

A detailed analysis of an accident will normally reveal three cause levels: basic, indirect and direct (Figure 4-3).

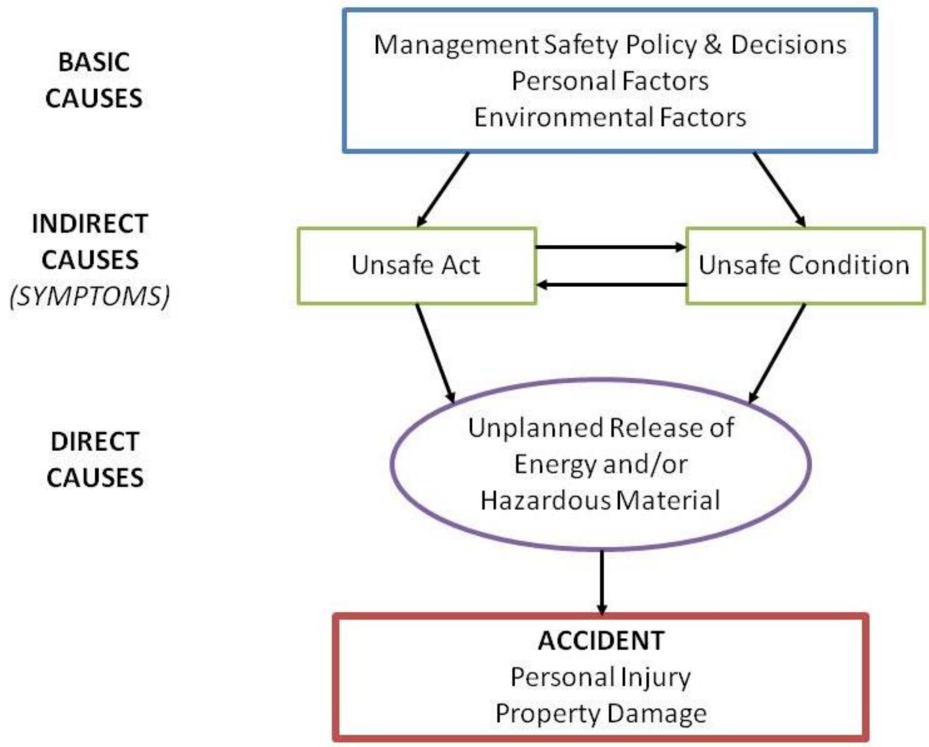

Figure 4-3: The three cause levels of an accident [based on 79, p. 350]

4.2.3 Motivation of SMEs and prevention of major accidents

Measures to prevent major accidents could lead to improved efficiency and lower production costs, as well as to improvements in the general health, safety and environmental performance of enterprises. Safe operations also protect the good will and reputation of industry, and foster improved relationships with members of the local communities.

At the local level, creating an effective major accident prevention plan might result in significant political implications. This could provide a platform for improving communication and trust between local leaders, the public and other stakeholders. Furthermore, communities typically blame local leaders for accidents if there has not been adequate warning or appropriate response.

4.2.4 Prevention of major accidents

Facilities that handle chemicals are actively engaged in dealing with risks to ensure the safety of their workers and their community. Most of their efforts focus on ensuring that the facility is designed and operated safely on a daily basis, using well-designed equipment, preventive maintenance, up-to-date operating procedures and well-trained staff [79, p. 343].

It is recognized that the safe functioning of an enterprise depends on its overall management. Within this overall management system, the safe operation of an enterprise requires the implementation of a system of structures, responsibilities and procedures with the appropriate resources and technological solutions available [34, p. 6-7].

Each enterprise should establish and implement a major accident prevention policy, which provides a basis for major accident prevention in order to minimize the likelihood of an accident and to protect human health, the environment and property. The elements of the safety management system (SMS) should be appropriate to the nature and extent of risks posed by hazardous installations and take the available resources into account [34, p. 92-95].

A safety management system should address[8] the organizational structure, practices, procedures and resources for implementing the major accident prevention policy and should include at a minimum the following items:

- Organizational structure (including roles, responsibilities, training, education, qualifications and inter-relationship of individuals involved in work affecting safety)
- Identification and evaluation of hazards (developing and implementing formal procedures to systematically identify and evaluate hazards – including their likelihood and severity – arising from normal and abnormal operations, and including the hazards arising from handling, production, transportation, storage or disposal of dangerous substances)
- Facilities and operational control (addressing design and construction as well as the procedures for safe operation, including maintenance of plants, processes, equipment and temporary stops)
- Management of change (planning and controlling changes in various areas such as organization, personnel, plant, processes including prestart-up reviews, maintenance and decommissioning, materials, equipment, procedures, software, design and external circumstances that might affect safety)
- Planning for emergencies (related to developing, adopting, implementing, reviewing, testing and, if appropriate, revising and updating emergency plans)

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[8] Based on the OECD Guiding Principles for Chemical Accident Prevention, Preparedness and Response (second edition, 2003).

- Monitoring performance (concerning the ongoing assessment of compliance with the safety policy and safety management system, and mechanisms for taking corrective action in the event of non-compliance)
- Audits and reviews (addressing the periodic, systematic assessment of the major accident prevention policy as well as effectiveness and suitability of the SMS)

Guidance for SMEs on specific safety management system elements

Small and medium enterprises (SMEs) are a very important part of the global economy, since they are the source of most growth in employment. They are flexible, adaptable and quick to respond to changes in the marketplace and new opportunities.

But if SMEs are to grow and become sustainable, enterprises must learn to consolidate and improve practices, to become more productive, to manage and mitigate risks more effectively and to understand their value chain and business environment more fully. This is why codes, standards, guidelines and frameworks that bring the experience of major companies to small companies in a useable way are so valuable.

UNEP's Responsible Production (RP) Framework for Chemical Hazard Management provides guidelines for small and medium enterprises. It provides a systematic, continuous improvement approach to chemical safety along the value chain. Moreover, the approach provides technical materials and tools to help SMEs understand hazards, control chemical exposure, reduce the risk of accidents and engage stakeholders [35].

The "Guidelines on a Major Accident Prevention Policy and Safety Management System" published in cooperation with the Major Accidents Hazards Bureau of the European Union provide very good advice on safety management systems. The publication provides guidance and descriptions on what is required by the Seveso II Directive [33].

Guidance on safety management systems

Development of a major accident prevention policy

The development of a major accident prevention document/policy is recommended as best practice. This document is intended to give an overview of how the company ensures a high level of protection for humans and the environment. Furthermore, it should clearly indicate the arrangements, structures and management systems required for each of the seven areas described in more detail further below [36, p. 2].

The safety management strategy defines how safety and health are organized, measured and monitored. The development of a safety policy and safety plan is a key point to ensure that the strategies and procedures are implemented at all levels. All seven elements have to be incorporated into the system, including monitoring, audit and review processes which are essential components of the system [37, p. 5].

Organization and personnel

The safety management system should reflect the top-down commitment and the safety culture of the company's organization, translated into the necessary resources and direct responsibilities of personnel involved in the management of major accidents at all levels in the organization. Furthermore, it is helpful to identify the skills and abilities needed by such personnel, and ensure their provision [35, p. 2].

The responsible production (RP) approach provides a systematic method of mapping key aspects (inputs, outputs, modes of production, stakeholders) related to reducing the risk of accidents. It often involves a quick on-site assessment of the company and consultation with management in order to gain a better understanding of the company's needs, priorities and potential areas for improvement.

Hazard identification and evaluation

Hazard identification and risk assessment are two major elements of the risk management process. They are necessary to be able to make decisions relating to risk, for example in terms of risk avoidance, reduction or transfer, or acceptance of the residual risk.

When undertaking a risk assessment, it is important to carefully consider the various possible approaches and methods available, and choose an approach/method that is appropriate for the particular circumstances, since all approaches/methods have their own strengths and weaknesses and none is perfect.

The methodology used for these processes is known as risk analysis or risk assessment. The spectrum of specific methods is broad and covers various degrees of depth and complexity in the analysis as well as various systems of investigation. Risk assessment methods include hazard mapping, check-lists, hazard and operability study (HAZOP), "What if" analysis and risk matrix[9].

Techniques that are recommended for the analysis of major hazards include the "Dow Fire and Explosion Index" [38] and the "TNO Purple Book" (guidelines for quantitative risk assessment) [39]. The Responsible Production Toolkit (UNEP) provides tools which can help SMEs undertake hazard identification and risk assessment including prioritization of the identified risks.

Operational control

The company should prepare, update and keep readily available the information on process hazards, design and operational limits and controls resulting from the hazard identification and risk evaluation procedures. Based on these, documented procedures should be prepared and implemented to ensure the safe design and operation of plants, processes, equipment and storage facilities [35, p. 5].

Straightforward guidelines on how to prepare a company's process flow diagram can be found in the Responsible Production Toolkit. An objective is to clearly map the process flow in order to understand what the activities are and who is involved in them. This will help getting a better understanding of where chemicals are used and located. Process flow means both the sequence of activities that are undertaken in the company and the external activities that the company can influence within its business, ranging from the products and services the company procures to the products and services the company provides [35, p. 14].

Management of change (MOC)

According to the International Social Security Association (ISSA), management of change (MOC) is defined as "a systematic process to ensure the transition from an initially safe state to a new – again safe – state, along a safe path. The new state may be permanent or temporary." In 2007, the ISSA published a practical guidance document on maintenance and changes in plants with high safety requirements [40]. This document is a valuable source for helping companies institute MOC.

Maintenance and changes are part of normal plant operation in the chemical industry, yet serious accidents often occur due to changes in processes. Changes frequently leading to unsafe conditions if not properly analyzed include the change of [40]:

- Construction materials
- Process parameters
- Inerting procedures
- Equipment parameters

[9] An overview of the listed methods can be found in UNEP's Flexible Framework for Addressing Chemical Accident Prevention and Preparedness, SG-2 Guidance on Risk Assessment (p. 122-125).

Such changes can be temporary or permanent, small or large. Nevertheless, any changes or modifications that result in deviations from the safety protocols (or safety management plan) are subject to a hazard analysis and risk assessment procedure. This is fundamental to all MOC activities.

According to the ISSA, typical items on a plant change form include:

- Administration (sequential number, date, plant, piping and instrumentation diagram)
- Description of the change (What will be changed? Why? What are the objectives?)
- Additional information (deadlines, cost)
- Schedule including the sequence of work (planning, preparation, main work, auxiliary work, termination) designed so that the work flow clearly appears from the entries
- Document update (P&I sheets, permits, explosion protection documents, safety checks and hazard analyses)
- Checks before start-up (process control system (PCS), pipes, pressure vessels, unloading points and filling stations)
- Approvals (with signature and date)

Further practical information relating to planning changes and accounting for safety in the various phases of changes (i.e. preliminary planning, basic design, detailed design, construction, commissioning and production) are found in the ISSA publication.

The following table provides an overview of MOC requirements according to the US Environmental Protection Agency (US EPA) and can be a useful guideline for implementing a company's MOC policy.

Table 4-1: Management of change requirements, Chapter 7.8 (2004) of the EPA General Risk Management Program Guidance [based on 41]

MOC procedures must address:	Employees affected by the change must:	Update process safety information if:	Update operating procedure if:
Technical basis for the change Impact on safety and health Modifications to operating procedures Necessary time period for the change Authorization requirements for the proposed change	Be informed of the change before start-up Trained in the change before start-up	A change covered by MOC procedures results in a change in any process safety information	A change covered by MOC procedures results in a change in any operating procedure

<u>Emergency planning</u>

The safety management system should include the procedures necessary to ensure that an adequate emergency plan is developed, adopted, implemented, reviewed, tested, and, where necessary, revised and updated. The company should develop and maintain procedures to identify foreseeable emergencies arising from its activities, identified through hazard and risk assessment, and to record this analysis and keep it up-to-date. Plans to respond to such potential emergencies should be prepared, and arrangements for testing and review on a regular basis should be included within the SMS. The procedures should also cover the necessary arrangements for communicating the plans to all those likely to be affected by an emergency [36, p. 6].

Proper assessments can only be made by undertaking a detailed safety and risk assessment audit of the operations, worker practices, company policies and the workplace environment [79, p. 418]. Section 3 of the Responsible Production Toolkit gives recommendations on how to respond to the hazards and risks identified through reviewing the company's processes and activities. Furthermore, it provides guidelines on how to develop an appropriate response to chemical hazard issues and the associated impacts and how to communicate them to the concerned community. There are also a number of international publications that provide guidance on emergency planning related to major accidents, some of them being listed in the following paragraph.

4.2.5 Additional sources of information

Websites

Health and Safety Executive (**HSE**), UK website: provides a wealth of information and advice on work-related health and safety and the prevention of accidents: http://www.hse.gov.uk/

UNEP Safer Production website: provides a list of additional resources related to safer production: http://www.unep.org/resourceefficiency/Business/CleanerSaferProduction/SaferProduction/AdditionalResources/tabid/101149/Default.aspx

Documents

European Commission, Major Accidents Hazards Bureau (**MAHB**): "Guidelines on a Major Accident Prevention Policy and Safety Management System"

OECD: "Guiding Principles for Chemical Accident Prevention, Preparedness and Response" (second edition, 2003)

GTZ: **"**Chemical Management Guide for Small and Medium-Sized Enterprises" (2007).

UNEP: "Responsible Production Booklet; A Framework for Chemical Hazard Management for Small and Medium-Sized Enterprises" (2009).

European Process Safety Centre (**EPSC**): "HAZOP: Guide to Best Practice" (second edition, 2008)

4.3 Safe handling of chemicals

This section provides a brief overview of:

- Hazards associated with the use and handling of chemicals
- Hazard communication in the form of labels and SDSs
- Performing a basic risk analysis
- Developing workplace operating instructions based on SDSs
- Preventive measures including:
    - Hierarchy: elimination, substitution, control: TOP hierarchy
    - COSHH Essentials Toolkit or ILO Toolkit (focus on essentials)

Chemicals are used in virtually all work activities, thus presenting certain chemical risks in a large number of workplaces all over the world. Many thousands of chemicals are used in substantial quantities, and many new chemicals are also introduced on the market every year. Hence, there is an urgent need to establish a systematic approach to safety in the use of chemicals at work.

An effective control of chemical risks at the workplace requires an efficient flow of information on potential hazards and the safety precautions to be taken from the manufacturers or importers of chemicals to the users. Employers should follow up on this information and ensure on a day-to-day basis that the necessary measures are taken to protect workers, and consequently the public and the environment.

Chemicals can be corrosive, reactive, flammable, explosive, oxidizing and inert, and contribute to serious health effects such as burns, rashes, kidney damage, lung damage, heart conditions, cancer, damage of the central nervous system, etc.

Routes of occupational exposure include:

- Inhalation: Nearly all materials that are airborne can be inhaled. This is the most common route. Gases and vapours can pass into the blood whereas solid particles are inhaled into the lungs.
- Dermal absorption: Skin contact with a substance can result in a possible reaction and many solids, liquids, vapours and gases can be absorbed through the skin.
- Ingestion/swallowing: Workers do not deliberately swallow materials they handle, however, the failure to wash hands, or eating in the presence of chemicals can lead to ingestion.
- Injection: Though uncommon, accidents occurring during the handling of sharp objects can result in the injection of a chemical into the bloodstream.
- Ocular: Chemicals are absorbed through the eyes or cause physical damage.

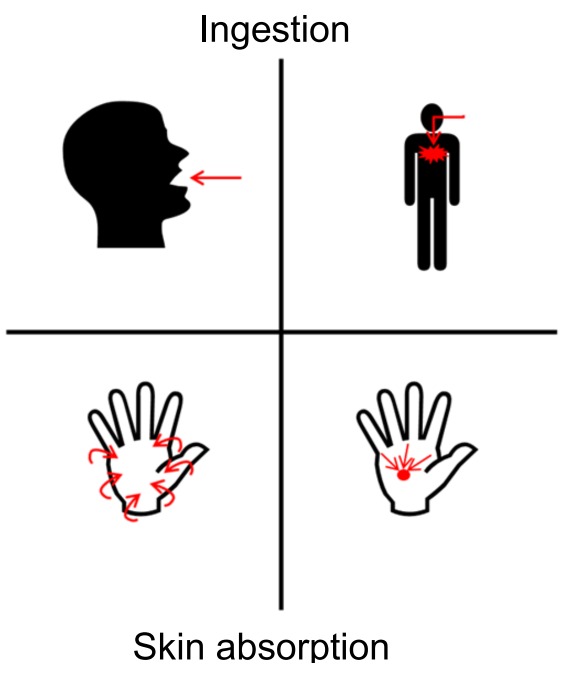


Figure 4-4: Routes of occupational exposure [1]

The safe use of chemicals involves several building blocks in which the GHS is a key element (see the following sub-chapter).

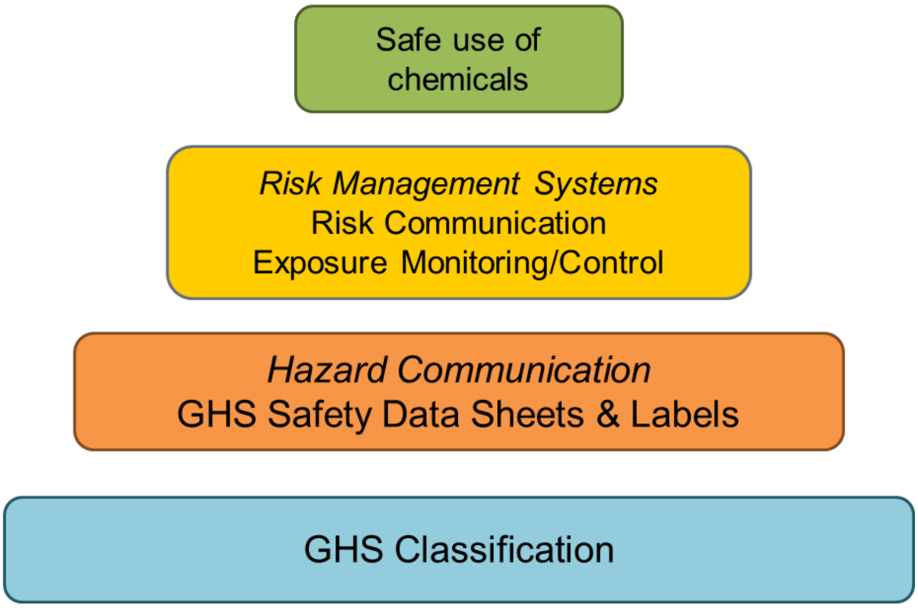


Figure 4-5: Building blocks for the safe use of chemicals

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

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) is an internationally agreed-upon system, created by the United Nations. The GHS is a worldwide initiative to promote standard criteria for classifying chemicals according to their health, physical and environmental hazards. It is an international approach to hazard communication, providing agreed criteria for the classification of chemical hazards, and a standardized approach to label elements and safety data sheets (SDSs). The primary goal of the GHS is better protection of human health and the environment by providing chemical users and handlers with enhanced and consistent information on chemical hazards [42, p. 63].

It is important to note that the GHS is currently being implemented in many countries, which means that users of chemicals will still encounter systems currently used in many major chemical producing countries.

The key elements of GHS include:

- Harmonized classification criteria
- Harmonized labelling elements
- Harmonized safety data sheet elements

The GHS uses the **signal words** “Danger” and “Warning”, **pictograms**[10]**, hazard statements**, and **precautionary statements** to communicate hazard information on product labels and safety data sheets.

[10] Note: Not all categories have a symbol associated with them

Hazard classification

The GHS distinguishes three major hazard groups:

- Physical hazards
- Health hazards
- Environmental hazards

Each hazard group consists of classes and categories (sub-sections of classes). For example, the hazard class “self-reactive substances and mixtures” has seven hazard categories (A-G). In general, the hazard categories are either in numerical or alphabetical order with “1” or “A” representing the most hazardous category.

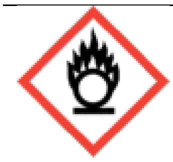
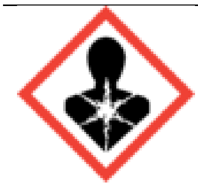
Table 4-2: Hazard classification [based on 50]

Classes in the group “Physical Hazards”	
• Explosives • Flammable gases • Aerosols • Oxidizing gases • Gases under pressure • Flammable liquids • Flammable solids	• Self-reactive substances and mixtures • Pyrophoric liquids • Pyrophoric solids • Self-heating substances and mixtures • Substances and mixtures which, in contact with water, emit flammable gases • Oxidizing liquids
Classes in the group “Health Hazards”	
• Acute toxicity • Skin corrosion/irritation • Serious eye damage/eye irritation • Respiratory or skin sensitization • Germ cell mutagenicity • Carcinogenicity	• Reproductive toxicity • Specific target organ toxicity – single exposure • Specific target organ toxicity – repeated exposure • Aspiration hazard
Classes in the group “Environmental Hazards”	
• Hazardous to the aquatic environment (acute and chronic)	• Hazardous to the ozone layer

The following figure presents an overview of the pictograms used in the GHS and the UN Model Regulations on the Transport of Dangerous Goods (UNTDG) and their meanings.

Table 4-3: Pictograms used in the GHS and the UN Model Regulations on the Transport of Dangerous Goods (UNTDG) [based on 51]

Hazard pictogram	GHS hazard	Dangerous class labels (pictograms)	Dangerous good classes
	Explosive Self-reactive Organic peroxides		Explosive

Hazard pictogram	GHS hazard	Dangerous class labels (pictograms)	Dangerous good classes
	Flammable Self-reactive Pyrophoric Self-heating Emits flammable gas in contact with water Organic peroxides		• Flammability (liquid, solid or gas) • Pyrophoric • Emits flammable gas • Organic peroxide
	Oxidizers		• Oxidizer • Oxidizing gas
	Gases under pressure		• Non-toxic non-flammable gas • Flammable gas • Oxidizing gas • Toxic gas
	Acute toxicity		• Acute toxicity • Acute toxic gas
	Acute toxicity Skin irritant Eye irritant Skin sensitizer	No equivalent	
	Carcinogen Respiratory sensitizer Reproductive toxicant Germ cell mutagen	No equivalent	

Hazard pictogram	GHS hazard	Dangerous class labels (pictograms)	Dangerous good classes
	Eye corrosion Skin corrosion Corrosive to metal		Corrosive to metals
	Aquatic toxicity Not covered within the scope of workplace hazardous chemical requirements		Environmental hazard

Labelling

A label is the key to organizing chemical products for storage. Tanks, containers and bulk stores should be identified and marked with signs indicating the name/identity of the chemical product. The labels must be comprehensive and easily understandable to provide full information about each class and category of hazards according to the GHS.

Containers (including cylinders of compressed gases) must not be accepted without the following identifying labels:

- Identification of contents (for example chemical name)
- Description of principal hazards (for example flammable liquid)
- Precautions to minimize hazards and prevent accidents
- Appropriate first aid procedures
- Appropriate procedures for cleaning up spills
- Special instructions to medical personnel in case of an accident

Below, a model label is shown as adopted by the EU Classification, Labelling and Packaging Regulation (CLP Regulation), which aligns EU legislation to the GHS.

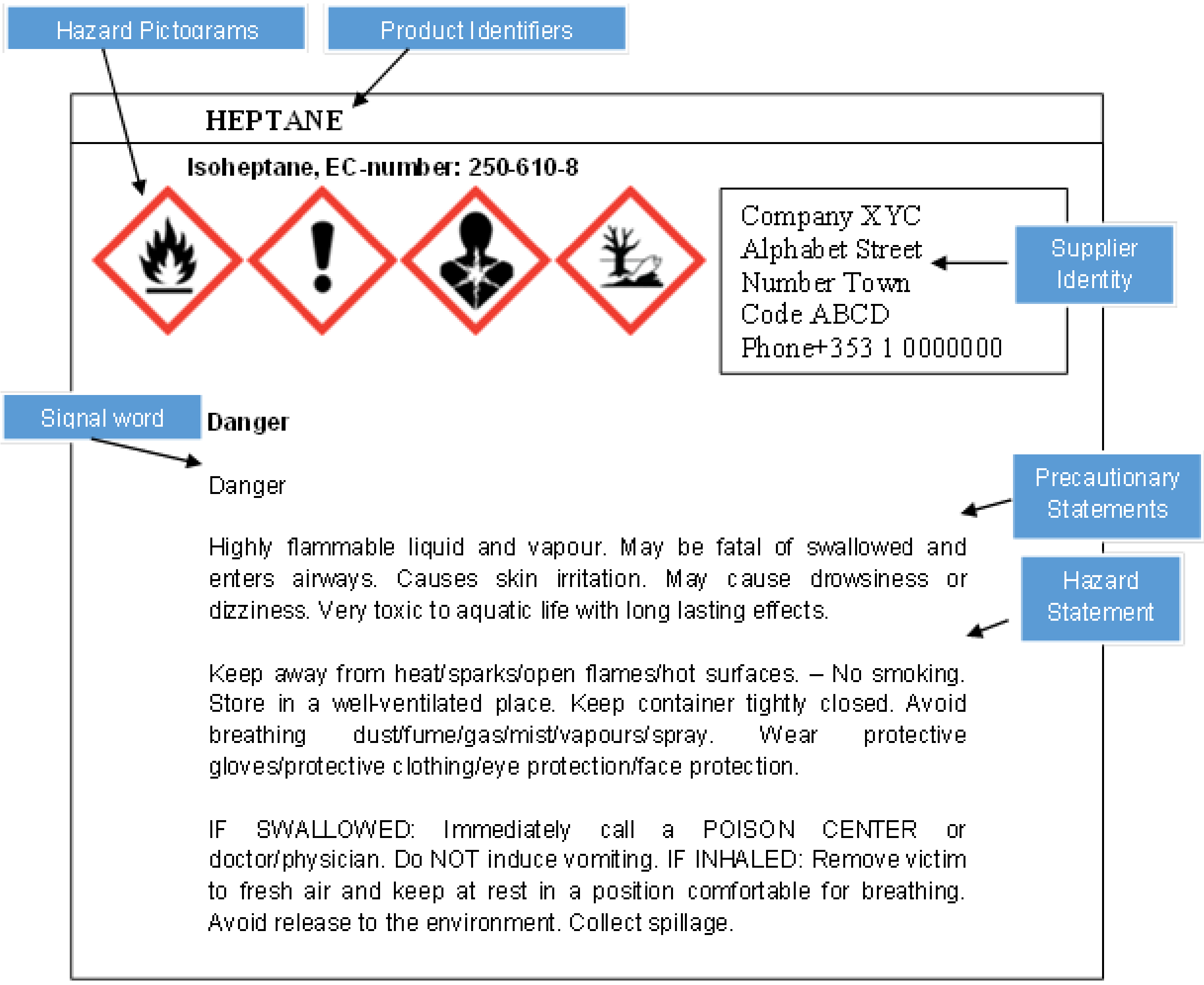


Figure 4-6: Model label according to the EU CLP (harmonized with GHS) [based on 50]

Additionally, a label for combining transport pictograms and GHS requirements is shown.

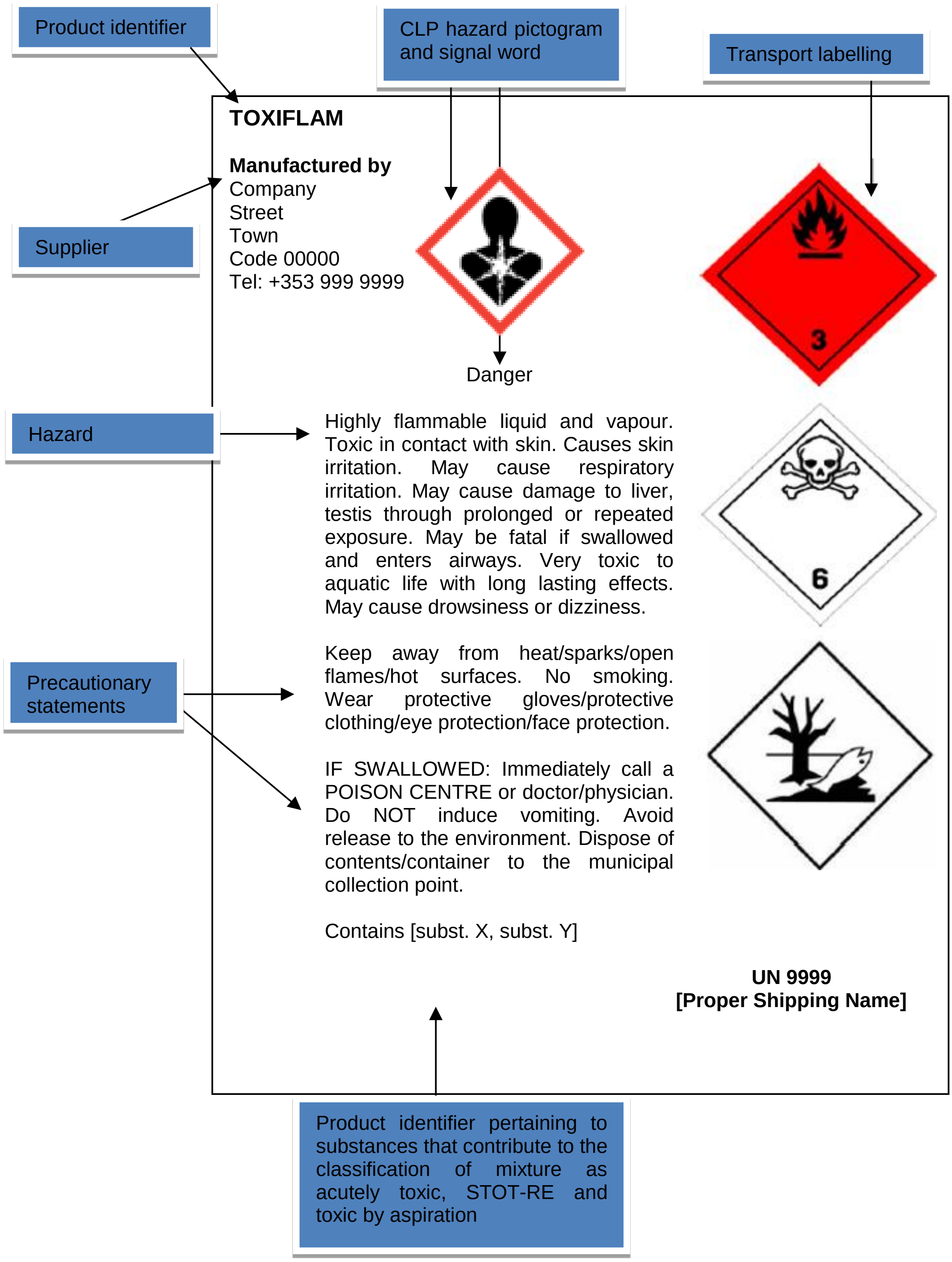


Figure 4-7: Label for combining transport pictograms and GHS requirements [based on 50 and 51]

GHS safety data sheets

The GHS safety data sheets are key documents in the safe supply, handling and use of chemicals. They should provide comprehensive information about a chemical product that allows employers and workers to obtain concise, relevant and accurate information on the hazards, uses and risk management associated with the substance in the workplace.

An SDS provides the following information:

- Substance properties
- Health, environmental and physical-chemical hazards
- Storage, handling, transportation and final disposal
- Safety instructions for workers and measures to be taken in the event of a fire or accidental release as well as first aid procedures.

Based on this information, a hazard analysis is drawn up and workplace operating instructions are provided.

The SDS should contain 16 sections: [43, p. 5-9, p. 39]

- Identification
- Hazard(s) identification
- Composition/information on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure control/personal protection
- Physical and chemical properties
- Stability and reactivity
- Toxicological information
- Ecological information
- Disposal considerations
- Transport information
- Regulatory information
- Other information

In many countries, the chemical producer is under legal obligation to provide an SDS. If the SDS is not delivered together with the chemical or provided electronically, the downstream user should request the SDS from the supplier (always the latest version).

Further information on the preparation of SDSs in compliance with the GHS was developed by the European Chemicals Agency (ECHA) and can be found in the section “Additional sources of information” further below. An example of an SDS complying with the EU CLP legislation is provided on the website indicated below[11].

4.3.2 Hazard identification and risk analysis

The following section is based on UNEP’s Responsible Production Approach [44].

Understanding your operational processes

“Hot spots” are defined as:

- Places where you can observe inefficient handling or use of chemicals
- Particularly hazardous situations where chemicals are being stored or used and where the potential harm could be reduced or prevented by implementing appropriate control measures

To identify hot spots, you need to look at your operations in a different way. Rather than focusing on the end product, you need to look in a detailed way at the storage, handling and use of chemicals in the production process. Look specifically at how chemicals are being treated in steps involving their purchase, storage, handling and processing with the aim of spotting inefficiencies, waste, losses and risks. [45, p. 20]

The hazard analysis should not only focus on production but include cleaning operations (cleaning of reactors and equipment), maintenance activities (preventive and corrective) and start-up/shut-down procedures.

[11] http://reachteam.eu/english/compliance/SDS/docs/CLP_REACH_Compliant_SDS.html

Drawing up a chemical process flow diagram

The objective is to clearly map the process flow of chemicals in order to understand what the activities are and who is involved in them. This will help you to understand where chemicals are used and located (chemical streams). [44, p. 14-15]

The basic strategy for a block flow diagram preparation is:

1. List all the steps and activities in the process.
2. Arrange the activities in sequence.
3. Discuss the sequence of activities with the relevant people in your company.
4. Review the flowchart with your workers and your business partners.
5. Check to see if they agree that the process has been drawn accurately.

Identification of chemicals, their quantities and the hazards involved in the process

The next step is to identify chemicals, their quantities and the hazards associated with their use at the company. It is important to identify the hazards for all chemicals involved in the process [44, p. 14-15].

The objective is to systematically identify all chemical substances that are stored, handled and used at your business, along with information on their quantities and type of storage, and to classify them according to chemical product information, labels and GHS safety data sheets. Check this against the process flows to make sure you have not missed anything. Establish what information already exists within the company regarding chemicals (for example, purchasing records, stock control cards, inventories, suppliers' product information, GHS SDSs, etc.). List all chemical substances in an *inventory*. Begin with one department or process and proceed on a step-by-step basis until you have a complete inventory for your whole operation [46, p. 16].

Assessing health, environmental and economic risks

Tool 1.3 of the Responsible Production Toolkit provides a methodology to estimate the impact and likelihood of an accident situation. Note that the assignment of both the severity of impact and the likelihood of occurrence are *subjective* decisions, and therefore a multi-disciplinary team should be involved. The rating of the severity of a hazard should be based on the hazard and precautionary statements outlined in the SDS (hazard and precautionary statements are found in section 2 of the GHS SDS template). Further information on physical and chemical properties, stability and reactivity as well as health effects can be found in sections 9 to 11 of the GHS SDS template.

An essential component to assessing chemical risks is the creation of a compatibility matrix of hazardous substances. This tool can assist in determining the chemical reactivity of substances and mixtures (for example, toxic by-products or extreme heat generation). The Chemical Reactivity Worksheet[12] predicts possible hazards resulting from the mixing of hazardous substances (chemicals) as well as data on whether the substance reacts with air, water or other materials. This hazard information can be entered in the risk matrix of the Responsible Production Toolkit.

4.3.3 Preventive and protective measures

Once you know where the chemicals are, what kind of chemicals you are handling and what their hazards are, you can use a hierarchy of controls to choose the best way of handling the chemicals safely as shown in the figure below.

[12] The Chemical Reactivity Worksheet can be downloaded at: http://response.restoration.noaa.gov/oil-and-chemical-spills/chemical-spills/response-tools/downloading-chemical-reactivity-worksheet.html

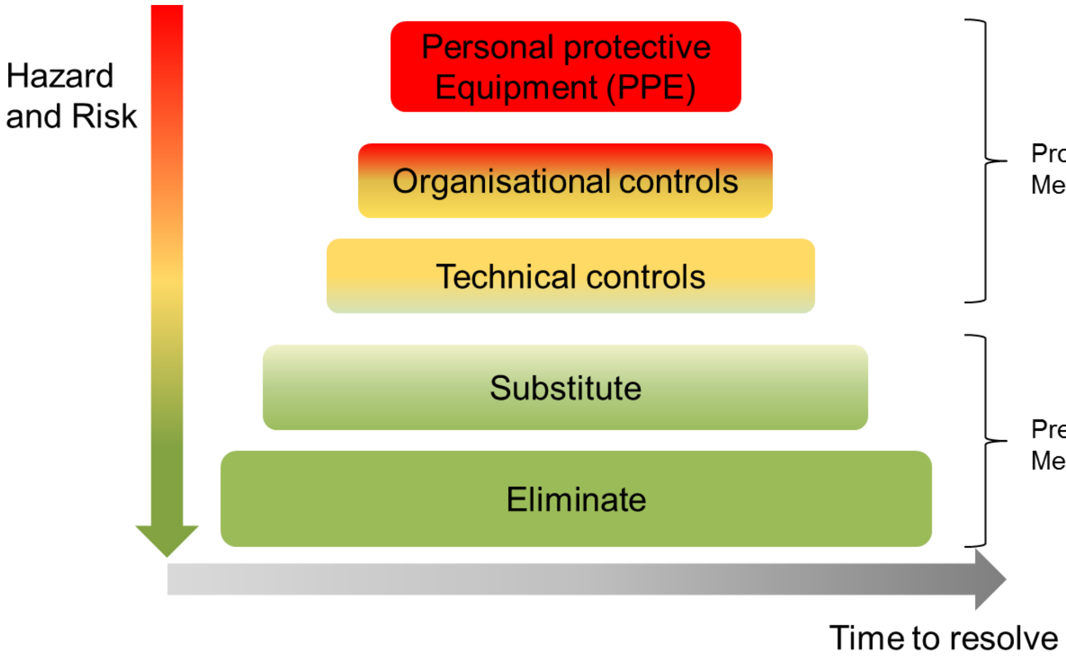


Figure 4-8: Hierarchy of steps according to the control strategy [based on 46, p. 22]

Preventive measures

Before the materials discarded from a process or a part thereof become waste, there are some measures that can be taken in order to prevent this conversion.

Eliminate

If you are not using a hazardous chemical, then there is no risk. Eliminating the hazardous chemical is the best way to control the risk. Consider whether you really need to use a chemical at all. For example, in recent years paint manufacturers have been able to eliminate hazardous solvents such as xylene [47, p. 23]. You could also consider whether it is possible to use a different process which does not require a hazardous chemical.

Substitute

It may be possible to replace your hazardous chemical by a less hazardous one. For example, you could replace isocyanate-based paints by water-based paints. You could also use a less hazardous form of the same chemical, For instance, using the chemical in pellet form rather than the powder could have a significant effect on reducing inhalable dust levels [47, p. 23]. It is important that you consider hazards and potential exposure associated with the replacement chemical to ensure that no new hazard is introduced to the workplace.

The CatSub database (www.catsub.eu) provides a publicly accessible catalogue of more than 300 examples of substitution of hazardous chemicals including case studies that describe successful substitutions with less hazardous chemicals or hazard-free products. Furthermore, the European Agency for Safety and Health at Work provides some factsheets to support in the substitution of hazardous chemicals (Factsheet 34 – Elimination and substitution of dangerous substances[13]).

[13] See http://osha.europa.eu/en/publications/factsheets/34

The internet portal SUBSPORT[14] (SUBStitution Support PORTal – Moving Towards Safer Alternatives) combines information from several countries (for example, Denmark, Germany, Spain, Sweden and the USA) regarding tools and case studies for the substitution of hazardous substances in products and processes with less hazardous alternatives. The portal is available in English, French, German and Spanish.

Protective measures

Protective control measures can be subdivided into the following TOP hierarchy:

- Technical control measures
- Organizational control measures
- Personal protective equipment

Technical control measures

Technical control measures are designed to move an air contaminant away from personnel and/or to create a barrier between a hazard and the employee. Some common types of engineering control measures are discussed below [47, p. 2-3].

Chemical fume hoods

Chemical fume hoods are the primary containment devices used to protect personnel and the laboratory environment from hazardous chemicals that may become airborne through volatilization or aerosol formation.

Use a chemical fume hood when working with

- Flammable liquids
- Particularly hazardous substances that are volatile or that are in powder form
- Other volatile compounds
- Chemicals with a strong odour
- Other materials as indicated by the chemical- or lab-specific standard operating procedure

Local exhaust ventilation

Local exhaust ventilation is used with a localized source of chemical vapours that can be captured. Examples include snorkel-type exhaust and downdraft sinks. Local exhaust ventilation should only be installed with the involvement of the facility management for your building.

Isolation devices

These devices physically separate a contaminant-generating process from the work environment. They will often involve a sealed plexiglass box, and may be combined with local exhaust.

Process modification

Process modification involves changing the temperature or pressure at which a process is conducted, or using inert gas, or any other change in the procedure to reduce the likelihood of exposure or incidents.

Organizational control measures

The use of management and administrative procedures aims to reduce or eliminate exposure [42, p. 24].

Look how the work is done and consider how employees are exposed to the chemical. Think about how the job could be done differently to avoid exposure. Where it is not possible to eliminate or

[14] http://www.subsport.eu/

isolate the chemical hazard, you should minimize exposure to it. This can be achieved by introducing written procedures in your workplace to:

- Minimize the number of employees who might be involved in a task, for example by introducing job rotation
- Exclude other employees not involved in the task from the area where the chemical is being used
- Provide training to your employees on the hazards and safe use of the chemicals they work with
- Ensure chemicals with hazardous properties are correctly stored
- Ensure emergency procedures are in place in the event of an accident, for example spillage

These procedures should be known by and available for all organizational levels.

Note: The posting of *operational procedures* highlighting the necessary precautions and methods of handling chemicals for certain tasks can help reduce the risk of accidents. The operational procedures (or working instructions) should contain the following sections: identification of the hazardous substances, hazards to human health and the environment, protective measures and rules of conduct, conduct in the event of danger, first aid and proper disposal. An example of how to obtain working instructions out of an SDS can be found in the annex of the document available at the link indicated below[15].

Personal protective equipment (PPE)

The use of personal protective equipment (PPE) should be the last line of defence and not regarded as an alternative to other suitable control measures which are higher up the hierarchy. It should provide adequate protection against the risks arising from the hazardous chemicals to which the wearer is exposed, for the duration of the exposure, taking into account the type of work being carried out. [42, p. 27]

Section 8 of the GHS SDS gives advice on steps needed to reduce exposure, including advice on appropriate PPE. Examples of precautionary pictograms to be included on an operational procedure sign are shown in the figure below:

Figure 4-9: GHS precautionary pictograms [based on 50]

Personal protective equipment can include:

- Eye/face protection (for example safety glasses, goggles, face shields)
- Skin protection (for example chemical-resistant footwear including shoes, boots and rubber boots, and clothing such as aprons or suits)

[15] http://www.baua.de/en/Topics-from-A-to-Z/Hazardous-Substances/TRGS/pdf/TRGS-555.pdf?__blob=publicationFile&v=2

- Hand protection (for example gloves or gauntlets, disposable or otherwise, that are suitable for the task)
- Respiratory protection (for example respirators, masks or hoods that give adequate protection)
- Thermal protection (employees may need to be protected from excess heat or cold with appropriate clothing)

There are several methods for determining the level of protection for PPE in the workplace. The US agency OSHA defines the four levels A, B, C and D, with A signifying the highest level of protection for skin and respiratory safety in the workplace. The method for determining the level of protection and the following table are provided in chapter 5 of the book "Practical Guide to Industrial Safety" [79].

Table 4-4: Level of protection and corresponding required personal protective equipment [based on 79]

Personal protective equipment	Level of protection			
	A	B	C	D
Hard hat				
Face shield or safety glasses				
Boots				
Inner gloves				
Outer gloves				
Work coveralls				
Chemical-resistant coveralls				
Chemical-resistant suit				
Fully encapsulating suit				
Air purifying respirator				
SCBA (self-contained breathing apparatus)/airline respirator				
Two-way radio				
Cooling system				

OSHA provides online tools to help in the selection of appropriate protective equipment, including eye and face protection[16] and respiratory protection[17]. Furthermore, most suppliers provide the ability to search appropriate PPE according to an identified chemical.

Contractors' and maintenance activities

Two additional sources of accidents that are often neglected are *contractors'* and *maintenance activities* (preventive and corrective). Regular servicing and maintenance work is required due to the high stress placed on equipment in the chemical industry by exposure to very aggressive substances. Three kinds of maintenance work may be identified in the chemical industry: ongoing or daily maintenance work (executed without shutdown of the installation but where the equipment may be isolated), maintenance with a shutdown of the installation, and modification or construction of new units. Subcontractors may be involved in all three kinds of maintenance work. Outsourcing maintenance work is becoming the norm in the chemical industry.

[16] https://www.osha.gov/SLTC/etools/eyeandface/index.html

[17] https://www.osha.gov/SLTC/etools/respiratory/index.html

In many countries, the company has legal responsibility for the safety of any personnel working within its installations, including contractors and external workers (revise local regulations carefully). Therefore, any occupational safety and health (OSH) management plan should include contractors and maintenance activities. Several fact sheets are available from the European Agency for Safety and Health at Work (EU-OSHA) to assist companies in integrating maintenance activities and any related (sub)-contracting[18].

4.3.4 Online tools for controlling health risks from chemicals: COSHH Essentials

The COSHH Essentials website[19] provided by the UK Health and Safety Executive is similar to the ILO International Chemical Control Toolkit[20], but it goes a step further and provides direct guidance based on input to an interactive website. After entering data of processes and operations in the online tool[21], users are given advice on a range of tasks involving chemicals, such as mixing or drying.

Details on relevant control measures such as “drum emptying” or “transferring liquid by pump” are available for download and are valuable tools for protecting workers.

4.3.5 Additional sources of information

Websites

UNECE (United Nations Economic Commission for Europe): provides more information about the GHS and the application of the GHS criteria:
http://www.unece.org/trans/danger/publi/ghs/guidance.html

HSE (Health and Safety Executive): UK website providing a wealth of information and advice on work-related health and safety, and guidance on the control of hazardous substances:
http://www.hse.gov.uk/

Documents

UNEP: Responsible Production Handbook. A Framework for Chemical Hazard Management for Small and Medium Sized Enterprises

HAS (Health and Safety Authority), Ireland: Your steps to chemical safety. A guide for small business

GTZ Chemical Management Guide for Small and Medium Sized Enterprises, 2007

4.4 Storage of hazardous chemicals

All substances or mixtures presenting one or several hazards that could have adverse effects on humans’ and animals’ health or life, harm the environment or damage infrastructures are considered as hazardous materials. The presence of these substances in a company requires special rules for handling, processing, disposal and, of course, for storage. The aim of this chapter is to present general

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[18] https://osha.europa.eu/en/publications/e-facts/e-fact-62-safe-maintenance-working-with-contractors-and-subcontractors/view ; https://osha.europa.eu/en/publications/e-facts/e-fact-66-maintenance-and-hazardous-substances/view ; https://osha.europa.eu/en/publications/e-facts/e-fact-67-maintenance-chemical-industry/view

[19] http://www.hse.gov.uk/coshh/essentials/index.htm

[20] http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/toolkit/icct/

[21] http://www.hse.gov.uk/coshh/essentials/coshh-tool.htm

and specific rules for the storage of hazardous substances in order to prevent fires, explosions, the formation of gases and toxic vapours, the pollution of soils, surfaces and groundwater, etc.

The literature is rich with information, and it is not possible to provide here an exhaustive list of the standards regarding the storage of hazardous substances. The objective of this chapter is to present the most relevant rules, applicable in an industrial context, in order to enable the safety manager (or equivalent) to analyze the storage conditions in the company, identify gaps and define where measures need to be taken to ensure compliance with standard storage policies. However, it is important to keep in mind that national regulations and safety values have to be complied with at any time.

4.4.1 Storage concept

A storage concept includes all the relevant information needed to ensure the safe storage of hazardous materials and compliance with regulations as well as environmental and safety requirements. It gives an overall view of the local situation and available measures. By drawing up a storage concept, the following objectives can be achieved [48]:

- The local conditions and measures are perfectly adapted to the hazards arising from the stored products.
- As a result of the overall consideration, conflicting measures are identified and may be adjusted.
- Legal requirements are met.

To achieve these goals, a storage concept must include the following information:

- A description of the local environment including storage conditions, physical properties of storage rooms and definitions of the stored substances
- The nature and the quantity of the hazardous substances
- Structural, technical and organizational measures

4.4.2 Classifications/categories

Hazards

The hazards associated with chemical substances were presented in the previous chapters of this manual. The various properties need to be described in safety data sheets and other relevant documents, and marked on containers. The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) is a standardized system to classify substances and hazards and was covered in Section 4.3.1, where the different hazards and their pictograms were described.

Storage classes (SC)

Based on the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) [52] and the UN Recommendations on the Transport of Dangerous Goods [51], nine material classes (and additional subclasses) were defined, for which specific handling and storage rules were developed. Three of them are not dealt with here as they are too specific (infectious, radioactive and explosive materials). The categories are listed in the following table.

Table 4-5: Storage classes [based on 51 and 52]

Storage class	Substance properties	ADR/UN labelling	GHS labelling
SC 2	Liquefied gases or gases under pressure		
SC 3	Flammable liquids		
SC 4.1	Flammable solids		
SC 4.2	Substances liable to spontaneous combustion (auto-flammable)		
SC 4.3	Substances which, in contact with water, emit flammable gases		
SC 5	Oxidizing substances/organic peroxides		
SC 6.1	Toxic substances		
SC 8	Corrosive or caustic substances		
SC 9	Miscellaneous dangerous substances and articles, including environmentally hazardous substances		

Examples of hazardous substances and their reactions

As a general rule, the storage of chemicals must be organized in different areas, according to the storage classes defined above. Moreover, possible chemical reactions between substances that can be severe and dangerous have to be considered, for instance:

- When acids react with non-precious metals (aluminium, silicon, zinc or iron) or when alkali metals (sodium or potassium) come into contact with water, or just humidity from ambient air, hydrogen is created. Hydrogen is an extremely flammable gas and can be explosive when mixed with air.
- Powerful oxidants such as hydrogen peroxide can cause fires if they come into contact with organic materials such as wood, paper, cardboard, etc.
- Sulphuric acid mixed with caustic soda creates an important exothermic reaction, which can lead to overflowing or dangerous corrosive projections.

For this reason, the storage of chemical substances requires proper organization, taking into account the hazard of each substance separately as well as the potential reactions between them. The incompatibility rules are presented in chapter 4.4.3, whereas the next table [48] shows most frequently observed dangerous reactions.

Table 4-6: Dangerous reactions

Substance A	+	Substance B	=	Danger
Acids	+	Metals	=	Spontaneous combustion (gaseous hydrogen)
Oxidants	+	Organic substances	=	Fire, explosion
Sulphide	+	Acids	=	Toxic gaseous sulphurated hydrogen
Alkali metals	+	Water	=	Spontaneous combustion (gaseous hydrogen)
Acids	+	Bases	=	Exothermic reaction (heat emission)
Metal powders	+	Aqueous solution	=	Spontaneous combustion (gaseous hydrogen)
Metal powders	+	Air	=	Spontaneous combustion
Nitric acid	+	Organic substances or metals	=	Toxic nitrous gas
Chlorine bleach	+	Acids	=	Toxic gaseous chlorine

4.4.3 Technical solutions

General storage rules

The next chapters present the requirements that must always be met, for the storage of any hazardous material, including the waste generated by the use of these materials.

Marking and labelling

The hazardous substances must be stored in a specific place, room or cupboard, clearly identified and separated from the process areas. The hazard must be indicated and the access restricted.

Every container, from the smallest bottle to the largest tank, must be labelled, in order to provide immediate information on the substance contained and the related hazard. For more information about labelling according to the GHS, refer to Section 4.3.1.

Inventory and safety data sheets (SDS)

In order to have a complete overview of the situation and of the potential hazards in case of an incident (leakage or fire), the company systematically needs to register the stored hazardous substances, including:

- Maximum quantities for every category and updated currently stored quantities
- Storage position(s) on a map

The fire brigade must be informed about the inventory. Furthermore, safety data sheets of every substance must be registered and easily available. Ideally, copies of these SDSs are stored with the substances. They provide information about the hazards, the storage requirements and the expected reactions in case of an accident.

The manufacturers of hazardous materials have to provide safety data sheets with the products they are selling. These SDSs must be regularly updated to comply with national and international standards and requirements. Specific information about SDSs, as specified by the GHS, is provided in Section 4.3.1 in the subsection “GHS safety data sheets”.

Water protection

Every liquid must be stored on a catch basin in order to manage overflow, leakage or accidental spillage. The objective of containing the liquid and avoiding its dispersion is to prevent:

- Environmental contamination and human exposure
- Dangerous reactions

If the substances stored present a high aquatic toxicity, or if this toxicity is low, but the quantities stored are high (over 1,000 kg), the retention capacity must provide for 100% of the highest volume stored plus the retention of the water that would be used to extinguish a fire.

A flow to the sewage system or to surface water must be prevented. The position of evacuation grids must be checked. They might be covered. In case of a dangerous spillage, they must be covered by appropriate means (for example special bags).

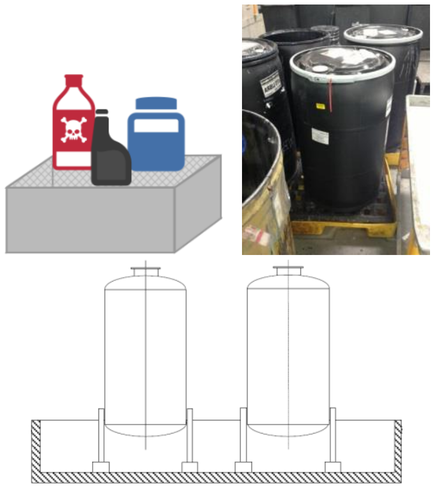

Figure 4-10: Different kinds of catch basins, according to the required volume [75], [1], [54]

Storage incompatibilities

Hazardous substances must be stored separately from any other non-hazardous material, and especially from food or drugs.

This matrix shows a classification of substances that, according to their hazardous properties, must not be stored together (red), can be stored together under certain conditions that have to be verified in the SDS (orange) or can usually be stored together without disadvantages (green).

Acids and bases must not be stored together.

Appendix 3: Storage shows storage incompatibilities for 16 substances commonly used in industry.

	O	-	-	-	-	-	+	-	-
	-	+	-	-	-	-	+	-	-
	-	-	+	O	-	-	-	-	-
	-	-	O	+	O	-	-	-	-
	-	-	-	O	O	O	O	O	O
	-	-	-	-	O	+	+	+	+
	+	+	-	-	O	+	+	+	+
	-	-	-	-	O	+	+	+	+
	-	-	-	-	O	+	+	+	+

Figure 4-11: Storage incompatibilities [based on 56]

Other safety and organizational requirements

- The flooring of the storage area must be impermeable. A special coating (sealing) will often be necessary, as concrete is permeable to many substances. This coating must be incombustible.
- The storage room and the facilities must be made of fire-proof material.
- The separation of the storage areas (or compartments) according to the storage categories must be clearly identified and labelled (flammable, toxic, corrosive, etc.).
- Other non-hazardous materials should not be stored in the same place (wrapping, paper, cardboard, spare parts, etc.).
- A substance must never be stored in a container that is not the original one, unless it has been specifically designed for this use (sufficient mechanic, thermal and chemical resistance).
- The containers must be protected from any mechanical or thermal influence (heat sources, falling objects, pressure through weight, etc.).
- Training must be conducted regarding chemical hazards and behaviour in case of an accident.
- There must be one responsible person (and one deputy) appointed for the storage area(s).

- Appropriate personal protective equipment (PPE) must be easily available and properly maintained.
- At least one eye shower must be installed. An emergency shower can be necessary.

Specific rules for each storage category

Storage category 2: Liquefied gases or gases under pressure

In case of accidental destruction or fire, pressurized containers can turn into dangerous projectiles. Hence, the following safety measures have to be taken:

Figure 4-12: Storage of liquefied gases or gases under pressure [76]

- Gas bottles must be protected by a fence.
- Use natural or forced ventilation (air renewal 3 to 5 times per hour, extraction near the ceiling or the floor depending on the properties of the gas).
- If the flammable gas is heavier than the air, consider an explosive atmosphere extending from the ground up to 1 metre (Zone Ex 2[22]) [77].
- If the flammable gas is equal in weight or lighter than the air, consider an explosive atmosphere in the whole room (Zone Ex 2).

If the vapours or gases are heavier than the air, the openings should be located near the ground. It they are lighter than the air, the openings should be located near the ceiling.

Ammoniac or gaseous chlorine storage requires very specific storage conditions that are not described here.

Storage category 3: Flammable liquids [48], [49]

The vapours of these substances are usually explosive. In exposed rooms, active ignition sources[23] must be avoided. Even the spark of a switch or an electrostatic discharge can set fire to these vapours. Therefore, smoking is strictly forbidden in those areas. In addition, electrical devices must be grounded and used so as to avoid ignition.

Figure 4-13: Fire-proof cabinet [76]

Explosive air or gas mixtures are often created in empty containers that have not been cleaned. In a fire situation, flammable substances burn fast or explode. Their flow accelerates the spread of fire.

Flammable liquids are divided into six categories, according to their flashpoint[24].

F1 = Liquids with a flash point below 21°C

F2 = Liquids with a flash point from 21 to 55°C

F3 = Liquids with a flash point from 55 to 100°C

F4 = Liquids with a flash point above 100°C

F5 = Not easily flammable liquids

F6 = Non-flammable liquids

[22] According to ATEX regulations
[23] Active ignition sources include flames, incandescent materials, hot surfaces or sparks emitted electrically, mechanically or electrostatically.
[24] The lowest temperature at which a liquid can vaporize to form a combustible concentration of gas

The storage place shall meet the following requirements, according to the category of the liquid and the quantity stored:

Table 4-7: Storage place depending on the flammable liquid category and the volume (expressed in litres) [based on 49]

Storage place (small container/tank)	Indicative maximum authorized quantity [litres]	
	Categories F1 and F2	Categories F3, F4 and F5
Any type of room	5	30
Cabinet made of materials with low flammability	100	450
Premises with specific structural properties designed to resist fire	> 100	> 450

- For quantities over 100 litres (F1, F2) or 450 litres (F3, F4, F5), the flammable liquid must be stored in a specific room built with material showing specific fire-resistant properties and fire compartments. Consider an explosive atmosphere (Zone Ex 2) extending up to 1 metre above the installation that requires earthing.
- For quantities over 1,000 litres, each substance must be isolated in a specific fire compartment[25]. Consider an explosive atmosphere (Zone Ex 2) extending up to 1 metre above the installation that requires earthing. For quantities over 2,000 litres, protection against lightning is required.

The storage area must be naturally or artificially ventilated:

- Natural ventilation is sufficient if the room is situated above the ground and has two openings directly connected to the ambient air. One of them has to be placed at a maximum of 0.1 metres above the ground. Each opening requires at least 20 square centimetres per square metre of floor area.
- Without sufficient natural ventilation, forced ventilation of the storage area is mandatory (3 to 5 air renewals per hour). The opening has also to be placed at a maximum of 0.1 metres above the ground.
- Storage areas in high-rise warehouses where flammable liquids are stored must be artificially ventilated.

Storage rooms (or racks) must be equipped with drip pans capable of collecting at least the volume of the biggest can, drum or intermediate bulk container (IBC).

Non-buried outdoor storage sites must meet the following requirements:

- Access is limited to authorized persons (a fence is mandatory, surveillance might be needed).
- A safety distance of 5 to 25 metres to neighbouring buildings must be observed, depending on the category, the volume of liquids and the risks for the neighbourhood (see Appendix 3: Storage; [49]).
- An adequately dimensioned drip pan providing for at least the volume of the biggest tank must be installed.

Storage category 4.1: Flammable solid

Dusts can be explosive and therefore dust deposits must be avoided and regularly cleaned.

- For quantities over 1,000 kg, the substances must be isolated in a specific fire compartment.

[25] A fire compartment is an area encircled by fire breakers (walls and ceiling must be fire-resistant) in order to prevent fire or smoke from spreading to other areas.

Storage category 4.2: Substances liable to spontaneous combustion (auto-flammable)

These substances can ignite very fast when in contact with the air, even in very low quantities. Examples include phosphor and freshly prepared metallic powders.

- Auto-flammable substances must never be stored outdoors.
- The storage area must be protected from any heat source. Ambient temperature should be controlled.
- They must not be stored with combustive, explosive or flammable substances.
- For quantities over 100 kg, the substance must be isolated in a specific fire compartment.

Storage category 4.3: Substances which, in contact with water, emit flammable gases

The reaction usually releases heat and the gas can ignite spontaneously. Examples include calcium and zinc powder.

- These substances must be stored in a dry place in hermetically closed containers.
- They must not be stored with halogens (fluorine, chlorine, bromine).
- For quantities over 100 kg, the substance must be isolated in a specific fire compartment.
- Specific extinguishers must be available and the sign “Do not extinguish with water” must be visible.

Storage category 5: Oxidizing substances/organic peroxides

These substances form highly flammable or explosive mixtures with any combustible material, flammable substance or just paper, sugar or wood. Notably **organic peroxides** must be carefully stored and handled, as they usually burn explosively.

- These substances must not be stored with combustibles (not even non-hazardous materials such as wood or paper) or caustic substances.
- They can be stored in the same room as other substances, but in a separate specific metal box or cupboard. Some organic peroxides must be refrigerated (well below their decomposition point).
- For quantities over 100 kg, the substance must be isolated in a specific fire compartment.

Storage category 6.1: Toxic substances

Even in very small quantities, these substances can be very harmful, even fatal.

- The storage must be secured and only accessible to authorized persons (key or code).
- For quantities over 1,000 kg, the substance must be isolated in a specific fire compartment.

Storage category 8: Corrosive and caustic substances

These substances can be very harmful, even fatal, in case of contact with the skin, the eyes or in case of ingestion or inhalation of vapours.

- They must not be stored with substances that form toxic gases with acids, or with combustive and oxidizing substances.
- Containers and catch basins must be resistant to corrosion (special plastics).
- Acids and bases must be physically separated and stored on distinct catch basins.
- For quantities over 1,000 kg, the substance must be isolated in a specific fire compartment.
- Storage rooms (or racks) must be equipped with drip pans capable of collecting at least the volume of the biggest can, drum or intermediate bulk container (IBC).

Storage category 9: Miscellaneous dangerous substances and articles, including environmentally hazardous substances

This group includes halogenated hydrocarbons such as perchloroethylene, chloroform or methylene chloride. Concrete is permeable to these highly pollutant substances.

- The catch basin must be capable of collecting at least the volume of 100 per cent of liquids utile volume (real volume occupied by the substance) and not only 100 per cent of the biggest container.
- The storage floor must be coated (sealed).

4.5 Fire protection

Every company should have a fire protection concept. Industries storing or processing any kind of flammable substances are by nature more exposed to the risk of fire, and developing a fire protection concept is therefore mandatory.

This chapter aims primarily at explaining the procedures and working methods for drawing up a fire protection concept and defining associated measures designed to reduce the fire risk.

Fire protection has the following objectives:

- Prevent fire occurrence and fire/smoke propagation
- In case of a fire, ensure effective response
- Provide health protection to persons, rescue teams and animals through safe escape routes
- Protect property (movable and immovable) and the environment

The organization of fire protection must comply with national and regional legislation. As presented in the figure below, it includes the two main aspects fire prevention and rescue procedures.

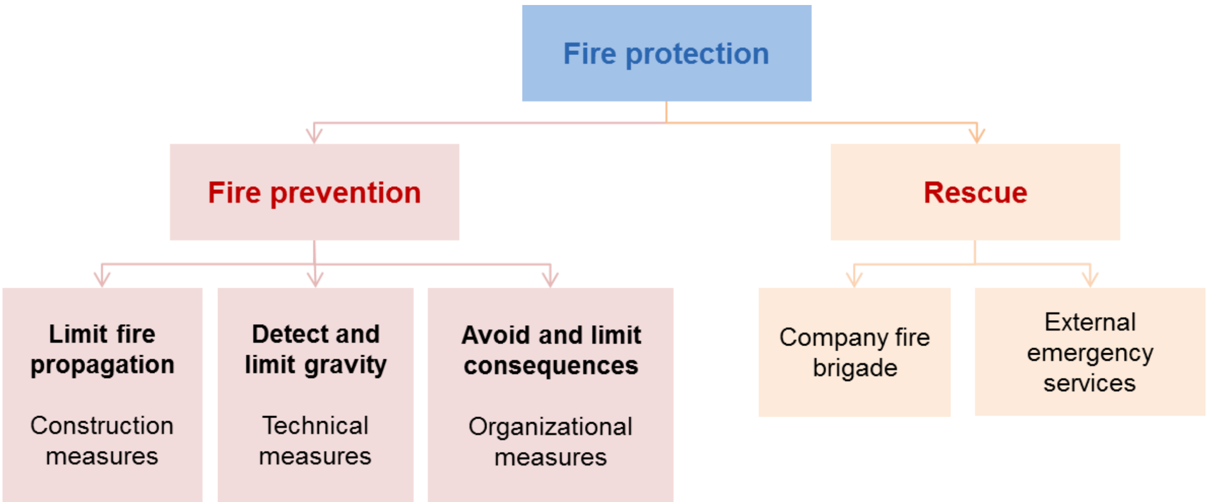

Figure 4-14: Fire protection [75]

Prevention includes structural, technical and organizational measures to limit, detect and avoid the risk of fire. The rescue phase covers support from internal and external emergency services and the fire brigade.

A fire protection concept should include all essential protection measures in terms of construction, technology, processes and organization likely to achieve the objectives of protection.

A fire protection concept is the result of a methodical procedure, as shown in the Figure 4-15, where a range of essential protection measures (structural, technological, process-based, organizational) are planned, taking into account the current situation, the identified hazards and the protection objectives. The concept should ideally be integrated in the planning of new facilities but can as be included in the conversion or restoration of already existing buildings [60].

Figure 4-15: Fire protection concept [75]

4.5.1 Classification/categories

Hazardous materials (hazard inventory)

The Table A4-1 presents the main hazardous material classes affected by fire or explosion hazards, including GHS pictograms and statement codes for different classes of flammable, explosive and oxidizing materials as well as gases under pressure.

The first step of a fire protection concept is to draw up an inventory of flammable, explosive, gaseous and oxidizing materials used in the company in order to define the concerned materials, their quantities and the conditions of storage, handling, processing and disposal.

Fire activation risk (hazard inventory)

The probability of accidentally setting fire to a tank of benzene is higher in a production area (where movements, heat sources or physical dangers are likely to be present) than in a secured storage site. The diagram below shows the increase in probability of the fire activation risk depending on the environmental context and the related physical constraints.

The fire activation risk can be defined as the probability of realization of the risk, depending on the environmental context and related physical constraints. It increases as shown in the diagram below:

- Storage
- Storage + process
- Storage + process + distillation/condensation
- Storage + process + distillation/condensation + pressure (storage and/or process)

The evaluation of the fire activation risk is the basic information to be considered in the fire risk assessment, as shown in Table 4-9. In addition, the following internal and external causes can increase the fire activation risk and might be considered in the risk analysis:

Table 4-8: Internal and external hazards [based on 59]

Internal hazards	External hazards
• Ignition sources • Shortage of facilities and missing or damaged fire safety equipment • Lack of organization • Lack of ability to respond to an emergency (lack of training)	• Arson • Natural disasters • Proximity of neighbouring buildings

Fire risk evaluation (risk analysis)

Based on the information collected through the hazard inventory, a rough assessment of the fire risk can be performed, considering the "Largest Individual Quantity" (LIQ) and the "Total Quantity" (TQ) of material identified in the area and the constraints on these materials. The figure below shows how this information can be used for the allocation to one of the three risk categories in order to define the level of protection measures required. The matrix presented here applies to solvents with a boiling point of up to 150°C [57].

Table 4-9: Determination of the fire risk category [based on 57]

Constraints	Largest Individual Quantity, LIQ (t), Total Quantity, TQ (t)							
	<0.5 LIQ	<1 TQ	<1 LIQ	1-10 TQ	<5 LIQ	10-30 TQ	<10 LIQ	>30 TQ
Stored in tanks, receptacles, bulk containers, drums								
The above and processed in reactors								
The above and distilling, condensing								
The above and/or processing under pressure								
Category 1: Basic fire risk	Basic fire protection measures are sufficient.							
Category 2: Medium fire risk	Additional fire protection measures are required.							
Category 3: High fire risk	Additional fire protection measures are mandatory.							

In order to define specific measures, the fire risk should be assessed separately for each area.

4.5.2 Technical solutions (risk reduction measures)

Based on the categories defined by the risk analysis, appropriate measures can be taken in relation to construction, technology and organization in order to reduce the fire risk.

The following sections are inspired by the CFPA Guidelines "Fire protection on chemical manufacturing sites" [57] and "Safety distances between waste containers and buildings" [58].

Construction measures

The global purpose of applying structural measures is to limit fire propagation. These measures prevent the propagation of a fire by using suitable construction materials and confine the fire through fire compartments.

Table 4-10: Fire protection – Construction measures (non-exhaustive list) [based on 57]

Construction measures	**Fire risk**		
	Basic	Medium	High
Maintain safety distances to other buildings (2.5 metres), especially for premises where hazardous products are stored.	X	X	X
Use non-combustible building materials, especially for supporting structures and exterior walls.	X	X	X
Separate different types of activities in separate fire-compartments (administration, storage, production).	X	X	X
Limit the size of the fire compartments, especially of those with a high fire hazard.	X	X	X
Adapt the fire resistance of the compartments to the amount of flammable/explosive products and the fire activation risk.	X	X	X
Provide enough safe escape routes.	X	X	X
Install drainage and spill control systems designed to contain leakages and firefighting water.	X	X	X

In addition, the following information should be observed:

- The minimum horizontal safety distance between combustible objects and buildings is 2.5 metres. Certain situations require a larger safety distance (4, 6 or 8 metres) depending on the content, number and volume of the containers. Other parameters can affect this safety distance. Interested readers can find more detailed information in the corresponding guideline published by CFPA Europe [58].
- Buildings where flammable products are stored and handled must be made of non-combustible materials, including the insulation in roofs and walls. Floors of multi-level buildings, open structures and load-bearing structures should preferably be made of concrete.
- The maximum size of a fire compartment is about 3,200 square metres.
- The drainage and spill control systems must be designed for simultaneous flow of flammable liquids and fire-fighting water away from the building.
- It is essential that there is enough retention capacity for the firefighting water, especially if the products stored are dangerous to the aquatic environment or the soil.

Technical measures

Technical measures are implemented to detect the fire risk by using alarms and fire or gas detection devices, and to limit the impact by using water, fire extinguishers or a sprinkler system. Specific installations and devices are needed to protect an object from fire risk [57].

Table 4-11: Fire protection – Technical measures (non-exhaustive list) [based on 57]

Technical measures	Fire risk		
	Basic	Medium	High
Provide air handling and smoke exhausting systems (automatic + manual)	X	X	X
Provide manual firefighting equipment in adequate quantity (internal fire hydrants, fire extinguishers, etc.)	X	X	X
Provide manual alarm points	X	X	X
Provide an automatic fire detection system		X	X
Provide an automatic fire extinction system (with adequate extinguishing agents)			X
Provide a gas detection system			X
Install a lightning rod for all production buildings with significant amounts of flammable or explosive products	X	X	X
Install a safety lighting system	X	X	X
Provide sufficient fire water capacity	X	X	X

Furthermore, the following items have to be considered:

- The maximum distance between internal fire hydrants should be around 75 metres.
- Manual fire alarm points must be strategically located throughout the site and production units. Alarm points need to be provided at 60 metre intervals.
- Fire detection systems are mandatory in areas with low manning levels (automated plants). The system has to be strategically positioned in order to detect fires starting inside processing equipment.

Figure 4-16: Fire alarm [75]

- Gas detection systems should be provided where potential leak sources could occur (pumps, compressors, tank cars, control rooms, etc.) in order to be used for emergency functions like shutdown of processes and/or activation of emergency ventilation.
- According to evaluations of firefighting statistics, fire water volumes of 8,000 l/min up to 12,000 l/min are required without fixed extinguishing systems. The water supply should provide fire water for a minimum of two hours and preferably 3 to 4 hours. The water retention capacity must be designed accordingly.

Figure 4-17: Gas detector [75]

Organizational measures

Organizational measures are implemented to avoid and control the impact of a fire and include the training of employees, the maintenance of equipment and the provision of safe escape routes.

Table 4-12: Fire protection – Organizational measures (non-exhaustive list) [based on 57]

Organizational measures	Fire risk		
	Basic	Medium	High
Establish a preventive maintenance programme for all equipment, including fire protection equipment	X	X	X
Appoint an adequately trained person responsible for fire protection	X	X	X
Organize an employee training programme		X	X
Organize a training programme for visitors			X
Develop an escape and emergency plan		X	X
Organize evacuation exercises with local emergency services		X	X

Responsibilities include the coordination and implementation of the fire protection measures, focusing in particular on the following points:

- An internal inspection system should be implemented to ensure the periodical checks of installations and organizational measures that are relevant to fire protection.
- A person responsible for fire protection must be appointed and given practical training.
- All employees must receive periodical training on fire safety and emergency procedures.
- The fire protection documentation such as escape and emergency plans has to be continually updated and made available in every building in case of an emergency. An example is provided in Appendix 4: Fire protection)

4.6 Management of chemical waste

Out of 5 to 7 million known chemical substances, more than 80,000 are used by companies in their production processes and operations. Numerous new chemicals are developed and produced every year. Today, almost every company uses some type of chemicals and generates chemical waste. Those enterprises which effectively manage chemicals and chemical waste can gain concrete benefits.

In general, hazardous waste is any waste or combination of waste which may have detrimental effects on the environment or human health because of its specific nature. These wastes not only pose risks and hazards because of their nature but also have the potential to contaminate large quantities of otherwise non-hazardous wastes if allowed to mix. [45, p. 9]

Benefit by reducing costs and environmental impact

Chemicals can represent a major part of the production cost for companies. Any measures that can be taken to reduce the loss, waste, contamination and expiry of these substances will bring cost savings to companies and, at the same time, reduce their environmental impact.

Benefit by becoming more competitive

By improving the management of chemicals and chemical waste, companies that are striving to achieve certification under management system standards such as ISO 9000 (quality) and 14000 (environment) will gain synergies. Many of the activities required for Environmental Management Systems (EMS) certification are aimed at reducing the use of hazardous substances, protecting the health of workers and reducing negative effects on the environment.

Benefit by improving workers health and safety

Reducing health and safety risks for employees improves their motivation and productivity and reduces absenteeism due to injury and illness.

4.6.1 Waste management options

In Europe, waste producers have a statutory duty to consider the **waste hierarchy** when deciding how to deal with waste.

Hazardous waste hierarchy

The waste hierarchy is a concept at European level that provides a preferred order of priorities for selecting, ranking and deciding upon waste management options with the aim to conserve resources and to minimize environmental damage. It gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal (for example landfill).

In the European Union Waste Framework Directive (2008), the waste hierarchy has five steps: prevention, preparing for re-use, recycling, other recovery (for example energy recovery) and disposal. [61, p. 3]

Prevention means measures taken before a substance, material or product has become waste in order to reduce:

- The quantity of waste, also through the re-use of products or the extension of the life span of products
- The adverse impacts of the generated waste on the environment and human health
- The content of harmful substances in materials and products

Re-use means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

Preparing for re-use means checking, cleaning or repairing operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances, whether for the original or other purposes. It includes the reprocessing of organic material but not energy recovery or the reprocessing into materials that are to be used as fuels or for backfilling operations.

Recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.

Disposal means any operation which is not recovery even where the operation has a secondary consequence, the reclamation of substances or energy.

Other recovery is not specifically defined in the revised Waste Framework Directive, although ‘energy recovery’ is referenced as an example. Since the term ‘other recovery’ is explicitly excluded from the definition of recycling, ‘other recovery” can be considered the processing of wastes into materials to be used as fuels or for backfilling.

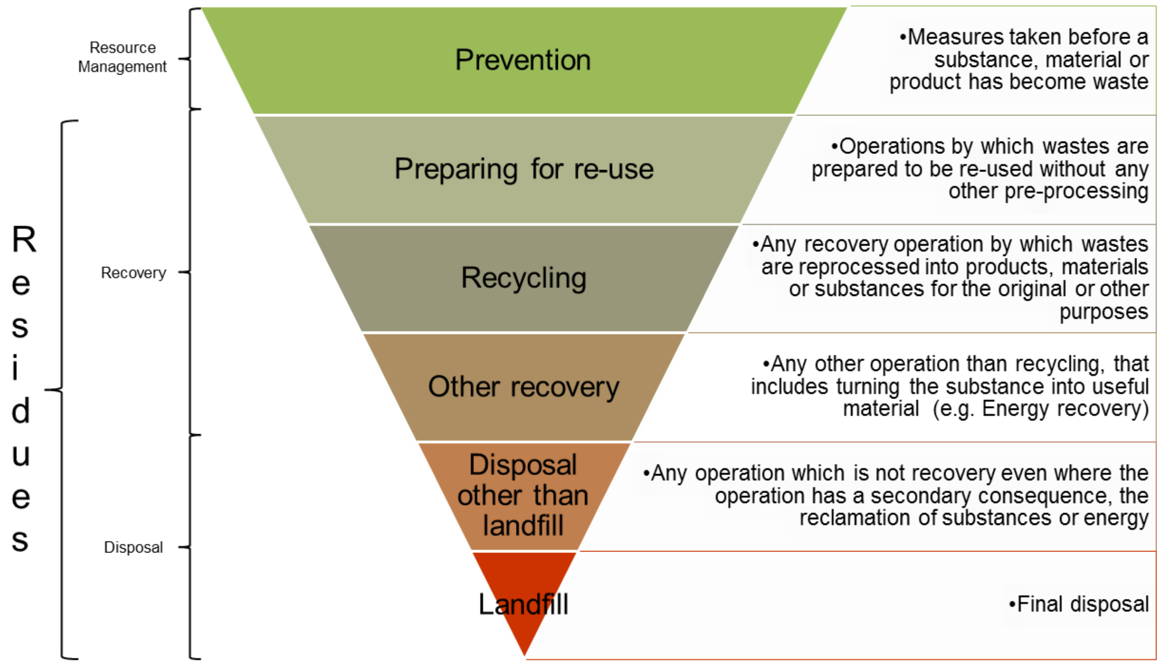

Figure 4-18: Hazardous waste hierarchy [based on 78]

4.6.2 Good practices in hazardous waste management

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal defines the **environmentally sound management of hazardous wastes** as "taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes" [65, p. 17].

Therefore an overarching objective of the sound management of hazardous waste is to minimize the negative effects of the generation and management of hazardous waste on human health and the environment.

A very useful flow diagram to start a hazardous waste management plan, is shown in the document "Guidance on applying the waste hierarchy to hazardous waste" by DEFRA [78, p. 15].

Handling of hazardous waste

Adequate handling of hazardous waste is an integral part of the waste management system. The list below provides an overview of good management practices that help avoiding accidents:

- Train personnel on safe procedures to transfer chemicals to waste containers.
- Ensure that waste containers are in good condition.
- Check whether waste containers are compatible with the waste type they are expected to contain.
- Keep an adequate spill control kit nearby. The kit should be big enough to control the release of the largest type of container in the storage area. Clean up spills quickly.
- When handling waste containers, use mechanical aids such as drum lifts, drum hand trucks and drum dollies. Do not roll drums on their side or edge.
- Make sure container caps are secure.
- Train personnel on spill clean-up procedures.
- Maintain good general housekeeping. Keep aisles and walkways clear [79].

Identification, classification and labelling of hazardous waste

The hazardous waste identification and classification process is the crucial first step in the hazardous waste management system.

Identification and classification

The waste producers usually possess the best knowledge of the generated waste, as they are aware of the raw materials[26] used in the production process and the technologies applied. They should be in charge of the proper classification and registration of their waste. If already available, the national classification system should be used. In any case, a basic characterization with the indication of the main physical and chemical properties is necessary. Further information on other hazardous properties such as explosivity, corrosivity, etc. should be provided. If possible, indications for the appropriate waste treatment could already be given (for example methods of stabilization) [62, p. 234].

Two of the main systems for hazardous waste identification are that of the European Union (EU) and that of the US Environmental Protection Agency (US EPA). These systems determine whether a waste is recognized as hazardous or non-hazardous and are based on defining threshold concentrations for the hazardous characteristics. If the waste exhibits hazardous characteristics at a quantity above such thresholds, it is then considered to be hazardous [63, p. 9].

Labelling

As a generator of hazardous waste, you are responsible for assuring that any container used to accumulate hazardous waste is properly labelled in order to meet regulatory requirements and assure the safety of those around you. During storage and transport, it is important that your waste can be easily identified and that containers are labelled with the following information:

- Indication that it is waste
- Contents of the container (where it is a chemical you should use the chemical identity rather than a trade name)
- Data of the waste generator
- State of the substance (solid, liquid or gas)
- Hazard(s) where applicable
- Emergency contact details [64, p. 4]

Hazardous waste management components

In principle, waste management comprises any step of handling waste from the moment of its generation up to the moment of its final disposal or its re-entering into the product status by means of recycling or recovery. Accordingly, the EU Waste Framework Directive defines waste management as "the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker".

Segregation

It is important that hazardous waste is segregated properly because of the effects it may have on human health or the environment if it is not properly controlled.

You must keep separate:

- Hazardous waste from non-hazardous waste
- Different types of hazardous waste from each other, and
- Hazardous waste from other materials [64, p. 3].

[26] Safety data sheets (SDSs) are an important information source to determine whether the waste you produce is hazardous.

Storage

Hazardous waste should be properly stored on-site. The storage areas should be away from public places in order to prevent any harm to the public or those persons exposed to the waste, and should be adequately dimensioned for the waste quantities to be stored.

The key factors which a company needs to ensure are that waste is:

- Secure
- Contained so that it cannot escape
- Protected from the weather, vehicles (including fork lift trucks), and scavengers and pests [64, p. 4].

It is important to ensure that any container used for waste meets certain minimum requirements. First and foremost, the container and its closure need to be compatible with the contained waste.

For certain wastes, there are additional storage requirements, for example chemicals which can have different properties and have the potential to react dangerously if not properly stored. The Health and Safety Executive, UK, have produced guidance on dealing with chemical storage (HSG 71)[27] and the storage of flammable chemicals (HSG 51)[28].

In small and medium enterprises, often only small quantities of hazardous wastes are generated. Therefore, on-site collection and temporary storage is necessary until quantities are large enough for shipment by a licensed hazardous waste transporter.

Hazardous waste should be stored so as to prevent or control accidental releases to air, soil and water resources in a location where [81, p. 48-49]:

- Waste is stored in a manner that prevents the commingling or contact between incompatible wastes, and allows for inspection between containers to monitor leaks or spills. Examples include sufficient space between incompatibles or physical separation such as walls or containment curbs.
- Waste is stored in closed containers away from direct sunlight, wind and rain.
- Secondary containment systems should be constructed with materials appropriate for the wastes being contained and adequate to prevent loss to the environment.
- Secondary containment is included wherever liquid wastes are stored in volumes greater than 220 litres. The available volume of secondary containment should be at least 110 per cent of the largest storage container, or 25 per cent of the total storage capacity (whichever is greater), in that specific location.
- Adequate ventilation is provided where volatile wastes are stored.

Hazardous waste storage activities should also be subject to special management actions, conducted by employees who have received specific training in handling and storage of hazardous wastes. These activities include [81, p. 49]:

- Providing readily available information on chemical compatibility to employees, including labelling each container to identify its contents
- Limiting access to hazardous waste storage areas to employees who have received proper training
- Clearly identifying (label) and demarcating the area, including documentation of its location on a facility map or site plan
- Conducting periodic inspections of waste storage areas and documenting the findings
- Preparing and implementing spill response and emergency plans to address their accidental release
- Avoiding underground storage tanks and underground piping of hazardous waste

[27] Health and Safety Executive, 2009. Chemical warehousing: The storage of packaged dangerous substances. HSG 71

[28] Health and Safety Executive, 1998. The storage of flammable liquids in containers. HSG 51

Collection and transportation

On-site and off-site transportation of waste should be conducted so as to prevent or minimize spills, releases and exposures of employees and the public. A licensed waste transporter[29] must ensure that hazardous waste is packaged, documented and labelled in compliance with the method of transport used (road, rail, air or sea) [65, p. 49].

Moreover, the transporter must ensure that the emergency response information contained on the manifest is immediately accessible to emergency responders. The transporter regulations do not apply to the on-site transportation of hazardous waste by generators who have their own treatment or disposal facilities, nor to TSD facilities transporting wastes within a facility.

All waste containers designated for off-site shipment should be secured and labelled with the contents and associated hazards, properly loaded on the transport vehicles before leaving the site, and accompanied by a shipping paper (i.e., EU consignment note [30] or US hazardous waste manifest[31]) that describes the load and its associated hazards [81, p. 49]). Completion of the documentation together with proper marking and labelling of containers and vehicles enables police, ambulance, fire and other first responders to react effectively and safely in the event of a spill or other accident involving hazardous waste while in transit.

Information required for consignment notes in the UK including an example can be found in the Guide to Hazardous Waste Regulations for small businesses published by the UK Environment Agency [64, p. 6]. However, local regulations and requirements must be observed.

Treatment and disposal of hazardous wastes

The purpose of treating hazardous waste is to convert it into non-hazardous substances or to stabilize or encapsulate the waste so that it will not migrate and present a hazard when released to the environment. Treatment methods can be generally classified as chemical, physical, thermal and/or biological.

Some types of waste may be managed properly and legally at company premises (for example in case of reuse). Other types require particular handling and shipment to businesses that are specialized and licensed in storage, recycling, treatment and disposal technologies. It is the responsibility of an enterprise to decide which method of management is best for the facility in terms of future liability, potential adverse environmental impact and cost [65, p. 48].

Selected management approaches should be consistent with the characteristics of the waste and local regulations, and may include one or more of the following [81, p. 48]:

- On-site or off-site biological, chemical or physical treatment of the waste material to render it non-hazardous prior to final disposal
- Treatment or disposal at authorized facilities specially designed to receive the waste. Examples include composting operations for organic non-hazardous wastes, properly designed, licensed and operated landfills or incinerators designed for the respective type of waste, or other methods known to be effective in the safe, final disposal of waste materials such as bioremediation.

In the absence of qualified commercial or government-owned waste disposal operators (taking into consideration proximity and transportation requirements), companies should consider [81, p. 50]:

- Installing on-site waste treatment or recycling processes

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[29] US EPA regulations governing hazardous waste transporters: http://www.epa.gov/osw/inforesources/pubs/orientat/rom34.pdf

EU DIRECTIVE 2008/68/EC on the inland transport of dangerous goods:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:260:0013:0059:en:PDF

[30] EC detailed description of consignment note data: http://ec.europa.eu/transport/rail/interoperability/doc/aeif-annex-a3-en.pdf

[31] US EPA hazardous waste manifest system: http://www.epa.gov/waste/hazard/transportation/manifest/index.htm

- As a final option, constructing facilities that will provide for the environmentally sound, long-term storage of wastes on-site or at an alternative appropriate location until external commercial options become available

The following table shows the main processes for waste treatment and disposal:

Table 4-13: Waste disposal technologies [based on 82, p. 147]

1. Physical treatment processes			2. Chemical treatment processes	3. Biological treatment processes	4. Thermal treatment processes	5. Disposal processes
a. Gas cleaning	**b. Liquids-solids separation**	**c. Removal of specific components**	**a. Absorption**	**a. Aerobic systems**	**a. Incineration**	**a. Deep-well disposal**
i. Mechanical collection	i. Centrifugation	i. Adsorption	**b. Chemical oxidation**	**b. Anaerobic systems**	**b. Pyrolysis**	**b. Dilution and dispersal**
ii. Electrostatic precipitation	ii. Clarification	ii. Crystallization	**c. Chemical precipitation**	**c. Activated sludge**	**c. Vitrification**	**c. Ocean dumping**
iii. Fabric filter	iii. Coagulation	iii. Dialysis	**d. Chemical reduction**	**d. Spray irrigation**		**d. Sanitary landfill**
iv. Wet scrubbing	iv. Filtration	iv. Distillation	**e. Wet oxidation**	**e. Tricking filters**		**e. Land burial**
v. Activated carbon adsorption	v. Flocculation	v. Electrodialysis	**f. Ion exchange**	**f. Waste stabilization ponds**		
vi. Adsorption	vi. Flotation	vi. Evaporation	**g. Neutralization**	**g. Rotating bio contactors**		
	vii. Foaming	vii. Leaching	**h. Chemical fixation and solidification**			
	viii. Sedimentation	viii. Reverse osmosis	**i. Dehalogenation**			
	ix. Thickening	ix. Solvent extraction				
		x. Stripping				

Monitoring

Monitoring activities associated with the management of hazardous and non-hazardous waste should include:

- Regular visual inspection of all waste storage and collection areas for evidence of accidental releases and verification that wastes are properly labelled and stored. When significant quantities of hazardous wastes are generated and stored on site, monitoring activities should include:
  - Inspection of vessels for leaks, drips or other indications of loss
  - Identification of cracks, corrosion or damage to tanks, protective equipment or floors
  - Verification of locks, emergency valves and other safety devices for easy operation (lubricating if required and keeping locks and safety equipment in standby position when the area is not occupied)
  - Checking the operability of emergency systems
  - Documenting results of testing for integrity, emissions or monitoring stations (air, soil vapour or groundwater)
  - Documenting any changes to the storage facility and any significant changes in the quantity of materials in storage
- Regular audits of waste segregation and collection practices including tracking of waste generation trends by type and amount of waste generated, preferably by facility departments
- Characterizing waste at the beginning of the generation of a new waste stream, and periodically documenting the characteristics and proper management of the waste, especially hazardous wastes
- Keeping manifests or other records that document the amount of waste generated and its destination
- Periodic auditing of third-party treatment and disposal services including re-use and recycling facilities when significant quantities of hazardous wastes are managed by third parties. Whenever possible, audits should include site visits to the treatment storage and disposal location.

4.6.3 Additional sources of information

Websites

UNEP-Global Partnership on Waste Management (**GPWM**): provides a guideline platform that deals with different aspects of waste management, including hazardous waste: http://www.unep.org/gpwm/InformationPlatform/WasteManagementGuidelines/tabid/104478/Default.aspx

UK Environment Agency: provides information and guidelines that will help you classify your waste (using the List of Waste), identify if it is hazardous waste, and understand the controls that apply to hazardous waste: http://www.environment-agency.gov.uk/business/topics/waste/32180.aspx

Website of the **European Commission**: provides information on EU hazardous waste legislation: http://ec.europa.eu/environment/waste/hazardous_index.htm

Documents

DEFRA (Department for the Environment, Food and Rural Affairs, UK):"Guidance on Applying the Waste Hierarchy to Hazardous Waste" (2011). This guidance is for any business or public body which generates, handles or treats hazardous waste.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) "Manual on industrial hazardous waste management for authorities in low and middle income economies" (2012): gives an overview of key issues related to legal requirements and practical procedures pertaining to the environmentally sound management of hazardous waste, taking into account requirements, recommendations and guidelines supplied by the Basel Convention and OECD, where relevant, and providing provisions and procedures, in particular from the European Union, as model examples.

IFC (International Finance Corporation, World Bank Group): "General EHS Guidelines: Environmental Waste Management" (2007): provides general guidelines for the management of non-hazardous and hazardous waste

EU: "Reference Document on Best Available Techniques for the Waste Treatments Industries" (2006): provides BAT in the waste treatment sector, including generic BAT and BAT for specific types of waste treatments

Environment Agency UK: "Guide to the Hazardous Waste Regulations for Small Businesses" (2013): explains how to determine if your waste is hazardous and what your responsibilities are as a producer of hazardous waste

Blackman, William C. "Basic hazardous waste management", third edition (2001), Lewis Publishers, CRC Press LLC.

4.7 Energy efficiency and chemicals

Industrial boiler design and operating conditions can have a significant impact on the production of persistent organic pollutants (POPs). Boilers are used for heating water for industrial processing or for domestic and industrial heating but also for producing steam. They can unintentionally form or release dioxins and furans (PCDD/F) or hexachlorobenzene (HCB). It has been demonstrated that it is possible for these compounds to be unintentionally formed during the combustion of fossil fuels. The volumetric concentrations of these pollutants in the emissions from boilers are generally very low. However, the total mass emissions from the boiler sector may be significant because of the scale of fossil fuel combustion in terms of tonnage and distribution. Besides the emission of POPs, the combustion of fossil fuels also forms other types of pollutants like SO_2, NOx, CO and particulate matter that may have a significant effect on the environment [68].

The unintentional production of POPs compounds during the combustion process follows three general pathways:

- Undestroyed compounds originally present in the fuel
- Gas-phase formation from precursors (for example polyhalogenated phenols, chlorinated aromatic compounds) at temperatures higher than 500°C
- Re-formation of POPs in the cooling of flue gases

Modern industrial boilers are normally identified by the methods of heat transfer utilized.

4.7.1 Heat transfer systems

- Water-tube boilers: Heat transfer tubes containing water are directly contacted by hot combustion gases. Commonly used in coal fired boilers but can accommodate almost any combustible fuel including oil, gas, biomass and refuse-derived fuel (RDF).
- Fire-tube boilers: Water surrounds tubes through which hot combustion gases are circulated. The application is more common for pulverized coal, gas and oil fired boilers but various types can also burn biomass and RDF. They are generally used for lower pressure applications.
- Cast-iron boilers: Cast sections of the boiler contain passages for both water and combustion gas, used for low-pressure steam and hot water production. They are generally oil or gas fired with a smaller number of coal-fired units.

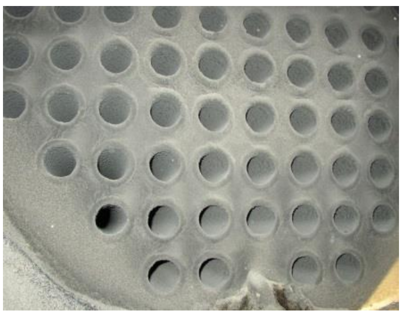


Figure 4-19: Fire-tube boiler (opened) [75]

4.7.2 Fuel type

Various types of fuels such as coal, oil, gas and biomass are used either individually or in combination with energy-containing waste products from other processes for steam and hot water generation in boilers. The type of fuel used depends on fuel availability and process economics.

Heavy fuel oil is still combusted for steam generation and is usually burned in specially designed burners incorporated in the boiler walls. The formation of PCDD/PCDF is favoured during co-combustion when liquid or sludge wastes such as waste oil or used solvents are added to the fuel mix, possibly due to lowered combustion efficiency.

Figure 4-20: Fuel oil operated boilers [75]

Light fuel oil and natural gas are always fired in specially designed burners and are generally unlikely to generate large amounts of PCDD/PCDFs, since both are very high calorific, clean-burning fuels with little ash.

Coal use in less efficient sectors could be a significant source of local emissions. It is acknowledged that the reduction techniques for dusts, SO2 and NOx on a flue gas can also reduce or remove PCDD/PCDF. This reduction is inconstant.

The use of **biomass** energy derived from renewable animal and plant sources can contribute to the energy requirements of industrial boilers. Usually the combustion of renewable biomass is less efficient than conventional fossil fuels and it is mostly burnt as a supplement along with feed from a conventional fossil fuel energy source. Potential for POPs emission may be increased by co-firing biomass if the boiler efficiency is not maintained by appropriate system redesign or control.

4.7.3 Emission reduction measures

In order to reduce the emission of POPs from fossil fuel-fired industrial boilers, the three pathways mentioned above must be minimized in the design and operation of the process. This will be effectively achieved by addressing:

- Energy conservation
- Fuel quality
- Combustion conditions
- Installation of most appropriate air pollution control devices

While the low level of precursors necessary to promote the unintentional formation of POPs via gas formation above 500°C occurs in most fuels, attention must be paid to reduce, as much as possible, the unintentional introduction of contaminated fuels, which may promote the formation of POPs. This is especially valid when co-firing fossil fuels with waste material. Other types of pollutants like SO_2 can also excessively occur due to low fuel quality.

The table below shows the scale of the potential firing technique savings achieved by the designated remedial actions. This is only a rough calculation. The actual savings would have to be calculated based on the actual plant and using the current operating profile. The designated values depend on the plant's condition.

Table 4-14: Energy saving potential in different areas of an industrial combustion plant

Loss	Remedy	Energy savings
Flue gas losses	Economizer Air pre-heater Condensing technology	3-15%
Surface losses	Appropriate insulation Lower boiler pressure Combustion air from top of boiler house	0.3-1%
Purging losses	Optimize control circuits Hot standby Set wider turndown ratio of burner	0.2-5%
Boiler scale	Correct feedwater preparation Clean boiler Optimize flue gas temperature	Up to 10%
Water losses	Replace pipes Renew seals Change valves and cocks	0.2-1%
Blowdown losses	Retrofit continuously regulated blowdown Fit blowdown heat exchanger Correctly adjust blowdown valve	0.5-5%
Excess air	Retrofit electronic compound regulator Retrofit O_2 and CO control system	0.5-1.5%
Plumes of steam	Retrofit vent condenser Retrofit deaerator control unit Retrofit magnetic shut-off valve	0.3-4%

Combustion conditions

To achieve the complete combustion of POPs contained in the fuel, special attention has to be paid to the four cornerstones of high destruction efficiency: **temperature**, **time**, **turbulence** and **excess oxygen**. In this way, precursors are destroyed and soot formation is reduced, allowing fewer possible sites for solid catalysis in the cooling gas effluent. It is generally accepted that a temperature over 900°C and a gas residence time of 2 seconds are sufficient to achieve the complete oxidation of dioxins as long as the gas flow is sufficiently turbulent and excess oxygen is present.

The air-fuel ratio for every firing has to be precisely calculated and adjusted accordingly to obtain the required output. Each level of output or quantity of fuel requires an exact amount of air. A regulator is required to calculate how much air is needed for which quantity of oil and gas. Mechanical regulators are robust, easy to use and have an air curve for all fuels but the mechanical tolerance could result in excess amounts of air being used and might not compensate temperature variations [69].

With electronic compound regulation, a microcontroller adjusts all firing functions individually. For this purpose, each valve and trap has its own actuator which is individually programmed at each load point. This means that different programmes can be used for different fuels. By using precisely adjusted valves and traps, the fuel consumption can be drastically reduced, whilst allowing O_2 and CO regulation.

The different densities of the hot and cold induction air have an effect on the oxygen transfer and may change fuel consumption significantly. Fixed regulation means that a burner set up in winter with little excess air may be operated in summer with an air deficit if the supply is not manually adjusted. A combined O_2/CO regulation always prevents an excess of air within a defined, lower range and equalizes the constant variations between temperature and pressure in the ambient air. It includes a broad regulation range for the O_2 content. In addition, CO occurs as a stop signal. Gases are measured by a lambda wave in the waste gas stream and the measurement signals are used to regulate the amount of air. A lower quantity of excess O_2 therefore results in fuel savings of up to 2 per cent.

Heat recovery

Usually, the waste gas temperature is slightly above the medium temperature when heat is generated at 30-50 K, which represents the lowest threshold at which the waste gas can be cooled inside the boiler. Waste gas temperatures of 250° C or even 400° C downstream of thermal oil heaters therefore occur inside the plant. The residual heat contained in the exhaust gas can be partially recovered through heat exchange by using so-called economizers that preheat the feed water, or through air-to-air heat exchangers that heat the fresh air. Regardless of the type of heat exchanger, a retrofit achieves significant savings if the plant discharges large quantities of waste gas. As a rule of thumb, a 100 K reduction of the waste gas temperature saves 4 per cent of fuel, whatever the operating method.

An **economizer** passes boiler feed water through the waste gas stream at a temperature of 103° C, before it returns to the boiler, causing the temperature to increase from 125° C to 135° C while the waste gas is cooled down. This temperature should not be exceeded in order to avoid the condensation of the waste gas in the chimney, which may cause construction damage or corrosion. If the sulphur concentration in the waste gas is elevated, the temperature must be even higher. In addition, if the waste gases contain dust, the heat exchanger’s geometry will have to be adjusted to prevent blockage. Using an economizer has been tested worldwide and it works: the higher the waste gas temperature the longer the full-load operation and the quicker the amortization.

Economizers must not be used, if the boiler contains high-pressure condensates or if thermal oil is used instead of water. In this case, **air-to-air heat exchangers (air pre-heaters)** are used. This type of heat exchanger uses the residual energy of the waste gas to heat the burner’s combustion air and can reduce energy costs by over 5 per cent. Usually, however, the burner control has to be reconfigured, if the fuel-air ratio is altered.

If the waste gas is cooled again downstream of the economizer, condensate is formed. In this case, the so-called **condensing technology** can be used to recover condensation heat. It involves a heat exchanger in the waste gas with sufficiently cold surfaces, on which water vapour can condense. The heat exchanger must be made of stainless steel and is connected to a condensate removal system in order to avoid corrosion by the acidic condensate. The waste gas is cooled down to a temperature of 45 to 50°C and fresh water can be heated to approximately 60°C. A 50-per cent condensation of the waste gas may result in 5.5 per cent fuel savings.

Depending on the heat generator, it is also possible to combine all three heat recovery technologies, specifically economizers, condensing technology and air pre-heaters. The table below summarizes the potential energy savings achieved by these three technologies.

Table 4-15: Potential energy savings of different heat recovery technologies

Technology	Medium	Operational area	Potential saving
Economizer	Waste gases/water Boiler supply water pre-heated	Downstream of heat exchanger; for supply water	4-7%
Air-to-air heat exchanger	Waste gas/air Combustion air pre-heated	Downstream of heat exchanger at high temperatures (water tube boilers, thermal oil heaters) or residual heat final phase	4-10% (water tube boilers, thermal oil heater) 0.5-4% (final phase)
Condensing technology	Waste gas/water Prepared water/process water pre-heated	As second heat exchanger downstream of an economizer or air-to-air heat exchanger	4-7%

Blowdown

When vapour is removed from the boiler, salts are concentrated as water is continually added to the boiler. The amount of salt and additives depends greatly on the way the water was previously processed and is lowest in de-ionized supply water. The dissolved salts, particularly sodium hydrogen carbonate, are expelled from the boiler using the blowdown valve, with hot water being discharged along with the accumulated salt. The manual operation of the blowdown valve often results in unwanted water and energy losses, since the salt concentration is not always visible in the water. By continuously measuring the electrical conductance, an undesired high carbonate content of the water can be determined. Coupled with a regulator and an automatic blowdown valve, the conductance, and therefore the salt content in the boiler water, may be kept exactly below a set threshold level and no more water than necessary is discharged.

Using a blowdown cooler, the residual water may then serve to heat up additional water, which then flows from the water processor into the degasser.

These measures discharge cool salt water while heat and expensive supply water remain in circulation and can achieve energy savings of up to 5 per cent.

5 Case studies

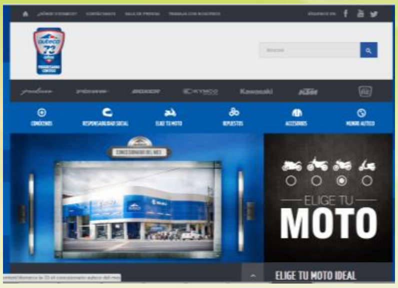
In the following selected case studies with findings of assessments in the paints and varnish industry are presented that were elaborated by the National Cleaner Production Centres (NCPC) participating in the present project on *Innovative Approaches for the Sound Management of Chemicals and Chemical Waste.*

CASE STUDY: AUTECO S.A.

PROJECT AIM

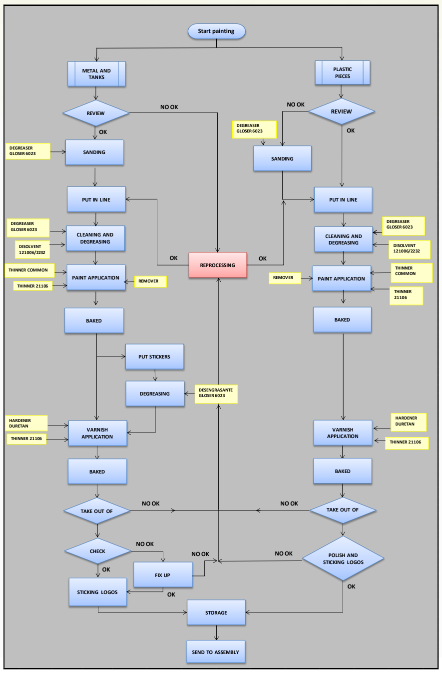
The aim of the project *Innovative Approaches for the Sound Management of Chemicals and Chemical Waste* is to facilitate the implementation of innovations in the production and application of chemicals to achieve a reduction in the consumption of chemicals, energy and water; improvements in the safe management of chemicals and risk reduction related to chemical accidents. Resource efficient options and technologies will be addressed as well as replacement of hazardous chemicals by chemicals with lower risk.

GENERAL COMPANY INFORMATION



Company	AUTECO S.A.
Address	Carrera 42 No. 45 – 77, Itagüí, Colombia
Sector	Motorcycle Assembler
Products	Twenty (20) models of motorcycle from following lines: Kawasaki from Japan, Bajaj (India), Kymco (Taiwan) and KTM (Austria)
Market	The target market of AUTECO is exclusively national.
Workforce	Around 1,800 employees

PRODUCTION



Process flow diagram for key processes

Key processes	Sanding, cleaning & degreasing, paint application, varnish application, sticking logos, assembly and test the motorcycle
Raw Materials	Solvents, paints, varnishes, motor oil
Equipment	Booth paints, ovens and spraying guns
Wastes	Dirty solvent, paint sludge and varnish sludge, towels & gloves, sandpaper dirty plastic (with paint), metal & plastic containers, and dirty oil
Wastewater	Wastewater from curtains
Emissions	VOC's
Project focus	Valorization of the sludge generated in the booths from application of paints and varnish. The challenges are: eliminate landfill disposal and convert to useful byproducts.

INNOVATION ASSESSMENT

Paint booth

Auteco S.A. was approached to conduct an innovation assessment to determine the two basic technical components of increasing material and energy efficiency to produce more products with correspondingly less waste and pollutants, a reduction in toxicity of materials used and safety and risk reduction. Particular focus lied on the innovative solutions in these areas which were generated, implemented, monitored and documented together with the company representatives.

PROCESS IMPROVEMENTS

Mix of paint and varnish sludge

About 60%-50% of paint applied in the booths is lost and the same occur with the varnish application.
AUTECO made a physicochemical characterization of the sludge mixed in an external laboratory and the result was that this sludge is not hazardous.
Approximately 62 ton of total sludge is generated by year; this sludge is disposal in ordinary landfill at a cost of USD 16,355/year.
Auteco and NCPC, with the support of Esmalgres S.A. (Ceramic Company Study) and Econotermia Ceramica S.L. from Spain, are making an evaluation for the option of introducing this sludge into ceramic products. The purpose is to use the sludge as alternative raw material for ceramic pastes and glass production

BENEFITS

Tiles made with waste

With the perspective of sludge valorization, Auteco could sell this sludge to Esmalgres and other ceramic companies. Natural resources could be saved with alternative raw material recovery, recycling and reintegration to production cycle.

Further significant benefits are:
- 62 ton /year of sludge are diverted from the landfill;
- Economic savings: US$ 16,355/year (amount of money that Auteco pays for sludge disposal)

Clean Technology	Environmental/Safety benefits		Economic savings		
	Waste reduction		Total Savings [USD/yr]	Investment [USD]	Simple payback [yr]
	ton/year sludge	% reduction			
Valorization of the sludge generated in the distillation column	62	100	16,355	0	NA

COMPANY STATEMENT

The owner of "Auteco S.A." is committed to protect the environment by generating less waste while meeting the growing market demands and ensuring jobs for his workers.
Owner:

FURTHER INFORMATION

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CASE STUDY: BONEM S.A

PROJECT AIM

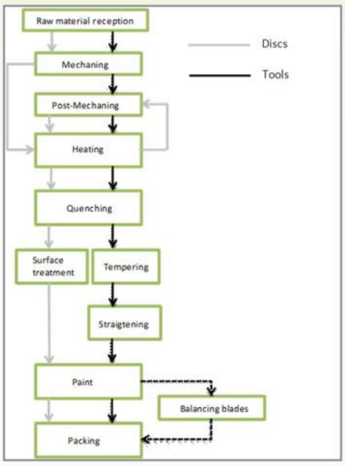
The aim of the project *Innovative Approaches for the Sound Management of Chemicals and Chemical Waste* is to facilitate the implementation of innovations in the production and application of chemicals to achieve a reduction in the consumption of chemicals, energy and water; improvements in the safe management of chemicals and risk reduction related to chemical accidents. Resource efficient options and technologies will be addressed as well as replacement of hazardous chemicals by chemicals with lower risk.

GENERAL COMPANY INFORMATION

Paint dipping process

Company	BONEM S.A
	Street 6 South # 50C -104
Sector	Manufacture of Fabricated Metal Product
Principal Products	Auto line (clutches and other parts) and agricultural machinery line (discs, tools and bearings).
Market	Mainly agricultural machinery line
Workforce	Approximately 170 employees

PRODUCTION



Agricultural machinery line

Key processes: Machining, heating, quenching, surface cleaning, painting process (dipping, spraying)

Raw Materials: Paints, solvents, quench oil.

Energy sources: Electricity and natural gas

Equipment: Winches, furnaces, paint booth

Wastes: Sawdust with solvents and oils, solvent contaminated drums, plastic bags contaminated with solvents and paints, contaminated towels from quench cleaning, contaminated solvents, sludge with paint and grease, sludge with calamine.

Wastewater: Suspended solids, COD (mg/l), BOD (mg/l)

Emissions: VOC.

Project focus: Implement two lines for quenching: water quenching for steel with low content of carbon and oil quenching for steel with high content of carbon.

INNOVATION ASSESSMENT


Bonem process

Bonem s.a was approached to conduct an innovation assessment to determine the three basic technical components of increasing material and energy efficiency to produce more products with correspondingly less waste and pollutants, a reduction in toxicity of materials used and safety and risk reduction. Particular focus lied on the innovative solutions in these areas which were generated, implemented, monitored and documented together with the company representative.

PROCESS IMPROVEMENTS


Quenching process

The company carries out an annealing process of low carbon and high carbon steel tools in a large industrial oven following an immersion of the parts in thermal oil thereby quickly quenching them to achieve the targeted hardness. A manual cleaning process using cloths is required to remove the oil from the parts' surface thereby generating a lot of hazardous waste. The parts need to be additionally cleaned before the paint coating process.

Additionally, calamine oil sludge forms during the quench process and has to be removed from the oil quench baths and must also be disposed of as hazardous waste. To reduce these chemical waste streams and reduce the costs of this process, the quenching of low carbon steel tools will be made with water. This eliminates significant amounts of hazardous waste and will lead to downstream benefits including reduced chemicals in the finishing section before paint application. The high carbon steel tools will continue to be quenched using the oil because the quality of the product is affected by using water.

BENEFITS


Quenching pieces

Among the main benefits are taken with the new production line are:

- Reduces significantly oil consumption
- Reduces significantly the generation of waste in this process
- Decreases hazardous waste generated by the company
- Less costs of hazardous waste disposal due to the decrease in waste
- Reduces vapors

Clean Technology	Environmental/Safety benefits		Economic savings	
	Chemical consumption			
	Oil Gallon/ year (old/new)	% reduction	$ Oil/ Gal	Saving by not buying oil for low carbon tools gallon (USD/year)
Substitute oil by water in quenching of tools and discs of low carbon	2640 / 2014	76	8 USD	16,114

COMPANY STATEMENT

The owner of Bonem s.a is committed to ensure the quality of products with less chemicals and energy consumption to meet increased market demands and ensure jobs for his workers.

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Fact sheet Bonem s.a. 19/03/2014. NCPC. CSD/ISSPPRO

CASE STUDY: Alico S.A.

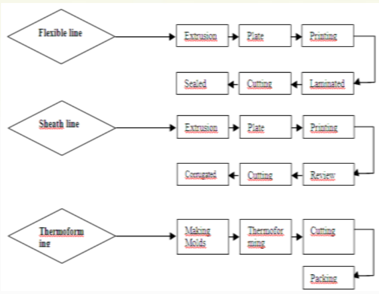
PROJECT AIM

The aim of the project *Innovative Approaches for the Sound Management of Chemicals and Chemical Waste* is to facilitate the implementation of innovations in the production and application of chemicals to achieve a reduction in the consumption of chemicals, energy and water; improvements in the safe management of chemicals and risk reduction related to chemical accidents. Resource efficient options and technologies will be addressed as well as replacement of hazardous chemicals by chemicals with lower risk.

GENERAL COMPANY INFORMATION

Company	Alico S.A.
Address	Calle 10 Sur No. 50FF – 63, Medellín, Colombia
Sector	Packaging solutions
Products	From the plastic films to the final labeled packaging
Market	**Alico S.A**. serves both domestic and international markets.
Workforce	Around 800 employees
Turnover	USD 65.602.325

PRODUCTION



Process flow diagram for the three lines

Key processes	Extruding, plating, printing, sealing, and laminating
Raw Materials	Inks, solvents, surfactants, adhesives, granules of polymers
Energy sources	Electricity, natural gas
Equipment	Extruding machine, plating machine, printing machine, sealing machine, laminating machine
Wastes	Solvents (Perchloroethylene, Solvid QD, thinner: N propyl acetate, ethyl acetate, and others), inks, towels, plastic, used cans
Wastewater	Wastewater of cleaning process
Emissions	VOC's

Packages made by Alico S.A.

Project focus Valorization of the sludge generated from dirty solvent distillation column. The aim is to divert the sludge from bioremediation treatment.

Fact sheet Alico S.A., June 2014, NCPC Colombia, CSD/ISSPPRO

INNOVATION ASSESSMENT


Dirty solvent storage

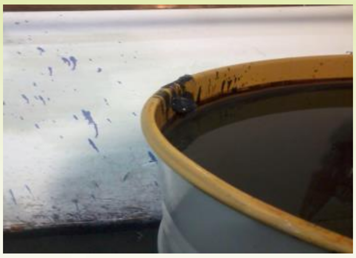
Alico S.A. was approached to conduct an innovation assessment to determine the two basic technical components of increasing material and energy efficiency to produce more products with correspondingly less waste and pollutants, a reduction in toxicity of materials used and safety and risk reduction. Particular focus lied on the innovative solutions in these areas which were generated, implemented, monitored and documented together with the company representatives.

PROCESS IMPROVEMENTS

Distillation column unit

Before 2013, Alico had a very small solvent recovery unit; most of the dirty solvents were delivered to a third company (Comerpa) in order to recover and reuse the solvent. In January 2013, Alico acquired a German distillation column (OFRU), for recovery inside the total dirty solvents used in the cleaning processes. The sludge generated (55,158 kg/y) in the distillation process which was disposed via bioremediation treatment.
In the course of the project, Alico found that this sludge can be used for coating woods, for which the distillation process can be stopped 1 hour before the typical end time.

BENEFITS


Sludge converted into value-added product

Alico sells this sludge to one of its providers for using as a coating of wood. With this approach to valorization of sludge, Alico closed the cycle of the solvent, and achieved zero solid waste from the distillation recovery unit.

Further significant benefits are:
- 55,158 kg/year of sludge that are left to pour to the land;
- Economic savings: US$38,760/year (amount of money that Alico paid for treatment of the sludge)
- Profit on sale of the sludge: US$ 3,313/year

Clean Technology	Environmental/Safety benefits		Economic savings		
	Waste reduction		Total Savings [USD/yr]	Investment under [USD]	Simple payback [yr]
	ton/year sludge	% reduction			
Valorization of the sludge generated in the distillation column	55	100	42,073	0	NA

COMPANY STATEMENT

The owner of "Alico S.A." is committed to ensure the quality of products with less chemicals and protect the environment by generating less waste while meeting the growing market demands and ensuring jobs for his workers.

Owner: Ovidio Salazar

FURTHER INFORMATION

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Fact sheet Alico S.A., June 2014, NCPC Colombia, CSD/ISSPPRO

6 Supporting policies

The implementation of innovative solutions for the sound management of chemicals and chemicals waste in the private sector is frequently hindered due to technical, financial, organizational and also political reasons. Thus, the creation of an enabling environment with stimulating policies helping overcome barriers is essential for enterprises.

The supplementation of national policy instruments at regional level considering local circumstances might be advantageous. For example, a national support programme for energy-efficient manufacturing processes might be linked with cantonal subsidies for renewable energy use and information-based instruments. In general, the following instruments facilitating the implementation of innovative process optimization measures in industry can be differentiated. A mix of these instruments has proved to be beneficial:

Market-based instruments: They internalize the environmental cost, i.e. the polluter pays, and take into account the “hidden” cost of production and consumption. For instance, a VOC tax compensates for the environmental cost of ozone formation. Market-based instruments also lead to technology innovation such as VOC-free products (paints, varnishes etc.) or waste gas burners.

Regulatory instruments: Command and control instruments typically form the basis of environmental policy frameworks and should be flexible. In Switzerland for instance, the handling of synthetic refrigerants (HFC) is restricted to trained personnel and the re-use of greenhouse gas (GHG) refrigerants is promoted. However, the substitution of HFC with environmentally sound and harmless natural refrigerants based on modern technologies is not facilitated at all, showing the one-sided approach of this instrument.

Voluntary agreements: They encourage businesses to improve their resource and energy efficiency beyond regulatory measures. The use of voluntary agreements in parallel with regulations, for instance CO_2 legislation, is most useful. In some countries, an agreement between businesses and the government for the reduction of GHG emissions through energy efficiency is possible. This might lead to a more proactive behaviour and a shift from end-of-pipe thinking to increased efficiency.

Monitoring: Compliance monitoring with relevant indicators is crucial to detect violations and provide evidence to support enforcement actions. Second monitoring allows for assessing whether policies have been effective over the long term. In some European countries, regular monitoring inspections by parties contracted by the government are conducted for wastewater pollution and GHG emissions in industries.

Education: Training and outreach are relevant for the replication of resource efficiency in industry. For instance, through UNIDO’s Resource-Efficient and Cleaner Production (RECP) Programme[32], hundreds of workers were trained on the basics of industrial process optimization, and subsequent train-the-trainers programmes on RECP created the basis for further outreach in the countries involved.

Overlapping instruments: Some types of instruments overlap and can hamper each other. The enforcement of a CO_2 regulation, for instance, can lead to a switch from fossil fuel to electricity consumption for heating. Electricity, however, is to be reduced as well and regulated too (for example through a national energy law). A coordinated approach is needed to ensure policy coherence.

In the following sections, supporting policies and instruments are summarized for the countries involved in the UNIDO initiative *Innovative Approaches for the Sound Management of Chemicals and Chemical Waste*.

[32] UNIDO’s Resource-Efficient and Cleaner Production (RECP) Programme: http://www.unido.org/cp. html

6.1 Market-based instruments to promote efficient technologies and preventive environmental practices

Market-based instruments aim at addressing the market failure linked to environmental externalities by changing the economic conditions. Incentives or disincentives are created to encourage or discourage specific behaviours. For instance, prompting businesses to internalize costs induced by their polluting activities (for example taxation, non-compliance fines, etc.) or creating property rights (for example tradable pollution permits) are two economic instruments. Other market-based instruments can be used to stimulate the use of efficient technologies and preventive environmental practices, including [70]:

- Grants, subsidies and financial assistance (for example the National Environmental Fund in Colombia, Subsidy for Technological Conversion to avoid the use of CFCs in Chile)
- Marketable permits
- Deposits and product charges
- Harmful subsidy removal
- Reduction in taxes, duties and fees
- Targeted technical assistance
- Liability rules (Enterprises are held responsible for the environmental damage they cause which often leads them to minimizing their risks and take preventive measures.)

Because market-based instruments act as cost-effective pollution control measures, they have shown to be more economically efficient in reaching pollution reduction goals than just regulatory instruments. They allow a greater flexibility in the choice of technology and prevention strategy and may also provide the government with a source of revenue. The latter can, for instance, be used to support other environmental initiatives enhancing the sustainable development of the country. Before introducing economic instruments, the government should carefully analyze the impact of each instrument on the society and the economy. Indeed, subsidies can be used to make local industries more competitive, which may lead to reduced energy prices and therefore increases in energy consumption, shortages and pollution.

El Salvador - Market-based instruments

El Salvador has set a market incentive, known as the **"Green Seal"**, to foster the sustainable and efficient use of natural resources and to promote processes and activities preventing the contamination of the environment. The seal was conceived as an instrument of differentiation for the goods and services produced in an eco-efficient way, as well as for those exported to international markets.

El Salvador also has a **tax incentive law** for the promotion of renewable energies in electricity generation. This law promotes the realization of investment projects based on the use of renewable energy through the use of hydraulic, geothermal, wind and solar resources, as well as the biomass for power generation.

The benefits and tax incentives of this law on electricity generation projects are:

- Projects up to 10 MW: exemption from income tax for a period of 10 years
- Projects between 10 and 20 (MW): exemption from income tax for a period of 5 years
- Projects up to 20 MW: exemption from the payment of customs duties on the import of machinery, equipment, materials and supplies for the first 10 years
- Total exemption from payment of all tax revenues directly from the sale of "Certified Emission Reductions" (CERs) under the Clean Development Mechanism (CDM) or similar carbon markets

Colombian water quality policy and impacts on water quality

The Colombian water quality regulation is composed of five key elements [1]:

- **Registration and permitting**: Any discharger of liquid waste is required to obtain a discharge permit from the appropriate authority.
- **Discharge standards:** Discharge standards regulate the discharges of liquid waste in terms of location and quantity. None of these standards are industry-specific and firms may be inspected at any time to sample effluents and inspect equipment.
- **Licensing:** Prior to construction, facilities that intend to discharge liquid effluents are required to conduct an environmental impact assessment and hold a public hearing in order to obtain a licence from the environmental authorities.
- **Discharge fees:** Between 1997 and 2002, all water users discharging liquid effluents in lakes and rivers had to pay a monthly fee per unit of biochemical oxygen demand (BOD) and total suspended solids (TSS) discharged. Annual targets were set for the total quantity of BOD and TSS discharged into the same water basin by all the sources. If these targets were not met, the fees paid by the individual facilities were increased, every six months, by a factor of 0.5.
- **Quality standards:** They specify in considerable detail the maximum permissible levels of pollutants for each type of use.

Colombia's water quality regulation strategy, and especially the discharge fee programme, showed a significant and positive impact on the water quality, as pollution loads dropped dramatically. Indeed, according to a quality evaluation realized in 2002, the implementation of discharge fees reduced the total BOD discharge by 27 per cent and total TSS discharges by 45 per cent between 1997 and 2002.

6.2 Optimization of the use of natural resources and raw materials, minimization of emissions

The optimization of the use of natural resources and raw materials protects the environment, but provides also sustainable economic and business practices. One way of optimizing the use of resources is, for instance, by minimizing waste production. By setting objectives, defining and implementing resource optimization and waste reduction strategies, companies are able to:

- Gain efficiency in production practices by achieving greater output of product per unit input of natural resources and raw materials
- Improve the financial performance of the firm by using more efficient processes to reduce the raw material and natural resource input and, as a result, the related costs
- Enhance the firm's public image, as the environmental impact of a company and its willingness to protect the environment are important factors in its overall reputation
- Improve the quality of products manufactured by introducing new innovation and technological practices
- Meet targets set by environmental regulations, policies and standards. An environmentally responsible firm reduces its harmful emissions and impacts.

In general, governments and international organizations (for example ISO, the International Organization for Standardization) provide regulatory frameworks and guidelines to drive companies towards a more sustainable development. Below, examples of how different countries promote a more sustainable development country-wide are presented.

Egypt

The Government of Egypt has set a strategy to implement a number of policies by 2022 to diversify energy resources and rationalize the energy needs of different activities without hindering the development plans. On 10 April 2007, the Supreme Energy Council in Egypt adopted a resolution on an ambitious plan aiming at increasing the contribution of renewable energy to reach 20 per cent of the total energy generated in 2020 (8 per cent hydro power and 12 per cent wind power). This target will be achieved by private-sector participation in financing, building, owning and operating wind farms in Egypt. By 2020, a total installed wind energy capacity of 7,200 MW producing about 31 billion kWh yearly should be reached. The latter should result in annual fuel savings of about 7 million tons of oil equivalent and 17 million tons of CO_2 emissions.

Colombia

Rates of water use, as well as rates for the use of other natural resources, are indirect signals to producers to promote the rational use of these resources. Pollution fees are also a strong signal to firms that an improvement in the firm's pollutant release should be considered. Other voluntary mechanisms contribute to reaching these goals, especially in Colombian firms:

- Environmental management systems in firms
- Clean production programmes
- Eco-labels
- Sustainable procurement
- Efficiency programmes for the use and conservation of water
- Clean energy programmes
- Post-consumer and chemicals management (SAICM/OECD programmes)

Morocco

To reduce the emissions of greenhouse gases, the Moroccan energy programme will invest an estimated $18.95 billion by 2020 and will create about 50,000 jobs. It predicts that, by 2020, electrical power produced by renewable energy (solar, wind and hydro power) will account for 42 per cent of the total power produced. The main objectives of this strategy are to:

- Decrease energy dependence
- Preserve the environment
- Limit greenhouse gas emissions
- Combat climate change

6.3 Reward for good environmental performance and practices

Rewards for good environmental performance and practices are an innovative way to raise awareness of cleaner production at company, industry and national levels.

El Salvador award programmes

El Salvador has set up the National Environmental Award which is one of the incentives of the state to promote environmental management. For this award, the ministry has defined several categories. The Award for Business Efforts was established for private-sector companies which have carried out environmental restructuring in their processes. The winners receive a medal and/or an honourable mention. According to information provided by the ministry, during the period 1999-2007, 163 awards and honourable mentions were given for each of the existing categories. For the category "Business Efforts", 12 awards were granted for the same period.

The Cleaner Production Award is a strategy that the El Salvador Ministry of Environment and Natural Resources (MARN), the National Cleaner Production Centre (NCPC) El Salvador and the Central American Commission on Environment and Development (CCAD) have been promoting to the private sector to encourage and reward the companies implementing cleaner production as a tool for improving environmental performance and increase competitiveness.

The Energy Efficiency Award is a strategy that the National Energy Council and 21 organizations, including the NCPC, have been promoting to the private sector to encourage and reward the companies implementing energy efficiency as a tool for increasing competitiveness. This award was created by the programme "El Salvador is Saving Energy".

6.4 Minimization of practices leading to the exclusive use of end-of-pipe technologies

Environmental quality has often been built on regulation and authority control with specific targets and demands imposed by authorities on industries with very little flexibility with regard to reaching these requirements [71]. Such governmental control has improved the environmental conditions but also has some drawbacks such as encouraging the use of end-of-pipe technologies. Several environmental policy instruments, such as tax write-offs or financial support for environmental measures, also tend to sometimes support end-of-pipe measures and therefore work against the environmental preventive and cleaner production approach [70].

End-of-pipe technologies are generally used to control pollution rather than to prevent the pollution from happening. This approach most often comes down to fulfilling legal prescriptions and typically includes solutions like the reduction of waste and emissions through treatment units and filters. They generally also lead to higher additional costs compared to preventive and integrated solutions.

Pollution prevention and cleaner production approaches tackle the environmental problems at all levels and fields. Prevention of waste and emissions takes place at the source, and environmental protection is an integral part of process engineering. Environmental innovations are developed within the company and make environmental protection a permanent challenge. Moreover, prevention measures often help reduce costs by optimizing the material and resource consumption.

More recently, many authorities have developed a negotiated compliance approach to build cooperation strategies between the regulators and the regulated (companies, industries, etc.) to, for instance, set and enforce standards and promote an open exchange of information [71]. For example, the authorities might define the targets, but the means of reaching these targets are left to the hands of the companies [71]. This more flexible approach enables the adoption of innovative and preventive technologies.

In Colombia, for example, environmental preventive strategies are promoted in the productive general sectors through the Colombian policy of sustainable production and consumption.

Morocco – National Programme for the Prevention of Industrial Pollution (PNPPI)

In Morocco, the PNPPI allows harmonization and planning of actions that the Administration and the private sector must achieve in order to prevent pollution. It promotes and implements prevention methods by focusing on the reduction of emissions and waste as well as on the compliance with environmental laws and regulations.

The specific objectives of the program are:

- Diagnosis of the current status and the technical, institutional and regulatory framework for the prevention and fight against various forms of industrial pollution
- Identification of priority actions to be undertaken
- Development of terms of reference for studies to be carried out

6.5 Industry-lead initiatives

The various industry sectors in the economy have very different environmental impacts. The System of Environmental and Economic Accounts (SEEA), an international standard developed within the UN system, is used to assess the environmental impact of the different industries in a country and helps in identifying the domains the environmental policies should be focused on.

In Peru, illegal gold mining has been identified as a major issue in terms of environmental impact and pollution. Indeed, illegal gold mining has led to high mercury and lead contamination in the Peruvian rainforest. The Peruvian Ministry of Environment has formalized a programme to address this environmental issue.

Peru – Chemical industry-lead initiatives

In the chemical industry, different projects and technical committees aim to improve and develop the sustainable formulation, production and use of chemical substances. The following programmes and committees are managed by the Peruvian Ministry of Environment:

SAICM (Strategic Approach to International Chemicals Management)

The objective of SAICM is to strengthen the institutional capacities, regulations and techniques for managing chemicals in Peru. One output of this project was a toolkit on chemical management. The project was implemented by the Centro de Ecoeficiencia y Responsabilidad Social (CER) and the Ministry of Health with support of UNIDO from 2009 to 2011.

"Technical Group for Chemicals" (Grupo Tecnico de Sustancias Quimicas)

In 2002, the Technical Group for Chemicals (GTSQ) was formed. It is responsible for coordinating integrated actions on chemicals and implementing the Stockholm Convention on Persistent Organic Pollutants, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.

6.6 Regulatory instruments: command and control for environmental protection and safety

Regulatory instruments are used to set a legal framework in order to control the environmental impacts of industries by defining prohibited or permitted conduct and to establish procedures for certain environmentally risky activities. Public authorities usually set environmental standards and goals, and then inspect, monitor and punish transgressions with legal sanctions. A sound legal framework promoting environmental protection and safety is generally achieved in the following cases [1]:

- The public and private sector cooperate in the elaboration of environmental policies and regulations.
- The regulatory framework promotes continuous innovation by not specifying any particular technology.
- The decisions on innovations generated to comply with the regulation are taken by industry and not the regulatory entity.
- Environmental regulations do not promote end-of-pipe solutions but innovations designed to reduce resource consumption
- Low levels of compliance with the standards are not accepted.
- Incentives are created for the private sector, etc.

Examples of regulatory instruments for environmental protection and safety include [70]:

- Environmental standards and regulations
- Product bans and trade restrictions (for example cadmium, pesticides, CFCs)
- Quotas for raw material depletion (for example a forestry law in Costa Rica prohibiting exports of unprocessed timber)
- Facility operation standards and permits
- Liability assignment

El Salvador – Environmental regulatory instruments

El Salvador has a Cleaner Production Policy whose main objective is to incorporate ecological efficiency and effectiveness in the environmental performance and competitiveness of companies, minimizing pollution by the implementation of preventive actions in services, technologies and production processes.

During the governmental programme "País Seguro" (2004-2009), an environmental strategy was established that consisted in the establishment of voluntary agreements for cleaner production between companies and the Ministry of Environment and Natural Resources (MARN) to gradually restructure production processes into cleaner processes.

Voluntary Agreements for Cleaner Production (AVPL) are instruments of the environmental policy, based on an agreement between the private sector and the competent public administration. They are legally binding and seek to achieve specific environmental objectives and competitiveness.

Egypt –Environmental policy framework

The environmental policy of the Government of Egypt seeks to achieve environmental protection through the establishment of proper institutional, economic, legislative and technical frameworks at the local, regional, national and international levels. This is expressed through the seven directives of the policy statement of the Minister of State for Environmental Affairs (MSEA):

1. Strengthening partnerships at the national level
2. Supporting bilateral and international partnerships in the environmental fields
3. Enforcing Law 4 of 1994 and Law 9 of 2009 for the protection of the environment, and Law 102 of 1983 for natural protectorates as well as all other environmental legislation
4. Supporting institutional strengthening and capacity building for the Egyptian Environmental Affairs Agency (EEAA) and Environmental Management Units (EMUs) of the governorates
5. Supporting integrated environmental management systems
6. Integrating the use of market-based instruments in the field of environmental protection
7. Transferring and adapting environmentally friendly technologies

Within the national environmental policy framework, an Egyptian Environmental Policy Programme was initiated in 1999 with the support of the United States Agency for International Development. Based on this programme, the Government of Egypt implemented its priority environmental policy objectives and measures, through institutional and regulatory reforms, with a focus on a number of areas. These included economic and institutional constraints, cleaner and more efficient energy use, reduced air pollution, improved solid waste management, sustainable tourism as well as nature conservation.

Within this policy framework, institutional and regulatory reforms are carried out, aiming at the implementation of national environmental policy objectives and measures. The implementation of the environmental policies of the Government of Egypt, as expressed by the policy framework and directives of the MSEA, is undertaken with regard to four main principles underlying environmental management and protection initiatives:

1. Strengthening the integrative capacity of central and local government
2. Strengthening of public-private partnerships
3. Partnerships with environmental non-governmental organization
4. Integration of gender issues in environmental policies and programmes

7 Funding of innovations

In many countries, the lack of attractive financial conditions is a barrier to comprehensive investments in new technologies in companies, thus also limiting the success of clean, innovative and environmentally sound technologies. That is why numerous alternative finance instruments were developed in the past to facilitate industrial investments. In the following section, selected instruments are presented as examples in countries within the scope of the present UNIDO project.

7.1 Funding in Peru

7.1.1 Green Credit Trust Fund

The Green Credit Trust Fund (GCTF) was initiated in Peru in 2004 by the State Secretariat for Economic Affairs (SECO). It is oriented towards supporting sustainable industrial production initiatives in small and medium enterprises. The GCTF supports projects related to eco-efficiency and technological reconversion up to a maximum amount of $1 million worth of credit. To benefit from the fund, the enterprise must seek to improve its processes through green technologies. Projects that only aim to fulfil legal requirements are not supported by the credit fund.

To qualify for the GCTF, the enterprise must be registered in Peru, have a maximum of 25 per cent of foreign capital and be legally independent from any international organization. The GCTF is available to manufacturing companies but SMEs in this sector must not own more than $8.5 million worth of fixed assets and must not have more than 500 employees.

The company first applies for the credit through one of three different intermediary financing institutions (Banco de Crédito del Perú, Interbank and Scotiabank del Perú). Then, the enterprise selects environmental indicators, in consultation with the Peruvian NCPC. Next, an evaluation of whether the new technology will improve the production and reduce the environmental impact of the company is undertaken. Once the new technology is installed, the indicators are monitored and a report based on the improvements is sent to SECO.

SECO can also provide a guarantee of 50 per cent if required. If the report shows significant improvements of the enterprise’s environmental performance, the company receives a reimbursement from SECO.

The reimbursement levels are based on the credit amount or the investment amount, whichever the smaller of the two. The levels are the following:

- 15 per cent reimbursement for 30 per cent worth of environmental improvement
- 25 per cent reimbursement for 50 per cent worth of environmental improvement

There are no intermediate levels for the reimbursement.

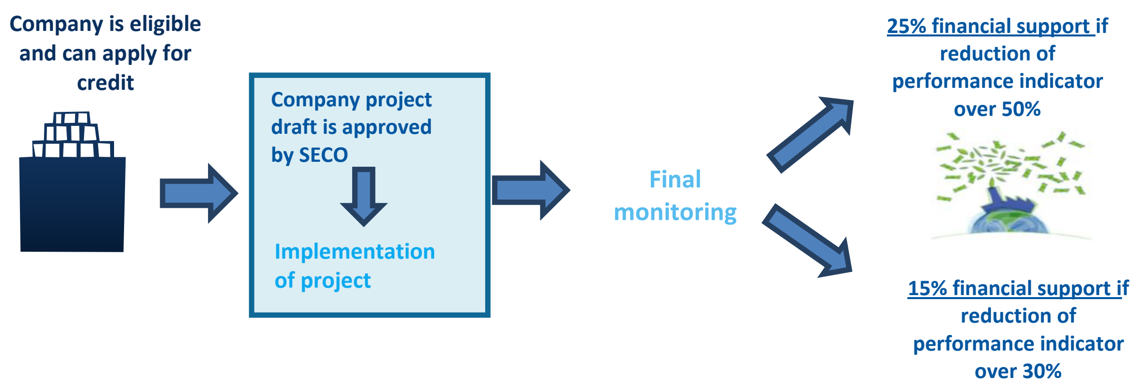

Figure 7-1 : The Green Credit Trust Fund [75]

Since the beginning of the initiative, 17 projects have been approved, with a total amount of more than $4.3 million.

The GCTF concept has proven to be operational. The success is embedded in combining a financial instrument with Sustainable Enterprise Development (SED) centres which have extensive environmental know-how (for example in Peru Centro de Ecoeficiencia y Responsabilidad Social (CER)). With the GCTF, no direct interferences in finance markets occur, which allows banks to assume their role as agents to analyze the creditworthiness of investments.

Most of the investments prove to be win-win solutions improving the economic aspects as well as reducing the environmental impacts of the companies. Some projects even improve social aspects, thus clearly demonstrating the potential of environmentally sound technologies (ESTs). With the GCTF, SED centres get access to clients who potentially have projects related to cleaner production.

7.2 Funding in El Salvador

7.2.1 FONDEPRO

The Productive Development Fund (Fondo de Desarallo Productivo, FONDEPRO) is an incentive created to promote the development of quality, productivity and innovation, and to support the adoption and implementation of technological improvements leading to cleaner production processes. The fund supports the competitive strengthening of small and medium enterprises by co-financing up to 60 per cent of the total cost of a project or timely initiative.

The fund has two co-financing models:

- Fast track model: support of up to $15,000 for a project focused on a specific activity
- Support of up to $100,000 for a project combining multiple activities

Annual sales must not exceed $7 million and the enterprise must be located in El Salvador.

From 2002 to 2008, 718 projects were supported through the fast track model, which represents a placement of more than $1.3 million.

7.2.2 BANDESAL-KfW Environmental Conversion Line

El Salvador’s bank for development BANDESAL (Banco de Desarollo de El Salvador) contracted with the German development bank KfW a three-phase credit line for the environmental conversion of companies. For the first phase from 2007 to 2010, $10 million were released, with $500,000 non-refundable and allocated for technical assistance in environmental projects. For the second phase from 2011 to 2013 and the third phase, respectively $27 million and $50 million were released.

The main objectives of the programme are to contribute to the reduction of environmental pollution, to promote the efficient use of natural resources by small and medium enterprises and to deepen the financial system by establishing long-term instruments for environmental investments for companies located in El Salvador. This programme supports entrepreneurs willing to invest in more efficient and environmentally friendly production processes. For an environmental project, the credit limit is set to $500,000. For a project concerning renewable energies, a credit of a maximum of $4 million can be provided (projects of more than $500,000 require an authorization by KfW). The credit finances up to 80 per cent of the value of the investment and has a fixed yearly interest rate of 3.6 per cent for the life of the loan.

With the technical support of the NCPC, the credit line has assisted 28 small and medium enterprises since 2010.

The benefits obtained in these 28 companies are, in average, the following:

- Energy consumption reduced by 6.7 per cent
- Fuel oil consumption reduced by 8.4 per cent
- Savings of $1.1 million achieved per year
- Investments of $1.3 million
- 2,300 tons of CO_2 emissions avoided per year

7.3 Funding in Egypt

7.3.1 Private Public Sector Industry Project

The Private Public Sector Industry (PPSI) Project aims to protect the environment by contributing to the reduction of industrial pollution. PPSI focused on private and public industrial establishments in Upper Egypt and the Delta, and operated from 2008 to 2012. PPSI was implemented by the Egyptian Environmental Affairs Agency and supported by KfW under the German financial cooperation with Egypt.

Grants covering 20 to 30 per cent of the pollution abatement investment costs, with a maximum of $1 million, were provided for eligible sub-projects. Preferential treatment was applied to SMEs (companies with a turnover of less than $2.8 million) and at least 30 per cent of the investment funds were allocated for SMEs. The second phase of PPSI ended in 2012. The third phase has not yet started.

7.3.2 Environmental Compliance Office Revolving Fund Programme

The Environmental Compliance Office (ECO) was set up in 2002 by the Egyptian Government and the Danish International Development Agency (DANIDA) to assist in achieving compliance in industry. A cooperation agreement was signed in February 2005 between the Egyptian Environmental Affairs Agency (EEAA), the Federation of Egyptian Industries (FEI) and the National Bank of Egypt (NBE) for the purpose of operating the ECO Revolving Fund to invest in new equipment.

DANIDA provided funds equivalent to more than $11 million to be allocated within the industrial sector to support initiatives aiming at abating pollution, encouraging safe working conditions and ensuring environmental legislative compliance. The revolving fund provided enterprises with the opportunity to make economic benefits and ensure proper compliance with environmental laws.

Small and medium enterprises being members of the FEI are eligible to apply. Loans can reach up to $420,000 per enterprise with a 2.5 per cent interest rate per year. Loans are repaid over 5 years and funds are reused for financing new cleaner production initiatives in other enterprises.

7.4 Funding in Morocco

7.4.1 National Fund for the Environment (FNE)

The National Fund for the Environment is a financial incentive instrument established in 2004 for the protection and valorization of the environment. This fund aims at:

- Funding programmes for domestic and industrial water treatment
- Financing solid waste management programmes
- Financing pilot projects for the environment

7.4.2 Fund for Industrial Depollution (FODEP)

FODEP promotes the environmental upgrading through technical and financial support of industrial companies. The subsidy covers up to 40 per cent of the investment, with a maximum of $625,000.

7.4.3 Voluntary Mechanism of Industrial Wastewater Treatment

This programme is funded by the Moroccan state and aims at encouraging industrial companies to invest in wastewater treatment processes. Industrial volunteers can benefit from a subsidy covering up to 40 per cent of the investment cost, with a maximum amount of $625,000 for individual projects and $1.25 million for collective projects.

7.4.4 Business Advisory Service Programme

Launched by the European Bank for Reconstruction and Development (EBRD), this programme aims at developing the expertise and local consultancy through technical and financial support to consulting assignments. The financial support covers 50 to 75 per cent of the mission’s expenses. Moroccan companies with a turnover of less than $68.2 million can benefit from this programme. Beneficiaries can be supported for the realization of:

- Technical studies: planning/architectural design, space optimization, IT infrastructure design, selection of machinery and equipment, installation, training
- Quality management system and certification: ISO 9000, Hazard Analysis and Critical Control Points (HACCP)
- Energy efficiency and environmental impact reduction: energy audit, mechanism for clean growth, renewable energy, environmental impact assessment, ISO 14000 implementation

8 Where do I find support?

The identification and implementation of innovative solutions and alternatives for chemicals and chemical waste management require extensive know-how of logistic processes, technical requirements, optimization techniques, standards and legal requirements. If a thorough analysis of possible innovations cannot be completely undertaken by a competent and experienced team within the company, the participation of external experts is highly recommended.

For assistance on innovative chemical solutions, the National Cleaner Production Centre (NCPC) Programme offers services such as RECP assessments on energy and resource efficiency, technology gap assessments and generation of process optimization measures.

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Further information and contacts please refer to the UNIDO NCPC website at www.unido.org.

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Appendices

Appendix 1: Technology Suppliers for Coating Applications

Cleaning Equipment

- Kerrick
- Nilfisk ALTO

Industrial Coatings

- Florite Coatings
- Helios Coatings
- Jotun
- Carboline
- Wattyl
- PPG Protective & Marine Coatings
- Altex Coatings
- Lacnam
- Dulux Protective Coatings
- Akzo
- Axalta (former DuPont)
- BASF

Paint & Equipment

- Jotun
- Carboline
- Wattyl
- PPG Protective & Marine Coatings
- Protec Paints
- Altex Coatings
- Lacnam
- Dulux Protective Coatings
- Hempel (Ships)
- BASF
- Akzo

Spray Equipment

- Finishing Brands UK Ltd
- Spraychief
- WALTHER Spritz- und Lackiersysteme GmbH
- Spraying Systems Co
- Anest-Iwata
- Wagner colora Srl
- GRACO N.V. - Fluid Handling Solutions
- Instalair
- Sprayline
- Canadian Importer & Distributor for SATA GmbH & Co.
- Eurotech Spray Products Ltd.
- Dürr
- Midway Industrial Systems
- Eisenmann

- Color parts
- Aie compressed systems
- Midway Industrial Systems
- Terronics Development corporation
- Applied Plastics CO
- OTP industrial solutions
- Elliot Equipment Co
- Paramount metal finishing
- E.L Stone Co
- Buhlinger e.k
- Döco GMBH
- AKU Oberflächentechnik GmbH h
- Börger

Paint Booths

I. Large scale plants:

- Eisenmann
- Gema
- Wagner
- WALTHER Spritz- und Lackiersysteme GmbH
- Global finishing solutions
- Spray systems Inc
- S.K. Bowling/Paint Perfect
- Ellert Equipment corp
- Elliot equipment corp
- Finishing systems Inc
- Barton Associates, Inc

II. Middle to large scale plants

- Rippert
- Wolf-Geisenfeld
- Slf-Oberflächentechnik
- Bartling Technik
- Azo Anlagen zur Oberflächenbeschichtung GmbH
- MEWES Oberflächentechnik GmbH
- Lawema Int. Spray booth engineering UG

Heating Hose Systems (Tools & Hoses Fittings)

- Hillesheim GmbH
- GRACO N.V. - Fluid Handling Solutions
- Alfagomma
- DEKORON/UNITHERM
- TotalRubber

Appendix 2: Chemical resistance selection chart for protective gloves

The ratings are abbreviated as follows: VG: Very Good; G: Good; F: Fair; P: Poor (not recommended). Chemicals marked with an asterisk (*) are for limited service.

Table A2-1: Chemical resistance selection chart [based on 79]

Chemical	Neoprene	Latex/Rubber	Butyl	Nitrile
Acetaldehyde*	VG	G	VG	G
Acetic acid	VG	VG	VG	VG
Acetone*	G	VG	VG	P
Ammonium hydroxide	VG	VG	VG	VG
Amy acetate*	F	P	F	P
Aniline	G	F	F	P
Benzaldehyde*	F	F	G	G
Benzene*	P	P	P	F
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulphide	F	F	F	F
Carbon tetrachloride*	F	P	P	G
Castor oil	F	P	F	VG
Chlorobenzene*	F	P	F	P
Chloroform*	G	P	P	F
Chloronaphthalene	F	P	F	F
Chromic acid (50%)	F	P	F	F
Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	F	G	VG
Dibutyl phthalate*	G	P	G	G
Diesel fuel	G	P	P	VG
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
Dioxane	VG	G	G	G
Epoxy resins, dry	VG	VG	VG	VG
Ethyl acetate*	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether*	VG	G	VG	G

Chemical	Neoprene	Latex/Rubber	Butyl	Nitrile
Ethylene dichloride*	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG
Freon 11	G	P	F	G
Freon 12	G	P	F	G
Freon 21	G	P	F	G
Freon 22	G	P	F	G
Furfural*	G	G	G	G
Gasoline, leaded	G	P	F	VG
Gasoline, unleaded	G	P	F	VG
Glycerin	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrazine (65%)	F	G	G	G
Hydrochloric acid	VG	G	G	G
Hydrofuoric acid (48%)	VG	G	G	G
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	F
Isooctane	F	P	P	VG
Kerosene	VG	F	F	VG
Ketones	G	VG	VG	P
Lacquer thinners	G	F	F	P
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	F	VG	VG
Lineolic acid	VG	P	F	G
Linseed oil	VG	P	F	VG
Maleic acid	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG
Mehylamine	F	F	G	G
Methyl bromide	G	F	G	F
Methyl chloride*	P	P	P	P
Methyl ethyl ketone*	G	G	VG	P
Methyl isobutyl ketone*	F	F	VG	P
Methyl metharcrylate	G	G	VG	F
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G

Chemical	Neoprene	Latex/Rubber	Butyl	Nitrile
Naphtalene	G	F	F	G
Napthas, aliphatic	VG	F	F	VG
Napthas, aromatic	G	P	P	G
Nitric acid*	G	F	F	F
Nitric acid, red and white fuming	P	P	P	P
Nitromethane (95.5%)*	F	P	F	F
Nitroprophane (95.5%)	F	P	F	F
Octyl alcohol	VG	VG	VG	VG
Oleic acid	VG	F	G	VG
Oxalic acid	VG	VG	VG	VG
Palmitic acid	VG	VG	VG	VG
Perchloric acid (60%)	VG	F	G	G
Perchloroethylene	F	P	P	G
Petroleum distillates (naphtha)	G	P	P	VG
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Potassium hydroxide	VG	VG	VG	VG
Propyl acetate	G	F	G	F
Propyl alcohol	VG	VG	VG	VG
Propyl alcohol (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Styrene (100%)	P	P	P	F
Sulphuric acid	G	G	G	G
Tannic acid (65)	VG	VG	VG	VG
Tetrahydrofuran	P	F	F	F
Toluene*	F	P	P	F
Toluene diisocyanate (TDI)	F	G	G	F
Trichloroethylene*	F	F	P	G
Triethanolamine (85%)	VG	G	G	VG
Tung oil	VG	P	F	VG
Turpentine	G	F	F	VG
Xylene*	P	P	P	F

Appendix 3: Storage

Storage incompatibilities

Table A3-1: Storage of hazardous substances commonly used in industry [based on 83]

		Formic acid	Solution of ammonia	Solution of iron chloride (III)	Solution of iron chloride (III) sulfate	Acetic acid	Hydrofluoric acid	Solution of potas-sium hydroxide	Solution of sodium hydroxide	Solution of sodium hydrogensulfite	Solution of sodium hypochlorite	Peracetic acid	Phosphoric acid	Nitric acid	Hydrochloric acid	Sulphuric acid	Hydrogen peroxide
	Storage category	**8**	**8**	**8**	**8**	**3**	**6.1**	**8**	**8**	**10/12**	**5**	**5**	**8**	**5**	**8**	**8**	**5**
Formic acid	**8**																
Solution of ammonia	**8**																
Solution of iron chloride (III)	**8**																
Solution of iron chloride (III) sulfate	**8**																
Acetic acid	**3**																
Hydrofluoric acid	**6.1**																
Solution of potassium hydroxide	**8**																
Solution of sodium hydroxide	**8**																
Solution of sodium hydrogensulfite	**10/12**																
Solution of sodium hypochlorite	**5**																
Peracetic acid	**5**																
Phosphoric acid	**8**																
Nitric acid	**5**																
Hydrochloric acid	**8**																
Sulphuric acid	**8**																
Hydrogen peroxide	**5**																

Safety distances

Table A3-2: Evaluation of the neighbouring risk [based on 73]

Type of storage building	Neighbouring building activity		
	Low danger[33]	Medium danger[34]	High danger[35]
Specifically resistant to fire	Low	Low	Low
Non-flammable (concrete)	Low	Medium	High
Flammable (wood)	Medium	High	High

Table A3-3: Safety distance in metres between outside warehouses and buildings, structures and facilities [based on 73]

Neighbouring risks (Table A3-2)	Storage in containers (in litres)					
	Categories F1 and F2			Categories F3, F4 and F5		
	Up to 5,000	Up to 50,000	Above 50,000	Up to 5,000	Up to 50,000	Above 50,000
Low	5	10	15	-	5	8
Medium	10	15	20	5	8	12
High	15	20	25	8	12	15

Table A3-4: Safety distance in metres between unburied tanks and buildings, structures and facilities [based on 73]

Neighbouring risks (Table A3-2)	Storage in tanks (in m^3)					
	Categories F1 and F2			Categories F3, F4 and F5		
	Tank resistant to overpressure	Vertical tank		Tank resistant to overpressure	Vertical tank	
		Up to 500	Above 500		Up to 500	Above 500
Low	12	20	30	6	10	15
Medium	16	25	35	8	12	18
High	20	30	40	10	15	20

[33] Production, treatment and storage of non-flammable materials

[34] Engineering workshops, car repair, offices, apartments

[35] Storage and treatment of hazardous materials, wood processing, printing, professional accommodation, buildings with space for a large number of occupants

Appendix 4: Fire protection

Table A4-1: Main hazardous product classes associated with fire or explosion hazards

Hazard class	GHS[36] pictogram	Hazard statement codes
Explosives		H200 – Unstable explosive H201 – Explosive; mass explosion hazard H202 – Explosive; severe projection hazard H203 – Explosive; fire, blast or projection hazard H204 – Fire or projection hazard
Flammable gases		H220 – Extremely flammable gas
Aerosols		H222 – Extremely flammable aerosol H223 – Flammable aerosol H229 – Pressurized container; may burst if heated
Oxidizing gases		H270 – May cause or intensify fire; oxidizer
Gas under pressure		H280 – Contains gas under pressure; may explode if heated
Flammable liquids		H224 – Extremely flammable liquid and vapour H225 – Highly flammable liquid and vapour H226 – Flammable liquid and vapour
Flammable solids		H228 – Flammable solid
Substances and mixtures which in contact with water emit flammable gases		H260 – In contact with water releases flammable gases which may ignite spontaneously H261 – In contact with water releases flammable gases
Oxidizing liquids or solids		H271 – May cause fire or explosion; strong oxidizer H272 – May intensify fire; oxidizer

[36] Globally Harmonized System of Classification and Labelling of Chemicals (GHS)

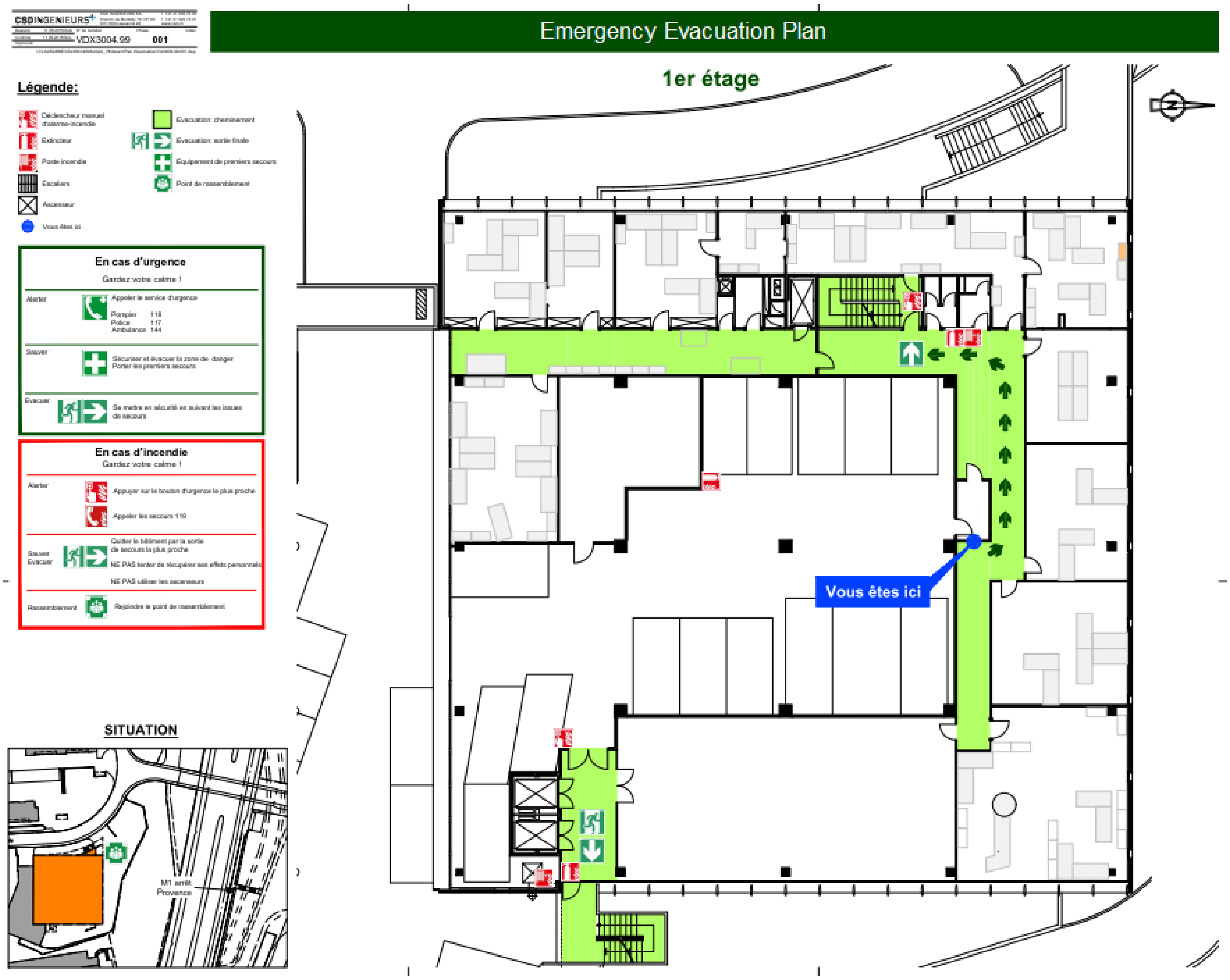

Figure A4-1: Emergency plan [75].