MEDITERRANEAN

Pollution prevention alternatives in the **Batch Chemical Sector**

CLEANER production

Regional Activity Centre for Cleaner Production (RAC/CP)
Mediterranean Action Plan

UNEP

MAP

Regional Activity Centre for cleaner Production

Ministerio de Medio Ambiente
España

Generalitat de Catalunya
Departament de Medi Ambient i Habitatge

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If you should consider that any point of this study could be improved or that there is any inaccuracy, we would be grateful if you would inform us of this.

Study completed in April 2006.
Study published in September 2006.

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Acknowledgements

National Focal Points (NFPs) of the Mediterranean Action Plan (MAP) countries

Anne Burril (European Commission)

ASCAME (Association of the Mediterranean Chambers of Commerce and Industry)

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0. EXECUTIVE SUMMARY

The chemical sector can be considered an important sector in the majority of Mediterranean countries, as can be seen from the figures showing its contribution to the GDP of each country. However, the chemical sector is structured differently in the different countries.

This fact, together with the heterogeneous nature of the information received, makes the comparison between countries with regard to the sub-sectors under study difficult. In some countries, these sub-sectors are not considered separately, and it has therefore not been possible to obtain figures referring exclusively to them.

An outline of the fundamental and generalised nature of the chemical sector, and therefore of the companies consulted during the writing of this guide, will be given, based on the heterogeneity of their processes and the difficulty that this implies when writing a guide of this type.

It becomes clear from the information received that the majority of the companies in these sub-sectors can be considered SMEs, although in the southern Mediterranean countries there are also large companies, which sometimes belong to the public sector.

The situation of the chemical sector with regard to environmental management is diverse, given that both the legal obligations and the infrastructures available in the different countries are too. With regard to costs related to environmental management, it can be concluded that the principal ones are related to water supply costs, to the cost of wastewater treatment and to the rates that are applied and the costs of waste management. Other costs, such as taxes on water consumption, the generation of waste or emissions into the atmosphere, or the cost of treating these emissions, are less important or non-existent.

The cost of the treatment and management of waste tends to rise and legislation is growing stricter. As a result, companies opt to minimise waste and improve their environmental management. This enables them to simultaneously increase productivity and the quality of their products as a result of the optimisation of processes, and to reduce costs as a result of the reduction in waste to be managed or in the lessening of its hazardous nature.

Not only has a sectoral study been produced, but also a useful and practical management guide for the real application of pollution prevention opportunities in their different guises.

<u>THE CHEMICAL INDUSTRY THROUGHOUT THE WORLD</u>

According to sources from FEIQUE (the Spanish Chemical Industry Federation) the general situation of the global chemical industry is as follows:

- Evolution in the Volume of Business

In 2004, the international economy began a solid recovery that, in the case of the chemical sector, was led by the United States and South East Asia. This was much less marked in Europe, due fundamentally to the lower levels of dynamism in consumption. The global volume of business in the chemical industry reached €1.768 billion.

In 2005, the estimated slowing of growth of global Gross Domestic Product from 4.1 % to 3.1 %, mainly due to the increased price of crude oil, has led to the deceleration in chemical production; in the United States, production registered growth of 1.3 %, while in Europe this level was 2 %.

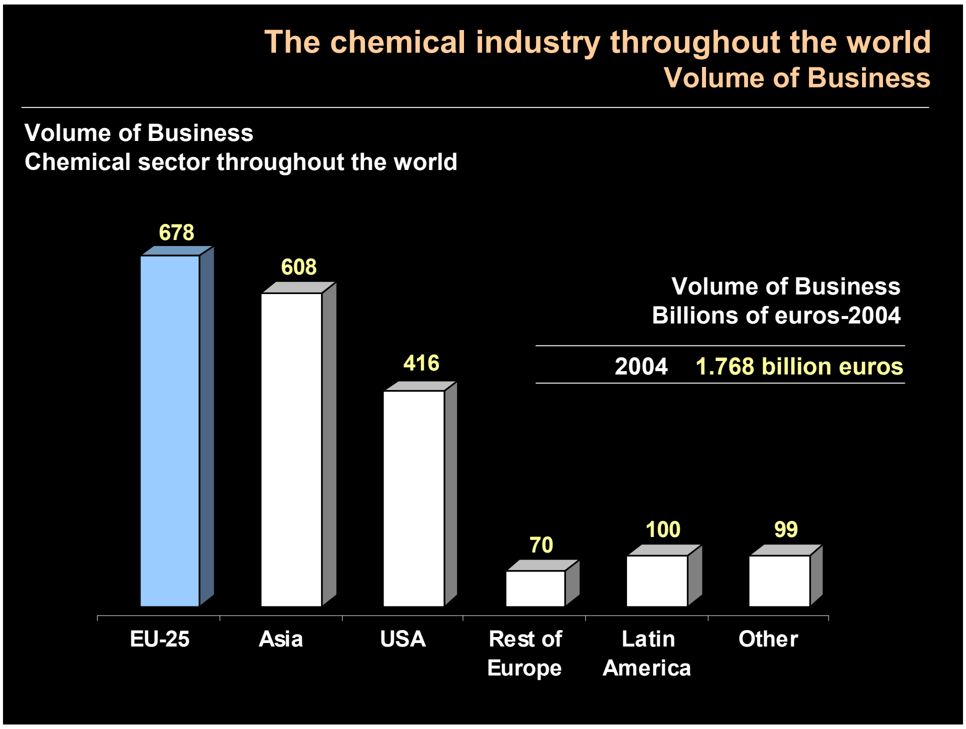


Figure 0.1. Volume of Business of chemical production throughout the world (Source: FEIQUE)

- Distribution of World Production

Based on the figures for 2004, the European Union of the 25 accounts for a third of global chemical production. Asia is currently the second largest production zone, driven forward specifically by growth in China and the countries of South East Asia. The United States, for its part, continues to represent a quarter of global production. The combined production of these three zones encompasses 84 % of the global total.

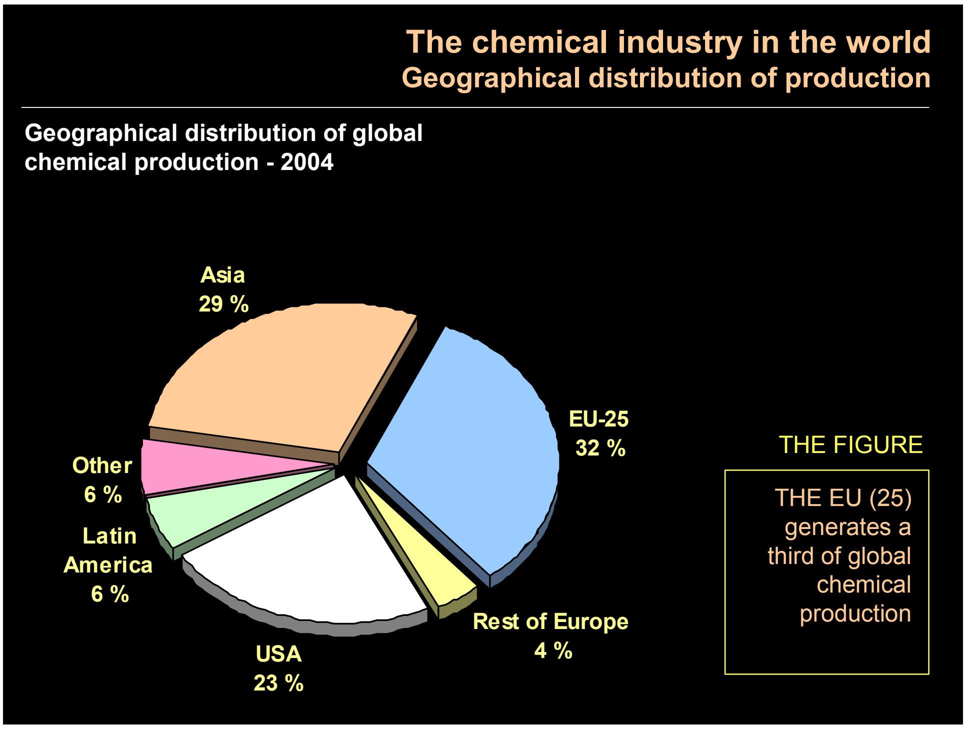


Figure 0.2. Geographical distribution of global chemical production (Source: FEIQUE)

- World Trade in chemical products

Exports and imports by area, represented in % of the global total and corresponding to 2004, show that the greatest percentage of both exports (highest) and imports correspond to the European Union of the 25.

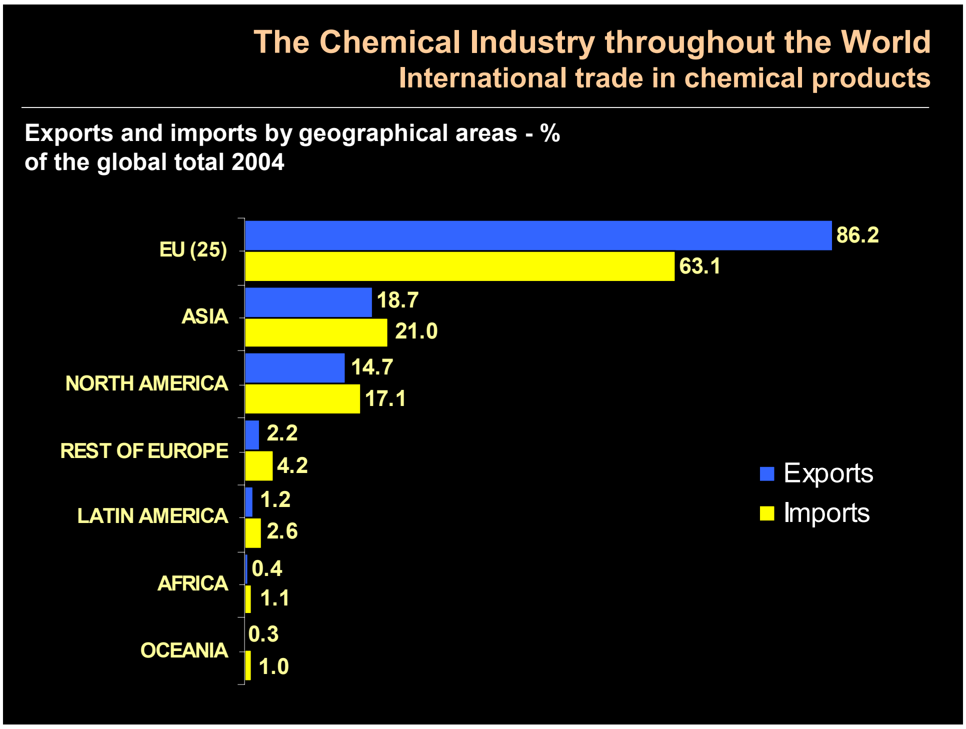


Figure 0.3. World trade in the chemical industry throughout the world (Source: FEIQUE)

1. INTRODUCTION

1.1. BACKGROUND AND AREA

The carrying out of the **Study of Pollution Prevention and Reduction at source in the Chemical Industry in the Mediterranean Action Plan (MAP) countries** by the **Regional Activity Centre for Cleaner Production (RAC/CP)** was one of the recommendations of the National Focal Points of the RAC/CP.

Specialists in environmental matters and industrial chemical processes from the environmental consultancy B&B Asesores collaborated in the study, which also benefited from the collaboration of and information provided by the National Focal Points of the MAP countries. Specifically, in writing the chapter describing the chemical sub-sectors under study in the MAP countries, a questionnaire was used that had been sent to the different focal points for them to fill in. To be precise, the geographical area of the guide focuses on the following countries, which belong to the MAP:

- *Albania*
- *Algeria*
- *Bosnia and Herzegovina*
- *Cyprus*
- *Croatia*
- *Egypt*
- *France*
- *Greece*
- *Israel*
- *Italy*
- *Lebanon*
- *Libya*
- *Malta*
- *Monaco*
- *Morocco*
- *Slovenia*
- *Spain*
- *Syria*
- *Tunisia*
- *Turkey*

Based on the completed questionnaire and on additional information and comments presented by each of the countries, a description was drawn up of the situation of all of the chemical sub-sectors under study in each country, and a comparison made between them. These texts were later sent to each country for their approval.

Data on the process of consultations carried out in drawing up the guide will be included in order to provide the reader with clear information on the scope of the guide, based on bibliographical data or on the analysis of the participating countries.

The study does not include figures for Cyprus, as this country does not have references for the chemical industries or the necessary information.

1.2. SCOPE

This manual is aimed at small and medium-sized enterprises with batch manufacturing processes, which includes a range of activities in different, highly heterogeneous sectors, with common environmental problems.

Batch production involves a large number of stages, which implies the use of a great deal of different equipment and the generation of a very diverse collection of waste flows, with characteristics that differ greatly. The wide variety of waste types, discharges and emissions generated, together with the added difficulty of the lack of continuity of environmental impacts due to the nature of the processes and the resulting difficulty in managing these impacts, constitute the main motive for focusing the content of this manual exclusively on the batch chemical industry.

The main characteristics of the sector are:

- A common form of working in batch plants, which are usually multi-purpose.
- Small or medium-sized enterprises.
- Production in batches, with frequent loading and unloading of equipment.
- Large amounts of raw original materials and of manufactured products.
- Capacity to produce a wide variety of products on different scales, from kilos to tonnes.
- Operational flexibility and capacity to respond rapidly to the demands of the market.
- Large numbers of cleanings due to the continuous variation in the processes, in themselves a source of pollution.

While the batch chemical industry encompasses very diverse sectors, the focus of this study is an attempt to establish those measures for pollution prevention and the good housekeeping practices associated with phases of the process and with basic operations that are common, either entirely or in part, to the majority of these sub-sectors. The chemical reactions themselves have been excluded from these operations, due to the enormous diversity and heterogeneity of these in synthetic chemical products.

This list below shows the sub-sectors at which this guide is aimed:

- The manufacture of basic pharmaceutical products and pharmaceutical laboratories.
- Phytopharmaceutical products, biocides and fertilisers.
- Fragrances and flavours.
- Colorants, pigments and paints.
- Cosmetics.
- Detergents / surfactants.
- Plasticisers, flame retardants.
- Food additives.
- The manufacture of other chemical products, both organic and inorganic, in batch processes.

1.3. OBJECTIVES

The objective of this manual is to provide a useful tool that can serve as a guideline for minimising the pollution generated in the batch chemical sector. To do so, the following points are described and developed:

- A presentation of the situation of the chemical industry in the MAP countries.
- A description of the main phases of the process, operations and auxiliary processes associated with the batch chemical industry.
- A presentation of the environmental aspects associated with these activities and the management and control of these aspects.
- A demonstration of the opportunities for the prevention and reduction of pollution in the batch chemical industry.
- The description of case studies that exemplify pollution prevention opportunities.
- The provision of specific responses to the need within the batch chemical industry to implement measures to improve environmental behaviour.
- The promotion of good housekeeping practices and techniques of pollution minimisation at source.

1.4. METHODOLOGY

A diagram of the methodology used in carrying out the study is shown in the figure below:

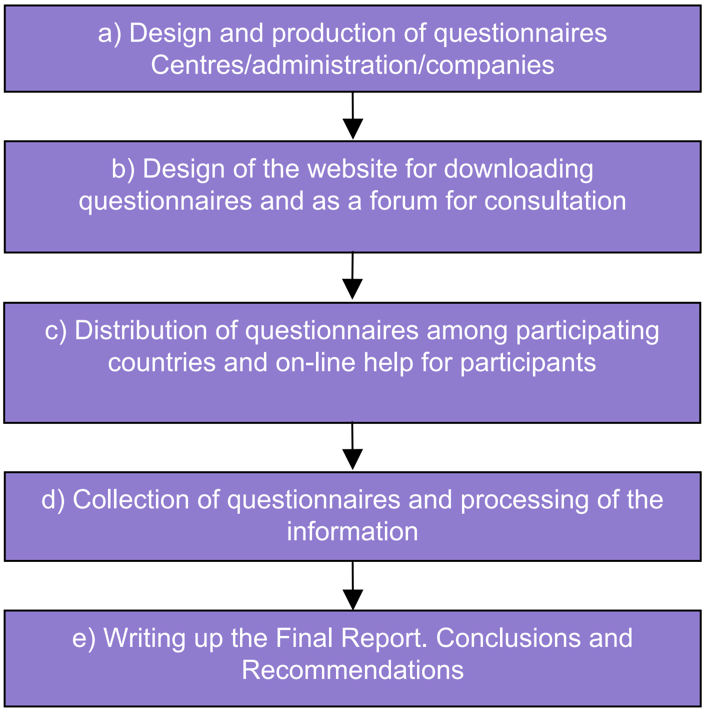


Figure 1.1. Methodology of the study

a) Firstly, two types of questionnaire were designed, to be answered by two types of organisation:
   - <u>Questionnaire for Public Administrations and associated centres</u>: ministries for industry, the environment, technological research centres or universities. Includes questions on structure, production, consumption, exports and imports in the chemical sector, together with questions

on pollution prevention policies, questions on products and cleaner production actions (good housekeeping practices, clean technologies, recycling at source, etc.).

- Questionnaire for companies: the batch chemical sector. Includes questions mainly about processes and equipment.

b) When the questionnaires were designed, a web page was set up so that participants could download these questionnaires in Word format in three different languages (English, French and Spanish) and ask about any doubts that they may have while filling in the questionnaire. Questionnaires were also distributed via e-mail and conventional mail to all of the countries.

c) In relation to the project, over 350 contacts were made with National Focal Points and public administrations, associations, committees and federations of the chemical industry, societies, centres and agencies for development, chambers of commerce and industry, embassies, statistical institutes and companies in the countries that were studied. It should be noted that the task of homogenising data and information between countries of such different cultures and resources is an extremely difficult one. To this end, the collaboration of the National Focal Points was key in attaining the objectives that had been set.

d) When the completed questionnaires were obtained, the data was processed and the next step was to write up the final report. The data provided by the Focal Points was used as the main source of information for the description of the situation in each country. This information was contrasted and/or completed with the data obtained from the USDA/CEFIC. The philosophy behind the study is to provide a tool for the improvement of pollution prevention by means of practical proposals which can be put into practice by the chemical companies of the MAP countries.

The collaboration with the National Focal Points was as follows:

- Through the web page.
- Through the questionnaire.
- Exchange of information. Examples.
- Corroboration of information.

The sources of information used by the companies to provide the requested information are: regulation declarations of emissions, discharges and waste, periodic analyses and controls, whether official, voluntary or carried out by the companies themselves, bills, registers, etc.

1.5. CONTENT

The guide contains 7 chapters. The first chapter serves as an introduction, in which the area and scope, the main objectives, the methodology used and the content of the guide are defined.

The second chapter describes the global and specific situation of the batch chemical industry in the MAP countries.

In the third chapter, the main operations considered to be common throughout the batch chemical sector are defined and the most significant environmental aspects associated with these operations are identified.

The fourth chapter refers to the control and management techniques applicable to the different waste flows once these are generated.

Chapter 5, which deals with the most important point in this guide, presents strategies for the minimisation of environmental impacts and makes clear the alternatives of optimisation and promotion of clean production. To this end, a number of tables have been produced, which provide several examples of the application of pollution prevention opportunities for each operation defined.

Following that, Chapter 6 provides real case studies of specific chemical companies in the different countries in the Mediterranean that have carried out actions aimed at pollution prevention. A methodology is also suggested for the implementation of an environmental impact minimisation programme.

Lastly, Chapter 7 details the conclusions and final recommendations for the application of measures for pollution prevention at source.

The bibliographical references consulted and a list of the tables and figures given in the manual can be found at the end.

2. SITUATION OF THE CHEMICAL INDUSTRY IN THE MAP COUNTRIES

2.1. OVERALL SITUATION OF THE CHEMICAL SECTOR IN THE COUNTRIES OF THE MEDITERRANEAN ARC

We have grouped the countries included in the Mediterranean Action Plan as follows, according to specific criteria which are detailed below:

- Southern Mediterranean countries: This group includes Algeria, Egypt, Lebanon, Libya, Morocco, Syria and Tunisia, which are all members of the League of Arab States. Despite the differences between their political respective regimes, all of these countries share similar cultural principles and languages, which can facilitate joint action and the transfer of information and industrial experiences.

- Northern Mediterranean countries: This group includes France, Greece, Italy, Monaco and Spain, which are all members of the European Union (with the exception of Monaco, which has been included in this group due to its geographical integration into France). These countries share the fulfilment of EU regulations and the adaptation of the appropriate means of meeting the requirements of this European legislation. In addition, Cyprus, Malta and Slovenia have recently joined the EU and are also included in this classification.

- Eastern Mediterranean countries: This group includes countries with a common tendency to implement regulations that are similar to those of the EU, such as in the case of the Balkan countries: Bosnia and Herzegovina, Croatia and Albania. Turkey may also join in the short or medium term. These countries that are candidates for EU membership have begun a process of adaptation depending on the date that they are due to join, which includes the adaptation of internal industry and of environmental conditions. Israel has also been included in this group, as, although it is not part of the EU, it has many connections with this organisation, due in part to the similarity in the characteristics of its industries and in the commitments it has made to the protection of the Mediterranean Sea.

In all of the Mediterranean Arc countries taken together, the chemical sector represents between 10 % and 30 % of the industrial sector as a whole.

The distribution of chemical companies in the different Mediterranean countries varies enormously, due to differences in population and levels of industrial development.

There are also major differences between the countries of the Mediterranean in terms of the number of chemical companies they have.

2.2. SPECIFIC SITUATION OF THE CHEMICAL SECTOR IN THE COUNTRIES OF THE MEDITERRANEAN

ALBANIA	POPULATION: 3,413,904
	AREA: 28,750 km^2

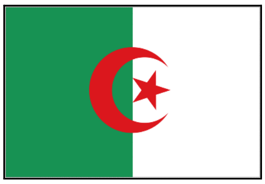
The chemical industry in Albania is focused mainly on the production of phytopharmaceuticals and chemical products used in the processing of minerals.

In the 1970s and 1980s, efforts were made to achieve the country's economic independence, and the Albanian government made frenetic attempts to increase the production of fertilisers in the plants at Krujë and Fier, which produce nitrogen and phosphates from imported phosphate rocks.

The production of nitrogenous and phosphate fertilisers reached approximately 350 billion tonnes between 1985 and 1990. The lack of spare parts and raw materials, particularly natural gas, stopped production in the middle of 1991. Some western economists estimated that the $3 million necessary for the renovation of the main phosphate plant could be too high a price to pay, as local deposits of key raw materials were projected to last for only 3 to 5 years under normal operating conditions. One of the two ammonia-urea plants planned to restart operations in 1992, but it desperately needed spare parts and environmental protection equipment.

The only pesticide plant in the country did not stop production of DDT and in 1991 this plant was working at less than 10 % of full capacity. The plant was a poor and environmentally unsound condition.

Other chemical companies include the manufacture of plastics in Lushnjë, rubber in Durrës, and a paint and pigment plant in Tirana.

 **ALGERIA**	POPULATION: 32,338,700
	AREA: 2,381,740 km^2

The industrial sector in Algeria represents an added value of 65 % of the country's GDP and contributes substantially to the country's economy. The growth in added value for industry was of an average annual value of 1.9 % for 1990-2002. The chemical industry in Algeria has been developed using the raw materials of its highly developed oil industry. The country is aiming to construct a broad and integrated petrochemicals industry in order to reduce dependence on imports and to increase the volume of petrochemical products and fertiliser produced for export.

It should be noted that in Algeria, the hydrocarbons sector is of major importance and the country is dependent on this sector. In 2003, this sector represented 35 % of GDP, 96 % of exports and 65 % of budget revenue. This dependence means that Algerian economic growth is unstable and brings with it a degree of difficulty in breaking the inertia of the production sector, which would enable the diversification of the Algerian economy, offering stable alternatives to the hydrocarbons sector.

The chemical industry in Algeria is dominated by Sonatrach, the state oil company, which is responsible for the management of the country's oil and associated industries. This means that it has an important role in the chemical industry, in which its chemical subsidiary is the Entreprise Nationale d'Industrie Petrochimique (ENIP). Sonatrach dominates the country's petrochemical installations and fertiliser plants through this subsidiary company.

Since 2001, one of the most significant changes that have taken place in Algeria in terms of cleaner and more environmentally sound production has been the drawing up of the National Plan of Action for the Environment and Sustainable Development (PNAE-DD), the object of which is to integrate environmental and socioeconomic problems into a global model of national development.

 **BOSNIA AND HERZEGOVINA**	POPULATION: 4,185,900
	AREA: 51,129 km^2

The greatest proportion of the chemical industry of the former Yugoslavia is located in Bosnia and Herzegovina, with Tuzla as the country's industrial centre, with coal and salt mines, thermal power plants and a major chemical industry.

The chemical industry is based on two classes of raw material: inorganic raw materials such as common salt, phosphorous and lime; and organic raw materials, such as coal and oil. The chemical industry in Bosnia and Herzegovina can be divided into two corresponding categories:

a) basic chemical industry

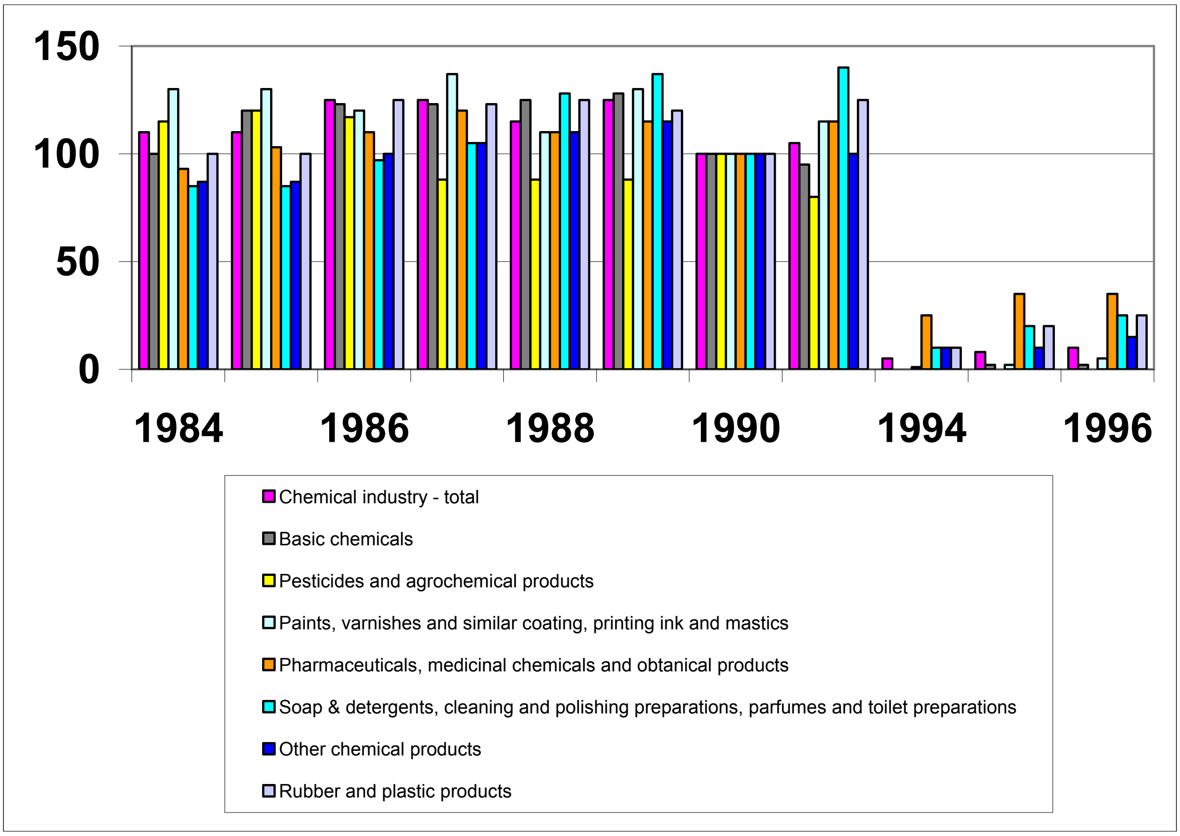
b) organic chemical industry

The inorganic raw materials that are generally used for chemical products are: phosphates, which are used to make phosphoric acid, fertilisers etc., and lime, which is used in the manufacture of calcium cyanide, which also serves as a basic product in other branches of the chemical industry. The chlorine industry is based on common salt, producing sodium hydroxide, hydrochloric acid and PVC.

The products derived from salt were previously manufactured for the protected, closed Yugoslavian market. Client requirements and distances for transportation were of no importance whatsoever. Even before the war, the volumes produced were modest, of only a few thousand tonnes per year (with the exception of ammonium nitrate and nitric acid, of which approximately 20,000 and 100,000 tonnes per year were produced, respectively). It should be mentioned that the production of detergents is based entirely on foreign suppliers. Statistics for 1989 indicate that 21,170 people were employed in the chemical industry in Bosnia and Herzegovina.

The chemical industry was seriously affected by the war, given that it was to a large extent dependent on the protected Yugoslavian market. The infrastructure, the transportation systems, the source of electricity and the suppliers of primary chemical products in Serbia suffered massive damage. Moreover, a considerable number of chemical technicians and process engineers have emigrated. In 1990, the country manufactured 900,000 tonnes of chemical products, but by 1998, this had decreased to 95,000 tonnes.

The following graph shows the situation of the chemical industry before, during and immediately after the war (guide volume 1990 = 100 %).



(Source: http://enrin.grida.no/htmls/bosnia/soe/chemical/pressure.htm)

Figure 2.1. Situation of the chemical industry in Bosnia and Herzegovina

After the war, as part of the basic sector of the chemical industry, the production of electrolytic caustic soda, the production of polyol, maleic anhydride and acetic acid by the dry distillation of wood, and artificial fertilisers, was re-established. An important company producing toluene diisocyanate is still inactive, but it is preparing for privatisation. In addition to this, the production of anhydride of phthalic acid is currently in the preparation phase.

Due to the massive devastation and the difficult privatisation process, the major companies in Bosnia and Herzegovina have made slow progress in regaining their pre-war capacity, and therefore the post-war development of the chemical industry has been more focused on opening and working in small and medium-sized enterprises that are dedicated to the production and export of drugs and medical products, paints and varnishes, surfactants, explosives and accessories (safety fuses and detonators), the processing of plastic and the production of packaging material.

 CYPRUS	POPULATION: 802,500
	AREA: 9,251 km^2

No data are available for this country.

 **CROATIA**	POPULATION: 4,456,000
	AREA: 56,610 km^2

Croatia, a country with an important industrial tradition, was the headquarters for major industrial conglomerates formed during the Communist era. Now, during the transition to a market economy, these companies are gradually reaching more rationalised sizes, with the consequent reduction in industrial weight.

The industrial sector was the one most affected by the reduction in markets, by the general economic crisis at the end of the 1990s and by the effects of the war. Although it has shown signs of recovery in recent years, the difficult restructuring of heavy industry and of the large industrial complexes inherited from the past is still to be undertaken. Despite all of this, industry has grown at a good rate in recent years, as a result of increased levels of investments. This is a sector of considerable importance in the economy, representing 24 % of GDP and accounting for 97 % of exports. Of importance in this country are the food, drink and tobacco industries, and the chemical, oil, metal, paper and electrical industries. Of these, the textiles, clothing, metal, electrical and shipping industries export significant amounts. Eighty per cent of industry is localised in the central region of the country, consisting of the Zagreb-Sisak-Karlovak triangle, which means that the majority of industrial production is concentrated in a small nucleus.

The petrochemical industry is fairly developed, although it does have an excess of capacity and is technologically outdated. The pharmaceutical industry, which was privatised, is one of the strongest in the zone and has a great deal of research potential, particularly in veterinary products, generic products and raw materials. National production of perfume and cosmetic products covers approximately 20 % of the market, and consumption of such articles is in a phase of full growth in Croatia. Nevertheless, the industrial chemical sector does not have a significant effect on the country's economy, as it represents only a small percentage of total industry.

With regard to environmental actions in industry, it should be noted that some companies have undertaken measures to reduce their water consumption by means of the reuse of treated wastewater for some functions in factories or by the conversion of the compressor cooling system into a closed circuit.

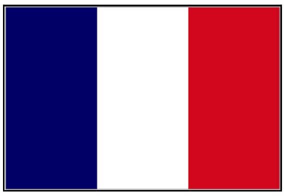
	POPULATION: 73,389,300
	AREA: 1,001,450 km^2
EGYPT	No. OF CHEMICAL COMPANIES: 35

The Arab Republic of Egypt (A.R.E.) has agricultural and fishing resources and oil and gas resources that contribute to obtaining foreign income. Egypt is a very broad market which, from both a geographical and a political point of view, has a strategic location between three important axes: the Mediterranean countries, Africa and the Middle East.

Egypt is a country with a great deal of agricultural activity, although industry, including the service industry, is progressively gaining importance. Among the country's industries, the iron and steel and textile industries stand out as the mainstays. The energy sector is also highly relevant and offers good opportunities for the environmental sector. The Egyptian government has promoted environmental protection and the fight against desertification and increasing pollution (industrial pollution, urban waste, hazardous waste, water pollution and air pollution in major cities) through the Egyptian Environmental Action Plan. The first phase of this plan places great emphasis on projects concerning water treatment, sewerage systems and water pipelines. In addition to this, the Egyptian Environment Law 4/94 was also passed to foster environmental protection.

Employment in the secondary sector represents around 13 % of total employment, a figure that has shown fairly stable evolution over recent years. The sector's contribution to GDP is approximately 32 %.

The organic chemical industry in Egypt has developed thanks to the efforts of the country’s oil industry, the sector that supplies the base materials, the raw materials and the infrastructure for this industry. In addition, an increase in the importance of other sectors, such as the pharmaceutical industries, fertilisers, polymers and other chemicals, can be seen. Other sectors, such as the cosmetics sector, are for the most part imported from Europe. Nevertheless, the chemical manufacturing sector in Egypt is still small: there are fewer than 50 chemical companies.

	POPULATION: 60,000,000
	AREA: 547,030 km^2
FRANCE	No. OF CHEMICAL COMPANIES: 1,190

France is the largest country in Western Europe and is the fourth most industrialised western economy. It has important agricultural resources, a wide and consolidated industrial base and a highly qualified workforce. The manufacturing industry is highly diversified and is the main source of income from exports. The added value in industry in general constitutes 26 % of Gross Domestic Product.

The French chemical industry (including pharmaceutical products) is the fifth largest in the world, after those of the United States, Japan, Germany and China. France is also the third largest exporter of chemical products and pharmaceutical products in the world, with 59 % of its trade orientated towards the international market.

The growth of French chemical production is shown in the following graph:

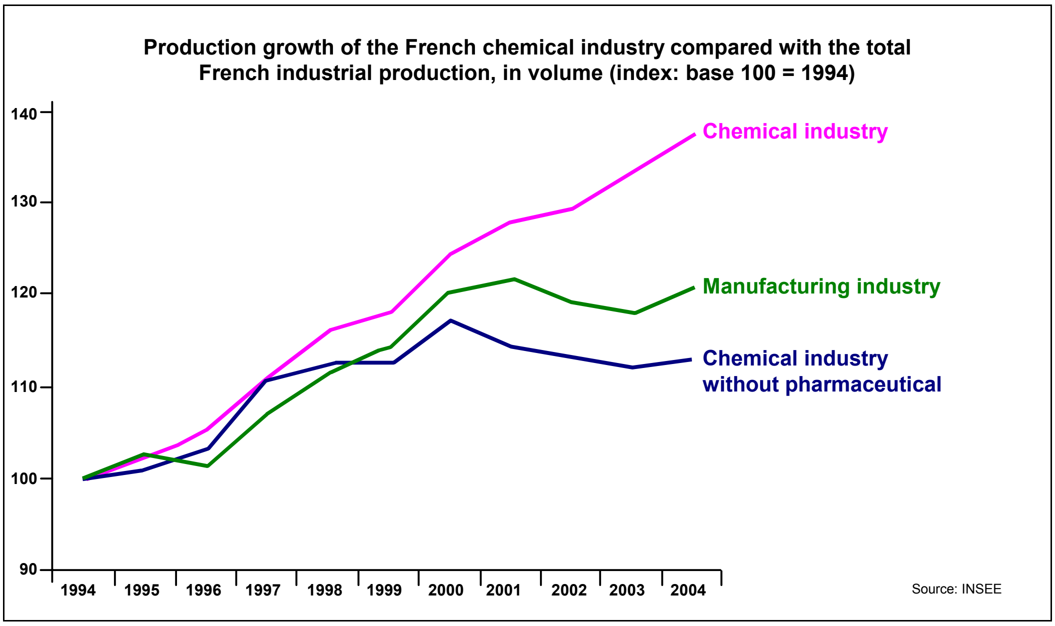


Figure 2.2. Growth of French chemical production

Chemical production, excluding pharmaceutical products, experienced lower average growth than that of the production of total manufactures for the period 1994-2004: + 1.2 % per year from 1994 to 2004 for chemical products, in comparison with 1.9 % for the manufacturing industry. The chemical industry as a whole, including pharmaceutical products, grew by 3.2 % per year over the same period.

In 2004, the volume of sales of the French chemical industry grew to €93.7 billion:

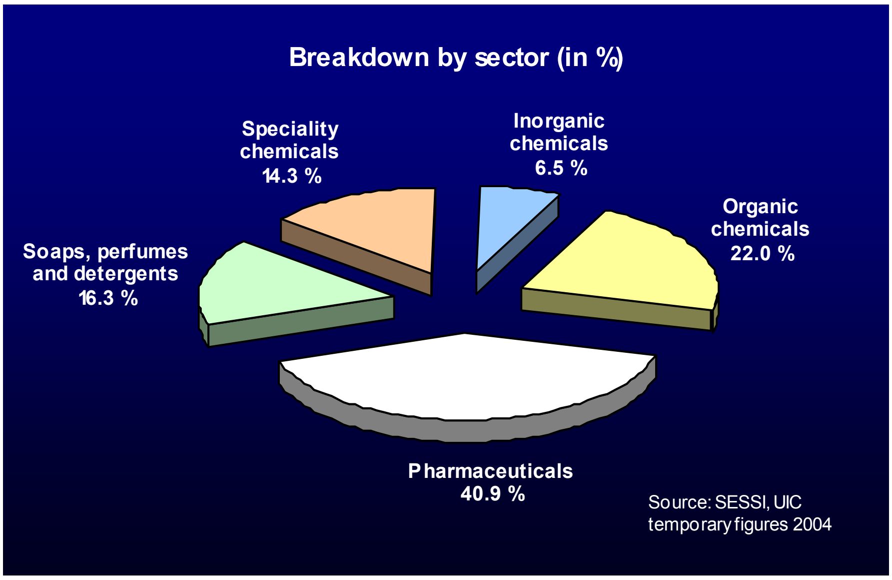


Figure 2.3. Volume of sales in the French chemical industry

The distribution of the French chemical industry ranges from the basic chemicals industry (organic and inorganic), fine chemicals and specialised chemicals to pharmaceutical products. As a result, a wide range of products are produced, which include industrial chemical substances, plastics, fertilisers, solvents, cosmetics and pharmaceutical products. Considering the size of companies and the diversity of products, the French chemical industry is extremely heterogeneous and is based on a large number of small and medium-sized enterprises.

Another of the main characteristics of this industry is its investment in research and development. In order to renew and improve products, over 30,000 molecules are produced and sold by French chemical companies, from inorganic and basic organic products to medicines, taking in fertilisers, plastics, flavours, glues, cosmetics, etc.

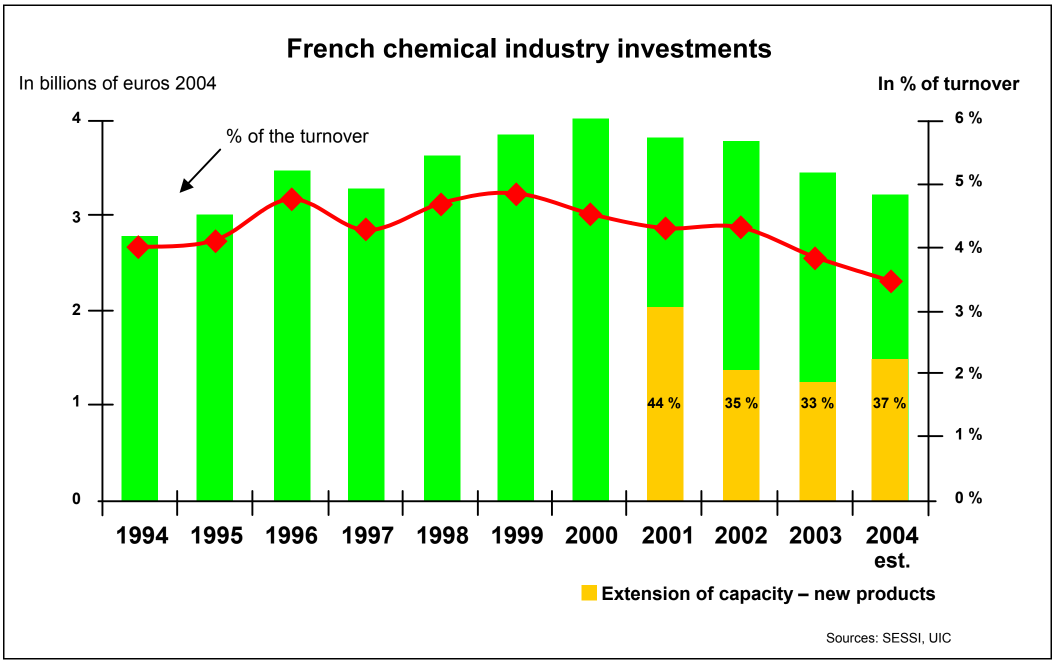


Figure 2.4. Investments in R&D in the French chemical industry

Over the last 4 years, investments within the French chemical industry have decreased regularly. Thus in 2004, expenditure on capital investment of the French chemical industry (including pharmaceutical products) decreased by almost 4 % in value compared to 2003.

With regard to environmental policy, in recent years this has been characterised by pollution prevention at source and strict legislation; as a result, progress has been made in reducing the environmental impact of industrial activities. Moreover, within the chemical sector, various voluntary actions and initiatives of recycling and recovery have been undertaken.

In terms of safety and the environment, the programme of responsibility and sustainable development adopted in 1990 is also important. In accordance with this commitment to progress, the French chemical industry is making significant continuous efforts to ensure the protection of the environment and therefore to improve safety and health protection.

Lastly, it should be highlighted that the French chemical industry is currently investing 28 % of total investment in environmental protection and risk management (figures from 2003). This figure was only 20 % in 2001. As a result of this effort, the chemical industry is currently first among the industrial sectors in France as regards risk management, safety and environmental protection.

 **GREECE**	POPULATION: 11,100,000
	AREA: 131,940 km^2
	No. OF CHEMICAL COMPANIES: 1,128

The Greek economy has experienced high levels of growth, above the average level forecast for the EU. However, industry has been slow to expand and is hampered by insufficient infrastructures.

The annual rate of growth of GDP is 4.2 %. Industry represents 22.3 % of GDP, involves 22 % of the total active population and provides over 50 % of Greek exports. The average annual rate of growth of added value is of some 2.3 % in the secondary sector, in which industry occupies 28 % of sectoral distribution.

Greek industry is characterised by the existence of industrial units that are small in size by European standards. The most important sectors are consumer products, textiles, footwear, agro-foodstuffs, drinks and tobacco and they use, above all, local raw materials.

Chemical production ranges from detergents, chemical products for water treatment, phytosanitary products and pharmaceutical products to cosmetics. It should be noted that yearly production for 2002 in the chemical product sector showed a variation of 9.2 %, according to sources from the National Statistics Service of Greece.

From an environmental point of view, this is a sector in which the companies that make up the sector have a particular need for a sustainable environmental profile. It should therefore be highlighted that the Greek chemical industry has adapted to international technological development in matters of pollution prevention and control, with intervention at source a priority.

	POPULATION: 6,560,500
	AREA: 20,770 km^2
ISRAEL	No. OF CHEMICAL COMPANIES: 400

The industrial sector in Israel represents 35 % of the sectoral distribution of added value and the country's annual rate of GDP growth is 4.3 %. Israel exports both organic and inorganic chemical products.

The chemical industry in Israel involves a wide variety of areas of activity, such as potassium, bromine and magnesium from the Dead Sea, phosphates and phosphate derivatives from Negev, petrochemicals, polymers, pesticides, pharmaceutical products, agricultural chemicals, fine chemicals, flavours and aromas and biotechnology.

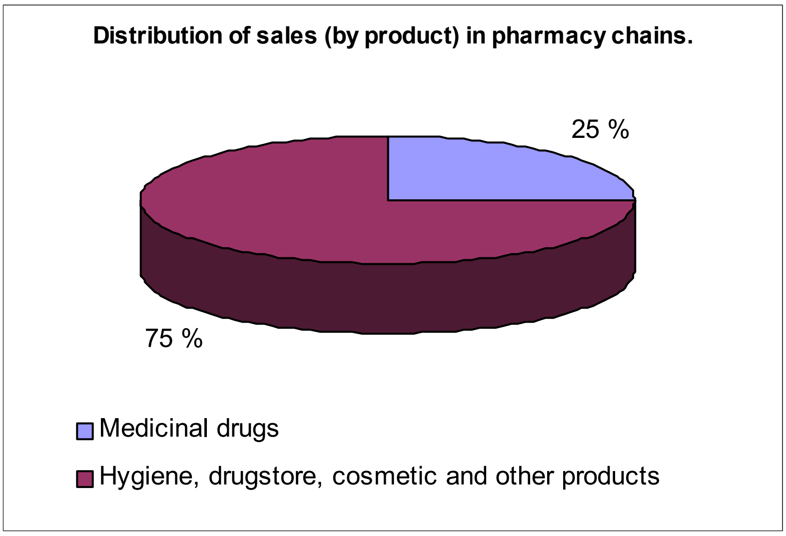
The chemical industry plays a highly important role in the country's economy. In total, around 400 companies are involved in the production of and trade in chemical products. Nevertheless, over 90 % of all of the chemical products are produced and sold by 22 large companies. In 1999, total chemical sales (including petrochemicals and distillates) were worth 7.94 billion dollars and in 2000, sales totalled 8.36 billion dollars. Exports in 1999 totalled 3.45 billion dollars, while in 2000 the figure was 3.66 billion dollars. 14 % of total industrial production corresponds to the chemical sector, along with 17 % of total exports (smaller only than the electronics sector).

Growth in the chemical industry in the 1990s was 8.4 %, in comparison with 3 % in Europe, 2.1 % in the USA and 1.8 % in Japan. In contrast, annual growth in sales (in dollars) was only 3 % in 1999 and 5 % in 2000, in comparison with a global average of 12 % in 1999. The chemical industry in Israel employs around 25,000 people.

Average investment in R&D in the chemical sector is 4 % of sales. Nevertheless, investment in the pharmaceutical industry and in biotechnology was 12 %. The relatively high level of investment in R&D in these sections of the chemical industry, in combination with strong collaboration between universities and industry, is a hopeful signal that the chemical industry will continue to grow in the future.

The areas of industry that focus on exports maintain a commitment to high quality standards and to the environment, always remembering that a successful chemical company requires much more than “good” chemistry to do well. In fact, successful companies combine “good” chemistry with chemical engineering, production, formulation, handling intellectual property, marketing and management.

In recent years the Israeli market for pharmaceutical products has grown by between 5 and 10 %. Local production is particularly important in the manufacturing of generic medicines. Two companies stand out: firstly Teva, which also produces ethical medicines protected by patents; and secondly, the Agis Group, which specialises in the production of active ingredients, cosmetics and hygiene products. An important proportion of the production of these companies is for export. As a result, the manufacture of pharmaceutical products in Israel is of considerable volume and is orientated mainly towards the foreign market, given the small scale of internal demand.

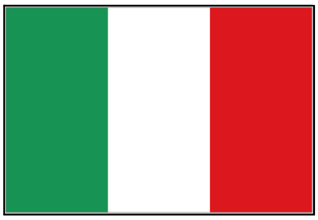


Source: The Pharmaceutical Association of Israel

Figure 2.5. Distribution of sales (by product) in pharmacy chains in Israel

With regard to environmental questions, the Israeli authorities consider the treatment and reuse of wastewater to be a national priority in environmental matters. Wastewater from industry represents around 17.5 % (68 million cubic metres) of total wastewater. All industrial plants are required by law to treat their wastewater sufficiently prior to discharging it into municipal drainage networks. The model of municipal regulation prohibits the discharge of wastewater that due to its characteristics or proportion could damage the drainage system, the waste flow or its treatment. As a result, many companies have incorporated measures for the primary treatment of their wastewater.

Existing landfill sites are obliged to treat solid waste using the latest technologies at all stages in the process - this includes the control of water pollution. The construction of new landfill sites has finished, and therefore the demand in this area is more for the maintenance of equipment and the improvement and modernisation of existing installations.

	POPULATION: 58,000,000
	AREA: 301,230 km^2
	No. OF CHEMICAL COMPANIES: 1,770 firms – over 10 employees
ITALY	PRODUCTION OF CHEMICAL PRODUCTS: €70 billion in 2004

Italy is a highly industrialised country and is currently fifth in world economic ranking.

The chemical industry in Italy is an important sector of the Italian economy, as it represents 6 % of total industrial production. The distribution by sectors of chemical production in Italy is:

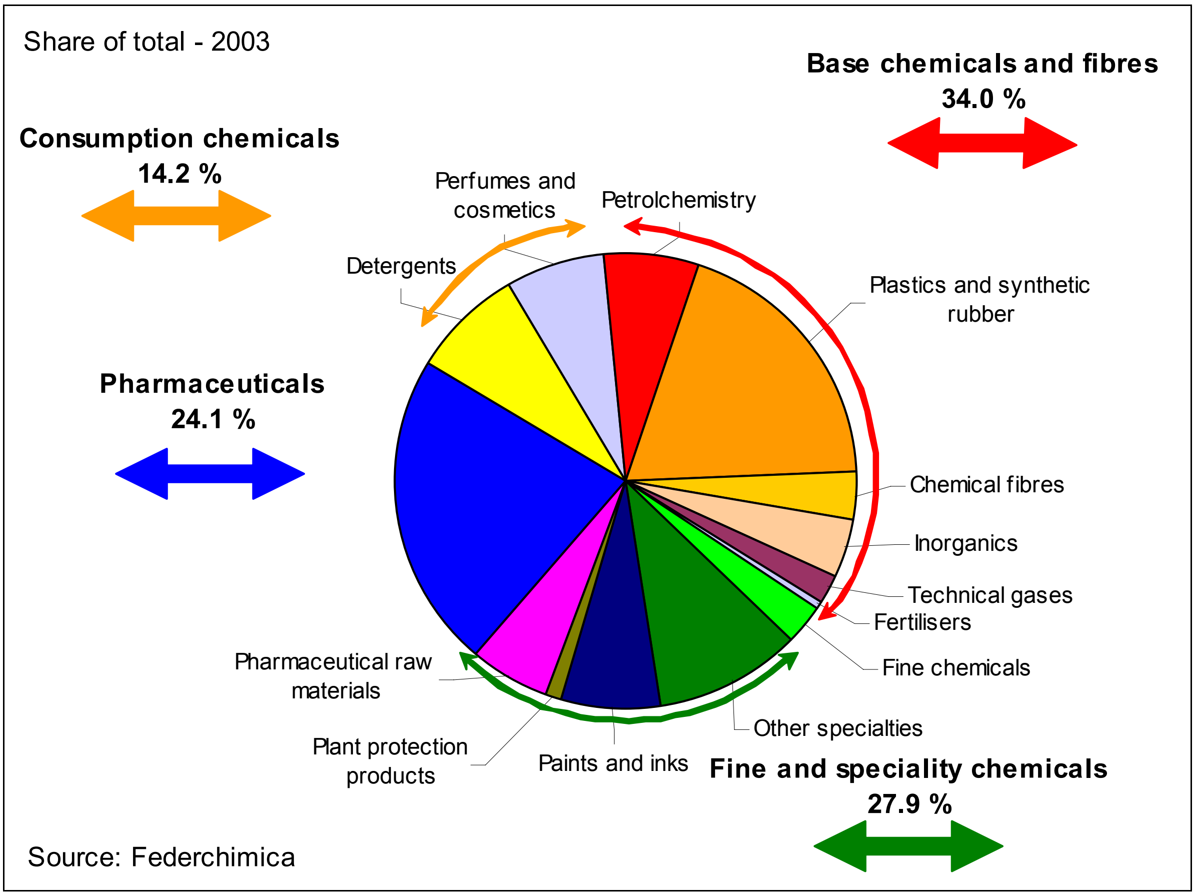


Figure 2.6. Distribution by sectors of the Italian chemical industry

Certain data providing an idea of the dimension of the sector in Italy are provided below:

- Production:
    - €48 billion in 2004 (€70 billion, including pharmaceutical products).
    - Fourth largest producer in Europe, with 12 % of overall chemical production.

- Exports:
    - €18 billion in 2004.
    - Together with pharmaceutical products, the Italian industrial sector is experiencing the highest growth since 1998 (i.e. since the introduction of fixed exchange rates).
    - Third largest Italian export sector.
    - Significant and established trade excess in detergents and cosmetics (over €1 billion in 2004) and in paints, coatings and glues (€450 million).
    - Global leader in active ingredients for generic products.
    - Growth of trade excess with non-EU countries.

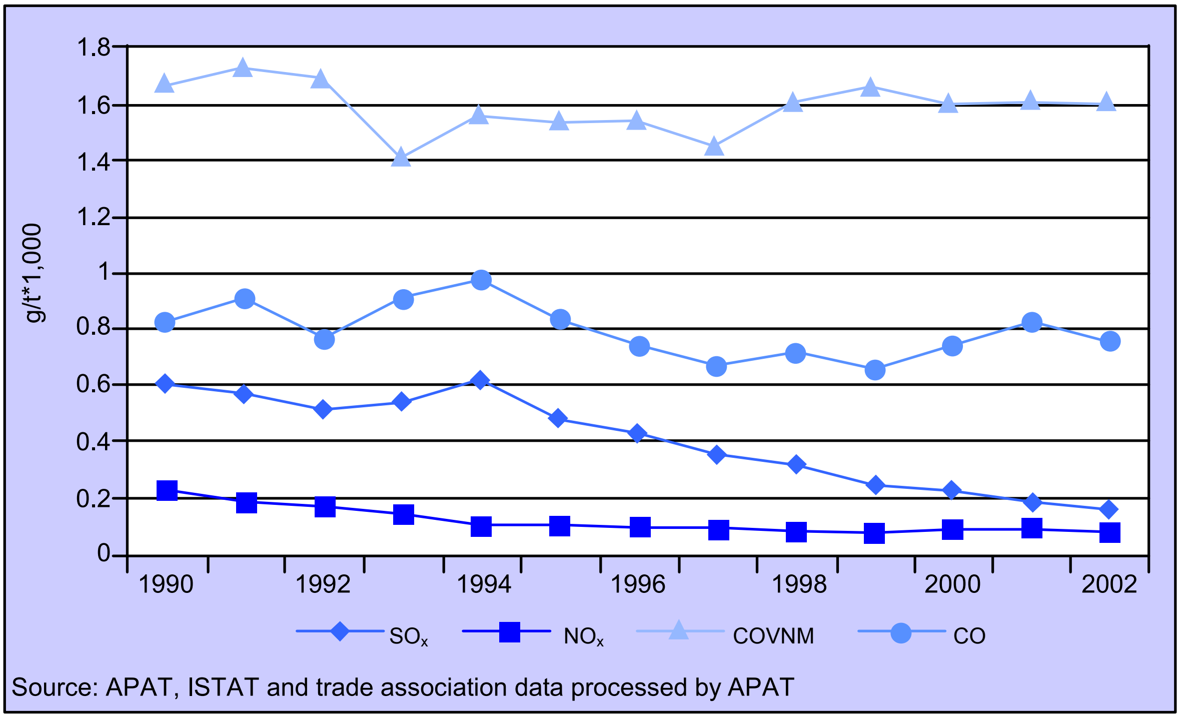
- Workforce:
    - 133,000 in 2004 (206,000 including pharmaceutical products).
    - Highest added value per employee in Italian industry.
    - For each employee in the chemical industry, another two posts are generated indirectly. in the economy for a total of 500,000 employees.

- Companies:
    - High presence of small and medium-sized enterprises (42 %).
    - Over 1,700 companies of over 10 employees.

Italian companies are distributed mainly in the north of the country, particularly in Lombardy, which is the second most important region in Europe in the chemical sector. The most prominent companies are small and medium-sized enterprises that are very active in base chemicals, but above all in fine and speciality chemicals, together with commodity chemicals (representing over half of the workforce and production).

Industries are concentrated on the outskirts of urban areas, and as a result the high population density of these centres in combination with industry, there is a great deal of pressure on the environment.

In recent years the Italian chemical industry has implemented measures to reduce the environmental impact it generates. For example, with regard to atmospheric emissions by the chemical industry, specific emissions indicators have been established (mass emitted per unit of mass produced) which enable the evolution of pollutant emissions such as SOx, NOx, VOCs and CO, etc. to be monitored. The following graph shows a reduction in all pollutants since 1990, particularly SOx (75 %) and NOx (66 %), while the reduction in VOCs and CO was less (of 4.4 and 8 %, respectively).



Specific emissions in the chemical industry

Figure 2.7. Specific emissions in the Italian chemical industry

Finally it should be pointed out that health, safety and the environment are three areas of management that require a strong commitment from the Italian chemical industry. To this end, Italy is part of the Responsible Care Programme of commitment to progress. Many of the commitments and objectives, both internal and international, of this programme have been attained.

 **LEBANON**	POPULATION: 3,707,500
	AREA: 10,400 km^2

The Lebanese economy is orientated mainly towards the service sector; the main growth sectors are banking and tourism, which are responsible for the high growth rate of GDP of up to 5 % in recent years. Industry, on the other hand, constitutes 21 % of GDP, although the industrial sector has shown negative growth in recent years, at a level of -1.2 %.

In over 90 % of cases, Lebanese industry consists of small industrial units with fewer than 10 employees. The large companies of the chemical sector are located in industrial zones and are prominent in the production of inorganic and phytosanitary chemical products, of which Lebanon is an exporter.

The majority of industrial installations are not equipped with pollution control equipment and discharge their polluted effluent into coastal and surface waters. The flow of wastewater and the illegal elimination of hazardous solid waste involve a serious pollution risk for surface and underground waters. In addition, there is also uncontrolled discharge of solid industrial waste and emissions into the atmosphere.

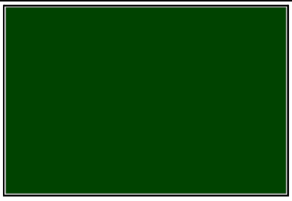
The Lebanese government has drawn up a draft bill related to the organisation of the Ministry of the Environment to specify its function, its mandate and its organisation along four main general political principles:

- The balanced development of all of the regions.
- Protection by means of prevention.
- The “polluter pays” principle.
- The integration of environmental policies into other development policies by sector.

A Lebanese Cleaner Production (CP) Centre has been established, with the main objectives of:

- Increasing competitiveness between industries.
- Reducing the negative environmental impact of industrial production processes.
- Promoting investments in CP (environmental management systems, energy audits, etc.), the development and transfer of technology.

The CDR (Council for Development and Reconstruction) is developing projects for the management and treatment of solid waste, such as incineration plants, crushing units and industrial waste classification centres. Lastly, a number of kilometres of water pipelines and distribution networks have been renovated and constructed, along with wastewater pre-treatment and treatment plants.

 **LIBYA**	POPULATION: 5,658,900 AREA: 1,759,540 km^2

In recent years, Libya has experienced extremely high rates of growth in GDP, at around 10 %. The industrial sector is a major contributor to this growth, as it provides 49 % of sectoral added value.

Thanks to its oil industry, Libya has succeeded in creating a relatively well developed chemical industry, so that in addition to mineral fuels it also exports organic chemical products that, according to Libyan foreign trade figures, represented 2.7 % of exports in 1999.

Marsa El-Brega is the main centre for petrochemical production, producing ethanol, ammonia and urea. This complex is operated by the National Petrochemicals Company (Napectco). There is a methanol production installation in Al-Burayqah and a small petrochemical complex in Abu-Kammash.

Ras Lanouf is the location for a project that is being developed by Ras Lanuf Oil and Gas Processing Company (Rasco) for the manufacture of various chemical products, including benzene, butadiene and butane-1, among others.

The first industry to be considered, therefore, is the one closest to the heart of the country's economy, that is hydrocarbons, oil refineries, the construction of gas pipelines and the liquefying of natural gas. Other important industrial plants are the petrochemical industries and the chemical industry in Aboukamash, together with the fertiliser plant in Sirte.

Chemical manufacturers have traditionally been small-scale companies producing simple commodity goods, such as basic chemical products.

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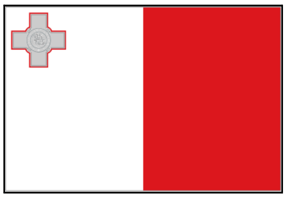
<tr><td rowspan="2">
MALTA</td><td>POPULATION: 400,000</td></tr>
<tr><td>AREA: 316 km^2</td></tr>
</table>

The Maltese economy has grown at a moderate rate in recent years, with annual growth in GDP of around 1.5 %. The manufacturing sector represents approximately 26 % of the sectoral distribution of added value, although it is progressively losing importance in favour of the service sector. Within manufacturers, the chemical sector represents 3.6 %. The chemical industry, therefore, is not an activity that is considered to be important or relevant to the country.

Nevertheless, the importance that the fine chemical sector is gaining should be noted. This sector represents 10 % of the total number of foreign operations in Malta, due to the promotion of this sector by the Maltese government to attract chemical companies with foreign capital. The products manufactured and included in this sector are steroids, oligopeptides, active ingredients for generic pharmaceutical products, antibiotics and chemicals for prescription drugs.

The following are examples of this policy of attracting investors to the fine chemical sector:

- Amino Chemicals Ltd (a subsidiary of DiPharma), which produces APIs (Active Pharmaceutical Ingredients) for all of the main markets, including the USA.
- Arrow Malta Ltd, which was established in Malta in 2000.
- Pharmamed Ltd, a company manufacturing generic pharmaceutical products.
- Cardinal Health Ltd, established in 1995.
- Baxter Malta, which is part of Baxter International Inc.
- Phoenicia Organics Ltd, which produces oligopeptide markers for use in the biotechnology sector.
- Medichem, which was set up recently and produces active pharmaceutical ingredients.

 **MONACO**	POPULATION: 32,100 inhabitants (2000 census)
	AREA: 2.01 km²
	No. OF CHEMICAL COMPANIES: 23

Monaco is a small country with an economy based mainly on the financial, commercial and tourism sectors, the latter providing 25 % of the country's annual income.

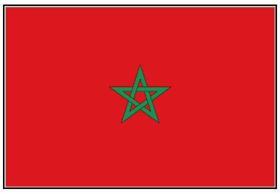
Its industrial sector developed considerably during the 20th century. In just the last 20 years, almost 200,000 m^2 of industrial installations have been constructed. There are approximately 70 small and medium-sized enterprises with premises in Monaco.

At present, it can be said that industry in Monaco is diversified, with a large number of companies in various sectors, of which 23 belong to the chemical, pharmaceutical, parapharmaceutical and cosmetic industries. This sector is of great importance to the country.

The base medicines industries using chemical and biological processes are important in Monaco. There are 3 sites of this nature with approximate sizes ranging from 1,720m² to 4,000m², and with an average of 10 to 70 workers. The geographical distribution of the centres of production is based on urban sites with chemical installations of between 1 and 4 floors in height. Their capacity for production varies between 1 and 330 mT per year. The products manufactured are mainly active ingredients for the synthesis of pharmaceutical products or cosmetics.

Among the most important environmental aspects, it should be noted that, of the solid waste treatment installations used by the sector, Monaco has an incinerator. On the other hand, wastewater that is generated is collected and can be combined with urban wastewater. However, all of the Monegasque companies in this sector separate wastewater and solid waste from industrial processes for their collection by special operators for their treatment in special plants outside Monaco.

The government of Monaco provides state grants or subsidies to companies for the improvement and promotion of environmental aspects in the sector, particularly in obtaining ISO 14001 environmental management certification. It should be highlighted that one of the chemical plants has a certified environmental management system in place (either EMAS or ISO 14001).

 **MOROCCO**	POPULATION: 31,064,100
	AREA: 446,550 km^2
	No. OF CHEMICAL COMPANIES: 2,041

The annual growth rate of GDP has been of 3.5 %, with industry representing an average yearly rate of 3.2 % of growth of added value and 30 % of sectoral distribution of added value.

Since the 1980s, industry has represented around a third of GDP in Morocco. Its current structure still reflects the effects of the post-colonialist industrial policy of the substitution of imports with local production and high levels of protection against international competition. However, the opening of the economy to international markets is causing the need for a gradual process of rationalisation, restructuring and modernisation of the industrial sector.

Generally speaking, the Moroccan industrial sector is characterised by high levels of geographical concentration, tending to be situated basically in large cities (mainly in Casablanca and in the industrial zones of Safi and Jorf Lasfar) and by the importance of heavy industry, including the petrochemicals industry. Statistics from the Ministry of Trade and Industry confirm the importance of the chemical and parachemical industries as part of Moroccan industrial structure. This comprises four sub-sectors: oil refining, processing of phosphates and other mining products, the cement industry and the pharmaceutical industry. The industry of processing phosphates and other mining products has shown positive evolution in recent years, resulting from its good vertical integration with the country's mining industry. However, the leading company in the oil refining industry, Samir, is experiencing difficulties due to its inability to compete in price with refined crude oil imports. The market is currently protected against international competition, but Morocco is committed to opening its markets from 2008.

The Moroccan chemical industry, like the Tunisian one, is dominated by the production of phosphates, as almost two thirds of world reserves of phosphate rock are found in Morocco. The main products manufactured are phosphoric acid and phosphate-based fertilisers. The extraction, processing and distribution of phosphates is carried out within a state monopoly by the OCP (Office Chérifien des Phosphates). Other important sectors within the chemical sector are the pharmaceutical products sector, the second most important in the African continent after South Africa, cosmetic products and the production of rubber.

With regards to the pharmaceutical sector, the ten largest global pharmaceutical groups are present in Morocco and hence this is a sector that since the beginning of the 1990s has undergone a process of concentration as a result of the mergers and acquisitions that have taken place in recent years. At present there are 26 laboratories, and local production, which follows international quality standards, satisfies 80 % of demand.

Lastly, it should be noted that in environmental matters, Morocco has made the commitment to an environmental policy based on the concepts of sustainable development and on making environmental protection a key factor in the country's economic and social development. On a legal level, Morocco is prepared to bring its laws into line with European standards, and is also carrying out actions involving environmental education and awareness-raising.

 **SLOVENIA**	POPULATION: 1,997,590
	AREA: 20,300 km^2
	No. OF CHEMICAL COMPANIES: 619 large, 44 medium-sized and 523 small

Slovenia is currently one of the most prosperous transition countries in Europe, and its companies have undertaken the move towards a market economy with fairly good economic and social management.

The average annual growth rate of added value for industry is 3 % and the percentage of added value in the sectoral distribution corresponding to industry is of 38 %. The annual rate of GDP growth is 4.6 %. Of the total active population, 29.7 % works in the sector of industrial activity.

The Slovenian industrial sector is well developed and is geographically concentrated to the north of Ljubljana, in the Gorenjska region. Many Slovenian industries, such as the metallurgy, furniture, paper, footwear, sports equipment and textile industries, have been in business for over 100 years. In post-war Yugoslavia, Slovenian industry had an open market for all types of product and “socialised” companies were created, in some cases dispensing with profitability or cost effectiveness criteria.

The chemical and pharmaceutical industry produces basic chemical substances, phytosanitary substances, paints and varnishes, detergents and synthetic fibres. The main companies in the sector are the pharmaceutical companies LEK (which belongs to the Sandoz group) and KRKA. Exports from the sector are directed mainly at Germany, Croatia, Russia, Poland, Italy and Austria.

Slovenia has important companies in the chemical industry that are dedicated mainly to the production of inks, waxes, colorants and pigments, phytosanitary or phytopharmaceutical products and biocides (herbicides, insecticides, fungicides), pharmaceutical products and cosmetics, active pharmaceutical ingredients and animal health products, flavours, colorants and essential oils, industrial gases, resins, adhesives, hygiene and cleaning agents, surfactants, tannins, varnishes, peracetic acid, H_2O_2, Pb_4, CO_2, starches, dextrins, esters, etc. There are no industries in the additives sub-sector. Installations are usually batch or semi-continuous of up to 15 m^3, and are located mainly in the centre, south and east of the country.

As for the environmental aspects, no data is available for industrial wastewater treatment plants. However, in accordance with the IPPC Directive, the commitment to progress and legal requirements, practically all producers of wastewater are obliged to have a plant for its treatment. To this end, all of the chemical companies in the country have installed such a plant. Some of these companies also emit waste into municipal treatment plants.

In addition to this, all companies are obliged to have analyses made of all waste types produced and to classify them according to legislation. Inert industrial waste is disposed of in authorised landfill sites. Hazardous waste or waste containing hazardous substances must be collected and managed by companies that have a state licence for the treatment of such waste. As Slovenia has only one landfill site for the disposal of hazardous and industrial waste, the remaining products are exported to other countries.

The Chamber of Commerce and Industry is responsible for the majority of questions relating to the IPPC Directive. In the capital, Ljubljana, there is also the National Institute of Chemistry, which promotes clean production (CP) in companies.

Basic figures for 2003
Number of companies: 619 (52 large, 44 medium-sized, 523 small)
Number of employees: 25,177
Income: *€3.319 billion*
Exporters: 50.7 % of companies
Company income from exports: *€2.229 billion*
After tax profits: *€309 million*
Losses: *€17 million*
Added value: *€1.072 billion*
Added value per employee: € *43,607*

 **SPAIN**	POPULATION: 42,100,000
	AREA: 504,782 km^2
	No. OF CHEMICAL COMPANIES: 3,744

Spain’s rapid development during the last quarter of the 20^{th} century turned the country into the eighth world economy among the OECD countries. Significant efforts were made during this time in the development and implementation of a coherent environmental policy that was in line with European directives.

The Autonomous Communities that directly affect the Mediterranean Sea are Catalonia, the Community of Valencia, Murcia, Andalusia and the Balearic Islands and indirectly, La Rioja, Navarre and Aragon via the River Ebro. There are large industrial complexes with a high concentration of chemical industries in this area.

The chemical products industry is among the country's main industries. In 2001, the manufacturing sector of refining and chemical products provided income of €40.108 billion.

Without taking into account those companies without paid employees that belong to the sector (National Classification of Economic Activities (CNAE) 24), 86 % of the 3,744 companies operating in the chemical industry in Spain have a workforce of under 50, with Spain, making it, together with Italy, the country with the greatest proportion of SMEs in Europe. The activities of the companies in the chemical sector currently generate 10 % of the Gross Domestic Product of the Spanish economy.

The chemical sector is the second largest exporting sector in the Spanish economy after the automobile sector, and it is anticipated that it will continue to direct almost half of production to foreign markets.

Table 2.1. Sub-sectors of the Spanish chemical industry (Source: FEIQUE)

SUB-SECTORS OF THE SPANISH CHEMICAL INDUSTRY – 2003		
BASE CHEMISTRY	Industrial gases Colorants and pigments Inorganic chemistry Organic chemistry Fertilisers Plastic and rubber raw materials Man-made fibres	**38 %**
HUMAN, ANIMAL AND PLANT HEALTH CHEMISTRY	Phytosanitary products Raw materials for pharmaceutical products Specialised pharmaceutical products Specialised zoosanitary products	**28 %**
CHEMISTRY FOR INDUSTRY AND COMMODITY CHEMICALS	Paints, inks, enamels and varnishes Detergents, soaps and cleaning products Perfumery and cosmetics Other chemical products	**34 %**

In Spain, the overall chemical industry had a production value of €32.120 billion in 2003 and €33.951 billion in 2004. It consists of over 3,700 companies that generate almost 140,000 direct jobs, a figure that can reach over 500,000 if indirect and induced jobs are included. From a territorial point of view, Catalonia represents some 47.3 % of the production of the country's chemical sector, followed by the Community of Madrid (15.9 %), the Community of Valencia (7.4 %), Andalusia (6.8 %) and the Basque Country (5.1 %). The table below shows the importance of each sub-sector in the Spanish chemical industry as a whole, according to production.

Table 2.2. Distribution of chemical sectors in Spain (Source: FEIQUE)

The chemical industry in Spain	Base chemistry	Fine chemistry related to human, animal and plant health	Fine chemistry for industry and commodity chemicals
Elements encompassed	Industrial gases Colorants and pigments Inorganic chemistry Basic organic chemistry Fertilisers Plastic and rubber raw materials Man-made fibres	Phytopharmaceutical products Pharmaceutical raw materials Speciality pharmaceutical Products Speciality zoosanitary Products	Paints, inks, enamels and varnishes Detergents, soaps and cleaning Products Perfumery and cosmetics Other chemical products
Percentage 2003	38 %	28 %	34 %

As can be seen in the comparative table of growth of the chemical sectors in Spain since 1977, the specific sectors, among which the fine organic chemistry sector stands out, are increasing their specific importance to the detriment of the base chemical sector, which reflects the trend of the increasing complexity and added value of these sectors.

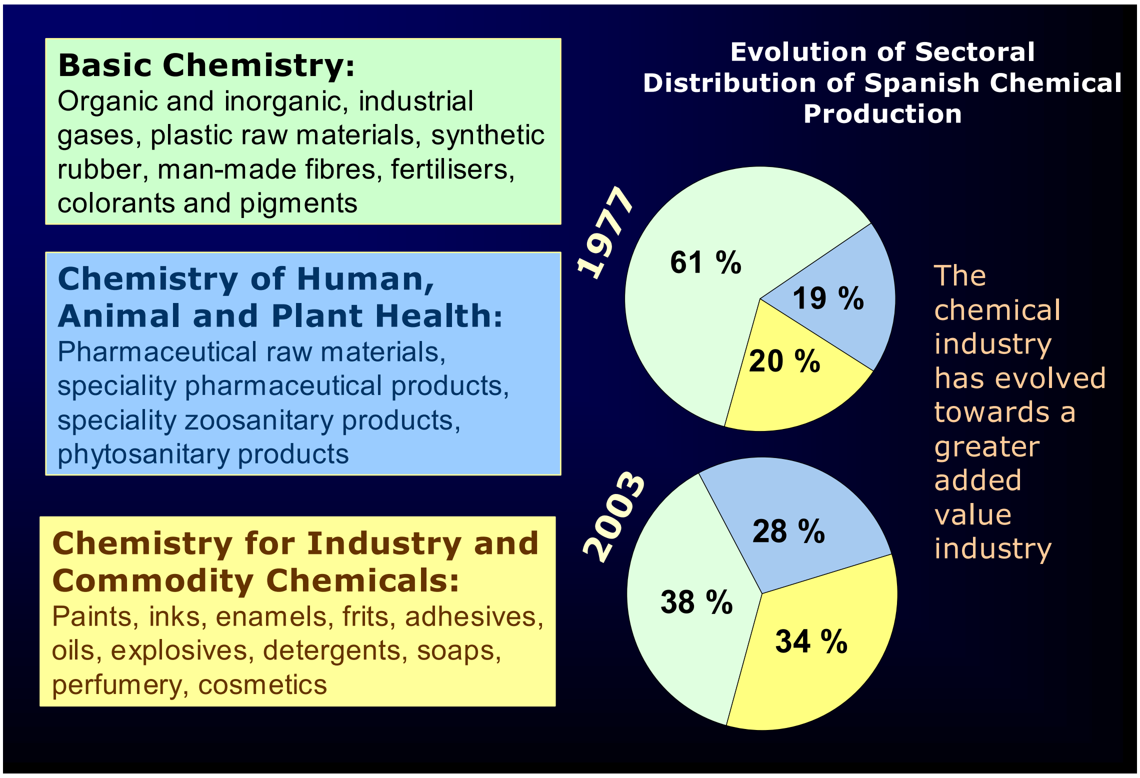


Figure 2.8. Sectoral distribution of Spanish chemical production (Source FEIQUE)

The fine organic chemistry sector in Spain includes some large multinationals with fine chemical units, but 90 % of all the companies in the sector are SMEs. Those sectors that have separated from other, clearer chemistry sectors to become the fine organic chemistry sector are of great importance and strategic value, despite their small and medium sizes.

Some more clearly-defined points related to the economy of the sub-sectors of fine organic chemistry will be pointed out later, without attempting to group these sub-sectors together as one single area.

	POPULATION: 18,222,700
SYRIA	AREA: 185,180 km^2

Syrian industry contributes 8.9 % of the growth in added value and represents 29 % of the sectoral distribution of this added value. The annual growth rate of GDP in recent years has been in the region of 3.5 %.

Since it gained independence, Syria has worked on the development of its industrial capacity, increasing the value of its extraction industries such as mining and oil production. Since 1980, Syria has shown significant industrial growth with an increase in the demand for chemical products. Those industries that use chemical products, either locally-produced or imported, include oil refining, the phosphate mines, the production of cement, textiles and the production of chemicals for agriculture such as pesticides and fertilisers. Syria continues to expand its chemical industry and one of the country's recent projects has been the construction of the first chloralkali plant in Aleppo, a project that was approved in 2001.

Syria is the world's fifth-largest exporter of phosphate rock, producing over 2.5 million tonnes per year, of which over 70 % is exported. A large part of this production is converted into phosphatic fertilisers or phosphoric acid. In addition to phosphatic fertilisers, Syria also produces ammonia, urea and nitrogenous fertilisers, such as ammonium nitrate and calcium nitrate, for local use.

The sulphur plant that is operated in association with the refinery at Homs has a production capacity of 150 mT/day. Syria converts part of its sulphur production into sulphuric acid, the consumption of which reached 318,000 tonnes in the year 2000. Around 78 % of sulphuric acid is consumed in the production of fertilisers. Despite its major fertiliser industry, Syria still needs to import around 500,000 tonnes of fertiliser each year.

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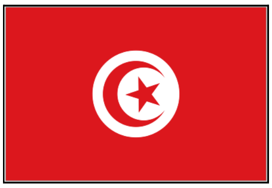
<tr><td rowspan="3">
TUNISIA</td><td>POPULATION: 9,936,700</td></tr>
<tr><td>AREA: 163,610 km^2</td></tr>
<tr><td>No. OF CHEMICAL COMPANIES: 213</td></tr>
</table>

The economic growth of Tunisia has historically depended on oil, agriculture, phosphates and the tourism sector. In 1986, the State implemented a programme of price liberalisation and tariff reduction, pointing Tunisia in the direction of a market economy.

Tunisian industry represents 4.6 % of growth in added value, with a 30 % share of the sectoral distribution of GDP and the creation of 22,959 jobs related to the industry in 2002. The annual growth rate of GDP is approximately 5.8 %.

The chemical sector (excluding the plastic industries) represents 10 % of Tunisian industry and is one of the manufacturing sectors to have undergone the greatest development in recent years, carrying out an activity that is principally directed at exports.

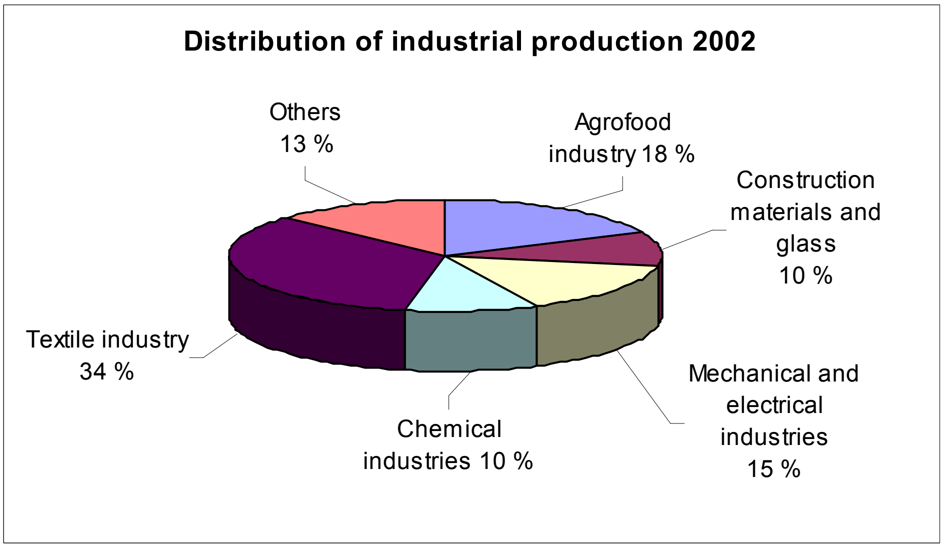


Figure 2.9. Distribution of Tunisian industrial production in 2002

The main environmental problems for Syria are linked to water and energy consumption and the generation of solid waste. As a result of this, the 10th Development Plan (2000-2006) establishes as priority areas for environmental action the management of waste and the treatment of industrial wastewater.

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TURKEY</td><td>POPULATION: 72,320,000</td></tr>
<tr><td>AREA: 780,580 km^2</td></tr>
<tr><td>No. OF CHEMICAL COMPANIES: 1,093</td></tr>
</table>

Turkey today is a country with an important industrial base that contributes 25.6 % of GDP and shows a great deal of potential, with major possibilities of attracting foreign industry. The declining importance of agriculture to the Turkish economy coincides with the rapid expansion of the service and industrial sectors. In the distribution of employment, industry provides 18.2 % of occupation.

The main industrial sectors in Turkey are those involved in the production of manufactured goods, amongst which the textile industry, the leader in terms of exports, and the chemical industry stand out.

With regard to the chemical sector, mention should be made of sub-sectors such as pharmaceuticals (which is one of the sectors with the highest levels of growth in Turkey, with annual growth rates of 6.7 %). Another relevant sub-sector is that of fertilisers. The agrochemical industry is key for the country and has huge possibilities, as Turkey has vast agricultural potential. On the other hand, the cosmetic and perfumery sector is a net importer of both manufactured products and raw materials and machinery. In addition, the sectors of colorants and pigments, phytosanitary products and biocides, basic medicines, fragrances and flavours, additives and surfactants are notable for their high production capacity, with a total of 45,436 employees.

The environmental sector is considered to be a high-priority sector by the Turkish Government. The rapid industrialisation of Turkey has created complex environmental problems, giving rise to impact on the environment and the provision of related public services: solid waste management, the supply of drinking water, the treatment of wastewater and the distribution of energy. In parallel to this, the increase in industrial production also causes environmental disruption, such as greater air and water pollution and an increase in industrial solid waste. Wastewater treatment systems (sewerage network and treatment plants) are clearly inadequate, as are investments in landfill sites and waste treatment plants.

The Ministry of the Environment, created in 1991, has helped environmental questions to gain greater relevance. In the official arena, the government is quickly adopting environmental legislation that is comparable to that of the countries of the European Union and has drawn up the Environment Law and created the Environment Foundation of Turkey.

3. DESCRIPTION OF THE MAIN PROCESS PHASES AND OPERATIONS OF THE CHEMICAL INDUSTRY AND THE ASSOCIATED ENVIRONMENTAL ASPECTS

The chemical industry has an environmental impact on the aquatic environment, the air and the soil. The types of pollutants that a chemical installation produces depend on the nature of the raw materials it uses, the production and auxiliary processes, the type of equipment, the organisation of tasks of both a maintenance and production nature, etc.

In addition to this, within a single installation the emission of pollutants changes a great deal throughout the working day or shift, depending on the operation or phase of the process that is being carried out at any time. For example, during batch processes, it is more likely that pollutants will be emitted at the start and the end of the process (during loading, unloading and transfer operations) than during the process itself. The table below shows the most common emissions into the different environments.

Table 3.1. Most common emissions from the chemical industry into different environments

TYPE OF EMISSION	SOURCE OF EMISSION
Gases, volatile compounds and particles	Single sources of emission: chimneys for processes and auxiliary activities such as boilers, venting (of distillation units, storage tanks, reactors, etc), loading and unloading processes (of raw materials, during the process). Non-point sources of emissions: pumps, valves, sampling procedures, mechanical seals, open tanks, spillways, etc. Secondary emissions: wastewater treatment plants, cooling towers, plant sewerage system and drains, overflows, leaks, etc.
Wastewater, liquid waste	Wash equipment using solvents/water, samples, leftover chemical products, products of purification/crystallisation, water from gas scrubbers, coolant water, steam streams, vacuum pumps, leaks, overflows, used solvents, floor cleaning, used oils, etc.
Solid waste	Used catalysts, used filters, sludges, wastewater treatment sludges, products that do not meet specifications, expired products/raw materials, packaging materials, used resins and coal, etc.
Soil pollution	Discharges into the soil (without channelling), leaks, overflows, storage areas, buried pipelines, raised pipelines, loading and unloading areas without retention ponds, etc.

Besides the emission of pollutants, other environmental aspects to be considered for the chemical industry are those related to the consumption of resources, particularly of water, and also energy consumption.

The chemical industry uses and produces an enormous quantity of chemical products, and as well as the large quantity, these products are of a very diverse nature, which makes the sector all the more complex. The main characteristics of the sectors dealt with in this guide are those of production in the form of batches of separate quantities, which results in various different products being manufactured in the same plant. In addition to this, in this sector and with similar characteristics there are complex sub-sectors of very diverse activities, with few similarities to each other.

It can be said that the chemical sector is made up of a large number of sub-sectors with very different processes. On the one hand is the basic chemical industry, which is dedicated to the manufacture of products (mainly oil derivatives) and to obtaining inorganic products (such as inorganic acids and their derivatives or industrial gases, among other substances). The manufacture of polymers, plastic raw materials, synthetic rubber and latex and artificial and synthetic fibres are also considered part of the basic chemical industry.

On the other hand is the transformation chemistry industry, which can be divided into four main branches of activity: the **agrochemical** sector, which manufactures products intended for agriculture, mainly fertilisers and phytosanitary products; **industrial chemistry**, which encompasses semi-finished products and finished products intended for other industries; **fine chemistry**, which manufactures products with high added value, with a high level of structural complexity and which requires highly refined synthetic techniques; and the **commodity chemical** industry, which produces those final products that are used directly by the consumer.

While the heterogeneous nature of the sectors is also clear when trying to establish a single production process, we can define an outline of common operations for most of them:

- Storage of raw materials, intermediate products and finished products.
- Loading and unloading of raw materials and chemical products.
- Production:
  - Dosing and weighing of materials.
  - Loading and unloading of reactors or mixers.
  - Internal transportation of products.
  - Reaction or formulation.
  - Separation and purification processes.
  - Final conditioning.
- Auxiliary processes:
  - Cleaning.
  - Conditioning of process waters.
  - Cooling systems.
  - Heating systems.
  - Treatment of wastewater.
  - Treatment of gas emissions.
  - Conditioning of waste.

The different processes are described below.

3.1. STORAGE

In chemical plants, the chemical products, whether raw materials, auxiliary materials, intermediate products or finished products are placed in an organised manner in specific areas. The operations that take place during the storage process are as follows:

- Loading and unloading of products.
- Transportation of the products.
- Arrangement and/or stacking of the products.
- Taking samples.

The most salient environmental aspects during storage operations are:

Table 3.2. Environmental aspects of the storage of products

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Diffuse emissions of volatile organic compounds and gases Particle emissions Emissions due to breakage or poor state of containers, drums and packaging Emissions from tanks, valves, pumps and tubes
Discharge into water	Unnoticed overflows Spillages from tanks, valves, pumps and tubes Leaks from underground tanks
Waste generation	Product residue, overflows Products that are out of date, obsolete or not within specifications Packaging materials (plastics, cardboard, labels, seals, etc.) Broken and/or empty containers, drums and packaging
Soil pollution	Unnoticed overflows onto non-paved ground Spillages from tanks, valves, pumps and tubes Leaks from underground tanks

When placing products in warehouses, a series of conditions must be observed:

- Separate zones must be established for flammable, toxic, corrosive or oxidising products, gases, etc.
- Safety distances enabling easy access should be respected.
- Distances from buildings, process units and boilers should be respected.
- Products should be labelled and should be easily identifiable.
- Receptacles of liquid substances should be provided with retention pools of a suitable size.
- The warehouse should ensure that spillages do not affect other premises by means of drainage systems.
- Samples should be taken in laminar flow booths.

- Incompatible waste types should be separated and kept apart within the warehouse:
  - Oxidising agents kept away from reducing agents.
  - Acids kept away from bases.
  - Waste that is sensitive to water kept away from taps or pipes.

The following page shows a diagram of the storage process for raw materials.

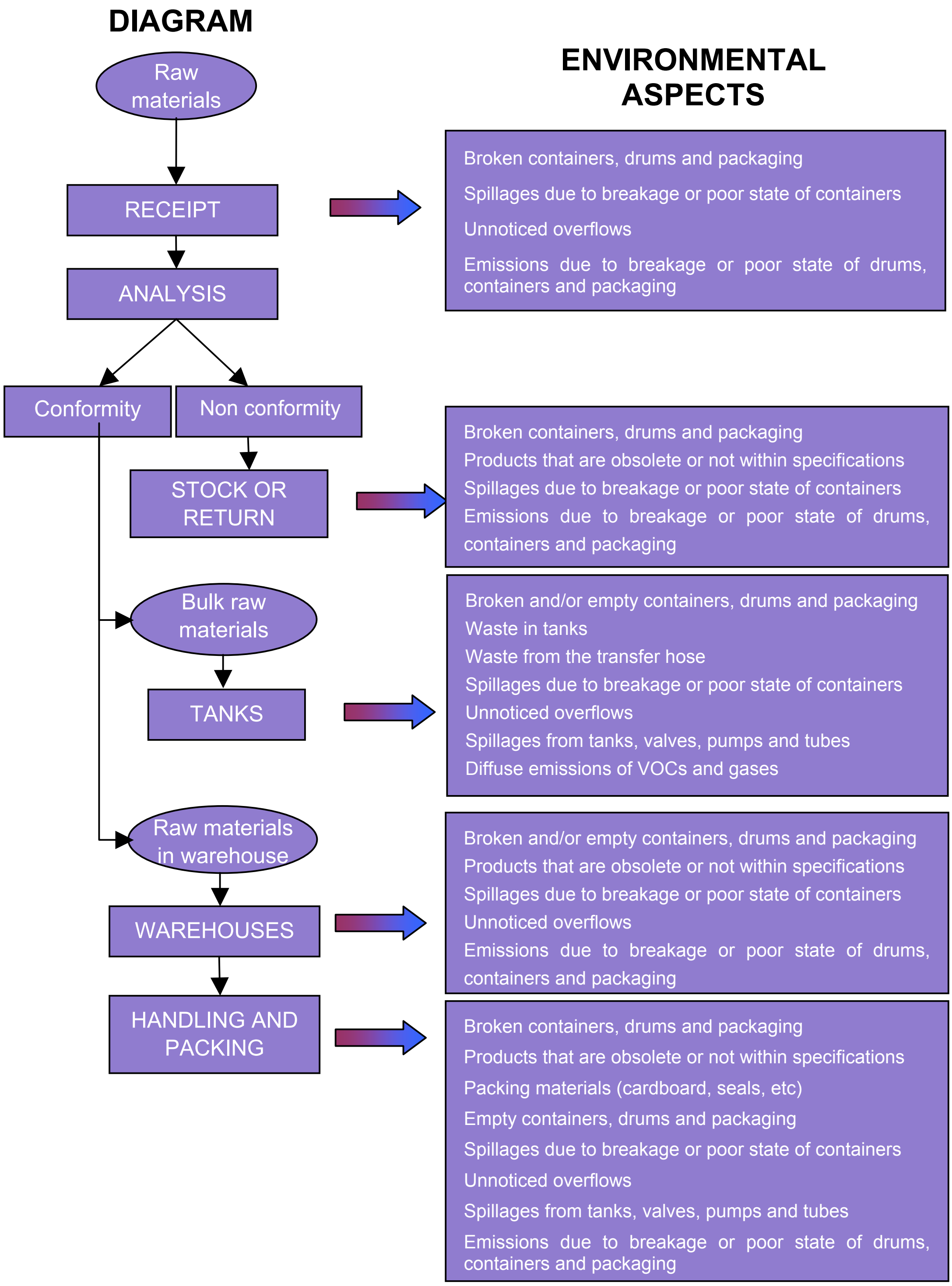


Figure 3.1. Diagram of environmental aspects of product storage

3.2. LOADING AND UNLOADING OF PRODUCTS

Operations of loading and unloading products take place in different areas of chemical plants and as part of various different processes:

- Transfer between transportation and storage units or vice versa.
- Transfer between storage units and process installations.
- Transfer between fixed or mobile receptacles during different phases of the process.

The most relevant environmental aspects associated with these operations are:

Table 3.3. Environmental aspects of the loading and unloading of products

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Diffuse emissions of volatile organic compounds and gases Particle emissions
Discharge into water	Overflows or uncontrolled spillages
Waste generation	Product residue, overflows
Soil pollution	Overflows or uncontrolled spillages onto non-paved ground

3.3. PRODUCTION

The implementation and design of the equipment and installations in the production plant facilitate the correct flow of materials and minimise energy losses, overflows, emissions, errors and accidents. A design that facilitates cleaning and one that uses gravity or short-distance transportation is very important to ensure that processes can be carried out correctly.

In addition to this, the production room should be provided with a drain for possible overflows from which the product can easily be recovered and/or sent to the wastewater treatment plant. It should also be furnished with a system of ventilation and extraction of gas and volatiles to the emissions treatment installation.

3.3.1. Measuring, weighing and dosing

This operation consists of preparing the necessary quantities of product for loading into reactors or mixers. Preparation can take place by weighing or by volumetric measurement (liquids) and the addition of products, dosing, can be manual or automatic.

The most relevant environmental aspects associated with these operations are:

Table 3.4. Environmental aspects of measuring, weighing and dosing

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Diffuse emissions of volatile organic compounds and gases Particle emissions
Discharge into water	Overflows
Waste generation	Product residue, overflows

3.3.2. Internal transportation of products

The internal transportation of chemical products between process units is carried out mainly in two different ways:

- Through pipelines (liquids and gases).
- Using mobile containers that can be moved to the units of production (liquids and solids).

The relevant environmental aspects associated with these operations are as follows:

Table 3.5. Environmental aspects of the internal transportation of products

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Diffuse emissions of volatile organic compounds and gases Particle emissions
Discharge into water	Overflows
Waste generation	Product residue, overflows
Soil pollution	Overflows or uncontrolled spillages onto non-paved ground

3.3.3. Reaction and/or formulation

The fundamental nucleus of chemical production in batch installations consists of the reaction or formulation stage. The object of this guide is not to analyse the operations, the environmental aspects and the good housekeeping practices related to specific synthesis or formulation processes. However, certain common environmental aspects associated with these operations could be mentioned here:

Table 3.6. Environmental aspects of reaction and/or formulation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Emissions of volatile organic compounds and gases
Discharge into water	Overflows Wastewater containing product residue
Waste generation	Product residue, overflows
Energy consumption	Extreme conditions of pressure and temperature, vacuums

3.3.4. Separation, purification and final conditioning operations

Obtaining a specific product or mix of products during the reaction or formulation stage is followed by a series of separation, purification and final conditioning operations.

3.3.4.1. Separation and purification operations

The operations used for separation and purification are classified according to the type of technology used and the sphere of application. Hence there are mechanical and diffusion technologies, which are applied to different types of separation. The following table shows the different technologies and their applications:

Table 3.7. Separation and purification operations

OPERATION		APPLICATION
Mechanical separation	Screening	Solid-solid separation
	Filtration	Solid-gas separation
		Solid-liquid separation
	Sedimentation	Solid-liquid separation
		Liquid-liquid separation
	Centrifuging	Solid-liquid separation
		Solid-gas separation
		Liquid-liquid separation
	Cyclone separation	Solid-gas separation
Diffusion separation	Distillation	Liquid-liquid separation
	Decantation	Liquid-liquid separation
	Extraction	Separation of solutes into a dissolution
	Crystallisation	Solid-liquid separation
	Absorption	Gas-gas separation
	Adsorption	Gas-gas separation
	Lixiviation	Solid-liquid separation

Below is a brief description of separation operations and their most significant environmental impacts:

SCREENING: an operation intended to separate the particles of a solid mixture by size. It is based on a process of passing the particles that are smaller in size through a mesh of a specific size.

The main environmental aspects of screening are:

Table 3.8. Environmental aspects of screening

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Particle emissions Noises and vibrations
Discharge into water	Wastewater with remains of the screened products generated during the cleaning of equipment
Waste generation	Residue of screened products deposited on the machinery Residue of screened products that are not of appropriate particle size and cannot be used in the process
Energy	Energy consumption

FILTRATION: filtration is an operation intended for solid-liquid separation based on the retention of particles of a size greater than a given value by a filtering mesh. It is used both to recover the solid present in the suspension to be filtered, and to reduce the turbidity of a liquid or to eliminate the suspended particles in a gas.

The main environmental aspects of filtration depend on the objective for which it is used. Depending on the process, the waste flows may be the fluids filtered or the solids retained after the process.

Table 3.9. Environmental aspects of filtration

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Filtered gases VOCs from the solvents used
Discharge into water	Mother liquor from the filtration process, when the liquid fraction is aqueous Wash waters from the filters, with residue of retained chemical products Residual effluent from the processes of filtration and liquid scrubbing of gases (base or acid solutions containing dissolved salts)
Waste generation	Filter cake or solid waste retained by the filters Filters and absorbent materials (cellulose, filter earth, synthetics) with remains of chemical products Organic solvents from the filtration process, when the liquid fraction is a solvent

SEDIMENTATION: this is an operation of solid-liquid or liquid-liquid separation in which the particles separate due to the different densities of the two phases present. It is used to concentrate solid particles or to obtain the liquid fraction free of solid particles.

The main environmental aspects of sedimentation depend on the objective for which it is used:

Table 3.10. Environmental aspects of sedimentation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Evaporation of the liquid, if it is volatile
Discharge into water	Liquid to be separated if the objective is to thicken a solid Wastewater with chemical product residue
Waste generation	Considerable quantities of sludge

CENTRIFUGING: this consists of the separation of two phases of fairly similar densities by creating a centrifugal force field using a mechanical rotation system. There are several different types of apparatus based on centrifuging for carrying out specific separation:

- Centrifuges: these are really centrifugal filters used to separate solids from a liquid. They generate solid and liquid residual fractions that, according to their composition, can have different destinations.
- Cyclones: static devices in which a mixture of particles suspended in a gas is subjected to a centrifugal force through the action of its own kinetic energy.

The main environmental aspects of centrifuges and cyclones are:

Table 3.11. Environmental aspects of centrifuging

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Noise and vibrations from the equipment Emissions of VOCs from the solvents used
Wastewater	Mother liquor from the centrifuging process, when the liquid fraction is aqueous Water used to clean the equipment
Waste generation	Solid material deposited on the interior cover or in the drum of the centrifuge Organic solvents from the centrifuging process, when the liquid fraction is a solvent
Energy	High energy consumption, particularly for acceleration operations

CYCLONE SEPARATION: cyclones are one of the most-used items of equipment in operations to separate solid particles from a gaseous medium, in addition to their use in the separation of solids from liquids. They are structurally very simple pieces of equipment, as they have no moving parts and scarcely require maintenance. By their use of centrifugal forces instead of gravitational forces, the speed of sedimentation of the particles is greatly increased, making separation more effective.

Table 3.12. Environmental aspects of cyclone separation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Noise and vibrations from equipment Emissions of fine particles
Waste generation	Coarse particles

DISTILLATION: the separation of two or more components from a liquid mixture, using the difference between their different heat pressures. The process consists of heating the liquid until its more volatile components move into the vapour phase and then cooling this vapour to recover these components in liquid form by means of condensation. The main objective of distillation is to obtain the most volatile component in its pure form. Distillation also enables the opposite, i.e to transfer contaminants of high molecular weight to the distillation still bottoms, recovering, in this case, the distilled fraction.

The main environmental aspects of distillation are:

Table 3.13. Environmental aspects of distillation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Atmospheric emissions of the distilled products, if these are of high volatility and the cooling system is not entirely efficient Non-condensed distillation vapours and incondensable gases Water vapour from the towers of the closed cooling systems Evaporation of VOCs during cleaning operations using solvents
Wastewater	Hot cooling water from open cooling circuits Water with residue of chemical products from cleaning operations carried out with water or steam
Waste	Distillation overheads, still bottoms (if the process is continuous) or distillation bottoms (if a batch process is used) with a high organic load Dirty solvents from cleaning operations
Energy	High energy consumption due to the heating of the liquid to be distilled
Resources	High water consumption if open cooling circuits are used

DECANTATION: the decantation procedure consists of the separation of different components containing different phases (for example 2 liquids that do not mix, solid and liquid, etc.), provided that there is a significant difference between the densities of the phases. Separation takes place by pouring out the upper, less dense phase or the lower, denser phase.

Table 3.14. Environmental aspects of decantation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Evaporation of the liquid, if it is volatile
Wastewater	If any of the liquids to be separated is undesired waste

EXTRACTION: separation based on the dissolution of one or more components of a mixture (liquid or forming part of a solid) in a selective solvent. A distinction is made between solid-liquid extraction and liquid-liquid extraction. In the case of liquid-liquid extraction, it is important that the liquids cannot mix between themselves.

Extraction operations can generate two different types of effluent according to whether it is the organic fraction or the aqueous fraction that is of interest in the process. The main environmental aspects of liquid-liquid extraction are:

Table 3.15. Environmental aspects of extraction

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Emissions of VOCs from the solvents used
Wastewater	Saline aqueous solutions Wastewater containing residue of organic solvents
Waste generation	Dirty organic solvents with other dissolved organic solvents Aqueous interphases with residue of organic solvents

LIXIVIATION: lixiviation is the term for solid-liquid extraction when the component extracted from the solid is of value.

The main environmental aspects of the lixiviation process are:

Table 3.16. Environmental aspects of lixiviation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Emissions of VOCs from the solvents used
Wastewater	Extraction liquid once the desired element has been separated
Waste	Spent solid

CRYSTALLISATION: the formation of crystalline solid particles within a homogenous phase, normally the formation of crystalline solids within supersaturated liquid solutions. This technique is used to obtain a product with the desired level of purity.

The main environmental aspects of centrifuges are:

Table 3.17. Environmental aspects of crystallisation

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Noise and vibrations from the equipment Emissions of VOCs from the solvents used
Generation of wastewater	Mother liquor from the process Water used to clean the equipment
Energy	High energy consumption

ABSORPTION: this consists of bringing a gas into close contact with a liquid so that the liquid in question dissolves specific components of the gas. The opposite operation is desorption (stripping), in which a gas that is dissolved in a liquid is dragged out by an inert gas.

The main environmental aspects of absorption are:

Table 3.18. Environmental aspects of absorption

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	In stripping, inert gas with element absorbed

ADSORPTION: elimination of some components from a liquid phase using a solid that retains the components. Adsorption is a surface phenomenon and only solids with a large specific surface are considered to be adsorbents of interest, such as activated carbon, silica gel, etc.

The main environmental aspects of adsorption are:

Table 3.19. Environmental aspects of adsorption

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Gases, waster vapour or air used for regeneration
Wastewater	Liquid
Waste	Encrusted adsorbent solids (regeneration)

3.3.4.2. Final conditioning

Final conditioning operations are intended to give the final product the required conditions of moisture, particle size, final presentation, etc. The most common conditioning operations are:

GRINDING: an operation with the objective of reducing the size of the elements in which a solid is presented, submitting the pieces of the material to forces of compression, impact, cutting, shearing and friction.

MICRONISING: type of grinding which results in a very fine solid.

The environmental aspects associated with grinding and micronising are:

Table 3.20. Environmental aspects of grinding and micronising

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Noise and vibrations from the equipment Particle emissions
Wastewater	Water from the cleaning of equipment
Waste	Residue of the product in the equipment

DRYING: reduction of the water content of a solid, or in general of any other liquid.

ATOMISING: a type of drying in which a suspension of the solid, in the form of particles, is placed in sharp contact with hot air at a high temperature in a cyclone device. The water in the solid vaporises rapidly, resulting in a highly porous solid.

The environmental aspects of drying and/or atomising are:

Table 3.21. Environmental aspects of atomising and drying

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Noise and vibrations from the equipment Emission of VOCs from the solvents used
Wastewater	Water from the cleaning of equipment
Waste	Residue of the product in the equipment Organic solvents that are evaporated and later condensed
Energy	High energy consumption

PACKAGING: the packaging operation consists of putting the product into the most suitable receptacle for its sale, transportation and use. The type of packaging used and the packaging operation will depend on the nature of the product, that is whether it is solid, liquid or gas.

The environmental aspects associated with this operation are:

Table 3.22. Environmental aspects of packaging

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Particle emissions Gas emissions Emission of VOCs from the solvents used
Wastewater	Residue from the cleaning of equipment
Waste	Residue of the product in the equipment
Energy	High energy consumption, particularly during acceleration operations

3.4. CLEANING THE INSTALLATIONS, EQUIPMENT AND PIPELINES

The cleaning system in these multi-purpose manufacturing plants should guarantee the absence of residue of products previously manufactured before beginning a new stage. Some sectors, such as the pharmaceutical sector, must take special care that remains of active products do not influence the following products, limiting, in general, the quantity of product remaining from a process to figures of under 10 parts per million in the next process, which requires extremely well established cleaning procedures. The cleaning of installations is therefore an important operation in this sector.

The cleaning of reactors, centrifuges and screens is carried out using water, caustic soda, hydrochloric acid, acetone, specific solvents and steam, according to the equipment or substances to be cleaned. The process is generally finished using water to rinse or, when the equipment is required to be dry, with an organic solvent. When the cleaning process is finished, the water used is sent for treatment in the plant’s own wastewater treatment unit.

Cleaning operations usually have the following environmental aspects associated:

Table 3.23. Environmental aspects of cleaning operations

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Diffuse emissions of volatile organic compounds, particularly if solvents have been used in the cleaning process
Wastewater	Wastewater with residue of products and agents used in cleaning (detergents, solvents, etc.) Overflows
Waste	Remains of solid product, from dry cleaning processes Overflows

3.5. CONDITIONING THE PROCESS WATERS

The majority of chemical industries using batch processes require the use of a conditioning treatment for the water that they use in their processes. The most commonly used techniques are decalcification and/or deionising, using ion exchange resins and reverse osmosis.

Conditioning operations usually have the following environmental aspects associated:

Table 3.24. Environmental aspects of water conditioning

ENVIRONMENTAL ASPECTS	
Wastewater	Wastewater with high saline content Overflows
Solid waste	Spent membranes Waste packaging of reagents and additives
Energy	High energy consumption depending on the conditioning techniques used

3.6. ENERGY GENERATION, COOLING, HEATING AND HEAT RECOVERY SYSTEMS

The generation of energy is an auxiliary process that is indispensable to the chemical industry.

The fuels that are most commonly used in the generation of energy are diesel or fuel oil and natural gas, both for the generation of heat energy (in the form of hot water or steam) and for the generation of electrical energy (in cooling equipment, equipment operation, illumination, ventilation, etc.). In some cases, electricity is generated in situ in cogeneration installations, which generally use natural gas as their energy source.

For the cooling of equipment, water is usually the most widely-used medium for the cooling of fluids and reaction or formulation environments, by means of heat exchange systems. Cooling towers are used to cool the water.

As a general rule, cooling systems are only used when residual heat has been minimised and all the opportunities for the use of the heat energy have been exhausted.

On occasion, refrigeration temperatures of below zero are required, for example to control extremely exothermic reactions or to condense highly volatile compounds. To obtain temperatures of below zero, compressor cooling is used, employing chilled saline water or glycol solutions. If temperatures of under –40 ºC are required, liquid nitrogen is used for cooling.

Heating takes place using steam/hot water or thermal oil, through heat exchangers. Obviously to generate the source of heat, a primary energy source is required, either a fossil fuel to generate steam in the boiler, or electrical energy to heat the thermal oil. The residual heat left over from heating operations is used for heating in other operations that require less heat.

As mentioned above, heat exchangers are the most commonly used equipment for cooling and heating operations. This equipment should be designed both from the perspective of efficiency and environmental impact, in line with the following criteria:

- Suitable design for the efficient exchange of heat.
- Appropriate construction to prevent the contamination of cooling liquid by the process fluid.
- Suitable choice of material for the efficiency of heat transfer, for resistance to corrosion in water and to corrosion due to the process medium.
- The possibility of using mechanical cleaning devices.

The environmental aspects related to these operations are:

Table 3.25. Environmental aspects of energy generation, cooling and heating operations

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Emissions of refrigerant gases, ammonia, CFCs Particle emissions Emissions of greenhouse gases Emissions of SO_2,, CO, CO_2 from boilers
Wastewater	Discharge of cooling water and water from boilers, purges
Waste	Spent thermal oil
Energy	High energy consumption to generate the source of heat and/or cold
Resources	Water consumption Consumption of non-renewable fossil fuels to generate the heat and/or cold
Soil	Underground fuel tanks (diesel)

3.7. WASTEWATER TREATMENT AND PURIFICATION INSTALLATIONS

The vast majority of plants in the chemical sector have their own end-of-pipe wastewater treatment stations. Due to the wide variety of types of wastewater generated by this sector, the treatment that wastewater is given in companies is highly varied, and depends on the specific pollutants contained by the water.

On occasions, the impossibility of treatment of specific effluent in situ means that such effluent must be treated externally as waste.

The environmental aspects associated with wastewater treatment are as follows:

Table 3.26. Environmental aspects of wastewater treatment and purification installations

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Diffuse emissions of VOCs
Wastewater	The waste effluent itself
Waste	Generation of solid or semi-solid waste by the treatment process (water treatment sludges)
Energy	High energy consumption depending on the treatment technique used
Soil	Unnoticed overflows onto non-paved ground Spillages from tanks, valves, pumps and tubes Overflows caused by torrential rain Leaks from buried tanks

3.8. INSTALLATIONS FOR THE TREATMENT OF ATMOSPHERIC EMISSIONS

Installations for the treatment of atmospheric emissions in the industries of the chemical sector are highly varied, depending on the compound or compounds that are emitted. The emission of acid gases (hydrochloric acid, hydrogen sulphide etc.) is quite common, as are emissions of alkaline gases (ammonia), volatile organic compounds, particles, etc. The technology applied to this will therefore vary according to the characteristics of the emission.

The environmental aspects associated with installations for the treatment of gases are also very varied and may be:

Table 3.27. Environmental aspects of installations for the treatment of atmospheric emissions

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	The emissions of gases and particles themselves
Wastewater	Water used in scrubbing the gases
Waste	Solid waste from particle filters
Energy	Energy consumption
Resources	Water consumption

3.9. WASTE CONDITIONING

In the chemical industry, various types of waste are generated: solid, aqueous and spent solvents. In situ treatment of the waste generated is not very frequent in the industries of the chemical sector. In general, such waste is managed externally.

However, on some occasions, waste management operations such as incineration are carried out within the plant itself, with the consequent use of the energy generated. This case is used specifically for waste with a high calorific value, such as solvents. Incineration and other operations, such as the heat drying of certain waste to minimise its volume and therefore the cost of its external management, have some environmental aspects that should be taken into account:

Table 3.28. Environmental aspects of waste conditioning

ENVIRONMENTAL ASPECTS	
Atmospheric emissions	Emissions of volatile organic compounds Particle emissions Emission of gases
Wastewater	Overflows, cleaning of equipment Water used in scrubbing gases in the incineration plant
Waste	The waste that is treated
Energy	Energy consumption
Soil	Unnoticed overflows onto non-paved ground Spillages from tanks, valves, pumps and tubes Leaks from buried tanks

3.10. WATER CONSUMPTION

Water is usually the resource of which the greatest amount is consumed in the chemical industry. The sources from which this resource is obtained vary from the exploitation of aquifers (wells) to the direct consumption of tap water. Moreover, in many industrial chemistry processes, water is incorporated into the final product.

In the chemical industry, water consumption arises from:

- Cleaning.
- Cooling.
- The process itself (formulations or synthesis in an aqueous medium).
- Auxiliary equipment: liquid ring vacuum pumps, open water circuit condensers, ejectors, etc.
- The manufacture of products in an aqueous base (incorporation into the final product).

The environmental aspects associated with the consumption of water are related to the impact produced by the consumption itself on the different water resources that are exploited.

3.11. ENERGY CONSUMPTION

The majority of options described in the sections above involve some energy consumption.

However, the greatest level of energy consumption occurs in those operations that require high temperatures and in cooling operations.

The environmental aspects associated with energy consumption are related to the impacts caused by the consumption of non-renewable energy resources that are used.

4. MANAGEMENT AND CONTROL OF ENVIRONMENTAL ASPECTS AND TECHNIQUES USED

The previous chapter provided a description of the different operations and stages of the process that are most common in the chemical sector, and it has been shown that each of these operations generates certain types of environmental impact, whether in the form of atmospheric emissions, the discharge of wastewater, the generation of solid waste or the consumption of resources and of energy.

In this chapter we will analyse the way in which the industries of the sector manage and control the impact caused by each of the environmental aspects, along with the Best Available Techniques (BATs) that are used.

4.1. WASTEWATER: GENERATION AND MANAGEMENT

In the industries of the chemical sector, different flows of wastewater are generated that originate from different sources:

- Process waters.
- Scrubbers.
- Deionising columns or equipment for specific treatment of the water (biocides, lime, corrosion inhibitors, etc.).
- Filter washes dragging out remains of solid particles.
- Disinfection or washing of equipment.
- Washing of infrastructures or overflows.
- Distillation still bottoms.
- Liquid ring vacuum pumps.
- Contaminated rainwater and overflows.

The good management of the generation of wastewater involves firstly the avoidance or minimising of discharges and the channelling of accidental overflows as much as possible. It should therefore be highlighted that the main issue is minimising sources of wastewater generation, reducing water consumption as far as possible, and attempting to optimise production to minimise the need for washing.

Wastewater generated with a very high pollutant load accounts for some 10-30 % of total wastewater. The pollutant load of the remainder is usually low. To reduce environmental impact, a reference technique for this industry is the separation of the different flows in order to apply the most appropriate treatment to each one. This means that an individualised treatment is applied to each flow before the centralised common treatment of effluent.

The most common treatment consists of a homogenisation and a physical-chemical and biological treatment of the wastewater, although at times specific treatments are required before or after the main treatment in order to eliminate specific aspects of the wastewater that are not destroyed during treatment. Thus biocides from the products or non-biodegradable compounds in the water should be given specific treatment before they enter the WWTP, so that they do not affect the biomass of the treatment plant. On other occasions, further treatment must be given to water that has already been treated in the treatment plant in order to deal with pollutants such as salts, colour, refractory COD, etc.

Therefore, in order to ensure the sufficient treatment of wastewater in the chemical industry, it is necessary to:

- Separate polluted flows from unpolluted ones.
- Characterise each one of the flows separated.
- Determine the most appropriate treatment technology or technologies for each type of effluent.

The following table shows the best available technologies that are most used in wastewater treatment, and their most appropriate application:

Table 4.1. Most commonly used techniques in the treatment of wastewater

TECHNIQUE	APPLICATIONS	OBSERVATIONS
Sedimentation	Solid COD Solids in suspension Non-dissolved heavy metals Aggregates	• Pre-treatment to separate suspended solids that can be easily decanted • Clarification of process waters of suspended solids or flocs
Skimming	Separation of coarse solids	• Pre-treatment in which different items of skimming equipment of different mesh sizes are used: grilles, rotating filters, static screens, etc.
Filtration	Undissolved COD Suspended solids Non-dissolved heavy metals	• Separation of finer solids than sedimentation • Danger of clogging the filters if the solids are too fine
Flotation	Undissolved COD Suspended solids Non-dissolved heavy metals Oils and grease	• Separation of oils, grease and floating solids • May require air introduced using cavitation to accelerate flotation • On some occasions, the process may require the addition of chemical reagents (coagulants and flocculants) to encourage flotation • The separated materials can be recovered
Physical-chemical: flocculation, coagulation and precipitation	Undissolved and non-coagulable COD Suspended solids Heavy metals	• Precipitation of metals • Elimination of matter in suspension by the addition of flocculants and coagulants • Optimum method for large flows due to its relatively low cost • The yield of removed suspended solids can exceed 90 %, whereas when treating COD the results are less impressive as only the insoluble matter is removed • Operating costs can be high at times due to the consumption of reagents

TECHNIQUE	APPLICATIONS	OBSERVATIONS
Microfiltration / Ultrafiltration	Dispersions of solids Emulsions Low concentrations of suspended solids Undissolved COD	• Capacity to separate even colloidal particles • Allows the reuse of the permeated water and the waste generated is very low (less than 5 %) • Membranes must be chosen correctly depending on the water to be treated • The yield in the elimination of suspended solids is almost 100 %, while undissolved COD remains invariable
Advanced chemical oxidation (peroxides, Fenton's reagent, ozonisation, etc.)	COD Refractory COD AOX Phenols Compounds with activity	• High capacity for the elimination of pollutants using H_2O_2 + iron salts or UV, O_3, O_3 + UV, Cl_2, ClO_2, OCl-, supercritical water, O_2, etc. • In some cases reaction conditions are extreme • Capable of eliminating refractory COD
Nanofiltration / Reverse osmosis	COD Refractory COD AOX Phenols Compounds with activity Salts	• Separation of ions by permeation of the membrane • These treatments generally require prior microfiltration • Permits the reuse of the output water • Rejects are quite high (> than 30 %), so waste is generated that should be managed appropriately • High pressure of operation and high energy consumption
Adsorption by activated carbon	COD Refractory COD AOX VOCs Compounds with activity	• Capacity to eliminate odours, colour, non-biodegradable and toxic compounds • A good refining technique, but expensive for removing high concentrations of pollutant load
Ion exchange	Ionic compounds Metals	• Substitution of pollutant ions in resins • The regeneration of the resins results in a waste flow with a high salts load
Extraction	COD Refractory COD AOX	• Transfer of a pollutant to a solvent with the possibility of its recovery
Distillation / rectification	COD Refractory COD AOX VOCs	• Transfer of volatile pollutants to the vapour phase: the condensation or treatment of volatiles should be anticipated • Restricted use depending on the characteristics of the water • High energy consumption
Vacuum evaporation	Metals Non-volatile COD Salts	• Evaporation of water to concentrate the waste: this does not eliminate the waste, but it reduces its volume by 4 to 20 times, depending on the effluent • Enables on many occasions the reuse of the distillate • Used for small flows, of up to 100 m^3/day
Stripping	VOCs AOX Ammonia	• Elimination of organic and inorganic volatiles by transfer to the gas phase by means of air diffusion • This technique should be carried out in such a way that the pollutants dragged out by the air can be treated appropriately

TECHNIQUE	APPLICATIONS	OBSERVATIONS
Anaerobic biological	BOD COD Biodegradable AOX Total nitrogen Sulphates	• Elimination of BOD of microorganisms without oxygen • Process very sensitive to possible changes • Sulphates reduced to sulphides via sulphites • Possibility of energy recovery through combustion of the biogas generated • Suitable for large flows • Installations are complex and very expensive
Aerobic biological	BOD COD Biodegradable AOX Phosphorous and phosphates	• Elimination of BOD of microorganisms in the presence of oxygen • Highly suitable for eliminating biodegradable compounds • The range of application in terms of flows is very wide • Sensitive to the discharge of toxic substances
Membrane bioreactor (MBR)	BOD COD Biodegradable AOX Phosphorous and phosphates	• Combines the technologies of biological oxidation and filtration by membranes • Increased yield with respect to conventional biological treatment, allowing up to 5 times the biomass capacity of the biological reactor (up to 20 g/L) • Yield of suspended solids removal is equivalent to micro/ultrafiltration • Installations are much more compact than those of conventional biological processes as the decantation stage is eliminated • Allows the water to be reused • Elimination of BOD of microorganisms in the presence of oxygen • Highly suitable for eliminating biodegradable compounds • The range of application in terms of flows is very wide • Sensitive to the discharge of toxic substances
Nitrification / denitrification	Total nitrogen Ammonia	• This is a complementary stage to a biological system, which is used to eliminate ammonia • Destruction of nitrogen compounds using specific microorganisms
Physical-chemical treatment and segregation of saline flows and discharge directly into the sea	Flows with high saline concentration: Cl- > 2500 mg/l Conductivity > 6000 µS/cm Sulphates > 1000 mg/l	• This is a technique that is appropriate where the geographical situation allows it and where the pollutant load is compatible with the recipient medium. Particularly appropriate for brine, osmosis rejects and other saline flows with a low presence of other pollutants • Improved functioning of WWTP due to reduction in salts
Recovery of acid and alkaline salts	Acid or alkaline flows	• These are recycled following their collection in scrubbers if they are gases and the evacuation of the waters when they reach near saturation, or by selective collection • On occasions their purity enables them to be marketed as solutions of varying concentrations • Reuse in other processes to enable pH adjustments • Avoids the appearance of salts in wastewater

4.2. ATMOSPHERIC EMISSIONS: GENERATION AND MANAGEMENT

During the processes and operations carried out by the chemical sector, emissions of gases, volatile compounds and particles are produced that are both diffuse and channelled. The chemical sector must therefore consider:

- The intervention of different volatile organic pollutants and of nitrous oxides in the cycle of photochemical oxidants. This process makes a decisive contribution to the formation and maintenance of significant amounts of low level ozone (photochemical smog).
- The capacity for participation of certain organic pollutants in the depletion of the stratospheric ozone layer.
- The ascertainment of the acute or chronic toxicity of different pollutant types (such as polychlorinated biphenols (PCBs), dioxins, polycyclic aromatic hydrocarbons, benzene, peroxy-acyl nitrates (PAN), nitriles, chlorobenzenes, acrolein, etc).
- Odours, VOCs that are non-toxic but with a very low detection threshold, such as mercaptans, which in certain sub-sectors such as that of fragrances and flavours can be extremely important.
- The increased concentration of greenhouse gases (CO_2, CFCs, methane and ozone) which are responsible for global warming and climate change.
- The emission of nitrous oxides and sulphur dioxide which in reaction with the water vapour in the atmosphere generate the acids responsible for acid rain.
- The emission of CFCs that are responsible for the depletion of the stratospheric ozone layer that provides protection from solar ultraviolet radiation.
- The emissions of particles forming aerosols that may be pollutant or hazardous.

The first step towards the correct management of emissions is to avoid or minimise emissions and to channel diffuse emissions as far as possible.

The first step for minimising atmospheric emissions is to carry out a thorough characterisation of emissions. This involves determining the flows of the different streams, including their maximum, minimum and average flows, together with their periodicity and frequency. Another important factor is to determine the pollutants contained in these emissions, the temperature, moisture content, presence of dust, etc. and to relate all of these parameters to the different processes carried out within the company. All of this enables the best possible technology or sequence of technologies for the reduction of emissions to be chosen.

With regard to particle emissions, which are relevant in grinding, micronising and packing operations, etc., systems for the internal containment of particles are used. These minimise or entirely avoid emissions of particles. In this way, on occasion, it is possible to make the most of substances of added value and to reprocess them.

To this end, closed systems and equipment with controlled ventilation and systems of pneumatic transportation by suction or air pressure from silos or dryers, filtering the air from the pneumatic transport systems, are used. Grinding, micronising, packing or any other operations that produce a large quantity of dust are carried out using systems that are practically closed, in premises with filtered air. In the case of pharmaceutical active ingredients and biocides, absolute filters (HEPA filters, which are specially designed to contain and deactivate this type of product) are used.

The table below shows the best available techniques for the treatment of gases and particles and their application in the cases of different pollutants:

Table 4.2. Techniques for the treatment of atmospheric emissions

TECHNIQUE	APPLICATIONS	OBSERVATIONS
Separators	Dry or moist organic and inorganic particles	• Separation using gravity, applicable only as a pre-treatment
Cyclones	Good capacity to reach up to PM_{10} and even PM_5	• Separation by gravity and centrifugal force • Economic and effective • Separation in dry and moist conditions
Electrostatic filter (ESP)	Excellent performance for dust up to $PM_{2.5}$ Flammable mixtures Acid mists	• Separation by electrical field • High volumes of operation • High costs
Bag filter	Dust up to < $PM_{2,5}$	• Fabric filter • Limited by the temperature of the gas and the abrasiveness of the particles
HEPA filters	Capacity to eliminate submicron particles of between $PM_{0.12}$ and $PM_{0,3}$	• High-density glass fibre filters • Obligatory in some sectors
Membranes	VOCs	• Selective membranes that permit the permeation of specific compounds. Allow the recovery of 99 % of the solvent, which can be recovered by condensation • The gas stream should be free of dust
Absorption with or without chemical reaction: Scrubber	< $PM_{2.5}$ Inorganic compounds NH_3 HCl HF H_2S SO_X VOCs	• Counterflow absorption system in which the pollutant is transformed from the gas phase to the liquid phase in a packed tower. The presence of the packing in the column ensures efficient contact between the polluted gas and the scrubbing solution • The pollutants eliminated depend on the solution used • This technique enables the recovery of the absorbed pollutant • It is efficient for inorganic gases, while its efficiency for VOCs is limited
Adsorption: activated carbon, zeolites, aluminium oxide, etc.	VOCs Odours Dioxins H_2S Hg	• Elimination of toxic and hazardous compounds. Useful for low flows and low concentrations of dust-free VOCs • Used to treat emissions from treatment plants or for one-off emissions, such as when loading tanks • The adsorbent can be regenerated using steam or nitrogen
Condensation and cryocondensation	VOCs	• Liquefaction by cooling of volatile compounds • Depending on the temperature, coolant liquids vary from water to liquid nitrogen. This technique is applied to small, highly concentrated flows • Enables the recovery of the condensed solvents

TECHNIQUE	APPLICATIONS	OBSERVATIONS
Biological treatments: biofilters, bioscrubbing	NH_3 H_2S Organic compounds Odours Inorganic compounds	• Biotic degradation of compounds at low concentrations. Requires the flow to be treated to be regular and homogenous in composition. Yield varies between 70 and 95 %, although it should be noted that this technique is only useful for biodegradable substances and is therefore not applicable to halogenated VOCs
Thermal oxidation	VOCs Organic compounds Toxic substances	• This process involves the oxidation of organic compounds by combustion. Its efficiency is of over 99 % in removing VOCs and it is therefore applied to with a high concentration of these compounds. The working temperature is around 850 ºC, although in the case of the presence of halogenated solvents, 1000 ºC is required to avoid the formation of PCDDs and PCDFs • There is a possibility of using heat recovery
Catalytic oxidation	VOCs Organic compounds Toxic substances Odours	• Oxidation of organic compounds at a relatively low temperature (400 ºC) in the presence of a catalyst. The efficiency of elimination of VOCs is of over 98 % • As the technique uses a lower temperature, energy consumption is lower than for thermal oxidation and there is less risk of the formation of undesired substances (CO, NOx, dioxins, etc.). However, the cost of substituting the catalyst should be taken into account
Selective catalytic reduction	NO_x	• Reduction of NO_X to N_2 with ammonia and catalyst beds of Pt, Va-Ti (WO_3) or zeolites+ Fe, Cu
Selective non-catalytic reduction	NO_X	• Reduction of NO_X to N_2 with ammonia or urea
Incineration	VOCs	• The use of certain organic compounds as fuel • Enables other fuel to be saved and permits energy recovery and the production of electricity or steam

4.3. NOISE AND VIBRATIONS

The majority of industries in the chemical sector are not noted for their high levels of external acoustic emissions, as the majority of operations that generate significant noise, such as grinding, centrifuging, etc. are carried out inside the installations, and on many occasions, take place in isolated zones. These emissions do represent an impact from the point of view of workplace health and safety, and therefore the necessary protective measures should be established for personnel involved in such operations.

However, it is possible to find some points of external noise emission that are fairly common in the chemical industry, such as compressors, cooling towers, systems of ventilation and extraction in production buildings, emissions treatment systems, wastewater treatment plants, etc. Depending on the proximity of urban and inhabited areas, these points can constitute a problem in terms of noise emission.

Another diffuse point of noise emissions is noise caused by the circulation of trucks, both in the receipt of raw materials and in the dispatch of finished products, as the continuous traffic of the trucks can lead to high levels of noise pollution.

Noise can therefore be a significant consideration in certain chemical installations that are situated in inhabited areas.

Notable preventive measures are:

- The sound and vibration insulation of the equipment involved.
- Carrying out noise level tests throughout the site.
- The installation of noise screens and plant barriers.
- Carrying out noise level tests within the establishment.
- Not scheduling operations that give rise to noise during night-time hours.

4.4. WASTE: GENERATION AND MANAGEMENT

The waste that is generated in the chemical industry can be in a solid or liquid state, and the latter can be aqueous or non-aqueous (waste solvents and oils).

Solid waste is generated in many sections of the plant, from the warehouse to the workshops, including the production process itself. The nature of this waste is very varied and it includes packaging materials, containers, chemical product remains (from the warehouse, from production, from the laboratory), wastewater treatment sludges, waste from the conditioning of used water (exchange resins, for example), dirty rags, inert waste, waste that is similar to domestic waste, etc.

The aqueous liquids that are managed as waste usually have some kind of characteristic that impedes their treatment in the plant's conventional wastewater treatment installation. These can therefore be water with a very high organic load that is beyond the treatment capacity, with a non-biodegradable load, toxic liquids, water with a high content in salts, etc. Their origin can range from formulation or synthesis (mother liquor) to operations such as centrifuging, some types of cleaning, coolant fluids, etc.

Waste solvents originate in production operations, formulation or synthesis processes, centrifuging, the drying of products and later condensing of the solvent, etc. They are therefore usually spent solvents.

Waste is usually managed in different forms:

- Internal recovery.
- External recovery.
- Internal treatment.
- External treatment.

Examples of recovery, whether internal or external, range from the recovery of packaging, the recycling of solvents, of oil from the workshops, and of scrap metal, to the regeneration of used catalysts and the recovery of cleaning water using membrane filtration techniques.

In situ treatment of waste usually uses techniques based on the reduction of waste volume, with the consequent saving in management costs. Noteworthy examples of this type of treatment are the thermal drying of solid waste with a high water content (wastewater treatment sludges, for example) and the concentrating techniques applied to aqueous waste (osmosis, vacuum evaporation).

On other occasions the waste is treated externally, applying the most appropriate treatment in each case. The external management of waste, including its transport, should be carried out by government-certified transport companies and waste management companies.

The following table summarises the different types of management, according to the nature of the waste:

Table 4.3. Management of waste depending on the nature of the waste

WASTE	PLACE OF GENERATION	MANAGEMENT METHOD
Acid and inorganic base waste (for example sulphuric acid, hydrochloric acid, nitric acid, calcium hydroxide, sodium hydroxide)	Diverse manufacturing and formulation processes	• Recovery: regeneration and recycling of acids and bases • Physicochemical treatment • Recovery of the acid using membrane filtration • Minimisation of waste using the application of vacuum evaporation
Salt and saline solution waste that does not contain heavy metals (sulphates, chlorides, nitrates, etc.)	Mother liquor from processes Regeneration of exchange resins Osmosis rejects	• Recovery: regeneration of inorganic salts using evaporation, drying, scrubbing and purification • Recovery of bases using membrane filtration • Minimisation of waste using the application of vacuum evaporation • Controlled disposal in landfill sites of the solid stabilised salt
Salt and saline solution waste containing heavy metals	Mother liquors from processes Regeneration of exchange resins Osmosis rejects	• Recovery: recycling and recovery of metals using electroplating or physicochemical precipitation. Regeneration of inorganic salts using evaporation, drying, scrubbing and purification • Controlled disposal in landfill sites of the solid, previously stabilised salt • Minimisation of waste using concentrating techniques such as vacuum evaporation or membrane filtration
Mother liquors and cleaning water (water with salt content, surfactant, organic substances)	Manufacturing, reaction and formulation processes Cleaning of equipment	• Recovery: recovery of surfactants using membrane filtration techniques • Minimisation of waste using the application of vacuum evaporation • Physicochemical and biological treatment
Non-halogenated solvents	Mother liquors from manufacturing, reaction and formulation Distillation still bottoms Cleaning and degreasing of equipment	• Recovery: regeneration, recovery and reuse of solvents using rectification and distillation techniques • Energy recovery: use as fuel wherever possible • Incineration of solvent waste

WASTE	PLACE OF GENERATION	MANAGEMENT METHOD
Halogenated solvents	Mother liquors from manufacturing, reaction and formulation Distillation still bottoms Cleaning and degreasing of equipment	• Recovery: regeneration, recovery and reuse of solvents using rectification and distillation techniques • Incineration of halogenated solvent waste
Oils and lubricants, mineral or synthetic, chlorinated	Workshops, maintenance processes, motors and machinery	• Recovery: external regeneration of oils • Incineration of halogenated oil waste
Oils and lubricants, mineral or synthetic, non-chlorinated	Workshops, maintenance processes, motors and machinery	• Recovery: external regeneration of oils • Incineration of oil waste
Filter cakes, absorbent substances and cleaning rags (containing halogenated and non-halogenated compounds)	Filtration and separation processes	• Recovery: regeneration of absorbent products • Stabilisation and controlled disposal of filter cakes and absorbent materials • Incineration
Catalysts containing Ag, Au, Pd, Pt, etc.	Reaction processes, catalytic oxidation of gaseous emissions	• Recovery: recovery of catalysts • Recovery and recycling of metals • Stabilisation and disposal in controlled landfill sites
Catalysts containing hazardous transition metals and other hazardous substances	Reaction processes, catalytic oxidation of gaseous emissions	• Recovery: recovery of catalysts • Recovery and recycling of metals • Stabilisation and disposal in controlled landfill sites
Catalysts containing phosphoric acid	Reactions of organic synthesis	• Recovery: recovery of catalysts • Recovery of the acid using separation membrane technologies
Non-conforming product (raw material, final product, semi-finished product)	Warehouse, process	• Internal recovery: recycling • Stabilisation and disposal in controlled landfill sites
Ion exchange resins	Conditioning of process waters Treatment of wastewater	• Reuse: recycling of used resins • Stabilisation and disposal in controlled landfill sites • Incineration
Activated carbon	Conditioning of process waters Treatment of wastewater Treatment of waste gases	• Recovery: regeneration and recycling of used activated carbon using a desorption process • Stabilisation and disposal in controlled landfill sites • Incineration

WASTE	PLACE OF GENERATION	MANAGEMENT METHOD
Sludges from effluent treatment	Treatment of wastewater	• Minimisation using thermal drying of sludges to reduce the volume of waste • External recovery: agricultural use of compostable sludge • Disposal in controlled landfill sites
Wooden pallets, plastic packaging, metal packaging, glass, paper and cardboard	Warehouse, process, packaging, returns	• Internal or external recovery of packaging • Recycling and reuse of materials: wood, plastic, metal, glass, cardboard, paper, etc. • Disposal in controlled landfill sites
Packaging of hazardous substances	Warehouse, process, packaging, returns	• Recovery, regeneration and reuse of packaging following the prior washing out of content • Disposal in controlled landfill sites • Incineration
Electrical cables, scrap metal	Workshops, maintenance	• Recycling and recovery of metals • Disposal in controlled landfill sites
Cells, batteries, accumulators, etc.	Workshops, maintenance, offices	• Recovery of batteries, cells etc. by an authorised waste manager • Stabilisation and disposal in controlled landfill sites
Toner and ink cartridges	Offices	• Recycling of toner cartridges through an authorised waste manager • Stabilisation and disposal in controlled landfill sites
Food waste	Kitchens, canteens	• Composting • Disposal in landfill sites
Rubble	Demolition, construction work	• Use for filling in sites • Disposal in controlled landfill sites

4.5. SOIL POLLUTION: GENERATION AND MANAGEMENT

Installations in the chemical sector in many cases have the appropriate equipment for containing overflows from the filling of tanks, the washing of manufacturing zones and other uncontrolled discharges or spillages due to rainwater or water used against fires. There are various types of equipment of this nature:

- Asphalt or concrete base with layers of sealed impermeable material or impermeable paint.
- Retention pools in the tank area.
- Perimeter grilles around zones with an overflow risk which drain to the wastewater treatment plant.
- Enclosures and banking to prevent the leakage of liquids on soils that have been rendered waterproof, with suitable coverings on liquids liable to overflow.
- Water collection areas in case of fire or torrential rain.

Despite the fact that companies have installations to prevent soil pollution, if a company is found to have caused pollution of the soil, it should then proceed to decontaminate it.

There is a series of treatment methods or techniques available for decontamination that can be used for different pollutants. A summary of these is provided in the table below:

Table 4.4. Techniques for the treatment of contaminated soil

TECHNIQUE	APPLICATIONS	OBSERVATIONS
Stripping	VOCs	• Extraction techniques for liquids with air or air and steam
Washing	Pollutants that are soluble in water	• Extraction techniques for liquids with water
Chemical treatment	Organic and organochlorine compounds	• Oxidative technique using O_2 and H_2O_2
Electrochemical treatment	Heavy metals (Cu, Pb, Zn, As, etc.) and organic compounds	• Introduction of electrodes into the soil to create electrical fields encouraging the movement of the pollutants
Bioremediation	Organic pollutants, PBCs, organic halogen compounds Hydrocarbons	• These are microbiological treatments in aerobic and anaerobic conditions
Phytoremediation	Heavy metals (Cu, Pb, Ni, Zn, etc.)	• The use of fixing plants for the stabilisation, accumulation or extraction of heavy metals
Incineration	Polyaromatic hydrocarbons, PBCs, chlorophenols, etc.	• Thermal treatment techniques at high temperatures (1000 ºC)
Thermal desorption	VOCs, volatile metals (Hg)	• Thermal treatment techniques at temperatures of between 250 - 550 ºC
Isolation techniques	Highly polluted soils, in extreme cases	• Sealing, enclosing isolating with waterproofing material, soil vitrification, etc.

4.6. WATER CONSUMPTION: GENERATION AND MANAGEMENT

Section 3.10, above, has already shown the most relevant sources of the consumption and use of water in a chemical plant (cleaning, cooling, the process itself, auxiliary equipment and even for the product in itself). Generally speaking, in the majority of industries the general consumption of water is monitored, by taking readings of the supplier company’s meter and/or the installation's own meters, if water is extracted directly from a well.

Apart from the quantitative control of water consumed, it is extremely important to carry out the qualitative control of the parameters of the water, both before its use in the processes and for its reuse (in processes, cleaning etc.) or discharge as waste.

On occasion, specific consumption in process operations and cleaning is also measured, which enables the identification of the points at which the greatest amount of water is consumed and the proposal of savings measures. To this end, one of the techniques for managing the consumption of water in cleaning operations is the optimisation of cleaning techniques and systems and the reuse of used water following its conditioning by filtration. In turn, the water that cannot be reused that comes from processes and cleaning is sent to the wastewater treatment plant.

Those cases where cooling systems do not work in closed circuits should be emphasised, as this involves high levels of water consumption. It is therefore recommendable to work in closed circuits, in order to decrease this consumption.

4.7. ENERGY CONSUMPTION: GENERATION AND MANAGEMENT

The main source of energy consumption in the chemical sector is usually the energy required for boilers for the generation of steam and hot water. Other relevant areas of energy consumption are:

- Generating refrigeration.
- Heating thermal liquids.
- Generating steam and hot water.
- Generating vacuums.
- Energy consumed by motors, pumps, stirrers, grinders, centrifuges, etc.
- Lighting, heating, etc.

To correctly control and manage the consumption of energy, the following measures can be taken in installations in general:

- Designing installations and equipment in a way that is energy efficient, using renewable energy sources.
- Acquiring energy-efficient machinery.
- Making the best possible use of natural heat, light and ventilation.
- Promoting the rational use of energy, switching off equipment, lights, machines, etc. when not in use.
- Minimising losses of heat or cold in working areas and in equipment (cooling, boilers, tubes, reactors, etc.).
- Insulating all pipes and equipment that work with steam, hot water or cooling liquids.
- Implementing automatic control and measuring systems that enable energy consumption to be measured in different equipment so that steps can be established to reduce consumption.
- Studying the possibility of heat recovery, whether from hot gases, steam or hot water.
- Substituting fuels such as diesel and gas oil with natural gas. Gas combustion is the cleanest of all fossil fuel types, as it produces 40 % less carbon dioxide that the combustion of coal and 25 % less than products derived from oil. In addition, it does not emit solid particles or ash and emissions of nitrous oxide are also lower than those of all other fossil fuel types.
- Studying the installation of a cogeneration plant for the production of electrical energy.

As mentioned above, boilers for the generation of heat and hot water are one of the items of equipment with the highest consumption of energy. A number of general recommendations are therefore given below to ensure that they are working at maximum efficiency:

- The recovery and recirculation of condensate from the vapour stream is a major energy saving in a chemical plant. The condensate can also be used for hot water which is required in the process, or can be re vaporised and used as steam.

- With regard to boilers, the correct sizing of this equipment ensures a reduction in heat loss.
- Oxygen levels should be controlled to ensure proper combustion. To do this, the mixture of air (O_2) in the combustion of the fuel must be adjusted. The substitution of solid fuels (coal) and liquid fuels (diesel, gas oil) with natural gas is important as a good housekeeping practice in energy generation.
- The necessary purges should be carried out to avoid excessive increases in salts concentrations and the formation of encrustations that prevent the correct exchange of heat.
- Input water should be treated, eliminating undissolved solids and ions such as lime in order to avoid deposits and the gumming up of pipes.
- Pre-heated water from the cooling of hotter products should be used as input water.
- Heat should be recovered from combustion gases.

5. POLLUTION PREVENTION OPPORTUNITIES (PPO)

The best way of reducing emissions, discharges and waste in general in the industry is their prevention at source. The application of pollution prevention techniques improves the efficiency of the processes used and increases profits, while at the same time minimising the environmental impact of the activity. Minimisation at source can be done in various different ways, whether by reducing the input of raw and auxiliary materials, redesigning the process, reusing secondary products, improving management, reusing resources such as water, increasing energy efficiency, substituting toxic or hazardous products for others that are more benign, etc.

The first consideration as the main measure for environmental improvement is therefore the prevention of pollution at source, which encompasses the organisational, operational and technological necessities required to reduce the quantity or hazardous nature of the waste flows associated with the production process, by means of reduction or recycling at source. It is thus said that the general principles of good practices are based on the three R's:

- Reduce: avoiding the generation of the environmental impact.
- Reuse: reuse wherever this is possible.
- Recycle: putting used material through the required process so that it can be used again.

Finally, suitable treatment should be given to the environmental aspects that are generated.

The use of pollution prevention techniques has many advantages with respect to end-of-pipe solutions, i.e. the use of final treatment techniques. The following list outlines a number of the direct and indirect benefits of prevention:

Direct benefits:

- Reduction in costs for the internal treatment and the external management of waste flows.
- Reduction in production costs as a result of the improved yield and efficiency of the process.
- Savings due to the reuse of products and resources.
- Reduction in costs resulting from the non-fulfilment of legal emissions limits.
- Reduction in secondary emissions, for example from treatment installations.
- Penetration of markets with a high demand for environmentally sound products, which were previously unattainable.
- Minimisation of environmental impact.
- Contribution of an important pedagogical component that has a substantial effect on raising worker awareness.
- Increased safety in the plant with regard to environmental protection.

Indirect benefits:

- Reduction in the possibility of being faced with future costs related to:
- Reparation.
- Legal responsibilities.

- Fulfilment of future regulations.
- Improvement of the company's relationship with and image for the community (people living nearby, etc.).
- Improvement of the working environment as a result of better internal communication and environmental training.
- Reduced social costs.
- Improved public health.

One tool which could be very helpful in identifying opportunities for minimisation and the subsequent application of environmental improvement methods is the implementation of an environmental impact minimisation programme, the development of which is outlined in Point 6.7 of this guide.

Other resources that are complementary to the implementation of a programme of minimisation and good housekeeping practices that contribute to creating an environmentally-sound culture in industry are:

- The implementation of an Environmental Management System, which consists of the organisational structure, procedures, responsibilities, practices and resources that define environmental policy and the means of putting it into practice.
- Life Cycle Analysis (LCA), which serves to identify, classify and quantify the pollutant loads and the material and energy resources associated with a product, a process or an activity from its beginning to its end.
- Environmental Audit, which consists of a systematic, documented, periodic and objective evaluation carried out to check the management system and the environmental behaviour of the company in question.

5.1. STRATEGIES TO PROMOTE THE MINIMISATION OF ENVIRONMENTAL IMPACT AT SOURCE

Pollution prevention can take place at any stage of the development of a process. In general, changes that are made during the research and development phase will have a greater impact. Nevertheless, changes made during the design phases of the process and the operational practices can also have significant results.

Due to the significant investment in technology and the long lifespan of the equipment in a chemical plant, pollution prevention is not easy to implement in the first stages of a process, unless this is done during the design of a new process. Moreover, the producers of certain speciality chemical products are subject to specifications made by clients or regulatory bodies, which limits their flexibility to make changes. Despite these limitations, there are numerous pollution prevention opportunities that can be taken through modifications in existing processes and installations.

To develop the opportunities for minimisation of the environmental impacts generated by an industrial activity and specifically by the chemical sector, a series of strategies must be established with the aim of achieving a cleaner production model.

5.1.1. Optimising the raw materials used

The use of environmentally hazardous substances in the process involves costs related to workplace health and safety and to waste management. One of the strategies that should therefore be considered is the choice of the most appropriate materials from an environmental point of view. A series of criteria are provided below that can be applied wherever possible to support this strategy.

- Using cleaner raw materials and thus avoiding emissions during storage, handling, the process or the elimination of the material as waste.
- Promoting the use of materials originating from renewable sources.
- Promoting the use of raw materials that have been prepared using environmentally sound criteria (for example that the energy used is clean energy).
- Using recycled materials, sub-products, products that do not meet specifications, etc. from the process itself or from others.
- Using recycled materials as part of the process, for example for final packaging.
- Reducing the use of materials.

5.1.2. Optimising production techniques

This strategic factor consists of establishing clean production practices, making the process as respectful as possible of the environment. Some of the criteria that should govern the implementation of this strategy, among others, are:

- Product design that avoids the use of hazardous substances and minimises the use of auxiliary materials.
- Trying to ensure that processes are as efficient as possible to avoid the formation of undesired sub-products.
- The avoidance of leaks and losses during the process.
- Designing processes taking into account the minimum amount of waste generation possible.
- Designing process so that they uses the minimum possible number of steps.
- The reduction of energy consumption or the use of cleaner energy from renewable sources.
- Looking for opportunities for the in situ recycling of waste.

5.1.3. Optimising distribution systems

The application of this strategy ensures that products are transported in the most efficient way possible. Some of the criteria related to this strategy are:

- Using returnable or reusable packaging materials whenever possible, depending on the type of product.
- Optimising the type of storage, transport and logistics of distribution.

5.1.4. Sectoral promotion of clean production

In some countries included within the scope of this guide, initiatives have emerged within the chemical industry itself for the promotion within the sector of pollution prevention and minimisation. For example, the Spanish chemical sector has a voluntary improvement programme, the "**Compromiso de Progreso**" (Progress Commitment), within the international Responsible Care Programme. This encourages companies to follow a code of environmentally responsible practice, with companies committed to carrying out their operations while implementing continual improvements in health, safety and environmental performance. The improvements made in their processes are evaluated regularly.

The objectives of the Progress Commitment Programme are as follows:

- Promoting and achieving continual improvement in companies in matters of health, safety and the environment.
- Establishing qualitative and quantitative targets for improvement to make progress made visible.
- Providing a demonstration to society of the appropriate individual and collective behaviour of the sector.
- Improving the credibility of the industry and increasing society's trust in it through the public presentation of the results obtained.
- Providing companies with a management tool to enable them to continually improve health, safety and the environment while carrying out their activities

For the period 1993-2003, per unit produced, the companies that were participating in the programme achieved an average reduction in pollutant discharges into water of 82 % and in emissions of 52 %.

In terms of safety, the Accident Frequency Index (no of accidents involving absence from work per million hours worked) was reduced by 45 % in the same period, with this index being an average of six times lower than the rate registered for total industrial activities.

On other occasions the different chemical sub-sectors, in collaboration with the Administration, have established voluntary emission reduction agreements. These agreements have enabled certain minimisation objectives to be established, and have shown that significant levels of sustainable development are possible, with the appropriate management of resources and emissions.

For example, the sub-sector of fine pharmaceutical chemicals, represented by AFAQUIM, the Spanish Association of Fine Chemical Manufacturers, has had a voluntary agreement for several years with the Department of the Environment of Catalonia, with which it has already had three collaboration agreements for the reduction of emissions. AFAQUIM has made significant environmental investments and has surpassed the objectives set by the agreements, with excellent results in terms of the minimising of its environmental impact. This shows that significant levels of sustainable development are possible, with the appropriate management of resources and emissions.

As a result of the innovation and investment efforts of the sector and the collaboration of the Department of the Environment, the results attained in achieving the objectives of the first agreement reached 50 % for the organic load and 76 % for matter in suspension.

The improvement was still more noteworthy given that these figures are absolute values, as the sector experienced overall growth of 10 % during those three years. The reduction in flows was also significant, as was the application of "green synthesis", with changes in chlorinated solvents or the application of alternative biotechnologies in aqueous media, which led to significant reductions in the use of solvents.

The second Agreement, from 1998 to 2001, broadened its objectives in terms of waste emissions and the introduction of environmental management systems, signing up to the EMAS register of environmental management and auditing and to ISO 14000 standards. Levels of recovery of 93 % of waste were reached, and a high percentage of companies in the sector have environmental management systems.

Another similar example carried out in Spain but throughout the whole of the chemical industry was the voluntary chemical agreement with the Basque Government. CIMAS dealt with the signature of the agreement and is currently responsible for monitoring its fulfilment.

This voluntary agreement, which was signed electronically in 2003 in Bilbao, took place between 28 companies in the chemical sector and stated a three-pronged aim:

Firstly, the companies that signed the agreement were to optimise their emissions, their discharges into the air and atmosphere, to minimise the generation of waste and/or to improve the recovery of waste. The second objective was for companies to be certified according to an environmental management system, either ISO 14001 or EMAS. Lastly, companies were to attain the objectives proposed by the Integrated Pollution Prevention and Control Directive (IPPC Directive 96/61).

The results for the year 2004 were as follows:

- environmental improvements: reduction in the consumption of raw materials by means of measures to improve processes (consumption reduced by 57 tonnes), reduction in substances emitted into the atmosphere or water by means of prevention measures (53 tonnes of different substances no longer emitted) and a reduction in the generation of waste (284 tonnes).
- improvements in management or processing: 1 installation with ISO 14001 certification.

One of the key factors governing these agreements is the undertaking on the part of both the companies involved and of the Administration, that their commitment to these agreements should go beyond the mere fulfilment of legal requirements. To this end, collaboration has been established between the companies involved and the Basque Government's Department of the Environment and Regional Planning, which has fostered a climate of consensus and exchange of proposals that has been highly enriching for all parties. For the companies involved, the agreements will be converted into a stable long term reference framework within the structure of the Basque Environmental Strategy for Sustainable Development (2002-2020).

The average satisfaction within the sector with regard to the agreements is 7.2 out of 10.

5.1.5. Green chemistry and environmental impact prevention measures

Green chemistry is the use of chemistry to prevent pollution. In particular, green chemistry is the design of products and processes that reduce or eliminate the use or the production of hazardous substances.

By offering alternatives of greater environmental compatibility in comparison with the products or processes that are currently available, which are more hazardous and which are used both by the consumer and in industrial applications, green chemistry promotes the prevention of pollution on a molecular scale.

5.1.5.1. Focal areas of green chemistry

The techniques of green chemistry can be classified into one or more of the following focal areas:

- The use of alternative synthesis routes based on green chemistry.
- The use of alternative reaction conditions based on green chemistry .
- The design of chemical substances that are, for example, less toxic than those that are currently available or substances that are inherently safer with regard to their potential for accidents.

Green chemistry represents an extremely effective means of pollution prevention through the implementation of innovative scientific solutions to resolve real environmental problems by means of voluntary collaboration programmes.

5.1.5.2. The twelve principles of green chemistry

The philosophy of green chemistry can be summarised in certain basic principles:

1. Pollution prevention is better than the later treatment of waste.
2. The methods used for the synthesis of chemical products should be designed for the maximum incorporation of all of the materials used in the process into the final product.
3. The synthesis of chemical products should use and generate substances that are not or are only very slightly hazardous to human health and the environment.
4. Chemical products should be designed in such a way that their functionality and effectiveness are preserved, while their hazardous nature is reduced.
5. The use of auxiliary substances should be avoided or minimised and when they are necessary, they should be harmless.
6. The demand for energy should be minimised, evaluating its economic and environmental impact. The synthesis methods should be carried out at normal air pressure and temperature.
7. The raw materials used and the natural resources consumed should preferably be renewable, provided that this is economically and technically viable.
8. Processes based on direct reactions are preferable to those in which intermediate reactions are required.
9. Catalytic reagents should be selected, as far as possible, to avoid the formation of unnecessary sub-products, and should be used instead of stoichiometric reagents.
10. Chemical products should be designed in such a way that at the end of their useful life they do not remain in the environment and that the products of their decomposition are harmless.
11. The analytical methodologies should enable the control of the process in real time in order to detect the possible formation of harmful substances.
12. The substances and the way in which they are used in a chemical process should be chosen in such a way as to minimise the potential risk of chemical accidents, including leaks, explosions and fires.

5.1.5.3. Examples of the application of green chemistry

CHANGE IN PROCESSES

Green chemistry is for the most part applicable to new processes, developing them from their outset, following the principles of this philosophy and seeking a balance between efficiency and environmental and human safety. Thus reagents that are as efficient as phosgene or non-flammable solvents such as dichloromethane, which are highly suitable from the point of view of the reaction, have toxicity levels that must be borne very much in mind.

In processes that are already established, there may be added problems when changing them for "green" technologies, and these should be considered before embarking on the change. This is the case in the manufacturing sector of pharmaceutical materials. A change in process for this type of product must adhere to complicated regulations laid down by the health authorities when approving any type of variation, which is a serious obstacle to implementing changes.

ENZYMATIC SYSTEMS AS AN ALTERNATIVE TO CHEMICAL SYNTHESIS

The substitution of classical hydrolysis methods for enzymatic methods is a candidate for consideration as a best available technique due to its limited use of solvents and its need for fewer steps than the synthesis process. Processes that require several protection steps for reagent groups, synthesis to introduce the desired radical, lack of protection against groups that were originally blocked to avoid secondary reactions and, on occasion, the separation of the active isomer using several further steps, can be carried out by means of the appropriate enzymes using few stages and directly obtaining the intermediate product desired, with the radical in the correct position and with the intended isomerism.

CHANGING RAW AND AUXILIARY MATERIALS.

As the principles of green chemistry indicate, the synthesis of chemical products should use substances that are not or that are only very slightly toxic to human health and the environment, and to this end the usual solvents should be substituted with others that are less toxic. The raw materials used and the natural resources consumed should preferably be renewable, provided that this is economically and technically viable, and so the use of water or inert gases such as supercritical CO_2 as a reaction medium avoids the toxicity or the difficult elimination of other solvents.

The use of water as a solvent in chemical reactions

- Diels-Alder reactions in water.
- Enzymatic reactions in an aqueous solution.
- Organic reactions mediated by metals in water.

Supercritical fluids

- Chemical processes in dense gaseous phases.
- Catalysis in supercritical CO_2.

Alternative less toxic solvents

Table 5.1. Examples of alternative solvents

Solvent	Less toxic substitute
Benzene	Toluene
Dimethylformamide	1-Methyl-2-pyrrolidone
2-Methoxyethanol	1-Methoxy-2-propanol
n-Hexane	2,5-Dimethylhexane

5.2. EXAMPLES OF OPPORTUNITIES TO MINIMISE ENVIRONMENTAL IMPACT

In order to serve as a guide for the industries in the sector, this section provides a series of examples of environmental aspects and the good housekeeping practices associated with them to minimise their impact.

While the list of examples is not exhaustive, the examples given are sufficiently general so that they can be useful and can be implemented by the majority of chemical industries. Each plant obviously has specific conditions that should be borne in mind when evaluating and designing its individual pollution prevention opportunities.

The most relevant pollution prevention opportunities are outlined below, classified according to the following diagram:

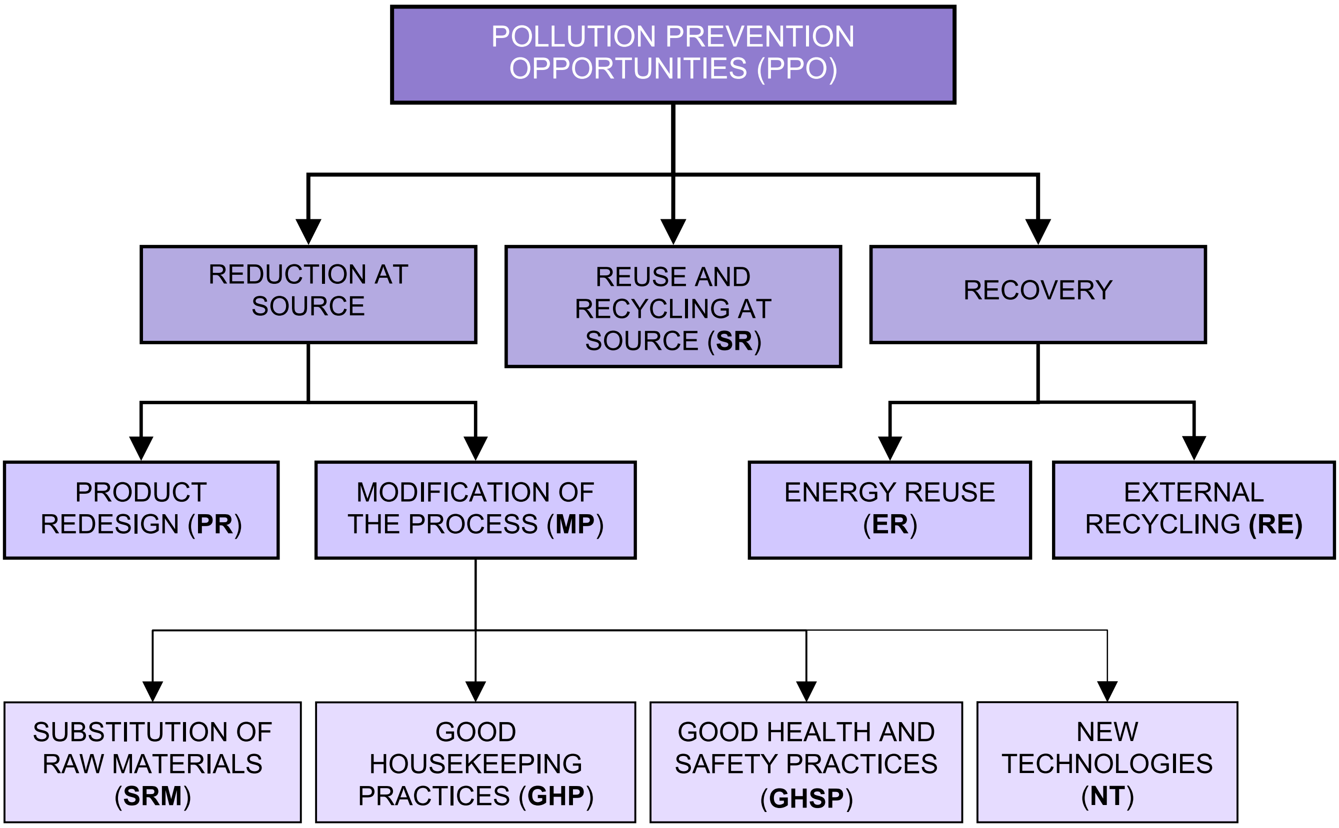


Figure 5.1. Diagram of pollution prevention opportunities

It should also be highlighted that some of the opportunities described could be classified in more than one of the categories mentioned above, and that they can also have positive effects on more than one environmental vector, generating the following environmental benefits:

- Reduced water consumption.
- Reduced energy consumption.
- Reduced consumption of raw materials.
- Reduced pollutant load of wastewaters.
- Reduced atmospheric emissions (more information is required in this regard).
- Reduced quantity of waste produced.
- Improvements for water treatment systems.
- Increased productivity.
- Improved efficiency of cleaning.
- Economic benefits.
- Other environmental improvements.

In each case, and given the abovementioned synergies, the category that is considered most appropriate has been selected.

To quantify the environmental benefit and economic cost, a system of colours has been used, as can be seen in the following table:

Table 5.2. Meaning of colours used to quantify the environmental benefit obtained and the economic cost of a GHP

COLOUR	ENVIRONMENTAL BENEFIT	ECONOMIC COST
	Very good	Low
	Good	Medium
	Moderate	High

The pollution prevention opportunities are listed below, organised according to operations/installations.

5.2.1. PPO in storage, sample taking and loading and unloading of products

Table 5.3. PPO in storage, sample taking and loading and unloading of products

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General	Good environmental management practices	Following the storage requirements for the different materials: storing products and materials according to availability, alterability, compatibility and hazard criteria. Isolating products (flammable, carcinogenic, pestilential) from other products, storing them according to the regulations anticipated for this and placing inert product between incompatible products.	Avoids the deterioration of products, accidental leaks and minimises the effects of accidents. Conservation of tools and installations. A well-managed and well-ordered warehouse leads to a reduction in waste generation and therefore a reduction in the cost associated with management or elimination.		
		Guaranteeing that the elements stored can be identified perfectly.			
		Evaluating the impacts resulting from possible accidents and taking the opportune preventive measures.			
Diffuse emissions of volatile organic compounds and particles	Adaptation of installations and equipment and good environmental management practices	Carrying out transfers in as closed a way as possible: by means of pipes, whether by pump, gravity of by conveyor (solids) to avoid emissions.	Fugitive emissions of volatile compounds are avoided.		
		Carrying out the filling of storage tanks by the lower part to avoid the evaporation of volatiles.			
		Keeping receptacles containing volatile substances hermetically sealed.			
Overflows	Adaptation of installations and equipment	Having retention pools for both fixed tanks and mobile containers and drums.	Minimises the effects of accidental overflows. Savings are made in waste management.		
		Not cleaning overflows with water. Using appropriate absorbent materials.			

Products that have expired	Good management practices	Carrying out appropriate stock management: putting just-in-time criteria into practice in supply and FIFO into practice for warehouse management.	Avoids the deterioration of products and the consequent generation of waste. Reduction in capital invested in stock (assets).		
		Ensuring appropriate purchase management: not purchasing what will not be used.			
Packaging materials	Good environmental management practices	Using returnable packaging.	Avoids the generation of packets and packaging waste. Saves packaging materials.		
		Requesting that suppliers reduce packaging and doing the same for packaging dispatched, provided that this does not affect the safety of the product.			
Type of packaging of supplies	Good management practices	Small containers increase the frequency of loading, unloading, transfers and also increase waste from unusable residue that is left in the container. Using larger containers or ordering products in bulk if large volumes are used. Using storage tanks. Direct supply through pipes.	Minimises the risk of fugitive emissions and accidental overflows and avoids the generation of waste. Economic saving in transport. Minimises the environmental impact due to transportation (emissions, fuel consumption, noise, etc.)		

5.2.2. PPO in measuring, weighing, dosing, handling and internal transportation of products

Table 5.4. PPO in measuring, weighing, dosing, handling and internal transportation of products

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General	Good management practices	Evaluating impact due to possible accidents and taking the appropriate preventive measures.	Anticipating the consequences of possible accidents enables the environmental impact of these accidents to be minimised.		
Diffuse emissions of volatile organic compounds and particles	Adaptation of installations and good management practices	Carrying out weighing in laminar flow booths and volumetric measurement using pipes and pumps.	Minimises the risk of fugitive emissions, overflows, leaks or other emissions, etc. Increased efficiency in the consumption of products.		
		Dosing of the products should be done in the most confined way possible: using pipes, whether by pump, gravity or conveyor.			
		Implementing mechanical dosing systems to make the best possible use of resources.			
		Carrying solids in closed containers.			
Overflows	Adaptation of installations and equipment	Having retention pools for both fixed tanks and mobile containers and drums.	Minimises the effects of accidental overflows. Savings in waste management. Avoids waste passing from one medium to another that is more dispersed and therefore more difficult to contain.		
		Programming effective preventive maintenance of pipes to avoid leaks and overflows.			
		Not cleaning overflows with water. Using appropriate absorbent materials.			
		Minimising the internal transportation of containers and the distances travelled by these.			

5.2.3. PPO in the production process: reaction and formulation

Table 5.5. PPO in production processes: reaction and formulation

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General	Redesign of the process during the R&D phase	Numerous steps in the process generate more opportunities for error. Ensuring that all of the steps taken are necessary.	A good design of the process, with only those steps that are strictly necessary, minimises the risk of errors and of waste generation as a result of these errors.		
	Design of the plant's installations	Designing the layout of equipment to minimise the distance covered by pipelines and the movement of products.	The risk of leaks, drips etc is minimised.		
	Good management practices	Evaluating impact due to possible accidents and taking the appropriate preventive measures.	Anticipating the consequences of possible accidents enables the environmental impact of these accidents to be minimised.		
		Repairing small leakages of steam and non-hazardous substances in pipes within a maximum period of a week following the report of these leaks by any factory operator.	Energy savings. Avoids 10 % of monthly losses. Cleaner installations. Reduction in emissions of VOCs.		
Emissions of gases	Adaptation of installations and equipment	Channelling the points of emissions of the different production equipment to a single point at which the gas treatment system is applied.	The centralisation of emissions at a single point makes their treatment easier.		
	Redesign of the process during the R&D phase	Redesigning the process to avoid the emission of gases: avoiding work carried out at high pressure and high temperatures.	Minimises the impact of emissions of gases.		
Emission of volatile compounds	Adaptation of installations and equipment	Collecting emissions and condensing volatiles. Studying the reuse of solvents recovered in the condenser.	Minimises the impact of the emissions of volatiles at source. Savings in the consumption of solvents.		
	Redesign of the process during the R&D phase	Carrying out the process in an aqueous medium instead of using volatile solvents.	Minimises the impact of VOC emissions due to the use of solvents.		
		Using solvents at higher steam pressure to avoid emissions.			
		Substituting halogenated solvents for others that are less toxic.			
		Working at temperatures as close as possible to normal air temperature. High temperatures increase the evaporation of volatiles.			

Generation of waste	Good environmental management practices	Purchasing raw materials of greater purity.	Less generation of waste and undesired products. Savings in the consumption of raw materials.		
		Reusing solvents as far as possible.			
		Separating waste types.	Avoids the mixing of hazardous waste products with other products that are less hazardous or innocuous. Avoids the passing of a pollutant from a medium that is not highly dispersed to one that is (such as from solid to liquid).		
		Separating different solvents.			
		Isolating liquid waste from solid waste.			
Formation of undesired sub-products	Redesign of the process during the R&D phase	Increasing the process' yield to reduce the formation of sub-products.	Avoids the generation of waste. Increases the capacity of production of the process, with the consequent economic benefits associated with this. Savings in energy consumption.		
		Using products of greater purity.			
		Working at high temperatures can products heavy compounds (tars) that dirty the equipment: Working at lower temperatures and using heat exchangers to avoid localised temperatures that are too high.			
Overflows	Adaptation of installations and equipment	Having retention pools for both fixed tanks and mobile containers and drums.	Minimises the effects of accidental overflows. Savings in waste management. Avoids waste passing from one medium to another that is more dispersed and therefore more difficult to contain.		
		Programming effective preventive maintenance of pipes to avoid leaks and overflows.			
		Not cleaning overflows with water. Using appropriate absorbent materials and diverting to the wastewater treatment plant when collection is impossible.			
Generation of waste process waters	Redesign of operations and good housekeeping practices	Carrying out formulation or synthesis in the smallest possible amount of water.	Minimises the generation of wastewater at source. Savings in water consumption and in water treatment costs.		
		Using membrane filtration units for the recovery of water so that it can be reused in formulation.			
	Good environmental management practices	Separating waste flows from the process wherever possible: the mixing of flows of waste products can provide an obstacle to reuse, recycling and treatment.	The separation of waste flows facilitates the reuse, recycling and treatment of these flows.		
		Avoiding contamination from rainwater by the use of separate networks for wastewater and rainwater, covered process equipment, runoff trays and separate drainage.			

5.2.4. PPO in separation, purification and final conditioning operations

Operations of purification and separation include: crystallisation, screening, centrifuging, extraction and adsorption.

The following operations are encompassed in final conditioning: grinding, atomising, micronising, drying and packaging.

Table 5.6. PPO in separation, purification and final conditioning operations

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General	Good management practices	Evaluating impact due to possible accidents and taking the appropriate preventive measures.	Anticipating the consequences of possible accidents enables the environmental impact of these accidents to be minimised.		
Product residue	Good operational practices	Avoiding product residue being left on equipment: good cleaning and removal of the product from equipment.	Improves process yield and minimises waste.		
Diffuse emissions of volatile organic compounds and particles	Adaptation of installations and equipment	Collecting emissions and condensing volatiles. Studying the reuse of solvents recovered in the condenser.	Minimises the impact of the emissions of volatiles at source. Savings in the consumption of solvents.		
	Good management practices	Carrying out weighing in laminar flow booths and volumetric measurement using pipes and pumps.	Minimises the risk of fugitive emissions, overflows, leaks or other emissions, etc. Increases efficiency in the consumption of products.		
		Dosing of the products should be done in the most confined way possible: using pipes, whether by pump, gravity or conveyor.			
		Implementing mechanical dosing systems to make the best possible use of resources.			
		Carrying solids in closed containers.			
Emissions of dust from solid products	Adaptation of installations and equipment	Working with closed systems of confined pneumatic transportation, in closed premises with forced air and systems of collecting solids in filters and appropriate solid washers.	Avoids the transfer of solid waste to a more disperse medium.		
		Installing a local suction apparatus in places where grinding, micronising etc. are carried out. Suction air should be filtered or wet washed.			

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Filter cakes, filtering media, resins, activated carbon, etc.	Good operational housekeeping practices	Managing waste in accordance with environmental regulations.	Fulfilment of legislation: avoids sanctions.		

5.2.5. PPO in cleaning operations

Table 5.7. PPO in cleaning operations

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Wastewater containing product residue and residue of cleaning agents (detergents, solvents, etc)	Good operational housekeeping practices and adaptation of installations and equipment	Planning production and / or the use of equipment by product lines, in order to minimise cleaning required.	Minimises the generation of wastewater. Saves water and reduces costs of the treatment of wastewater finally generated in cleaning processes. Reduces the final volume of discharge. Economic reduction in water expenses. Efficient cleaning saves resources and cleaning agents and avoids the generation of waste, wastewater and emissions.		
		Avoiding excessive use of chemical products and solvents for cleaning operations.			
		Using biodegradable cleaning products.			
		Using high pressure water equipment for cleaning surfaces, installing pressure nozzles on hoses or by using mobile units with water at high pressure and low flow.			
		Using CIP (Cleaning In Place) units for equipment, which enable cleaning to take place with low consumption of washing liquids, directly in place, using pressure sprinklers and recycling of wash liquids, with no need to disassemble pieces and with control of the water consumption level. Equipment is fitted with balls that distribute the cleaning substance (detergent, alcohol, solvent, according to the product to be cleaned) at pressure, followed by pressurised water. The equipment is air dried or dried by heating the reactor liners. The water used is channelled to a tank or to the wastewater treatment plant.			
		Reusing cleaning water for other cleaning, after the application of tangential membrane filtration to condition the water.			
		Having a wastewater treatment plant capable of absorbing the inevitable discharge resulting from cleaning.			

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Wastewater containing product residue and residue of cleaning agents (detergents, solvents, etc.)	Good hygiene practices	Isolating, collecting and cleaning: in leaks and overflows this means a reduction in the volume and in the pollutant load of wastewater generated.	Reduces pollution, enables recovery of the product that has overflowed, minimises the need for water or cleaning products.		
Solid product remains	Adaptation of installations and equipment	Using cleaning systems with suction or mechanical collection before using water or solvents.	Avoids the passing of solid waste into a more disperse medium.		
Emission of volatile organic compounds, especially if solvents have been used in the cleaning process	Adaptation of installations and equipment and good housekeeping practices	Collecting emissions and condensing volatiles. Studying the reuse of solvents recovered in the condenser.	Minimises the impact of the emissions of volatiles at source.		
		Not using halogenated solvents in cleaning operations.	Savings in the consumption of solvents.		

5.2.6. PPO in cooling systems

Table 5.8. PPO in cooling systems

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Improved efficiency	Adaptation of installations and equipment	Exposing the maximum possible surface area of water to contact with the air circulated in the cooling towers.	Energy savings.		
Generation of wastewater Excessive water consumption	Good housekeeping practices GHP	Recycling cooling water from the process wherever possible.	Savings in water consumed.		
CFC emissions	GHP / product change	Using alternative refrigerants to CFCs, such as ammonia, HCFCs, glycol, lithium bromide, etc.	Avoids the emission of CFCs, which contribute to the greenhouse effect.		

5.2.7. PPO in wastewater treatment installations

Table 5.9. PPO in wastewater treatment installations

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Generation of wastewater	Redesign of processes, operations and good housekeeping practices	Avoiding the discharge of untreated wastewater.	Minimises wastewater treatment costs. Fulfilling legislation: avoids sanctions and damage to the environment. Avoids the social consequences and image damage caused by pollutant discharges.		
		Avoiding the generation of wastewater at source by waste stream minimising projects.			
		Recycling all the water possible following its appropriate treatment.			
Treatment of wastewater	Good operational housekeeping practices	Correct categorising of all flows of wastewater, both in terms of composition and volume. Separating water that is untreatable by the treatment plant and providing the specific treatment or management required.	Avoids inadequately treated discharges that do not fulfil applicable legislation. Avoids impact on the receiving medium.		
		Viability studies and studies of the optimisation of treatments and treatment installations.	Optimises the quality of treated wastewater.		
	Redesign of the process during the R&D phase	Evaluating whether the chemical agents used (such as solvents, heavy metals) can be substituted in the process with others that are less toxic or less persistent.	Avoids the discharge of toxic substances along with wastewater. Enables the reuse of treated water.		
Emission of volatile compounds and gases	Redesign of the process during the R&D phase	Avoiding the use of solvents or, where this is not possible, separating them from the aqueous medium in the phases of the process.	Minimises the emission of pollutants at source.		
	Adaptation of installations and equipment	Carrying out the aeration of water in the treatment plant in closed tanks fitted with valves for gases and volatiles and subsequently treating said gases and emissions appropriately (for example activated carbon filters).	Avoids the impact of the emission of volatile substances if these have not been fully separated from the aqueous medium.		
Generation of solid waste	Good operational housekeeping practices and adaptation of equipment and installations	Minimising the waste generated during water treatment: using sludge drying systems.	Reduces the volume of waste generated, economic savings in the final management of this waste.		
		Correctly managing waste generated, in accordance with applicable legislation, prioritising its reuse, use as a sub-product (in agricultural applications, for example) or its recovery.			

5.2.8. PPO in atmospheric emissions treatment installations

Table 5.10. PPO in atmospheric emissions treatment installations

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Generation of atmospheric emissions	Redesign of the process during the R&D phase	Avoiding emissions at source by avoiding the use of volatile solvents in the different phases of the process.	Minimises the emission of pollutants at source.		
	Adaptation of installations and equipment	Confining, condensing and reusing solvents as many times as possible.	Savings in the consumption of raw materials, minimisation of possible emissions at source and internal recovery of solvents.		
		Using internal containment systems and collection systems for dust such as cyclones, dust scrubbers and filters.	Avoids the emission of dust into the environment. Reprocessing and marketing of these fines.		
	Good operational housekeeping practices	Working in closed systems and equipment with controlled ventilation and using pneumatic vacuum or air pressure transport systems from dryers, filtering the air used.	Avoids the emission of dust into the environment		
Generation of wastewater	Good operational housekeeping practices	Recirculating the water from the gas scrubbing towers as much as possible. Purges from the circuit should be sent to the wastewater treatment plant or managed appropriately.	Minimises the generation of wastewater and saves water.		
Generation of solid waste	Good operational housekeeping practices	Appropriate management of waste generated, prioritising its reuse: for example, regenerating activated carbon from filters.	Reduces the volume of waste generated, provides economic savings in the final management of waste.		

5.2.9. PPO in waste management and treatment installations

Table 5.11. PPO in waste management and treatment installations

<table>
<tr><th>POTENTIAL PROBLEM / ASPECT AFFECTED</th><th>CLASSIFICATION OF THE PROPOSED SOLUTION</th><th>PROPOSED SOLUTION</th><th>ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED</th><th>ENVIRON-MENTAL BENEFIT</th><th>ECONOMIC COST</th></tr>
<tr><td rowspan="12">General</td><td rowspan="6">Good environmental operational practices</td><td>Separating and conditioning different containers for each type of waste, taking the hazardous nature of certain waste into account.</td><td rowspan="6">The correct management of waste leads to economic savings in the management process.

Minimises the production of waste.

Internal recovery of waste.

Internal or external recovery of waste. Economic saving in waste management.

Fulfilment of legal requirements for waste management.

Minimises diffuse emissions of volatile compounds.</td><td></td><td></td></tr>
<tr><td>Reusing waste wherever possible.</td><td></td><td></td></tr>
<tr><td>Studying the possibility of selling waste as a sub-product or of its recovery</td><td></td><td></td></tr>
<tr><td>Managing the packaging of hazardous waste, rags and other impregnated materials as hazardous waste.</td><td></td><td></td></tr>
<tr><td>Managing cleaning rejects containing chemical products as hazardous waste.</td><td></td><td></td></tr>
<tr><td>Closing receptacles containing hazardous waste such as solvents carefully, in order to avoid emissions of VOCs.</td><td></td><td></td></tr>
<tr><td rowspan="6">Good environmental management practices</td><td>Using elements that contain recycled materials such as recycled plastics and paper.</td><td rowspan="3">Minimises the production of waste. Fulfilment of legal requirements for waste management.

Recovery of waste.</td><td></td><td></td></tr>
<tr><td>Using products with packaging that has high potential for recycling.</td><td></td><td></td></tr>
<tr><td>Managing rejects such as used solvents through “Sub-product banks”</td><td></td><td></td></tr>
<tr><td>Rejecting materials that are transformed into toxic or hazardous waste at the end of their use, such as organochlorinated elements (PVC, CFC).</td><td>Avoids the generation of toxic and hazardous waste.

Avoids the mixing of hazardous products with innocuous products.</td><td></td><td></td></tr>
<tr><td>Separating or segregating waste in general.</td><td>Isolates liquid waste from solid waste.</td><td></td><td></td></tr>
<tr><td>External management of waste that cannot be internally recovered following appropriate treatment using specialised transport firms.</td><td>Removes the possibly hazardous nature of the waste or possibility of disposal in an authorised landfill site</td><td></td><td></td></tr>
</table>

5.2.10. PPO for noise and vibrations

Table 5.12. PPO for noise and vibrations

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General: generation of noise and vibrations	Good operational housekeeping practices	Isolating sources of noise, confining them to closed spaces (for example having compressors in a closed and soundproofed room). Installing acoustic barriers.	Minimises the generation of noise.		
		Operating equipment only when absolutely necessary to avoid the emission of noise.			
		Using less noisy equipment and utensils and keeping them disconnected when not in use.			
General: generation of noise and vibrations	Good operational housekeeping practices	Establishing a programme for the control of noise and vibrations, which should include a minimum of the following elements: Initial and periodic checking of noise levels. Initial and periodic hearing tests for exposed workers. Applying preventive measures: isolating and closing off of sources, using individual protective equipment, etc.	Fulfilment of environmental and workplace health and safety regulations with respect to noise and vibrations.		

5.2.11. PPO for water consumption

Table 5.13. PPO for water consumption

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Excessive water consumption	Good operational housekeeping practices and adaptation of installations and equipment	Taking an inventory of water consumption in order to be able to promote its reduction in different sectors.	Awareness of the points of greatest water consumption before promoting savings. Possible reuse of wastewater in specific processes, such as in preliminary rinsing.		
		Periodic checking of the state of containers and stopcocks by maintenance personnel to avoid leaks.	Minimises losses and the consumption of water in general.		
		Requesting inspections of plumbing installations to detect leaks and drips.			
		Ensuring that taps in laboratories are not left on unnecessarily.			
		Installing automatic systems for the cleaning of equipment.			
		Using pressure equipment for the cleaning of equipment.			
		Cleaning paved surfaces using automatic sweepers.			
		Installing pressure-limiting devices to reduce water consumption.			
		Reusing water from cleaning in cleaning operations or in production.			
		Substituting liquid ring vacuum pumps for dry pumps.			
		Implementing procedures to minimise the consumption of industrial water: savings will be made on the quantity used and drainage will be made easier.			

5.2.12. PPO for energy consumption

Table 5.14. PPO for energy consumption

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Excessive consumption of electrical energy	Good operational housekeeping practices and adaptation of installations and equipment	Noting the electricity consumption of the different equipment to be able to promote savings in different sectors.	Savings of electrical energy.		
		Making the most of natural light.			
		Installing timed switches in areas where work does not take place continually in order to ensure that lights are not left on.			
		Regular cleaning of lighting systems to ensure that there is nothing affecting light intensity.			
		Carrying out energy audits within the company to set objectives for reduction.			
		Implementing quality controls during the energy saving process.			
Energy efficiency of installations and equipment: heat loss, excessive energy consumption	Good operational housekeeping practices and adaptation of installations and equipment	Evaluating the energy variable when choosing new equipment.	Improved energy efficiency of processes and installations in general.		
		Optimising processes to avoid energy losses.			
		Insulating pipes, tanks, exchangers and any other equipment applicable to avoid heat losses.			
		Using the hot streams on output from the process to reheat the input to the process itself by means of heat exchangers.			
		Using clean energies and/or high efficiency fuels.			
		Heat insulating tanks containing hot liquids			
		Calibrating and carrying out preventive maintenance on machinery as this saves energy.			
		Recovering residual heat in steam from boilers and making use of it to preheat water: for each increase of 7 ºC in water temperature, 1 % of fuel is saved in the boiler.	Minimises heat loss, saves fuel.		
		Controlling excess air in combustion.	Improved efficiency of combustion reduces the consumption of fuel and minimises the emission of toxic gases.		
		Controlling the percentage of CO_2 in smoke, providing the correct mixture of air and diesel.			
		Substituting diesel with natural gas. Natural gas has a greater yield and enables better control of combustion.	Reduced emissions of SOx and NOx.		

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Energy efficiency of installations and equipment: heat loss, excessive energy consumption	Good operational housekeeping practices and adaptation of installations and equipment	Using energy from renewable sources as much as possible: thermal and photovoltaic solar energy.	No need for fossil fuels for operation. Reduced emissions of SOx and NOx. No noise produced. No need for major infrastructures for distribution.		
	Good Housekeeping Practices: Steam boilers, steam distribution	Correct insulation of vapour streams. Inadequate or non-existent insulation of vapour streams is the greatest source of heat loss in the chemical industry. Moreover, it also results in excessive condensation in pipes, which has a negative effect on the quality of steam and on the productivity of the machinery.	Energy savings.		
		Recovering and recirculating condensates from the vapour stream constitutes the greatest energy saving in a chemical plant. Condensates can also be used as hot water, which is required in the process.			
		The steam distribution system should cover the smallest distance in the narrowest pipes possible, with the minimum condensation possible and with the minimum loss of pressure possible.	Minimises heat loss.		
		Regulating purges from the boiler automatically depending on conductivity and recovering the revaporised material and condensate.	Water and energy savings.		
		Using fluidised bed boilers to ensure efficient combustion	Energy savings.		

5.2.13. PPO in process water treatment

Table 5.15. PPO in process water treatment

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
Excessive energy consumption	Good operational housekeeping practices and adaptation of installations and equipment	The incorrect treatment of feed water can result in significant heat loss due to the encrusting of heat boilers, heat exchangers, reactor liners, pipelines, etc. It is therefore important to treat process water correctly: decalcifying, deionising, reverse osmosis, etc.	Minimises heat loss.		
		Parameters such as hardness, alkalinity, pH etc. should always be controlled.			

5.2.14. PPO in staff sensitisation and training. Environmental communication.

Table 5.16. PPO in staff sensitisation and training. Environmental communication.

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General	Good housekeeping and hygiene practices	Staff should be aware of the environmental implications related to the process and to their place of work. It is therefore useful to organise courses, seminars, conferences, etc. for worker training, motivation and sensitisation.	Increases efficiency of processes. Prevention of workplace risks and increased health and safety. Increases efficiency of processes. Prevention of workplace risks and increased health and safety.		
		Workers should be aware of the risks associated with their job and should know how to use the protective equipment available correctly, together with the applicable safety signs.			
		Joint work and sharing information to enable workers to carry out their habitual tasks and contribute to the global objective of prevention.			
		Carrying out information campaigns among the staff concerning energy saving.	Energy savings.		

5.2.15. PPO in preventive maintenance

Table 5.17. PPO in preventive maintenance

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General	Good housekeeping practices Good hygiene practices	Designing a programme of preventive maintenance that includes: an inventory of equipment a record sheet with the state of each machine an inventory of incidents and breakdowns	Avoidance of accidental halts to production: the probability of generating products that do not meet specifications and of waste is reduced. Savings of raw materials. Avoids the generation of products that do not meet specifications. Minimises the risk of accidents. Avoids the generation of pollution. Prevents breakdowns before they can cause production losses, generate pollution or affect the health of workers.		
		Technical instructions and written procedures for action.			
		Identification of non-conformity and proposal of corrective measures.			
		Monitoring and control of processes and activities.			
		Emergency and Communication Plan.			

5.2.16. PPO in the implementation of an environmental management system (EMAS or ISO 14001)

Table 5.18. PPO in the implementation of an environmental management system (EMAS or ISO 14001)

POTENTIAL PROBLEM / ASPECT AFFECTED	CLASSIFICATION OF THE PROPOSED SOLUTION	PROPOSED SOLUTION	ENVIRONMENTAL, ECONOMIC AND SOCIAL BENEFITS OBTAINED	ENVIRON-MENTAL BENEFIT	ECONOMIC COST
General environmental policy of the company.	Good housekeeping practices	Integration with quality management and workplace risk prevention.	Helps to implement good environmental practices. Improves the company's image. Implementation of best available techniques that are economically viable. Obtaining environmental certification from an accredited body.		
		Carrying out an initial diagnostic environmental evaluation.			
		Detecting the significant environmental aspects.			
		Defining applicable regulations in environmental matters.			
		Defining environmental objectives and targets to reach.			
		Defining the company's environmental policy.			
		Improving training and internal and external communication.			
		Producing an environmental management manual to be available to those interested.			
		Drawing up an environmental management programme in which the economic data, timescales and people responsible for the proposed measures are provided.			
		Registering documentation physically and digitally.			
		Carrying out corrective and preventive measures.			
		Carrying out environmental audits.			

6. CASE STUDIES

6.1. PROCESS MODIFICATIONS

CASE STUDY 1	
Company	Elastogran, S.A.
Country (location)	Spain (Rubí, Barcelona)
Industrial sector	Chemical. Manufacture of polyurethane systems for the automobile and construction industries and others.
Subject of the project	Process modifications: Improvements to the cleaning system: the CIP (Clean In Place) system.
Environmental considerations	Elastogran SA develops and manufactures polyurethane systems and markets the raw materials for polyurethane and cellular thermoplastic polyurethane. The principal target markets for these products are the automobile industry, the construction industry, the refrigeration industry, the furniture industry, the footwear industry and insulation. A batch production process is used and is based mainly on the mixture of raw materials (polyols or isocyanates) and other auxiliary materials (catalysts, expanders, fire resistant materials, colourants and additives) to obtain liquid polyurethane components (formulated polyols and isocyanates), which are used by the conversion companies to produce polyurethane. Together the two components formulated are known as a polyurethane system. Occasionally, a system can consist of three or more components as a result of the incorporation of auxiliary additives. To obtain the two components formulated, the company uses mixing containers (reactors) of different capacities. The dosing and mixing process is highly automatic and is managed by PLC. When the mixture has been made and the formulated liquid product has been obtained, the next step is its storage and distribution to the client. The system that was previously used to clean the reactors was entirely manual, using pressurised water. Due to the low solubility of the products in water, large amounts were needed to ensure the complete cleaning of the reactors. The cleaning water was collected in containers and managed as waste.
Background	In line with the commitments of its quality and environmental policy ELASTOGRAN, S.A., decided to adapt and rationalise its cleaning system. The actions taken were based on the following premises:

- A reduction in the quantity of water used in cleaning the installations.
- The maximum possible reuse of the products resulting from cleaning.

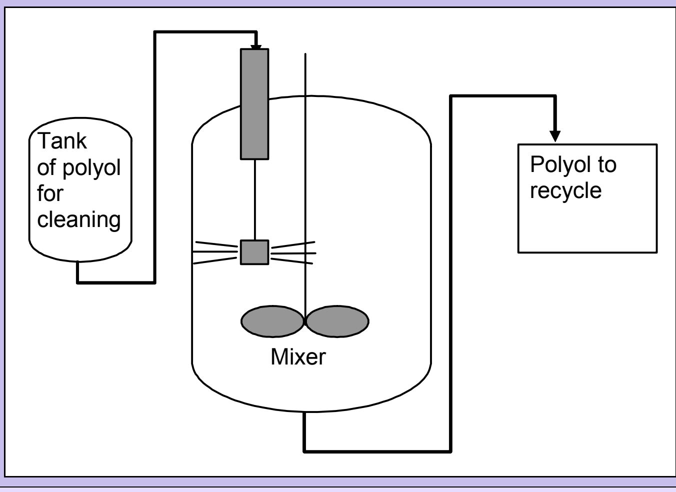
Summary of actions

The objective of the action is to substitute the cleaning water from most of the processes with reusable polyols.

This action consists of installing an automated controlled cleaning system (PLC) which consists of rotating nozzles inside the mixing containers, which are connected to 2 tanks of heated polyols for cleaning.

Once the cleaning has been carried out, the used polyols are stored in separate containers, according to the type of product, and are reused as raw materials in later manufacturing of the same products.

Process Diagram



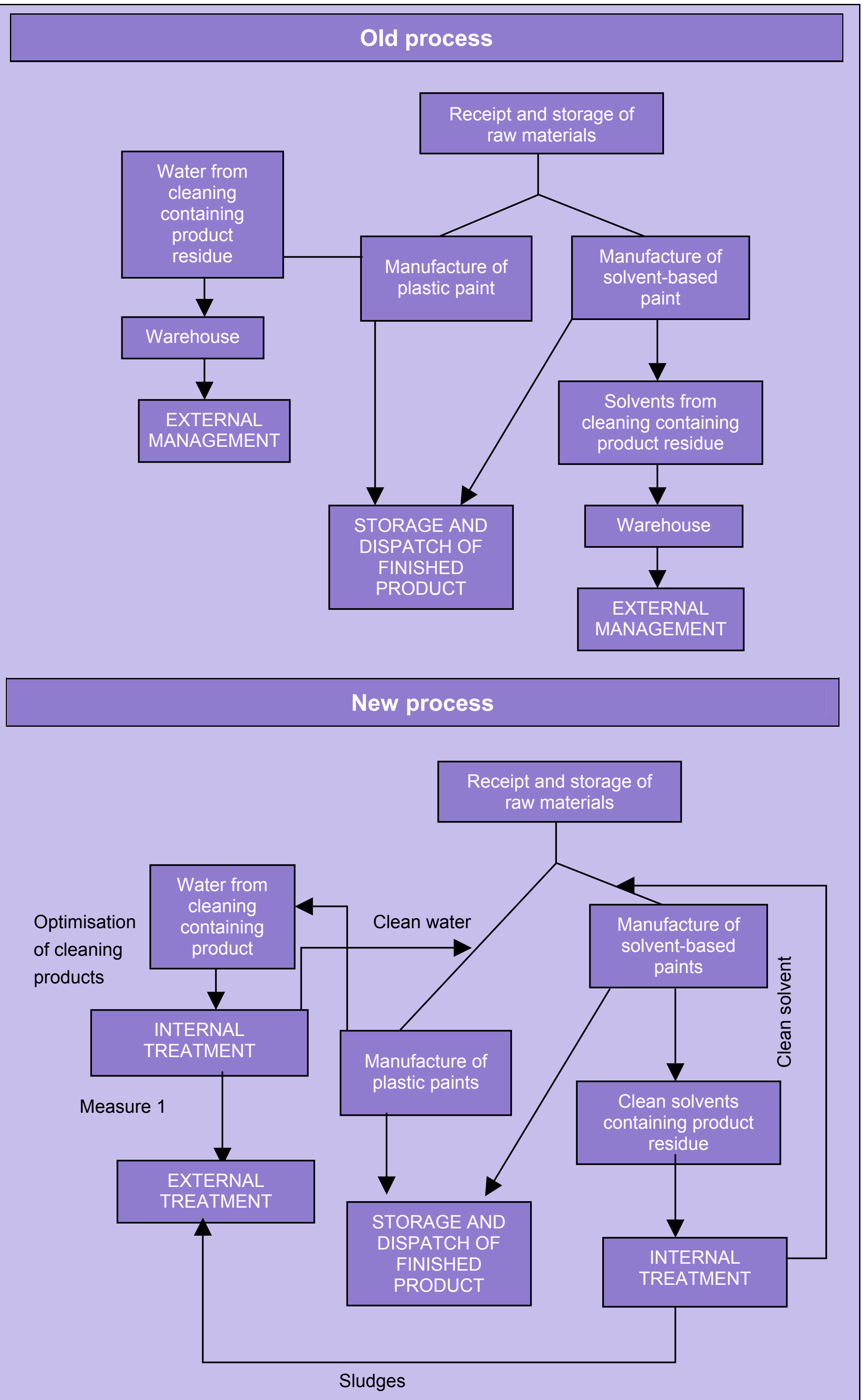
Balances

	Old process	New process
Balance of material		
Production	24,239 mT/y	**37,565 mT /y**
Waste cleaning water to be treated	77,860 l/y	**31,120 l/y**
Wastewater/tonne	3.21 l/ mT	**0.82 l/mT**
Wastewater	100 %	**25 %**
Economic balance		
Water costs	€70.07 /y	**€37.34 /y**
Waste cleaning water management costs	€25,140.00 /y	**€12,567.00 /y**
Savings		
Savings in water consumption	€32.73 /y	
Savings in the management of waste cleaning water	€12,483.00 /y	
Total savings	**€12,515.73 /y**	
Investment in installations	**€36,061.00**	
Payback period	**2.9 years**	

Conclusions	Carrying out this project has resulted in a reduction in the volume of waste originating from the cleaning of the mixing containers by some 75 % and the quantity of water used to this end has also been reduced. In addition, with the introduction of an automated system, the quality of cleaning has also been improved. This action of pollution prevention at source is the consequence of the environmental policy of Elastogran, S.A., as it falls within the framework of continual improvement undertaken by the company in 1997. In 2001, the company carried out a Minimisation Opportunities Environmental Diagnosis (MOED) in collaboration with the Centre for the Enterprise and the Environment and obtained EMAS certification that same year.

CASE STUDY 2	
Company	PINTURAS JALLUT IBÉRICA, S.L.
Country (location)	Spain (Polinyà, Barcelona)
Industrial sector	Manufacture of paints, varnishes and similar coating products.
Subject of the project	Process modifications: Reduction and recycling at source of water and solvents from cleaning.
Environmental considerations	In the manufacturing process of plastic paints, enamels and varnishes, the waste streams that are generated at the cleaning stage are, among other things, solvents that are contaminated with pigment residues and resins and water that are contaminated with solvents and/or pigment residues. This cleaning waste (solvents and water) was usually treated externally as liquid industrial waste. In the case of contaminated solvents, a percentage of these solvents, once distilled, was returned to the company and reused at the cleaning stage.
Background	The company Pinturas Jallut Ibérica decided to carry out a Minimisation Opportunities Environmental Diagnosis in collaboration with the Centre for the Enterprises and the Environment with the aim of reducing the generation of this type of waste (among other things), and secondly of recycling at source what waste that was left after these reduction actions.
Summary of actions	The company optimised the cleaning process by carrying out a series of actions to achieve both the reuse of the water and of the solvent used in the stage mentioned above. The optimisation of the process of cleaning with water was achieved by: • the installation of end-controlled high-pressure hoses with water flow control, which allow a reduction in the quantity of water used in the cleaning of installations used for the manufacture of plastic paints; and • as a complementary measure to this reduction at source action, equipment was installed for the physicochemical treatment (flocculation - coagulation and decantation) of the cleaning water to enable its reuse in the process. The optimisation of the process of cleaning the installations intended for the manufacture of enamels and varnishes with solvent was approached by taking into consideration an alternative involving recycling at source, with the installation of distilling equipment for the recovery of the solvent and its later reuse in the process. With this action, the company was able to reduce waste flows corresponding to water and solvents from cleaning by 100 %, generating two new waste flows as a consequence of this action: the sludges from the physical-chemical treatment process, and those from the solvent recovery process, respectively.

Diagrams



Old process
Receipt and storage of raw materials
Water from cleaning containing product residue
Manufacture of plastic paint
Manufacture of solvent-based paint
Warehouse
EXTERNAL MANAGEMENT
Solvents from cleaning containing product residue
STORAGE AND DISPATCH OF FINISHED PRODUCT
Warehouse
EXTERNAL MANAGEMENT
New process
Receipt and storage of raw materials
Optimisation of cleaning products
Water from cleaning containing product
Clean water
Manufacture of solvent-based paints
Clean solvent
INTERNAL TREATMENT
Measure 1
Manufacture of plastic paints
Clean solvents containing product residue
EXTERNAL TREATMENT
STORAGE AND DISPATCH OF FINISHED PRODUCT
INTERNAL TREATMENT
Sludges

Balances	(see table below)

	Old process	New process
Balance of materials for the cleaning stage		
Consumption of water	150 mT/y	**20 mT/y**
Consumption of solvent	7 mT/y	**1 mT/y**
Consumption of reagents for the physicochemical treatment of wastewater	0 mT/y	**2 mT/y**
Wastewater treated externally	150 mT/y	**0 mT/y**
Contaminated solvent managed externally	7 mT/y	**0 mT/y**
Generation of sludges from the physicochemical treatment of wastewater	0 mT/y	**30 mT/y**
Generation of waste from the distillation of the solvent	0 mT/y	**2 mT/y**
Economic balance of the cleaning stage		
Water consumption costs	€161.37 /y	€21.52 /y
Solvent consumption costs	€6,310.63 /y	€1,262.13/y
Wastewater management costs	€18,030.36 /y	€1,923.24 /y
Costs of management of solvent as liquid waste	€2,103.54 /y	€0 /y
Costs of management of sludges from physical-chemical treatment of wastewater	€0 /y	€6,310.63 /y
Costs of management of solvent distillation waste	€0 /y	€1,442.43 /y
Savings	€15,645.97 /y	
Investment End-controlled high-pressure hoses, solvent recovery equipment and physicochemical treatment unit	€50,611.23	
Payback period	3.23 years	

Conclusions

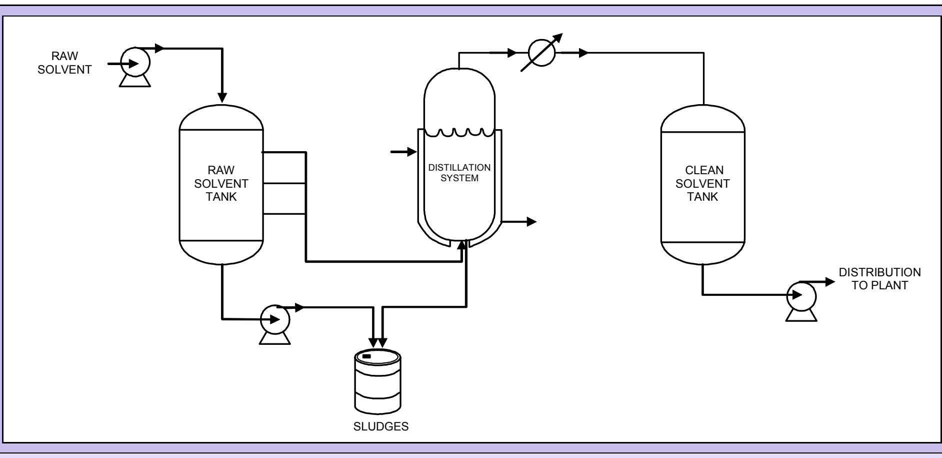
A combination of alternatives for reduction and recycling at source have enabled the company to optimise the cycles of water and solvents used for the cleaning stage. Having used the approach of adopting equipment that enables savings to be made in the amount of water used, this enabled the physicochemical treatment equipment of this water to be designed correctly, ensuring that it was not excessively large.

This action is an example of how minimisation actions can be combined in order to achieve the optimisation of processes, a reduction in the consumption of materials and resources and a decrease in waste flows generated.

6.2. RECOVERY AND RECYCLING AT SOURCE

CASE STUDY 3	
Company	Tintas K+E, S.A.
Country (Location)	Spain (Vilanova del Vallès, Barcelona).
Industrial sector	Manufacture of inks and varnishes for the graphic arts.
Subject of the project	Recovery and recycling at source (recovery of solvents used for cleaning using vacuum distillation)
Environmental considerations	The industries that manufacture inks with an organic solvent phase consume large quantities of these products, which are used both in the process of manufacturing the inks itself, with raw materials and in the cleaning operations of machines and manufacturing apparatus. The raw solvents, with pigment and resin residue, constitute special waste.
Background	Before this project was put into action, Tintas K+E, S.A. stored the contaminated solvent until a sufficient volume was accumulated to be able to send it for external treatment, during which a part of the solvent was recovered. This involved significant expenditure and the final destruction of over 70 % of the solvent, which once treated externally did not reach the minimum quality necessary for its use in cleaning operations within the company. In addition to the implementation of measures with the objective of reducing the consumption of solvents in the manufacturing and cleaning processes, Tintas K+E, S.A. decided to carry out this project, on the one hand, for the savings in virgin solvent that it could imply, and on the other hand, to reduce the expenses generated by the treatment of contaminated solvents, carried out by third parties.
Summary of actions	Installation of a compact vacuum distillation system for the continuous recovery of solvent. Of the contaminated solvent used in the cleaning of the installations 90 % is fed into the distillation system. The remaining 10 % must be managed as special waste due to its composition. The contaminated solvent, consisting of a mixture of solvents with residue of pigments and resins, is loaded into a first tank from which the solids are decanted. From there it is transferred to the boiler of the distillation equipment. The boiler has a system of levels, which detects the levels of sludge accumulated. When this level reaches a preset maximum, the process is halted and the boiler is emptied and cleaned. The clean solvent recovered is stored in a second tank, from which it is distributed to the points of use. With the current system of recycling at source, the quantity of virgin solvent to be incorporated into the distilled solvent to clean the installations corresponds to approximately 30 % of the total quantity of solvent used in the cleaning operations. Before this system was installed, virgin solvent corresponded to approximately 87 % of the total solvent used in cleaning operations.

Diagrams



Balances

	Old process (1992)	New process (1996)
Balance of materials		
Contaminated solvent recovered at source	-	**56,221 kg/year**
Contaminated solvent recovered externally	21,280 kg/year	**-**
Waste destined for final disposal	58,590 kg/year	**18,740 kg/year**
Virgin solvent for cleaning	69,230 kg/year	**18,740 kg/year**
Economic balance		
Cost of virgin solvent	€50,762.93*	**€13,741.11**
Cost of recovery at source	-	**€11,713.52**
Cost of external recovery	€5,115.82	**-**
Cost of final disposal	€19,015.18	**€5,631.60**
Total cost	€74,893.93	**€31,086.23**
Investment	**-**	**€82,068.20**
Payback period	**-**	**1.9 years**

* Extrapolation according to the current price of virgin solvent, approximately €0.73/kg.

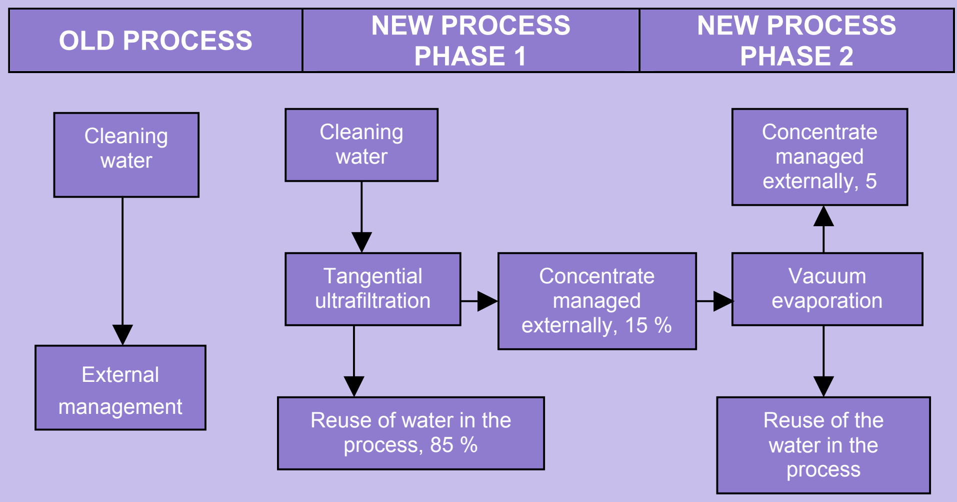
Conclusions

The minimisation project carried out by Tintas K+E, S.A. enables the quality of the recovered solvent to be assured, which represents, on the one hand, an important saving in the consumption of virgin solvent, and on the other hand, a reduction in the quantity of waste that the company sends for final disposal, thus reducing its environmental costs substantially. The implementation of this type of practice contributes to achieving a more environmentally sound manufacturing process.

CASE STUDY 4	
Company	Detervic, S.A
Country (location)	Spain (Vic, Barcelona)
Industrial sector	Chemical
Subject of the project	Recovery and recycling at source: Minimisation of aqueous waste and saving resources through recycling at source.
Environmental considerations	The company DETERVIC, S.A. is dedicated to the manufacture and marketing of soaps, detergents and other cleaning and polishing products for industry. DETERVIC, S.A.'s production process consists of the introduction of chemical reagents into mixers, according to the exact amounts required for the product to be manufactured, and their subsequent mixing, depending on the time specified for each formulation. Following this, the product is then directly packaged in the containers in which it will be supplied. At the end of the mixing process of the chemical products in the mixers, these are then cleaned, which generates wastewater that is managed as special waste.
Background	As explained above, DETERVIC generated liquid waste in which water was the main component, at a very high percentage, and the rest was entrainment of residue from the various products left in the mixers. This situation led the company DETERVIC to seek a solution to enable it to improve the company's environmental and economic situation, while also reducing its consumption of natural resources. The action taken was based on the following premises: • Achieving a process that would enable the reuse of the water contained in the waste. • Minimising the amount of waste finally managed externally having separated the aqueous part. • Obtaining the shortest possible payback period on the investment made and the lowest treatment cost. As membrane and vacuum evaporation technologies are an alternative to the classic techniques of wastewater treatment, the decision was made to study the possibility of implementing a process of this type in DETERVIC, S.A.
Summary of actions	The action was divided into two phases: • The first phase consisted of the implementation of a treatment system using a process of tangential ultrafiltration with a treatment capacity of 2 m^3/day. This is a selective filtration technique that uses semi-permeable membranes that enable the separation of solid particles of a very small diameter, with a yield and reuse of cleaning water of 85 %. The most highly concentrated waste, generated during ultrafiltration, is a special waste that was managed externally. • The second phase consisted of the treatment of the concentrated waste generated during ultrafiltration, using a vacuum evaporation plant with a treatment capacity of 150 l/day. This phase enables the minimisation of concentrated waste by 95 % and therefore the reuse of 95 % of the water obtained in the evaporation process.

The action as a whole has enabled a minimisation of aqueous waste by 99 % and the reuse of water generated in the process of the same percentage.

Process diagrams



Balances

	Old process	New process
Balance of materials		
Water consumption	424 m^3/year	3.2 m^3/year
Aqueous waste managed externally	424 m^3/year	3.2 m^3/year
Economic balance		
Water costs	€176.4/year	€1.33/year
Management costs for aqueous waste	€90,000/year	€1,120/year
Transport costs for aqueous waste	€10,800/year	€96/year
Energy costs	€0/year	€22,952/year
Savings and expenditure		
Savings on the cost of water	€175.07 /year	
Savings on the management of aqueous waste	€99,584 /year	
Energy costs	€22,952 /year	
Total savings	€76,807.07 /year	
Investments in installations	€79,100.9	
Payback period	1.03 years	

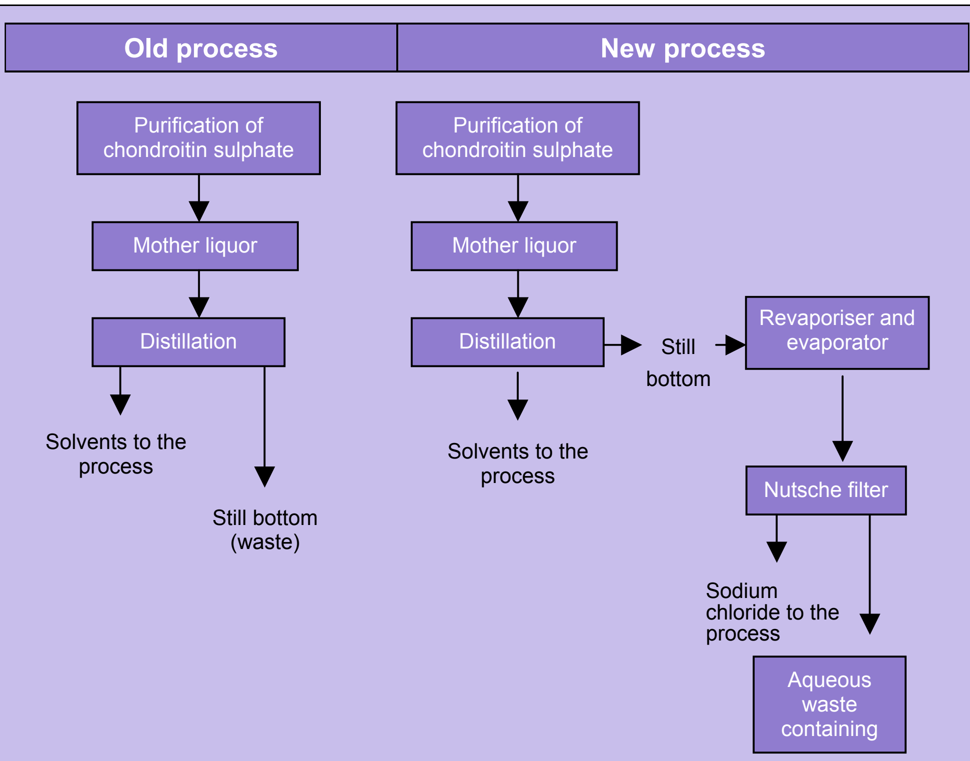
Conclusions

By carrying out this project, it has been possible to reduce the consumption of water used in industrial processes by 421.8 m^3/year, together with a reduction in aqueous waste generated in the cleaning of the mixers of the chemical products, a type of waste classified as hazardous, by 421.8 mT/year. In addition to this, the action taken allowed the company to attain the objectives that form part of the company's plans for continual improvement of ISO 14001.

This action is the result of the Minimisation Opportunities Environmental Diagnosis (MOED) carried out by the company in collaboration with the Centre for the Enterprises and the Environment (CEMA) during the year 2002.

CASE STUDY 5	
Company	BIOIBÉRICA, S.A.
Country (location)	Spain (Palafolls, Barcelona)
Industrial sector	Manufacture of pharmaceutical products
Project subject	Recycling at source: Installation of equipment for the reuse of sodium chloride used in the manufacturing process.
Environmental considerations	The company BIOIBÉRICA, S.A. is dedicated to the manufacture of pharmaceutical products, chondroitin sulphate and heparin, among others. The production process consists of various stages, including the receipt of raw materials, the extraction stages and the purification stages. In these phases, diverse chemical materials and products are used, such as proteins, organic solvents, sodium chloride, water, etc. which generate aqueous waste flows containing solvents. The waste flows generated by the process have a notable environmental impact and this is particularly the case for the mother liquor generated during the purification process of chondroitin sulphate. This waste flow of mother liquor is treated internally using a distillation column, which enables the solvents to be recovered and generates another waste flow, the *distillation still bottom*, the composition of which is a mixture of sodium chloride, water and proteins; these are difficult to manage, as the high concentration of soluble salts means that making the waste inert and its final disposal are difficult.
Background	As outlined in the explanation above, BIOIBÉRICA S.A., generated an aqueous saline flow known as the distillation still bottom from the distillation column which treats the waste generated in the chondroitin sulphate purification process. In 2002, the company decided to attempt to reduce the waste flow of distillation still bottoms generated during the treatment of the waste from chondroitin sulphate purification, and in parallel to this, to introduce a series of modifications to improve the production process. The action was based on the following premises: • A reduction in the consumption of raw materials • A reduction in the quantity of waste generated in the process of distillation of mother liquor (rectification process) • The reuse of sodium chloride • A reduction in the consumption of process water
Summary of actions	The waste generated in the distillation process of the mother liquor (the distillation still bottoms) are treated in a vacuum evaporator with revaporiser and forced circulation, to avoid deposits of crystals on the walls of the apparatus, until the point of distillation of sodium chloride. When the concentrate reaches this point, it is sent to a Nutsche type filter where the sodium chloride crystals are retained. These are then cleaned with a great deal of care to ensure that they do not dissolve again. The action enables the reuse of the water and the sodium chloride in the process. The waste containing protein is currently managed using destruction, but its recovery is being studied.

Process diagrams



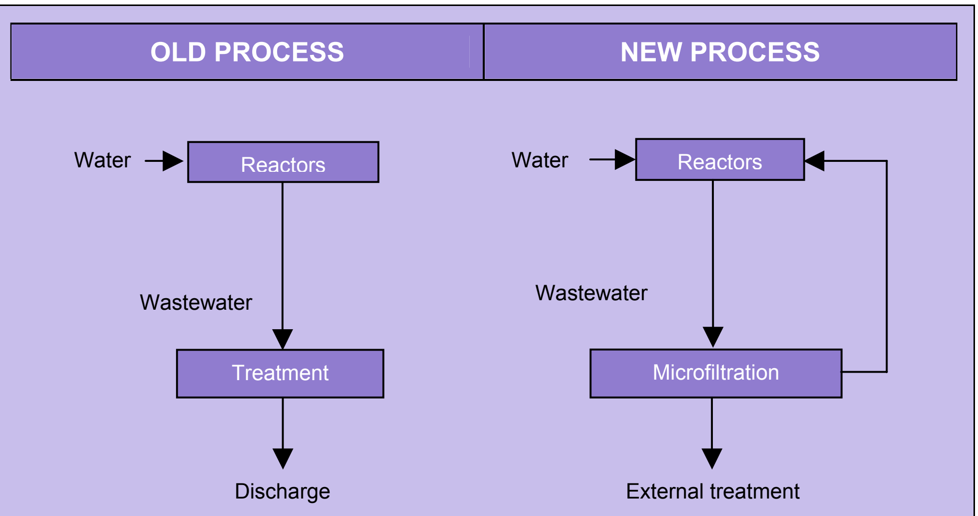
Balances

	Old process	New process
Balance of materials		
Aqueous waste	25,000 l/batch	5,000 l/batch
Consumption of sodium chloride	2.000 kg/batch	880 kg/batch
Water consumption	25 m^3/batch	5 m^3/batch
Economic balance		
Management costs for aqueous waste	€6,400/batch	€1,156/batch
Sodium chloride costs	€360/batch	€158/batch
Water costs	€7.75/batch	€1.65/batch
Process costs	€0/batch	€1,500/batch
Savings and expenditure		
Savings on aqueous waste management	**€5,264/batch**	
Savings on raw materials	**€208/batch**	
Water treatment and process costs	**€1,500/batch**	
Savings per batch	**€3,972/batch**	
TOTAL ANNUAL SAVINGS	**€1,449,780/year**	
Investment in installations	**€900,000**	
Payback period	**0,62 years**	

Conclusions	By carrying out the project, it has been possible to reduce sodium chloride consumption by 408.8 mT/year, and the waste associated with the manufacture of chondroitin sulphate by 7,300 m^3/year, which represents a reduction of 80 % in the amount of this waste that the company generated before this and that is difficult to manage. Moreover, the company is studying the possibility of converting the protein-containing waste into a sub-product rather than waste, which would imply the total elimination of the waste flow that used to be generated. This action was taken within the framework of the environmental improvement plans and the environmental protection policy of the area in which the company is based. This policy began with the joining of the ISO 14001 environmental management system in 1997 and of the EMAS in 1999.

CASE STUDY 6	
Company	CPQ IBÉRICA, S.A.
Country (location)	Spain (Mollet del Vallès, Barcelona)
Industrial sector	Manufacture of chemical products.
Project subject	<u>Recovery and recycling at source:</u> The reuse of water from industrial cleaning.
Environmental considerations	The production of certain auxiliary products for industry (cutting emulsions, detergents, lubricants, etc.) takes place using batch processes. The procedure of changing product during manufacturing involves the careful cleaning of the entire production line, and this implies the need to carry out intermediate cleaning to guarantee the elimination of product residue and to avoid the contamination of subsequent manufactured products. Due to this cleaning, wastewater with a high pollutant load of COD and suspended solids (SS) is generated.
Background	The company carried out a Minimisation Opportunities Environmental Diagnosis in collaboration with the Centre for Cleaner Production, in which the possibility of taking measures to improve the situation concerning wastewater resulting from cleaning was clear. The factors that encouraged the company CPQ Ibérica, S.A. to make this investment were: • The need to meet the environmental quality targets set by the company. • The possibility of wholly eliminating the generation of wastewater from the equipment cleaning process.
Summary of actions	The project in question involved a modification of the process consisting of the installation of a tangential microfiltration plant for the treatment of water from intermediate cleaning. The cleaning water is passed through a mesh filter to eliminate solid particles of over 1mm. The filtered water is then taken to the microfiltration machine, where all particles of over 0.1 microns are removed, thus reducing the quantity of SS and COD. Water that has been used for cleaning that is then treated using this microfiltration system can be reused in the process. As a result of the microfiltration of the water, a concentrate is generated that is a mixture of different products and which currently cannot be recovered, and must therefore be treated by an authorised waste manager.

Diagram



Balances

	Old process	New process
Consumption of materials and energy		
- water	529 m^3/y	53 m^3/y
- increase in power installed		5.5 kW.
Process costs		
- water	€2,143.3/y	€63.62/y
- increase in energy		€552.22/y
Environmental expenditure		
- waste management	€900.36/y	€1,500.60/y
Total cost (€/y)	€3,043.66/y	€2,116.45/y
Savings (€/y)	€927.22/y	
Investment (€)	€42,617.05	

Conclusions

The decision to make this investment and modify the cleaning process was not made in response to economic considerations, but rather as a result of a desire to fulfil certain environmental quality targets set by the company.

Nevertheless, the action taken by the company CPQ Ibérica, S.A., has resulted not only in a significant reduction in discharges, but also in economic savings.

In this way, the company has reduced its water consumption in the cleaning of the reactors purely as a result of these measures by approximately 90 %.

6.3. GOOD HOUSEKEEPING PRACTICES

CASE STUDY 7	
Company	SENIGRUP, S.L.
Country	Terrassa (Vallès Occidental) Barcelona, Spain.
Industrial sector	Manufacture of chemical products for industrial maintenance.
Project subject	Good housekeeping practices. Reuse of cleaning water containing product residue.
Environmental considerations	SENIGRUP uses a batch production system, which was adopted to deal with the wide variety of chemical products that it manufactures (soaps, detergent and cleaning and polishing articles). This production system involves an associated series of operations that correspond to the cleaning of reactors, tanks and installations in general, and which are necessary to guarantee the level of quality required for the company's products. Cleaning is carried out using end control hoses (low flow, high pressure), but although cleaning takes place with the minimum possible amount of water, some water is generated, which represents almost all of the company's wastewater.
Background	The company carried out a Minimisation Opportunities Environmental Diagnosis in collaboration with the Centre for Cleaner Production, which showed that it was possible to attain a level of zero discharge, with the consequent environmental improvement. SENIGRUP, S.L. has put a quality control system into practice in which continual improvement targets have been included in both the area of Product Quality and in the area of Environmental Quality.
Summary of actions	The actions that were carried out as a result of this diagnosis have led not only to a reduction in the waste flows generated by the company, but also to an improvement in the management of waste generated. These actions have affected both the treatment costs of this waste and the quality level of the product. As a result of a study on production processes, an analysis of materials and a balance of possible proposals and options for improvement to achieve a reduction in the waste flows generated by the company, the following actions were put into practice, always respecting the desired quality of the final product: 1. Reuse of water containing product residue from the cleaning of the reactors: a) Organising the order of manufacture of batches according to product families, to eliminate the need to clean the reactor between processes. b) Storing water from cleaning in drums to be reused in batches manufactured later. Depending on the viscosity of the products to be manufactured, the quantities to be added to each raw material are

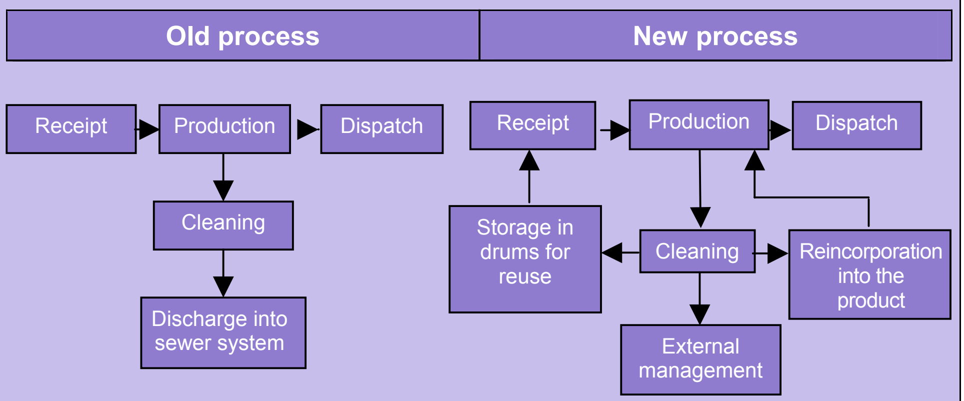
recalculated in order to include the collected cleaning water in the formulation of the products. Depending on the viscosity of the water and of the product to be manufactured, this water will be incorporated as a raw material, or will be added at the end of the process.

c) External management of the wastewater from cleaning following the production of batches that are manufactured in small quantities and/or occasionally.

2. Separation at source of the different types of waste generated (containers, packaging, absorbent material). This increases their potential for recovery.
3. Rationalising and optimising warehouse space: having and identifying storage zones. This encourages the conditions necessary to avoid the deterioration of the container or the product, and reduces the possibility of fire, confusion and leaks and/or spillages of the product.
4. The actions mentioned above were accompanied by training sessions for the company's staff. With the application of good housekeeping practices, a higher level of quality was achieved with a reduction in the generation of waste.

With the new strategy of recycling at source, only 10 % of cleaning water generated remains outside the closed water circuit, and is managed externally as liquid waste.

Process diagram



Balances

	Old process	New process
Water consumed (base 1998=1)	1	0.75
Unit price (including collection and treatment taxes)	€0.31/m^3	€0.2/m^3
Estimated cost	€104.9/year	€51.25/year
Generation of wastewater from the cleaning of the installations	1	0.10
Estimated cost in case of management as liquid waste	€14,376.21/year	€1,43642/year
Investment in installations	Insignificant	
Savings due to good housekeeping practices	**€53.66/year**	

Conclusions	With some simple modifications to the cleaning procedure, and above all with the application of good housekeeping practices identified and recommended in the Minimisation Opportunities Environmental Diagnosis, SENIGRUP, S.L. has achieved a level of zero discharge and a reduction in the cost of environmental management. These actions have enabled a revision of the parameters included in treatment taxes, which has led to a reduction in the water-associated costs. These actions form part of the objectives included in the company's environmental policy, which is defined in conjunction with the company's quality policy, thus integrating the concepts of quality and the environment into the company's management system.

CASE STUDY 8	
Company	KAO CORPORATION, S.A.
Country	Spain (Barberà del Vallès, Barcelona)
Industrial sector	Chemical. Manufacture of flavourings and fragrances.
Project subject	<u>Good housekeeping practices</u>: Reduction of effluent through the improvement of cleaning procedures of equipment and reactors.
Environmental considerations	Product quality and cost are the two most important factors in the highly demanding and competitive market of flavourings and fragrances. The manufacturing process of flavourings and fragrances requires extensive cleaning with water of both the installations in general, and the specific reactors. The operation is carried out in sequence, with water and steam. This results in the generation of effluent with high COD.
Background	The treatment of wastewater from cleaning operations is extremely expensive, and the cost of the obligatory external treatment is very high. This has substantial effects on the final cost of the products manufactured. The solution adopted by Kao Corporation was to minimise this waste flow by adopting a group of good housekeeping practices, with very little investment.
Summary of actions	The project involved several phases of action, which took place between 1992 and 1994. Following a revision of the parameters of process designs and an analysis of possible improvements, along with the repercussions that these could have on the quality of the finished product (which involved carrying out a number of pilot tests), the following specific actions were taken: a) Elimination of one of the four cleaning stages that were carried out in each manufacturing process. b) Reuse of the condensate from the final steaming for the next washing. c) Reduction of steaming time by 20 %. d) Structuring of the order of manufacturing according to product families. These actions were completed with the training of and provision of information to all staff involved in the processes subject to these changes and the way of making the changes. The rationalisation of the reactor cleaning processes also resulted in gains being made in time available for the manufacture of products and therefore in real production capacity.

Balances	Expressed relative to a base for the year 1991=1

	With the previous cleaning procedure (1992)	With the current cleaning procedure
Balance of water and energy		
- Water	1	**0.75**
- Steam	1	**0.75**
Generation of waste		
(kg of waste / mT of product)	1	**0.50**
Economic balance		
- General waste (€/year)	1	**0.50**
- Waste management (€/kg waste)	1	**0.73**
- Plant availability	1	**1.06**
Total cost of waste management (€/kg product)	1	**0.3775**
Savings due to the minimisation of waste		**€165,066/year**
Gains from increased production capacity		**€33,013/year**
Total gains		**€198,079/year**
Investment		**negligible**
Payback period		**immediate**

Conclusions	The results of the actions carried out have had a very notable effect on the economic and environmental balance of this centre of production. It should be highlighted that through reflection on the “whys” governing the procedures used - the good housekeeping practices - it is possible to bring about an improvement in the production processes that implies a significant reduction in the expenditure associated with the generation of high COD, while making practically no investment (with the exception of the training/information provided to plant staff and the pilot tests). In this case, as in many others, it should also be noted that production increased by 6 % due to the reduction in cleaning time between batches.

CASE STUDY 9	
Company	BAKELITE HERNANI, S.A.
County	Spain (Hernani, Guipúzcoa)
Industrial sector	Chemical. Manufacture of synthetic resins.
Project subject	Good operational housekeeping practices in production: Reduction in effluents through the improvement of cleaning procedures of equipment and reactors.
Environmental considerations	The company is dedicated mainly to the manufacture of synthetic resins, which are used in diverse sectors such as the composite wood and textile fibres industries, in the manufacture of kitchenware and bathroomware, in the automobile industry and in the smelting industry. The company has 2 production centres in the Basque Country, one located in Hernani (Guipúzcoa) and another in Lantarón (Alava). In the former, which is where the Phenol Recovery Plant has been set up, production is mainly of solid phenol resins (novolaks) and two types of compound derived from them: powder resins and casting resins. The company is quality certified according to ISO-9000 standard and it is anticipated that it will also obtain Environmental Management Certification according to ISO 14001 standard.
Background	As a result of the implementation in 1995 of a project on atmospheric environmental Impact of the company's activities, it became clear that the incinerator for the burning of effluent from the distillation of resins required modification in order to fulfil the legal requirements regarding atmospheric emissions. Due to the high cost of modification and the age of the equipment, an alternative was found that enabled the separation and reuse of some of the components of the water used.
Summary of actions	After a preliminary decantation stage, the water originating in the distillation of resins is sent to an absorption tower, where the phenol contained in the water (50,000 ppm), is extracted from the aqueous phase by means of a selective solvent. The phenol and the solvent are then separated in a distillation column. The end products of the process are phenol, which is 99 % pure and is used as a raw material, the solvent, which is reused in the absorption process and the water, with a much lower phenol content, which is discharged into an industrial collector with no problems. With the aim of further reducing the pollutant load of the water, a second distillation tower has been installed to recover the methanol contained in the water. This step of the process is currently at the test stage.

Images

Figure 1. Image of the plant

Figure 2. Image of the plant

Balances

Annual consumption of materials/annual impacts	Before	After	Reduction	Indicators (after)
Phenol consumption	**6,991 mT**	6,778 mT	**3 %**	**0.87 kg of phenol/kg of resin produced**
Volume of wastewater	**3,624 m^3**	**3,404 m^3**	**6 %**	**0.44 kg of water/kg of resin produced**

Annual economic balance	Unit cost	Total cost	Indicators (after)
Investment (€/year)	€432,728.72	**€432,728.72**	
Additional annual costs		**€26,000.83**	
- Financing costs (5 % finance)		€18,631	
- Maintenance (2 % investment)		€7,452.55	
Reduction in annual costs		**€140,820.9**	
- Savings on material costs	€0,66 x 213,365 kg	€140,820.9	**0.018 €/kg of resin produced**
Total annual savings		**€114,974.52**	
Payback period		**3.24 years**	

Conclusions	Benefits: - Annual savings of almost €120,000. - Reduction in the consumption of raw materials. - Reduction in the volume and pollutant load of water discharged into the collector.

CASE STUDY 10	
Company	ENERGIA PORTATIL, S.A.
Country	Spain (Oñati, Guipúzcoa)
Industrial sector	Chemical. Manufacture of dry batteries, lanterns, electrolytic manganese dioxide (EDM) and design and manufacture of special machinery.
Project subject	Good operational housekeeping practices for production: Reuse of furnace gases.
Environmental considerations	For the manufacture of electrolytic manganese dioxide, the following production process is used: 1. Drying of natural manganese dioxide in a natural gas rotating furnace 2. Grinding of the manganese dioxide together with charcoal 3. Reduction of the MnO_2 in a rotating furnace to obtain MnO and CO_2 4. Dissolution of the reduced mineral (MnO_2) with sulphuric acid at 80 ºC to obtain $MnSO_4$ 5. Separation of impurities by aeration (oxidation) and decantation 6. Deposition by electrolysis of the electrolytic manganese dioxide in electrolysis vats with titanium anodes and lead cathodes 7. Extraction of the MnO_2 from the electrolysis vats 8. Grinding in a grinder For its production process, the company consumes various types of energy: - Coal: in the grinding of the natural manganese dioxide - Natural gas: in the furnace for the drying process of the natural manganese dioxide - In the furnace for the process of reduction of the natural manganese dioxide - Electrical energy: operation of machines and mechanisms - Steam: for the heating of the electrolysis vat The company has ISO 9002 and ISO 14001 certification (Aenor).
Background	In recent years, the company has carried out research into the technological adaptation of its production process. As a consequence of this, the possibility has become clear of increasing productivity, reducing the consumption of raw materials and energy and improving the quality of the final product by means of the appropriate selection of the parameters of the different phases of production and the technological adaptation of these phases. This project forms part of these improvements, for which an increase of production capacity of 50 % is anticipated. The improvements in terms of energy are to be introduced into the series of drying-grinding-reduction processes of the natural manganese dioxide.

At present, the drying of the mineral takes place in a natural gas rotating furnace as a stage prior to reduction. The hot gases (880 ºC) that are produced in the mineral reduction furnaces are expelled without making use of their heat in the process. The annual consumption of energy in the furnaces is:

Natural gas……………. 12,800,000 thm (GCV) =…………….. 1,152 toe

Summary of actions

The improvement made consists of redirecting the hot gases (880 ºC) that are produced in the reduction furnaces so that they can be used in the drying process of the mineral.

The redirecting of the hot gases results in the following improvements in energy efficiency (greater yield) and environmental improvements:

- Reduction in the consumption of natural gas in the drying furnace, as the hot gases from the reduction furnace help in the drying of the mineral.
- Reduction in emissions (in general), as a direct effect of the energy improvement.

The reductions in emissions will be:

- Reduction in CO_2 emissions…………………………………..… 566.37 t/year
- Reduction in NOx emissions ………………………………….. 1,305 kg/year
- Reduction in SO_2 emissions ……………………………….…… 2.61 kg/year

Annual energy consumption will be:

- Natural Gas………………… 9,900,000 thm (GCV) =…………………891 toe

Balances

Annual consumption of materials / annual impacts	Before	After	Reduction
Consumption of natural gas	**1,152 toe/year**	**891 toe/year**	**22.66 %**
CO_2 emissions	**2,499,84 t/year**	**1,933.47 t/year**	**22.66 %**
NOx emissions	**5,760 kg/year**	**4,455 kg/year**	**22.66 %**
SO_2 emissions	**11.52 kg/year**	**8.91 kg/year**	**22.66 %**

Annual economic balance	Unit cost	Total cost
Investment		€39,066
Additional annual costs		€1,563
- Financing (4 %)		**€1,563**
Reduction in annual costs		€63,063
- Savings in natural gas consumption	€0.021746 x 2,900,000 thm (GCV)	**€63,063**
		€61,500
Total annual savings		0.64 years
Payback period		

Conclusions	Benefits: - Reduction in consumption of specific energy in the drying furnace. - Reduction in emissions of pollutant gases by 566.37 t/year of CO_2, 1,305 kg/year of NOx and 2.61 kg/year of SO_2. - Reduction in energy costs by €63,063 per year.

CASE STUDY 11	
Company	HUNOLT, S.A.
Country	Spain (Beasain, Guipúzcoa)
Industrial sector	Chemical. Fabrication of inks for printing such as offset, heat-set, gravure and flexographic, security (monetary notes, stamps, passports, lottery tickets, etc).
Project subject	Good housekeeping operational practices for production: The use of higher-capacity packaging formats.
Environmental considerations	The main production processes are based on the manufacture of liquid inks by mixing and by grinding in a horizontal grinder, and the manufacture of greasy inks, by mixing, by grinding in a vertical grinder and by triple roll grinders. The technological capacity of the company is based on the updating of knowledge, the application and adaptation of technologies according to client needs, professional experience and the search for new technological solutions. Among the latest developments are the inks for the manufacture of euro notes. The company's sales in over 20 countries bears witness to its international presence. Sales abroad represent 40 % of the company's turnover. The company guarantees the quality of its products and services with its fulfilment of ISO 9001 quality standards.
Background	Due to the need within the company to draw up a packaging prevention plan, the company studied possible actions for the reduction in consumption of containers and/or packaging in the distribution of its final products to clients.
Summary of actions	The company distributes its inks in containers that are small in dimensions and capacity, such as containers of 1-2 ½ kg and drums of 20-25 litres. Once these containers have been consumed by the client, they must be handed over to an authorised manager for treatment as containers that have held hazardous waste, which implies high management and transportation costs, apart from the high consumption of different containers. Based on the need to draw up a Packaging Prevention Plan, it was decided to distribute the product in containers of larger capacity formats, such as 200 litre drums and containers. 2 types of container are used: - ADR, which, due to the type of ink they contain, should be inspected every two and a half years. If the container passes the inspection satisfactorily, it will be reused for the same length of time. If the container does not pass the inspection, it should be managed as hazardous waste. - Non-ADR, which do not require inspections. Both containers are sent back by the client when the product has been consumed. In scarcely five years, a level of 25 % of the distribution of final products using this new distribution system has been reached.

Images	

Figure 1. Small containers, 1 - 2 ½ kg

Figure 2. Drums, 20 -25 litres

Figure 3. ADR container, 1,000 litres

Figure 4. Non-ADR container, 1,000 litres

Balances

Annual consumption of materials / annual impacts	Before	After	Reduction	Indicators (after)
Consumption of small containers **(1-2½ kg)**	**318 mT**	**265 mT**	**17 %**	**0.13 kg packaging / litre**
Consumption of drums **(20-25 l)**	**146 mT**	**99 mT**	**32%**	**0.07 kg packaging / litre**

Annual economic balance	Unit cost	Total cost	Indicators (saving)
Investment		**€199,344 €**	
- Drums, 200 l volume	€18.63 x 600 drums	€11,178	**€0.09/litre**
- Containers, 1000 l volume (non-ADR)	€510.9 x 340 containers	€173,706	**€0.51/litre**
- Containers, 500 l volume (ADR)	€108.2 x 17 containers	€1,839	**€0.22/litre**
- Containers, 1000 l volume (ADR)	€360.60 x 35 containers	€12,621	**€0.36/litre**
Additional annual costs		**€58,456**	
- Unreturned 1000 l containers (ADR)	€510.90 x 515 containers	€26,056	**€0.51/litre**
- Drums, 20 - 25 l	€2.70 x 12,000 drums	€32,400	**€0.12/litre**
Reduction in annual costs		**€198,862**	
- Savings on small container costs (1-2½)	€0.60 x 199,549 containers	€119,549	
- Savings on drum costs 20-25 l	€2.70 x 29,375 drums	€79,313	**€0.12/litre**
Total annual savings		**€140,406**	
Payback period		1.42 years	

Conclusions	Benefits: - Reduction in the consumption of packaging by 100 tonnes. - Increase in productivity to 562.2 tonnes of ink by distributing the product in larger containers. - Improved working conditions as the packaging and handling of the product is made easier.

CASE STUDY 12	
Company	A&B LABORATORIOS DE BIOTECNOLOGÍA, S.A.
Country	Spain (Beasain, Guipúzcoa)
Industrial sector	Chemical. A company with a technology and innovation base that as a research centre aims to respond to industrial maintenance needs with products that provide an alternative to traditional chemicals, using clean technologies and biotechnology.
Project subject	Good housekeeping operational practices in production: The elimination of little-consumed raw materials and an increase in product competitiveness. Green chemistry.
Environmental considerations	A&B aims to progress through research, innovation, eco-design and by carrying out life cycle analyses (LCA) with the aim of introducing "clean products" and industrial biotechnology to companies, with eco-products manufactured by means of the selection of natural, non-pathogenic strains of specialist microorganisms, thus avoiding pollutant waste and encouraging bioremediation. The technological objective of the company is to produce microorganisms (bacteria) and enzymes for the chemical sector, by means of their fermentation, freeze-drying, centrifuging, desiccation, etc. and their later activation, and in the short term (2-3 years) to be technically capable and to have the production capacity to meet the challenge of producing microorganisms for industrial sectors such as the agriculture, agro-foodstuffs, pharmaceutical, phytosanitary and metallurgical sectors, etc. A&B Laboratorios de Biotecnología S.A. aims to be a company focused on customer satisfaction, with sustained development and progress and the reinforcing of its competitive advantages, all of this within a management strategy adopted by the company's top management that follows the EFQM Excellence model, as a point of reference for the evaluation and continual improvement of the Integrated Management System as a whole. This was implemented in line with International Standards UNE EN ISO 9001:00 and UNE EN ISO 14001:96. The company has highly qualified staff, with extensive experience in R&D&I, in collaboration with technological centres and public bodies in activities of industrial design and development, and has been working with bioprocesses for over 10 years. Among the equipment that is currently available, the following items are of particular importance: turbostirrers, mixers, filling machines, decanting pumps, heating tanks, dilutors, water softeners, etc. In terms of laboratory equipment, the company has basic, high-quality research instrumentation.
Background	The Purchasing Department, the Warehousing Department and the Technical Department jointly noticed that there were certain quantities of raw materials that were used and rotated very little, which meant that the products had to be stored for long periods of time, with the consequent risk of these raw materials going past their expiry date. This would lead to their subsequent transformation into hazardous waste, with the consequent occupation of space in a part of the warehouse, which could not then be used to store other raw materials, and the existence of significant fixed assets. As a result of all of these things, the idea emerged of substituting those raw materials that were little used with others that were already consumed regularly or by a mixture of materials with the same functionality.

Summary of actions	The Technical Department carried out an in-depth study of the properties of the raw materials in the final product. To do this, technical information from suppliers (data sheets, specifications sheets and safety sheets) was used, and depending on the final qualities of the product on the market, and based on the experience of the Technical Department and on consultations with the Technical Departments of suppliers, a preliminary selection was made of other regularly consumed raw materials that could replace the other materials by themselves or in combination with other raw materials. Prototype alternative formulas to the original formulations were devised without the raw material to be eliminated, and experimentation took place in the form of laboratory tests and the final verification of properties with clients. Following this study, the Technical Department gave the final validation and the use of the new formulations was begun. It was also noted that the product could be improved in terms of greater effectiveness of action and environmental improvements, in accordance with the company's philosophy of encouraging clean technologies and the safety of the final product. As an additional consequence of the initial monitoring of warehouses, an intelligent control computer program has been established. This enables the optimisation of manufactures and warehouse control. Computer programs for the intelligent control of the warehouses have been implemented, enabling the process to be optimised, avoiding unnecessary transfers and minimising the generation of waste. All of this has led to an increase in sales of the products affected, by increasing their properties, thus increasing their competitiveness on the market. The substances that were substituted and the alternative substances used are shown in Figure 1. The substitution of anticorrosion elements in industrial maintenance grease with more biodegradable products, and the subsequent environmental impact results in cleaner products that are also more competitive, such as in the case of the ecological grease MT 139, with components that are totally inert with regard to the environment, which is appropriate for application in sensitive natural outdoor areas where machines are used or there is transit. The first step was to collect information concerning the process and to have associated data available through an Access database (e.g. quantities manufactured of each product and number of raw materials associated, manufacturing costs for each product, type of packaging, etc.). By studying this, minimum quantities for storage in warehouses were fixed, and manufacturing orders were optimised, taking into account for each product the associated personnel costs, rotation of raw materials involved, the possibility of storage, etc. (For example, it was noted that for product A it was more profitable to manufacture 3,000 litres each quarter than 1,000 litres each month, or that it was more profitable for product B to manufacture 500 litres each month than 1,500 each quarter, etc.) In addition, the type of container used and its rotation was studied in greater depth, optimising packaging (previously this was done by guesswork, packing a little in each type of container). This has led to a need for fewer transfers and the minimising of waste packaging.

The program receives the figures for each day via computer and is readjusted when the differences are greater than an established range. All of the production and warehouse staff have been involved, with the experience taken to be a positive and enriching one, in addition to its improvement in working conditions due to its optimisation of the process.

Table

Substance eliminated / substituted	Traditional use	Problem	Alternative used by A&B
ETHYLENE GLYCOL	Antifreeze	Harmful product	**Propylene glycol**
BENZALKONIUM CHLORIDE	Bactericide	Low activity in the presence of organic matter	**Tetraalkyl ammonium chloride**
ANTICORROSIVE ADDITIVES	Cutting fluids	Substance used in just one product	**Multifunctional anticorrosion additive used for more applications**
AROMATIC SOLVENT (with a mixture of toluene, xylene)	Oil removal and cleaning	Possibility of sensitisation and harmful by inhalation and contact irritation	**Hydrotreated solvents**
D-LIMONENE (ORANGE TERPENE)	Oil removal and cleaning	Hazardous to the environment, sensitising, skin-eye irritation	**Detergent formulations in an aqueous base and easily biodegradable alcohol-based solvents**
GLUTARALDEHYDE	Disinfectants	Highly toxic product	**Mixture of non-toxic disinfectants with synergic action**
SODIUM NITRITE	**Anticorrosive**	**Can generate nitrosamins that are harmful to users**	**Synthetic soluble anticorrosives**

Figure 1: Substances used and their alternatives

Balances

Annual consumption of materials/annual impacts	Before	After	Reduction
Ethylene glycol	1,250 kg	0 kg	**100 %**
Benzalkonium chloride	662 kg	0 kg	**100 %**
Aromatic solvent	327 kg	0 kg	**100 %**
Anticorrosive additive	1,915 kg	0 kg	**100 %**
D-limonene (orange terpene)	11,934 kg	5,822 kg	**43.78 %**
Glutaraldehyde	1,299 kg	773 kg	**59.5 %**
Sodium nitrite	50 kg	0 kg	**100 %**
Alternative products	0 kg	14,329 kg	**-100 %**
Volume of waste (hazardous metallic containers)	**1,564 kg**	**593 kg**	**37.91%**

Annual economic balance	Unit cost	Total cost
Investment		0 €
Additional annual costs		€33,725.32
- Cost of dedicated personnel	€17.06 x 45 hours	**€767.7**
- New cost of alternative materials	€2.30 x 14,329.4 kg.	**€32,957.62**
Reduction in annual costs		€45,059.91
- Saving in waste costs	€0.09 x 971 kg. (54 drums)	**€87.39**
- Reduction in costs of the material eliminated	€2.10 x 10,842 kg.	**€22,806.60**
- Reduction in storage management costs	€17.06 x 48 hours	**€818.88**
- Increased sales in alternative products (20 %)	€6.22 x 6,432 kg	**€21,347.04**
Total annual savings		€11,333
Payback period		0 years

Conclusions

Benefits:

- Reduction in the consumption of raw materials, materials with a single use have been eliminated.
- Reduction in the toxicity of raw materials, the alternatives all show marked environmental or usage improvements, in accordance with the company philosophy.
- Improved working environment, operators are working with products that are less hazardous.
- Improved company image, the company can present products that are more respectful of the environment and greater workplace safety to the market.

	- Improved warehouse operation and production; by eliminating products and replacing them with existing products, space is saved and logistics operations can be quicker. - Increased competitiveness, which translates as an increase in sales of €3,432 in 2002. A larger increase is anticipated for 2003 with the greater consolidation of alternative products and with sales for the full year.

6.4. SUBSTITUTION OF RAW MATERIALS

CASE STUDY 13	
Company	A&B LABORATORIOS DE BIOTECNOLOGÍA, S.A.
Country	Spain (Guipúzcoa)
Industrial sector	Chemical. A company with a technology and innovation base, which as a research centre aims to respond to industrial maintenance needs with products that provide an alternative to traditional chemicals, using clean technologies and biotechnology.
Project subject	Substitution of raw materials: The use of materials that are less toxic.
Environmental considerations	A&B aims to progress through research, innovation, eco-design and by carrying out life cycle analyses (LCA) with the aim of introducing “clean products” and industrial biotechnology to companies, with eco-products manufactured by means of the selection of natural, non-pathogenic strains of specialist microorganisms, thus avoiding pollutant waste and encouraging bioremediation. The technological objective of the company is to produce microorganisms (bacteria) and enzymes for the chemical sector, by means of their fermentation, freeze-drying, centrifuging, desiccation, etc. and their later activation, and in the short term (2-3 years) to be technically capable and to have the production capacity to meet the challenge of producing microorganisms for industrial sectors such as the agriculture, agro-foodstuffs, pharmaceutical, phytosanitary and metallurgical sectors, etc. A&B Laboratorios de Biotecnología S.A. aims to be a company focused on customer satisfaction, with sustained development and progress and the reinforcing of its competitive advantages, all of this within a management strategy adopted by the company’s top management that follows the EFQM Excellence model, as a point of reference for the evaluation and continual improvement of the Integrated Management System as a whole. This was implemented in line with International Standards UNE EN ISO 9001:00 and UNE EN ISO 14001:96. The company has highly qualified staff, with extensive experience in R&D&I, in collaboration with technological centres and public bodies in activities of industrial design and development and has been working with bioprocesses for over 10 years. Among the equipment that is currently available, the following items are of particular importance: turbostirrers, mixers, filling machines, decanting pumps, heating tanks, dilutors, water softeners, etc. In terms of laboratory equipment, the company has basic, high-quality research instrumentation.
Background	The Purchasing Department, the Warehousing Department and the Technical Department jointly noticed that there were certain quantities of raw materials that were used and rotated very little, which meant that the products had to be stored for long periods of time, with the consequent risk of these raw materials going past their expiry date. This would lead to their subsequent transformation into hazardous waste, with the consequent occupation of space in a part of the warehouse, which could not then be used to store other raw materials, and the existence of significant fixed assets. As a result of all of these things, the idea

	emerged of substituting those raw materials that were little used with others that were already consumed regularly or by a mixture of materials with the same functionality.
Summary of actions	The R&D Department develops new products based on the study of the LCA of the product as a fundamental phase and using the tool of eco-design, according to the IHOBE model of ECO-DESIGN based on 7 steps with specific modifications adapted to the company's products (preparation of the eco-design project, environmental aspects associated with the product, ideas for improvement, development of concepts, product in detail, action plan and evaluation). All of this is documented using internal design procedures, according to the ISO 9000:2000 standard, which covers legal and regulatory conditions, environmental considerations and other considerations of special interest groups. It establishes the organisational and technical interfaces together with the flow chart of responsibilities associated with eco-design. It also establishes the different phases of design, making the selection of raw materials and suppliers, taking into account environmental evaluation and workplace risk criteria. In the selection of valid formulations, environmental aspects related to the product and to production are taken into account. All of the different stages are controlled, revised and checked by qualified personnel (staff with higher degrees in the chemical and biological sciences). The eco-design process ends with the final validation that includes the environmental validation and the validation of operational conditions. The LCA is one of the tools available for the selection of raw materials and the production process. Investments of €300,000 were made in eco-design in the year 2002. **STEP 1. GATHERING INFORMATION** As a first step in the design and development of a new line of environmentally sound paints based on resins and pigments or loads with a lesser environmental impact with respect to traditional paints used in the waterproofing of facades and surfaces in general, a bibliographical study was carried out mainly in relation to raw materials (resins, pigments, additives, etc.) that could be used for this type of paint, and that have less of an environmental impact that those that are used traditionally (TASK 1), according to the paint cycle below (Figure 1). From this bibliographical research and their own knowledge, the raw materials were selected and contact was established with suppliers of these materials for their supply (TASK 2). The objective consisted of formulating a paint with a high solid content (greater than 60 %) in an aqueous base and with high performance in terms of the waterproofing of construction surfaces, carrying out the life cycle inventory according to the diagram shown in Figure 2. Characterisation of the formulations developed (TASK 6) is in progress, complying with Spanish standard UNE 53-413-87, "Flexible coatings based on polymers in aqueous dispersion, without substrate, for the in situ waterproofing of buildings" and specifically determining the following parameters and based on the following standards:

	- Behaviour of the packaged product: Relative density at 23 ± 2 ºC. UNE-EN-ISO 1675, Pigment content. UNE 48-235-82, Fixed material at 105 ºC. UNE-EN 3251-96, Viscosity. UNE EN ISO 2555-2000, Conservation in packaging. UNE 48083-92. - Behaviour in use: Behaviour in use. UNE 53-413-87, Drying times. UNE EN ISO 1517-96, Thickness. UNE EN ISO 2808-2000. - Behaviour of the flexible coating: Thickness. UNE EN ISO 2808-2000, Traction resistance and elongation at break. UNE EN ISO 527-96, Bending at –5 ºC. UNE 104302-2000, Resistance to impact. UNE 104302-2000, Accelerated aging at 70 ºC (1000 hours). UNE 53104, Thermal Aging (14 days). UNE 104302-2000, Chemical resistance to alkalis, cleaning products, etc. UNE 48027-80, Absorption of water. UNE-EN ISO 62, Adherence. UNE 48 099-85, Evaluation of the Action of Microorganisms. UNE EN ISO 846:98. In parallel to the characterisation of the products, samples have been distributed to different potential clients, and surveys have been carried out concerning ease of handling, quality of finish obtained and satisfaction with final results in order to check the acceptance on the market of the new water-based paint with a high solid content that has been developed. Some of the results relating to characterisation and acceptance on the part of the client are still being awaited and depending on these results, certain small adjustments may be made to the formulations, although the information received up to now has been satisfactory. **STEP 2. MANUFACTURING IN PILOT PLANT** In parallel to STEP 1 of the project, a preliminary evaluation has been made of the environmental impact of the processes that the company habitually uses for the manufacture of paints, in collaboration with the LEIA Foundation Technological Centre (TASK 7), detecting the critical points of the process and possible improvements that could be made to it, according to the diagram shown in Figure 3. In addition, some indicators for the monitoring of environmental behaviour have been established. Following this, a pilot plant for the manufacture of the paints developed in STEP 1 was designed, manufactured and set up (TASK 8), which takes in the operations of mixing, filtering and packaging, taking into account the raw materials to be used as defined in STEP 1. In this pilot plant, the first operational tests have already been carried out, according to which the company is incorporating modifications intended to minimise product losses, emissions and waste generated (TASK 9).

Diagrams

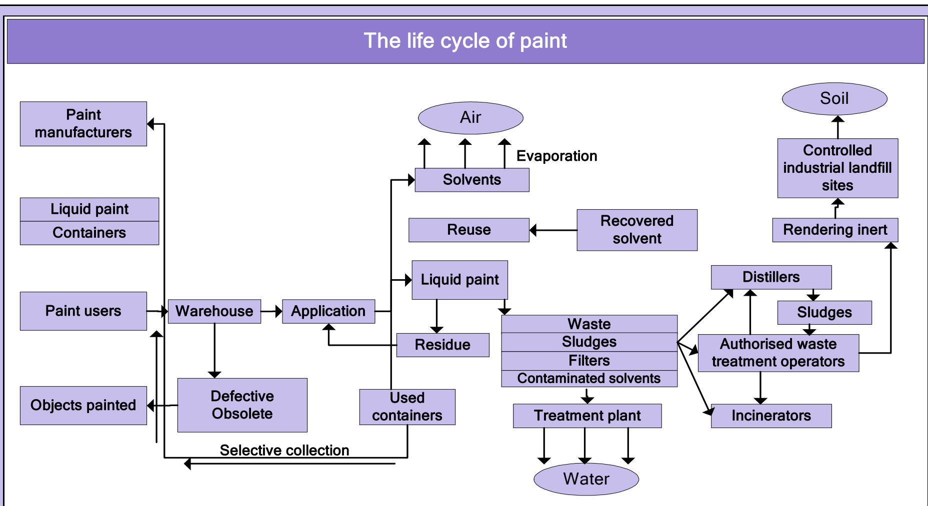


Figure 1

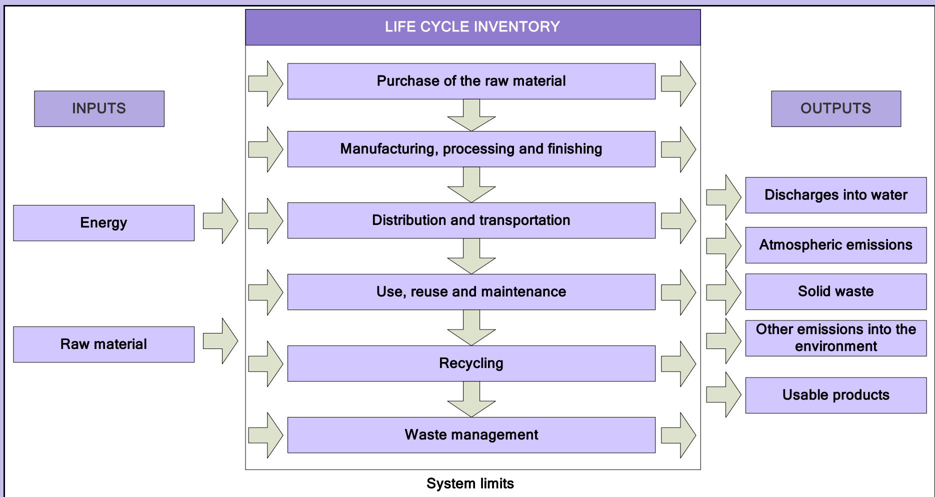


Figure 2. Manufacturing process for paints with the application of eco-design

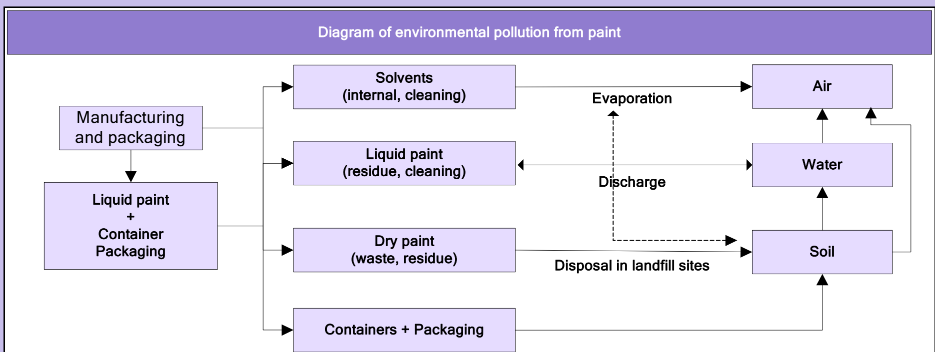


Figure 3

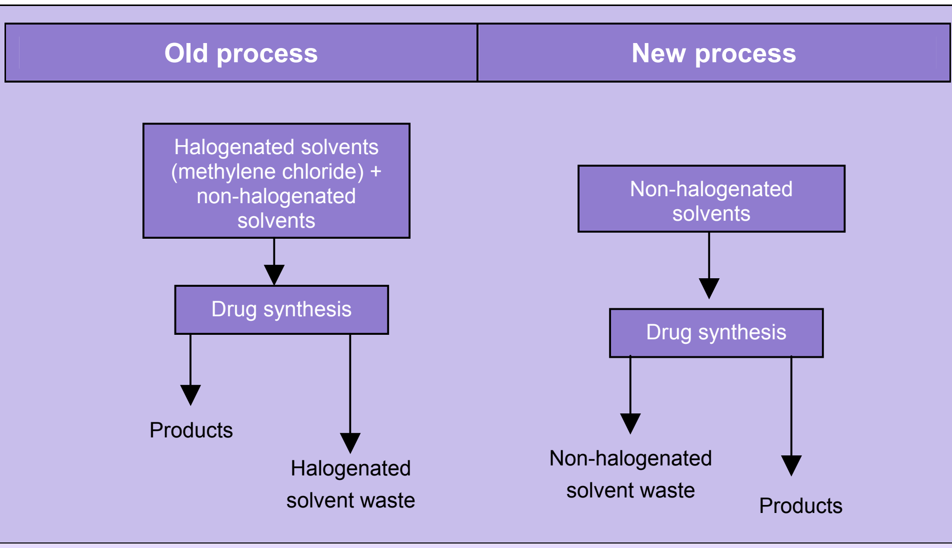
Conclusions

Benefits:

- Leadership in the sector.
- Improved company image.
- Environmental improvement of products (reduction in the toxicity of raw materials, reduction of the volume of waste, reduction of the pollutant load of wastewater discharged).
- Competitive improvement of the company and increased client satisfaction.

CASE STUDY 14	
Company	UNIÓN QUÍMICA FARMACÉUTICA, S.A. (UQUIFA)
Country (Location)	Spain (Lliçà de Vall, Barcelona)
Industrial sector	Fine chemicals. Manufacture of base pharmaceutical products.
Project subject	Substitution of raw materials: Green chemistry. Substitution of halogenated solvents.
Environmental considerations	The use of solvents, including halogenated solvents such as methylene chloride, is still of importance in the chemical sector due to their chemical and physical properties (e.g. their boiling point, low reactivity, low flammability, etc.) as a medium in which to carry out synthesis reactions.
Background	The company UQUIFA, S.A. was using two of these halogenated solvents in various processes involved in the manufacture of base pharmaceutical products and, therefore, waste flows of the solvents were generated, including some halogens that were recycled internally. In 2000, the company undertook a research programme with the objective of reducing or eliminating the use of these two solvents, which would eliminate the need for end-of-pipe treatments, or at least reduce them to a large extent. The action to be taken was based on the following premises: • Elimination or reduction of halogenated solvents. • Elimination or reduction of the generation of waste of halogenated and non-halogenated solvents. • A reduction in emissions of volatile organic compounds. • A reduction in the pollutant load of wastewater generated. • Affordable costs of the alternative processes.
Summary of actions	Actions taken have consisted of carrying out a research and development project following the principles of green chemistry to study the manufacturing process of anti-inflammatory and anti-ulcer pharmaceuticals in which halogenated solvents are involved. The R&D project has been focused on seeking non-halogenated solvents, and on the study of the different stages of synthesis of active pharmaceutical ingredients that allow the products to be manufactured and obtained with the same quality standards that are required. The solvent selected has allowed one of the drugs mentioned to be manufactured, bringing greater environmental benefits, lower levels of workplace risk, fewer manufacturing and purifying stages, shorter working times, lower costs and greater economic profitability. The internal efforts of the R&D team should be highlighted, together with the efforts made for the validation of the new system of synthesis as a result of changes made to the previously-accepted synthesis procedures.

Process diagram



Balances

	Old process	New process
Balance of materials		
Consumption halogenated solvent	27 l/kg drug	0 l/kg drug
Consumption non-halogenated solvent	43 l/kg drug	14 l/kg drug
Halogenated solvent waste	0 l/kg drug	0 l/kg drug
Non-halogenated solvent waste	57 l/kg drug	34 l/kg drug
Additional benefits		
Chemical yield	65 %	75 %
Maximum production capacity	3 t/year	7.5 t/year
Economic balance for		
Solvent costs	€36.6/kg drug	€4/kg drug
Management of liquid waste	€9.65/kg drug	€11.5/kg drug
Savings and expenditure		
Savings on waste management	- €1.85/kg drug	
Savings on raw materials	€32.60/kg drug	
Savings per kg of drug obtained	€30.75/kg	
Total annual savings	€46,125 /year	
Investment in installations	Negligible	
Payback period	Immediate	

Conclusions

By carrying out the project, it has been possible to eliminate the use of halogenated solvents and to reduce the use of non-halogenated solvents by 67 %. In addition, the company has managed to reduce the number of manufacturing stages and to reduce product manufacturing costs by 35 %, to increase chemical yield from the synthesis reaction by 10 % (which represents a global increase in production capacity by a factor of 2.5) and to obtain the intangible benefits associated with handling substances that are less hazardous.

	As a result of the advances made due to this project, the company is investigating new lines of R&D for the synthesis of other drugs that it manufactures. This action is included in the framework of the Twelve Principles of Green Chemistry, a strategy that is helping the company to fulfil its plans for environmental improvement and its environmental protection policy. This policy was first put into place by the company when it joined the environmental management system ISO 14001.

6.5. NEW TECHNOLOGIES

CASE STUDY 15	
Company	WITCO ESPAÑA, S.A.
Country (location)	Spain (Granollers, Barcelona)
Industrial sector	Manufacture of chemical products and speciality surfactants
Project subject	New technologies: Minimisation of waste through the application of advanced process control technology.
Environmental considerations	The impact of the activity of Witco España, S.L. on the environment affects the three environmental vectors: a) as wastewater from equipment cleaning operations, condensation water and material transferring operations. b) as special waste, consisting mainly of non-reusable sub-products. c) as gaseous emissions into the atmosphere due to the transference of materials and process operations.
Background	The waste and emissions generated represented management and treatment costs that Witco decided to attack by means of a system of advanced control of process variables that notably limited fluctuations. The interest of Witco España, S.L. in offering a range of high-quality products with appropriate levels of production costs, in combination with company policy aimed at increasing safety and reducing the environmental impact of the company's activity, were the starting point for the implementation of a Distributed Control System (DCS) using advanced technology for the manufacture of products in batch processes. A DCS can be defined as an interactive and multi-task modular electronic control system, which enables all of the signals connected to it to interact through a computer with its own control program. In terms of the action described above, the highly manual nature of process operations limited repetition and reliability. and was the cause of the excessive generation of non-reusable products. Moreover, the cleaning procedures of the equipment and the transfer of materials require significant water consumption which eventually become wastewater with a high pollutant load.
Summary of actions	The action outlined here consisted of the phasing in of a DCS made up of several units connected to a computer that controls the operation of the reactors (which have a capacity of between 5 and 40 t) and the auxiliary systems, such as the cooling circuit and the storage system for both raw materials and finished products. The action was completed with the implementation of a quality control system in accordance with the standard ISO 9001.

Balances	(see table below)

	Conventional process control	Process control using Distributed Control System (1)	Savings
Water balance	30,000 m^3/year	22,500 m^3/year	€5,409.11/year
Generation of waste	100 t/year	20 t/year	€24,040.48/year
Generation of wastewater	16,000 m^3/year	12,400 m^3/year	€43,272.87/year
Savings of raw materials	-	-	€45,075.91/year
Personnel/unit of production	Base of reference: 1	0.75	-
Investment		N/A (2)	-

(1) With an increase in production of 51 %

(2) The initial objective of the action was to increase productivity, improve product quality and reduce manufacturing costs, including environmental costs. The project therefore consists of an action related to global company management that incorporates environmental variables.

Conclusions

This is an interesting example of the way in which the precise control of process variables implies, in addition to an improvement in quality and a reduction in operating costs, environmental improvements that in turn lead to a reduction in waste management costs.

As a result of the increased precision with which the different manufacturing operations are controlled, less product that does not meet specifications is produced (specifically, 80 % less special waste is produced), less wastewater is generated, which results in lower treatment costs and a reduction in drainage costs, less raw material is consumed, etc.

The objective of this data sheet is to show that there is a connection between the control of process variables, quality, safety, reliability and the environment.

A company policy aimed at minimising waste will also achieve improvements in other aspects (economic, quality, company image, safety, etc.) that can be of great importance to the company's competitiveness.

6.6. WASTE AND EMISSIONS MINIMISATION ACTIONS

<table>
<tr><th colspan="2">CASE STUDY 16</th></tr>
<tr><td>Company</td><td>HERBOS, D.D</td></tr>
<tr><td>Country (location)</td><td>Croatia (Sisak)</td></tr>
<tr><td>Industrial sector</td><td>Chemical industry. Production of herbicides.</td></tr>
<tr><td>Project subject</td><td><u>Minimisation of waste and emissions:</u> Cleaner production in a chemical industry through the adoption of good housekeeping practices and process changes.</td></tr>
<tr><td>Environmental considerations</td><td>The chemical company Herbos was generating highly polluted wastewater due to the use of the herbicide Atrazine. Having been diluted, this wastewater was discharged. The rates that were paid for this wastewater were very high. As a result, Herbos focused its cleaner production project on improving the quality of wastewater and on reducing the rates to be paid for it.</td></tr>
<tr><td>Background</td><td>Prior to the introduction of the improvements proposed in the cleaner production process, the concentration of herbicide in the wastewater was 67.2 mg/l, due mainly to the suspended particles of the product Atrazine. In addition to the environmental pollution that this generated, the losses of herbicide in wastewater reached levels of 0.85 % of annual production.</td></tr>
<tr><td>Summary of actions</td><td>Two of the measures proposed in the cleaner production project were implemented:

1. The exhaustion of raw materials was increased (around 1 %) by an improvement in the control of the production process, followed by the implementation of good housekeeping practices and a slight modification of the process.

2. Pollution of wastewater was reduced by adding greater quantities of the chemical reagent (tenzide) during the Atrazine synthesis process. In this way the filtration possibilities of the suspension in the water were improved, which simplified the filtration phase and made it faster. With this practice in place, the decantation phase (which was the main source of pollution of the water) is no longer necessary.

No capital investment was required for the implementation of these two improvements.</td></tr>
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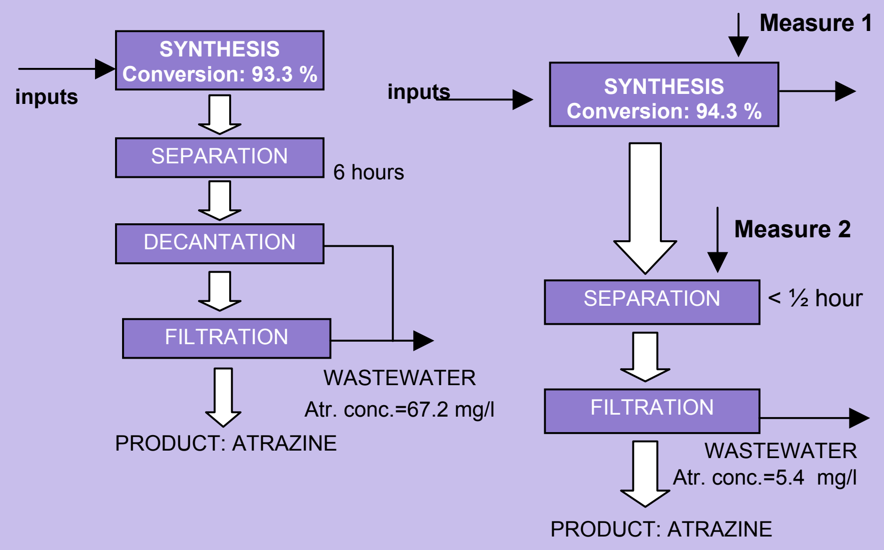
Diagrams

Old process	New process



Balances

	Old process	New process
Balance of materials		
Consumption of raw materials per unit of product (Atrazine).	1.99	1.89
Concentration of Atrazine in wastewaters.	62.7 mg/l	5.4 mg/l
Savings		
Raw materials		101 mT
COD		21 mT
Final product		54 mT 0_2
Economic savings		€179,167/year
Investment		0
Payback period		Immediate

Conclusions

The process of synthesis of Atrazine improved following the modifications made.

The exhaustion of raw materials (around 1 %) was increased by adding greater quantities of the chemical reagent (tenzide). In this way, the filtration possibilities of the particles in suspension in the wastewater were improved.

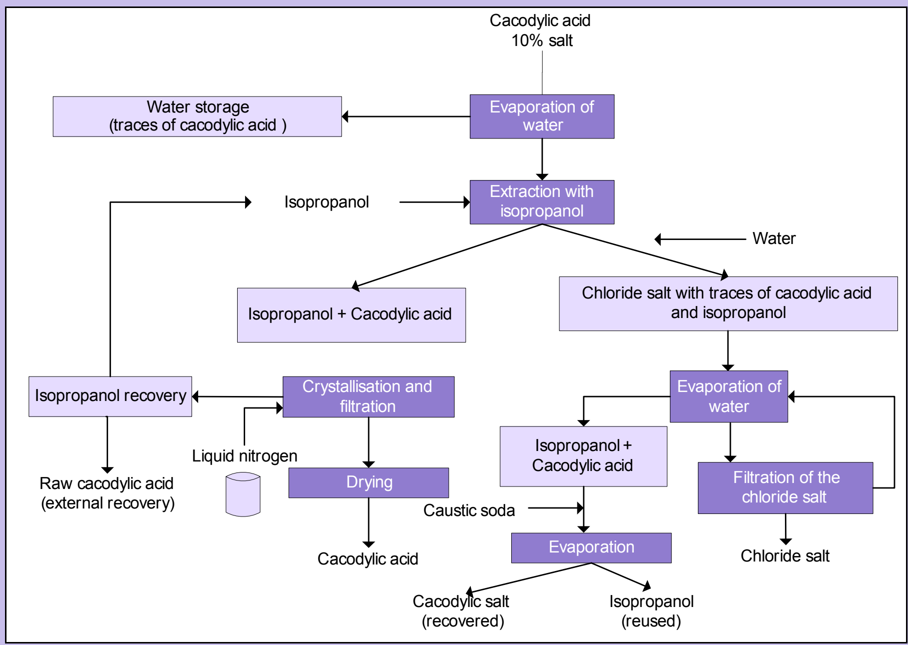
The economic savings made were the result of the reduction in: the consumption of raw materials, losses of final products, wastewater rates to be paid and the cost of treatment in the wastewater treatment plant.

This is an example of how the improved control of the process, followed by simple organisation and some technical modifications, can result in an economically viable solution to a problem of waste and emissions. In this way the company has become more environmentally sound.

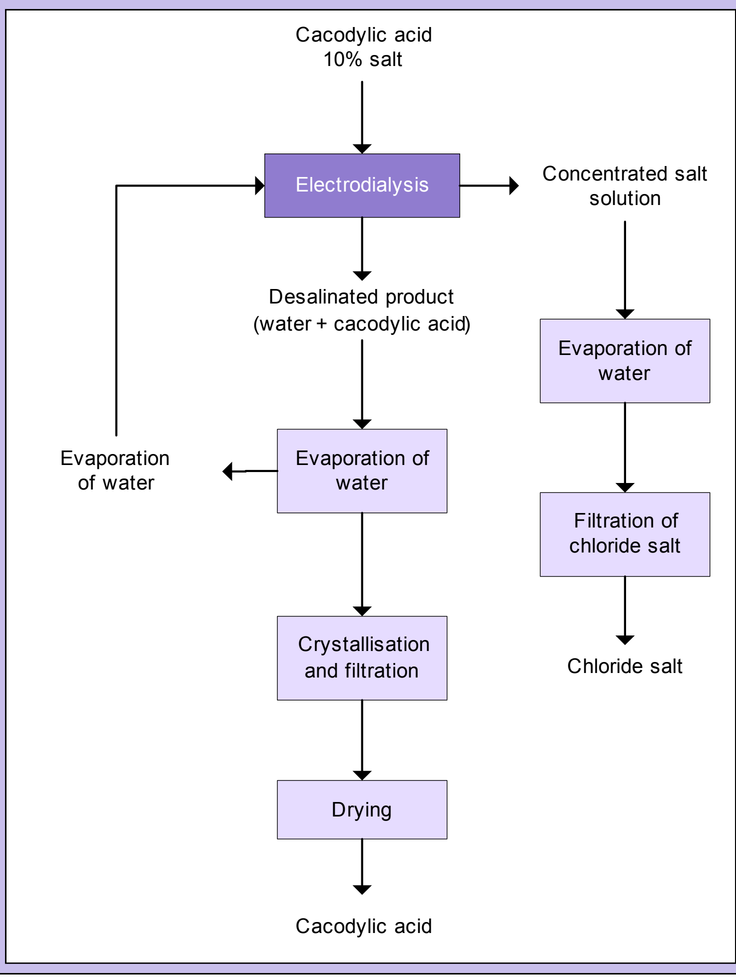
CASE STUDY 17	
Company	Las Industrias Luxembourg (Pamol) LTD (Arad, Israel)
Country (location)	Arad (Israel)
Industrial sector	Chemical industry. Production of various chemical products for crop protection together with intermediate chemical products for the chemical and biotechnology industries.
Project subject	Minimisation of waste and emissions: Cleaner production in a chemical industry through the adoption of good housekeeping practices and process changes.
Environmental considerations	When high quality cacodylic acid is purified, the elimination of chlorine salts is effected using isopropanol. The chlorine salt is waste and is saturated with cacodylic acid and alcohol. This salt cake is treated with water to recover the cacodylic acid and the alcohol. Following this, the water is evaporated to recover the alcohol and the acid. The treated chlorine salt is then sent to a chemical waste landfill site.
Background	The yield from this process is approximately 50 %. Although the acid is recovered, the treatment and the loss of alcohol are considerable. The supplementary water used for the treatment of the chlorine salt must be evaporated, which implies extra operational and energy costs.
Summary of actions	An entirely new process for the separation of the chlorine salts from the aqueous solution of cacodylic acid was put into place. The separation of chlorine salts takes place using electrodialysis. Using this technique the elimination of the chlorine salts from the solution of cacodylic acid eliminates the use of alcohol, and it is also no longer necessary to add water to the chlorine salt. The (acid) yield from this process is approximately 95-98 %.

Diagrams

Old process



New process



Balances	(see table below)

	Old process (tonnes/y)	New process (tonnes/y)	Savings €/y
Liquid nitrogen consumption	7.2	0	3,636
Losses of cacodylic acid	0.5	0.5	6,464
Isopropanol consumption	8.2	0	10,100
Operational costs (energy, salaries etc.)			30,300
Annual savings (€/y)			**50,500**
Total investment (€)			**59,338**
Payback period			**14 months**

Conclusions	A new technology which is usually used for the desalination of water is used successfully here to minimise waste. The most significant saving is in the operation, as the reprocessing of the chlorine salts is no longer necessary, but no less important is the increased safety of the process due to the elimination of the use of alcohol. The most significant proportion of investment costs is due to the extensive research work carried out in Ben Gurion University, Beer Sheva, Israel.

CASE STUDY 18	
Company	HIPERTIN, S.A.
Country (location)	Spain (Barberà del Vallès, Barcelona)
Industrial sector	Chemical. Manufacture of cosmetic products (production of oxygenated hair dyes).
Project subject	<u>Waste and emissions reduction actions</u>: Recovery of the final product and improved cleaning.
Environmental considerations	To manufacture oxygenated hair dyes, three different mixing operations are carried out. The first two operations consist of the separate heating of the aqueous and oil-based phases. Once they are heated, the third operation involves the mixing of the two phases in a reactor (in a vacuum) with stirring by blades on both sides until an emulsion is formed. When the emulsion is obtained, the product is ready to be packaged straight away by emptying the reactor from underneath. In the case of this company, the reactors, which have a conical bottom and in which the different phases of the dyes were mixed, were emptied when mixing was finished. In spite of everything, product residue was left on the base of the reactors. Before the reactors were cleaned, they were left open for a day. The characteristics of the oxygenated dyes meant that when the product came into contact with the air, it oxidised and hardened rapidly. It was therefore necessary to consume a large amount of water in the cleaning of the reactors. Additionally, due to this oxidisation and the location of the emptying valve, in each cleaning operation for each reactor approximately 3 kg of finished product were lost in the form of wastewater. Moreover, the cooling of the reactors that is necessary during the manufacture of the dye was effected by an internal coil fed by an open water circuit.
Background	The company decided to carry out an Minimisation Opportunities Environmental Diagnosis (MOED) with the aim of finding alternatives that would allow it to attain the following objectives: • A reduction in water consumption in both the cleaning of the reactors and in the cooling circuit. • A reduction in the losses of final product due to the incomplete emptying of the reactors and the oxidising of the finished product in contact with the air. • A reduction in the pollutant load discharged and the volume of effluent to be treated.
Summary of actions	HIPERTIN, S.A. has carried out many of the alternatives recommended by the MOED, but of those, the following can be highlighted: a) The emptying system has been improved by maintaining the stirrer in motion throughout the operation and by increasing the temperature. This encourages the evacuation of the product for recovery and avoids the product ending up being mixed with wastewater.

	b) The cleaning system has been improved by carrying it out directly after emptying, using high pressure and high temperature cleaning systems. This avoids the excessive oxidising of the product. c) The water from the last cleanings is stored for use as a raw material in later cleaning operations, which has enabled a greater reduction in water consumption. d) The coolant water circuit has been closed by means of the installation of coolant equipment that enables the water to be continually reused.
Images	 Reactors in which the dyes are mixed
Balances	see table below
Conclusions	The actions carried out and the application of good housekeeping practices have resulted in a significant reduction in the generation of wastewater from the cleaning of the reactors. This wastewater is currently managed as waste by an authorised manager.

Balances

	OLD PROCESS	NEW PROCESS
Water consumption*	2,177.7 m^3/a	**40 m^3/a**
Production per unit of raw material	97/100 t/t	**99/100 t/t**
Generation of wastewater**	2,177.7 m^3/a	**0 m^3/a**
Savings in water consumption***		**13,688.05 €**
Increased productivity and reduced losses		**54,091.09 €**
Savings in waste treatment		**13,674.23 €**
Investment	**66,111.33**	
Payback period	**14 months**	

*The water incorporated into the product, which remains constant, is not considered here.

**The 40 m^2 that are currently generated are generated as liquid waste.

***Savings in consumption, treatment and wastewater disposal rates are included.

	Thanks to the closure of the cooling circuit and the improvement of cleaning processes, needs, for the same process, the company currently 2 % of the water it required previously (water incorporated into the product not included), with no significant increase in energy consumption. On the other hand, the fact that part of the product that was retained in the reactor is recovered and sold results in highly significant savings, which will enable the company to approach new environmental improvement projects, such as the installation of a vacuum evaporator for the liquid waste that must be managed following cleaning.

6.7. HOW TO PUT AN ENVIRONMENTAL IMPACT MINIMISATION PROGRAMME INTO PRACTICE

The methodology of minimisation consists of the systematic identification, quantification and elimination of waste emissions. This methodology can be summarised as follows:

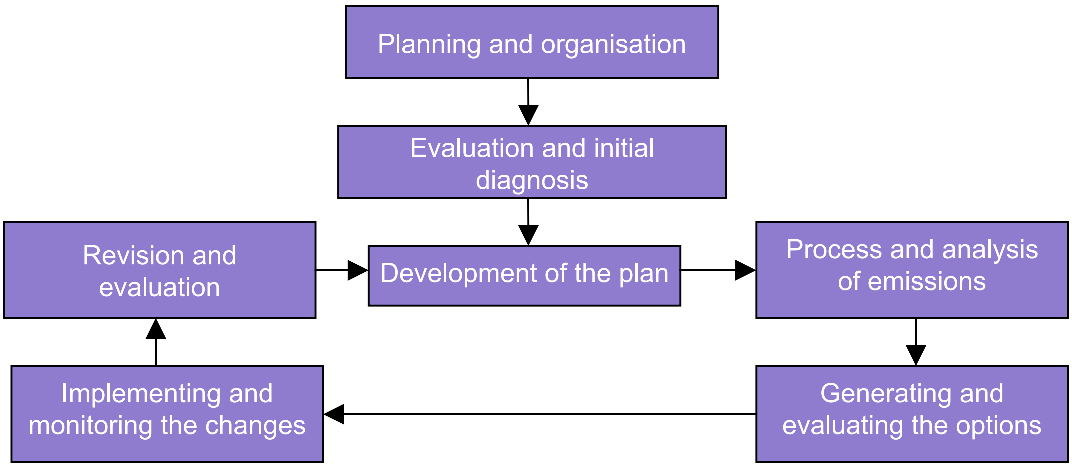


Figure 6.1. Methodology for putting an environmental impact minimisation programme into practice

6.7.1. Planning and organisation

The successful implementation of a minimisation programme requires good planning and organisation.

MANAGERIAL COMMITMENT

The first step towards establishing a minimisation programme is the commitment of the top management team. From this top level, the organisation should project its commitment to the application of good housekeeping practices aimed at minimisation. In addition, the company management should provide the resources, both human and material, that are necessary to guarantee that the targets set are met.

ESTABLISHING A TEAM

Putting a minimisation programme into place is more effective if a "minimisation team" is set up. The team should include people at different levels within the company, including intermediate levels and production staff. The number of members should be sufficient to enable the distribution of the workload that the team generates. The ideal team should have representatives from the following areas and/or knowledge bases:

- Production.
- Financial.
- Technical/engineering.
- Environmental.

The team should have a leader whose basic functions should be:

- To act as a contact person with top management.
- To coordinate collaboration between departments.
- To motivate the staff as a whole.
- To lead and motivate the minimisation team.
- To provide the team with sufficient authority to develop the programme.

FUNCTIONS OF THE TEAM

To put the minimisation programme into practice successfully, the team needs to carry out the following tasks:

- Organising and conducting meetings.
- Assigning tasks and establishing their monitoring and application.
- Collecting, filing and organising all of the data and the documentation generated.
- Motivating and communicating at all levels of the organisation.

TEAM OPERATION

The members of the team should know and understand their role and be able to carry out their work efficiently. They also need the support of their supervisors, and to have sufficient time for this task.

The team will have follow-up meetings to evaluate the progress of the implementation of the minimisation programme.

SETTING OBJECTIVES

It is essential to establish targets to ensure the development of the programme and its continuity. The objectives should be accessible and attainable by all the levels of the organisation. They should also be useful and, wherever possible, quantifiable.

COMMUNICATION

It is important to communicate the achievements and the progress of the implementation of the minimisation plan. To do so, it is helpful to establish a system of communication that identifies what, when and with whom communication is to take place, together with the way of doing so: reports, meetings, and letters to all employees.

6.7.2. Evaluation and initial diagnosis

To carry out the minimisation programme successfully, it is necessary to pose a series of key questions:

- What quantities and what type of waste and emissions are generated?
- What costs does this waste and do these emissions imply for the company?
- At exactly what point of the process are the emissions and waste generated?
- Why are the emissions and waste generated?
- What can we do to prevent and reduce these emissions and waste?

The initial evaluation begins by finding an answer to these questions. For this, it will be necessary:

- To identify and collect data of the consumption of resources and raw materials and of the production of waste and emissions, in order to establish a starting point based on which the improvement objectives will be set.

GATHERING DATA

The collection of data at the start of the minimisation programme will:

- Provide a starting point from which the success of implementation of the minimisation programme can be measured.
- Be helpful in prioritising actions and projects, according to:
  - The economic saving that they involve for the company.
  - The benefits in terms of the environment and workplace health and safety.

It should be remembered that in addition to helping the company to reduce waste and emissions and to use resources more efficiently, minimisation can contribute to the company's compliance with health and safety and environmental regulations, as well as saving capital.

The following information should be collected:

- Inputs
  - Raw materials: quantities and annual costs of the most significant raw materials.
  - Packaging: quantity and annual cost.
  - Auxiliary materials: quantities and annual costs.
  - Energy: sources of energy, uses, amount consumed and annual cost.
  - Water: quantity used, points of use and annual cost.
- Outputs
  - Transportation of waste: quantity sent, characteristics, annual cost of each type.
  - Solid waste: quantity and management costs.
  - Hazardous waste: quantity and management costs.
  - In situ treatment of emissions, water and waste: quantities and associated costs.
  - Internal recycling: materials recycled and associated costs.
  - External recycling: recycled materials and associated costs.

- Additional information
    - Legal compliance.
    - Health and safety risks.
    - Environmental risks.
    - Investments anticipated: extensions, investments in the treatment of emissions, water, etc.

INSPECTION

Inspection enables the identification of the types and the quantities of waste and emissions that are produced and the place in which they are produced.

Inspection is planned according to the following criteria:

- Selecting an inspection team incorporating people from outside the minimisation team.
- Developing a series of questions that enable particularly important information to be collected.
- Determining the best moment to carry out the inspection. Choosing a period in which emissions and waste are generated. It is useful to carry out the inspection at different times, including the different working shifts in the company.
- Asking the staff (operatives, supervisors, etc.) about points of emissions or waste generation that they are aware of.
- Planning the monitoring of the process from the entry of raw materials to the final product.
- Carrying out a monitoring of waste from its generation to its management and elimination.
- Making a written note of findings. Preparing templates for the collection of data.
- Informing all of members of staff in the company that the inspection is to be carried out and asking for their collaboration.

IDENTIFICATION OF OPPORTUNITIES

The Information gathered during the inspection, together with the starting data already collected, will be the basis for identifying and prioritising potential opportunities for improvement and minimisation. With this data it can be decided which processes, waste flows or emissions will be the priority for action. It is good always to start with an objective that is easy to attain, as it will be implemented quickly and will reinforce the idea of teamwork.

DEVELOPMENT OF A PLAN

It is useful to develop a plan for the waste and emissions minimisation programme. The plan should be in writing, and should include:

- A declaration of support from the management for the minimisation programme.
- A description of the minimisation team that includes the responsibilities of each member.
- The objectives of the minimisation programme.
- The communication plan for progress in the implementation of the programme.
- The data collected during the initial evaluation and inspection.
- The opportunities for improvement detected during the inspection and initial evaluation.
- The priority objectives that are to be worked on immediately, including the assignation of responsibilities and the planning process.

6.7.3. Analysis of the process and the waste and emissions generated

For this point, a detailed study should be made of the waste and emissions that are generated. To do so, it will be necessary to:

- Draw up a process diagram.
- Identify the inputs and outputs of each step of the process.
- Quantify and evaluate the cost of each of the inputs and outputs.

PROCESS DIAGRAM

The process diagram will illustrate the flows of materials, energy and water that take place during the process and the points at which emissions and waste are produced.

An example of a process diagram could be:

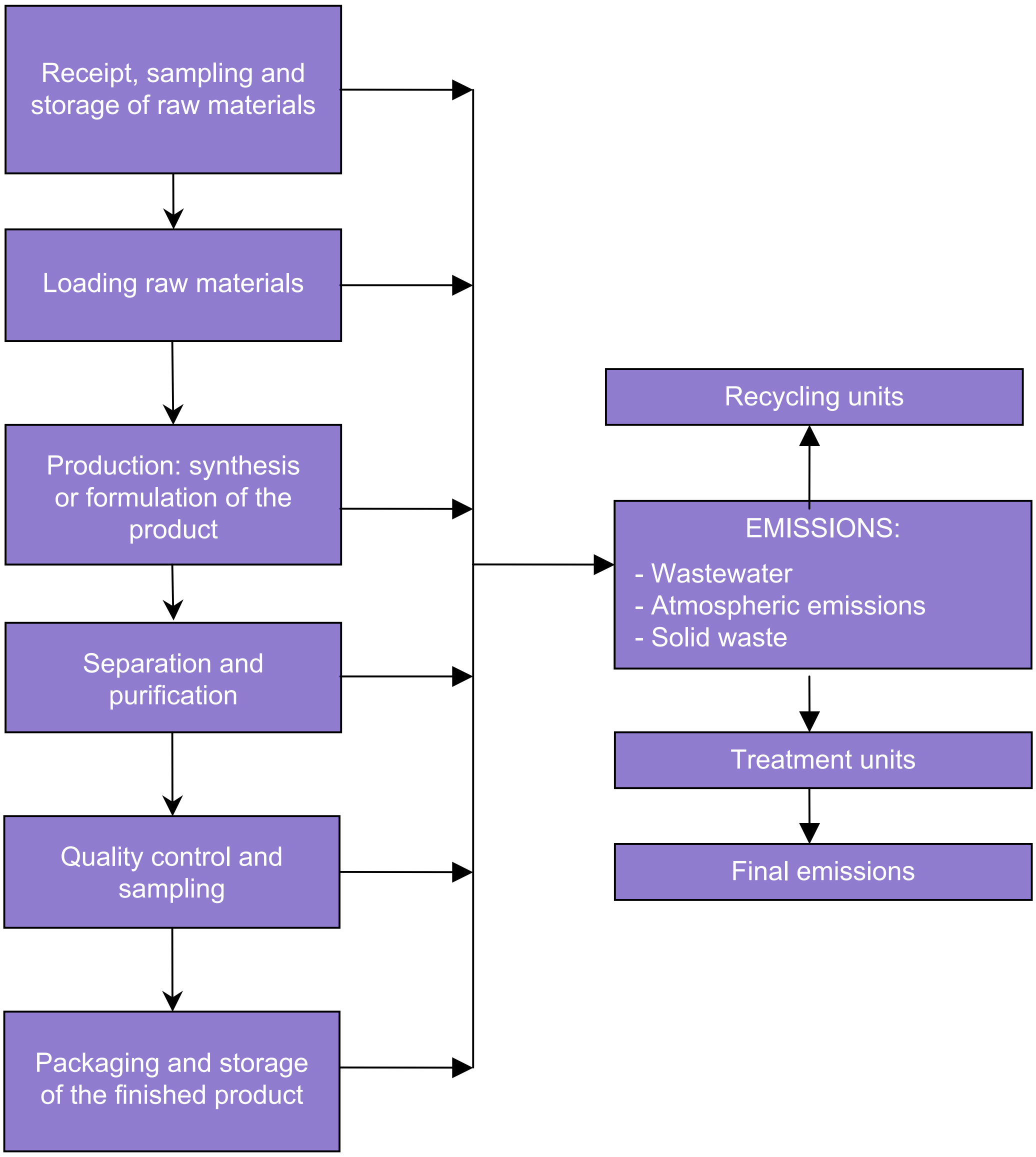


Figure 6.2. Example of a process diagram

IDENTIFICATION AND QUANTIFICATION OF INPUTS AND OUTPUTS
The next step is the identification and quantification of the inputs and outputs that take place during the process. This quantification is, in short, a balance of masses in which inputs should be the same as outputs: everything that we introduce into the product comes out as product, waste, heat, emissions, etc.

A large part of the information needed to calculate this balance will be easily available, while on the other hand, a certain amount must be collected from various sources, such as:

- Historical data, particularly with reference to the consumption of energy, water and raw materials.
- Data collected at the time from in situ measurements of flows, weights, etc.
- The measurement of waste and emissions.

CALCULATION OF THE COST ASSOCIATED WITH THE PRODUCTION OF WASTE AND EMISSIONS
The cost associated with the generation of waste and emissions includes more aspects than just treatment and final disposal. It includes all those costs that are incurred during the production and management of waste and emissions. Some of the costs to be considered are:

- Transport costs.
- Storage costs.
- Costs of the treatment of emissions and discharges.
- Costs of the collection and management of solid waste.
- Losses of raw materials.
- Costs of raw materials that are converted into waste or emissions (for example of a solvent or of water).
- Costs of processes associated with the production of the waste or emission.
- Labour costs.
- Depreciation of capital.

Thus the total cost of a waste flow can be expressed by the following equation:
Total cost = cost of raw material + added value + opportunity costs of sales + costs of management, treatment and disposal.

6.7.4. Generation and evaluation of the minimisation opportunities

In general there is usually more than one option for the reduction of emissions and waste, and it is therefore important to know how to opt for the most appropriate for each situation. It is therefore necessary to evaluate the costs and benefits of each of the options carefully.

GENERATION OF OPPORTUNITIES
During the initial evaluation and research phase, ideas will begin to be generated on how to change the way of doing things, whether in the consumption of raw materials, energy or other aspects, in a way that is more efficient from an environmental perspective. To encourage the generation of ideas, a suggestions box can be set up or a brainstorming meeting can be called, in which different levels of the organisation participate.

Minimisation opportunities can be organised into three large groups: those intended to achieve reduction at source, those that promote reuse and/or recycling, and lastly those that focus on improving the management of such waste as is inevitably produced. The following table shows some of the opportunities for minimisation, in accordance with the classification above:

Table 6.1. Examples of pollution prevention opportunities

MINIMISATION OPPORTUNITY	EXAMPLES
Reduction at source	**Improvement in maintenance:** many minimisation options arise from carrying out a good maintenance programme that reduces losses in installations and equipment, such as valves, pipes, seals, joins, etc.
	Modernisation of equipment: replacing equipment with more efficient models can help with the minimisation of energy and other consumption, for example.
	Substitution of materials: the substitution of toxic substances by other non-toxic ones contributes to the minimisation of the generation of toxic waste. An example of this practice would be substituting solvents used in cleaning with water-based products.
	Redesign of the process: on occasion, the same product can be produced using different techniques. For example, many chemical products can be manufactured by applying green chemistry techniques, using materials that are less toxic, etc.
	Redesign of the product: the redesign of the product to generate less waste and emissions or waste and emissions that are less toxic may be viable. For example, water-based colorants and inks generate lower levels of emissions and toxic waste than solvent-based ones.
Reuse and/or recycling	**Recycling and reuse in the process:** the waste from a process can be used as a raw material in the same or other processes. For example, mother liquor or cleaning water from certain processes can be filtered and reused for new formulations.
	External recycling: there are numerous external recyclers that recover waste such as solvents.
Treatment and final disposal	**Separation of waste:** the mixing of waste types that require final treatment with those that do not increases the generation of waste. For example, separating toxic waste from non-toxic waste reduces the quantity of toxic waste to be managed. It also allows the reuse or recycling of the waste, both toxic and non-toxic.

EVALUATION OF THE OPPORTUNITIES

Some of the opportunities generated involve hardly any costs or risks and can be applied immediately, while others are rejected due to their lack of practical viability. The rest of the opportunities generated should be evaluated to determine their viability. Evaluation should consider the following aspects:

- Technical evaluation:
  - Potential for the reduction of waste and emissions.
  - Safety of the workers affected.
  - Maintenance or improvement of product quality.
  - Availability of space.
  - Compatibility of new equipment, materials or procedures.
  - Training and skills development requirements.
- Environmental evaluation:
  - Effect in quantity and toxicity of waste and emissions flows.
  - Energy consumption.
  - Environmental impact of the alternative raw materials introduced.
  - Risk of transference of the environmental impact from one medium to another (for example from solid waste to liquid discharge or gaseous emission).
- Economic evaluation:

  To evaluate the economic viability, we have to know the cost associated with the waste before and after the application of the minimisation opportunity and the investment cost of that same opportunity. With this information we can calculate the payback period on the investment, which will give us an idea of the viability of the option:

$$\textit{Payback period (years)} = \frac{\textit{Investment cost (capital + implementation + other costs)}}{\textit{Annual cost of initial waste – Annual cost of final waste}}$$

6.7.5. Implementation and monitoring of changes

IMPLEMENTATION OF THE CHANGES

It can be difficult to put the changes, even the smallest changes, into practice. Some of the reasons making this implementation difficult include resistance to change within the company itself, inertia and time restrictions. In general, receptivity to the changes is greater when the people involved know the reasons for the change and their role within the change. It is therefore important to plan the implementation of changes well, and for this the following elements should be considered:

- Knowing who has the authority to make the changes: it is important to obtain the support of the company management to ensure the authorisation, the financing and the necessary equipment to make the changes. For small changes, it will be enough to involve the shift leaders or supervisors, while for major changes it will be necessary to obtain financing and to programme this into the annual budget.
- Assigning someone to supervise the change and ensure that it is introduced smoothly.
- Deciding on the information that should be provided to the personnel involved in the change.
- Determining the need for training of the personnel involved.

MONITORING THE PROJECTS

Once the waste and emissions minimisation opportunities have been implemented, it is then time to monitor them, thus enabling the company to have information available on the development of the projects put into practice. A decision should be made for each project concerning:

- What is to be monitored: for example, energy consumption, waste generation, consumption of raw materials.
- When monitoring is to take place: daily, hourly, every shift, occasionally, etc.
- The way monitoring is to take place.
- The person responsible for carrying out each monitoring step.
- The way that data is to be collected and interpreted: drawing graphs, statistics, etc.
- Determining the responsibility of communicating the results and to whom.

6.7.6. Measuring progress: programme and evaluation of the projects

The regular revision of the progress of the minimisation programme is important in order to determine whether the objectives that have been set are being attained or not, and in the latter case to determine how they can be attained. When the minimisation programme is evaluated, it is important to identify both the aspects that work and those that do not or that can be improved.

One way of measuring the progress of the programme is by monitoring the results individually, such as the amount of waste reduced, the money saved and whether the project has been implemented correctly, on time and within budget.

Some of the criteria that could be useful in measuring the progress of the waste and emissions minimisation programme are shown in the table below:

Table 6.2. Criteria for measuring the progress of the minimisation programme

ASPECT OF THE PROGRAMME	EVALUATION CRITERIA
Projects	Reduction of waste and emissions achieved Savings of raw materials achieved Money saved Improvement in product quality Improvement in worker safety Fulfilment of the budget Compliance with the time frame
Support from management	Declaration of support Approval of projects Contribution of ideas and suggestions Publicity for success
Operation of the team and staff involvement	Capacities of the team and the operation Staff participation Contribution of ideas and suggestions Attainment of individual objectives Support for projects Availability for training
Knowledge of the process and the waste and emissions generated	Map of the process made Identification of all sources of waste and emissions Quantification of waste and emissions Waste cost calculated
Integration in day to day management	Establishment of key indicators relating to waste, consumption etc. Annual establishment of objectives Establishment of monitoring of the programme Responsibilities assigned and written into job descriptions Projects included in the budget Integration into existing management systems Minimisation forms part of the work agenda of company managers
Maintenance of the minimisation programme	Monitoring and revision of the minimisation procedures established Employees are kept up to date and involved The documentation and control of the system is established New projects are identified

6.7.7. Maintaining the waste and emissions minimisation programme

Once the minimisation programme is implemented, thought must be given to how it is to be maintained. Some ideas for maintaining the programme are given below:

CHANGES IN THE MINIMISATION TEAM
The minimisation team should rotate its members in order to keep the flow of ideas fresh.

TRAINING
Training in the minimisation of waste and emissions should be included in training programmes for both new staff and the continuous training of the staff as a whole.

COMMUNICATION OF SUCCESS
The communication of the minimisation programme and its successes is a good tool for maintaining it. Internal communication increases staff involvement and participation.

In addition to internal communication, the company should establish an external communication programme as a public relations tool in order to communicate the success of the minimisation programme to the authorities, local people and public opinion in general.

INTEGRATION OF MINIMISATION INTO DAY TO DAY OPERATIONS
To ensure that minimisation is integrated into the day to day operations of the company, it is important to:

- Assign the costs associated with waste generation to the units that generate this waste.
- Include the minimisation objectives in company policy.
- Develop indicators related to the minimisation objectives and assign responsibilities for attaining them.
- Ensure that management receives the annual evaluation programme.
- Establish the responsibilities related to minimisation in job descriptions.

7. CONCLUSIONS

7.1. GLOBAL PROPOSALS

As outlined in previous chapters, the chemical sub-sectors have a series of characteristics that determine and condition the environmental problems they pose:

1. Raw materials originating in other companies and even in other countries, and often a lack of awareness of the chemical products that are handled. The wide variety of processes that exist within one company requires the handling of a high number of raw materials, auxiliary products and chemical products.
2. A wide variety of processes (a single establishment usually processes various types of chemical products, with the same or different equipment).
3. Rapidly changing processes depending on market demand, so that these procedures can differ significantly from season to season.
4. Processes can be continuous, semi-continuous or batch, but they always require various processing stages.
5. A large number of stages in the process necessitate significant consumption of water and energy.
6. Some stages with moisture require water of a specific quality and therefore water conditioning processes such as electrolysis or reverse osmosis are required.

Given these basic characteristics of the sub-sectors studied, the following environmental problems or the main effects of these problems on the environment are generated:

1. Significant consumption of water and energy.
2. Consumption of auxiliary materials and chemical products is higher or lower, depending on the technology available.
3. High flow of wastewater with a significant pollutant load (although the pollutant load of wastewater generated depends on the processes carried out, the parameters that are usually most significant are COD, BOD, total solids, AOX, toxicity, nitrogen and chlorides).
4. Generation of expired raw materials and chemical products due to the wide variety of these that a single establishment handles, and to changes in the level of consumption from one season to another, together with warehouse errors.
5. Generation of a large number of empty containers corresponding to auxiliary products and chemical products used in the process.
6. Emission into the atmosphere of volatile organic compounds in the case that solvents and/or auxiliary materials are used that incorporate these compounds in formulation.

Nevertheless, as explained in this manual, this situation enables a large number of improvements to be made to ensure the prevention of pollution and the saving of natural resources. Broadly speaking, bearing in mind the diversity of the sector and in order to maintain company competitiveness, the solution is based on the implementation, in each specific case, of the **environmental improvements** considered to be the most appropriate of all the possible options.

However, in order to carry out some of these options, specific raw materials must be substituted, certain installations must be acquired and/or particular new technology must be put into practice and although these may be interesting objectives in themselves, due to the environmental benefits that they imply, they can also be prerequisites for achieving more global objectives.

The analysis of the economic viability of the different alternatives that exist should be made for each individual case, given that the investment required will depend on the technology that already exists in each company.

In any case, putting any of the cleaner production options mentioned above into practice, particularly when this involves the substitution of raw materials or modifications to processes, should be accompanied by the provision of information and training to staff, so that the desired environmental benefits are obtained and maintained, without this having negative effects on the quality of the product or the productivity of the establishment.

7.2. SPECIFIC PROPOSALS

Following an exhaustive analysis of the situation of the chemical industry in the Mediterranean, the evaluation of the situation of chemical companies in the Mediterranean countries is explained below.

The information quoted in this section has been obtained from the information given in the questionnaires that were filled out by the countries in question, and is not intended to imply any sort of value judgement on the environmental behaviour of the industries; rather the aim is to indicate, based on that information, some of the possible initiatives of application of measures for pollution prevention at source. These include:

1. The implementation of good housekeeping practices, minimisation plans and pollution prevention projects, particularly those related to cleaning operations, as these are usually simple and economically viable to carry out.
2. Carrying out campaigns of environmental awareness-raising and training for operators and technicians in chemical companies, thus encouraging interest in cleaner production. Publishing educational material and distributing it among all of the companies in the industry. Holding internal environmental awareness-raising and training courses in chemical companies.
3. Running campaigns to train technicians specialised in the environment.
4. Avoiding losses in the final product during production processes, and in any case, ensuring that the waste product is not incorporated into wastewater.
5. Establishing at least a wastewater pre-treatment system for the homogenisation and neutralisation of wastewater prior to its discharge.
6. Improving the maintenance of boilers, circuits and cooling systems.
7. Substituting obsolete systems for continuous, more advanced and efficient systems of innovative new technology in larger companies.
8. Establishing a system of collective collection for production residue from small companies, for its centralised recovery and suitable management based on its separation at source.
9. Progressively substituting manual cleaning systems for CIP (Clean in Place) systems. Standardising cleaning procedures and recovering cleaning solutions with the aim of reusing the chemical substances present wherever such a system has been put into place.
10. When a manual cleaning system is used, implementing measures to reduce and control water consumption during the process by using specific techniques.

11. Avoiding the discharge of product residue, and implementing a system for its collection and recovery.
12. Carrying out discharge reuse projects.
13. Ensuring the appropriate management of waste based on separation at source.
14. Minimising waste packaging, avoiding errors in packaging and implementing a system for the recovery or recycling of used containers.
15. Reducing the pollutant load of wastewater from the manufacture of final products.
16. Studying possibilities for environmental improvement, particularly for the possible recovery of chemical waste.
17. Avoiding losses of product during the process, losses of final product during processing and reducing the quantity of final product incorporated into final effluent.
18. Recovery of energy and the implementation of measures to make use of and optimise its consumption, together with the use of cleaner fuels such as natural gas. Installing cogeneration systems with a view to optimising energy yield.
19. Promoting the use of clean technologies.

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European Integrated Pollution Prevention and Control Bureau: http://eippcb.jrc.es/

United Nations Population Fund: http://www.unfpa.org/index.htm

Information for Africa: http://www.mbendi.co.za/index.htm

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