SECTORIAL MASS BALANCE STUDY FOR THE UK CHEMICALS INDUSTRY

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FORWARD

This report forms part of the Biffaward programme on sustainable resource use. The aim of this programme is to provide accessible, well researched information about the flows of different resources through the UK economy based either singly or on a combination of regions, material streams or industry sectors.

In addition to the projects having their own means of dissemination, their data and information will be collated in a common format to facilitate policy making at corporate, regional and national levels.

EXECUTIVE SUMMARY

In October 1997 the report *Great Britain plc* by Biffa Waste Services set out, at a macroeconomic level, estimates of resource flows within the British economy. The report recognised that data on overall mass flows within the British economy as a whole is poor, and argued the case for using physical mass balances as one measure of economic activity.

The UK Chemical Industry is a significant contributor to the UK economy with a good reputation for reporting on current and future issues. However material flows as an element of sustainable development have not historically been a focus of attention. This report sets out to highlight on the current position of the industry with regard to sustainable development, presenting in-depth material flows into and out of the key industry sub sectors.

This report presents a mass balance of the UK chemical Industry, including:

- the quantification of raw materials usage in the industry as a whole, and for the principal sub-sectors of which it is comprised;
- the identification of the relationships between resource inputs, product outputs, losses, emissions and waste streams, again at industry and sub-sector level;
- the identification of the extent to which the industry's waste streams are currently reliant on landfill for their ultimate disposal and the type of material so disposed;

The outputs of this study are targeted at the key stakeholders, Government, the Regulators and the Industry itself. By providing an understanding of the flow and quantity of materials and resources through specific UK chemicals manufacturing sectors the report should support these stakeholders in their decision-making processes by ensuring that a macro perspective of current resource use and waste management practices within the industry is available.

The key conclusions of this study are:

- this highly regulated industry has already made significant efforts in recent years to optimise energy consumption, raw material usage and minimise waste streams in order to remain competitive on global basis.
- the industry currently converts in excess of 80% of its raw material consumption into saleable product.
- the limiting factor to continued waste minimisation within the industry is the nature of the chemistry involved.
- water is the most significant raw material to the industry, used both as a raw material and a transport medium for material movement and energy transfer.

The report concludes with a set of recommendations suggesting that voluntary programmes to set targets and review performance may enable the industry to further optimise material usage, specifically water consumption.

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1 INTRODUCTION

1.1 Background

In its October 1997 report *Great Britain plc*, Biffa Waste Services set out at a macroeconomic level estimates of resource flows within the British economy. The broad conclusions of this work were:

- Personal consumption of food and other materials totals around 1 tonne per capita per annum, or around 60 million tonnes per annum (tpa) for the entire economy;
- The input of physical resources to service this consumption amount to around 660 million tpa (divided roughly equally between energy, aggregates, and other materials);
- This resource consumption equates to 10 tonnes of inputs for every 1 tonne of personal consumption (or 100:1 if water resources are included);
- Resource consumption is not sustainable and points to the urgent need to develop effective means of reclaiming, reprocessing and reusing of 'nearly new' resources otherwise discarded.

The report recognised that data on overall mass flows within the British economy as a whole is poor, and argued the case for using physical mass balances as one measure of economic activity.

Since *Great Britain plc* was published, Biffa has stimulated a number of studies to understand better the mass flows and mass balance in several industry sectors and/or geographic areas.

This study into the resource flow of a sector of the chemical industry, was funded by Biffaward, a multi-million pound environment fund managed by RSNC, which utilises landfill tax credits donated by Biffa Waste Services, with the Chemical Industries Association (CIA) contributing a percentage of the funding and access to its information within the sector. Under the rules of the scheme, projects are awarded to Enrolled Environmental Bodies, in this case SWEET (South West England Environmental Trust). Enviros March was appointed as the consultants to carry out the study.

1.2 Project Aim

The aim of this project was to:

- gain an improved understanding of the flow and quantity of materials and resources through a specific UK chemicals manufacturing sector;
- provide a further insight into more sustainable resource use and waste management practices within the industry;
- understand and identify potential areas for improvement and to place these in a broader environmental context.

This study conforms to the methodologies currently in place in many other sectoral studies currently underway and will build towards the eventual understanding of the total UK mass balance equation split down by industry sector. Biffaward is naturally keen to ensure that data provided by each study is in a standardised format. This format is based upon Standard Industry Classification (SIC) codes for manufacturing activity and Intrastat (Customs & Excise) codes for finished product.

1.3 Project Scope

This project builds strongly on the data already available within the Chemical Industries Association (CIA). It seeks to provide a significant reference source and methodology towards the sustainability initiative launched by the CIA. In outline it provides:

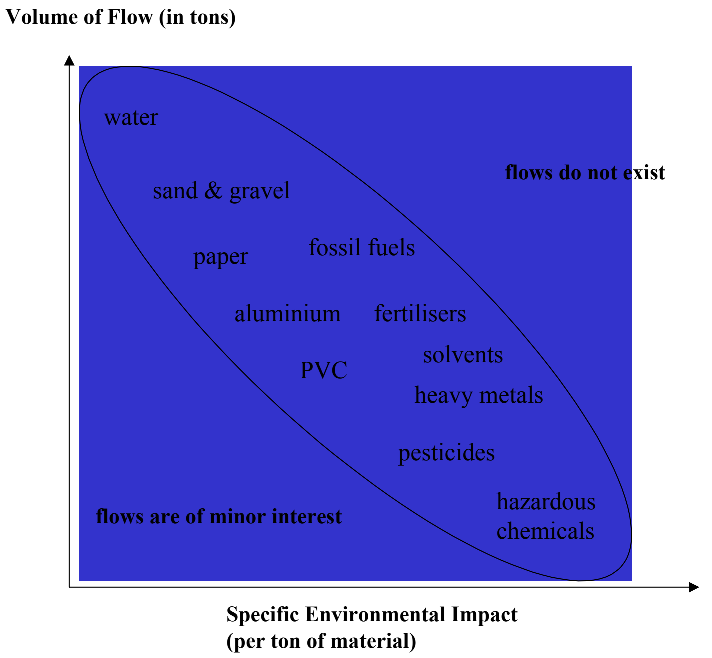
- Quantification of raw materials usage in the industry as a whole, and for the principal sub-sectors of which it is comprised;
- Identification of the relationships between resource inputs, product outputs, losses, emissions and waste streams, again at industry and sub-sector level;
- Identification of the extent to which the industry's waste streams are currently reliant on landfill for their ultimate disposal and the type of material so disposed;
- Quantification of the tonnages of recycled material being used within the industry, and the importance of such materials in the different sectors relative to the use of virgin material;
- Prioritisation of the areas where further action can be taken to minimise wastes and divert materials from landfill;

The data used within this section of the report has come from a number of sources eg UK Government and the CIA . Ideally the data refers to 1999 but in some cases the latest available from that source has been used.

1.4 Mass Flow Accounting in the European Community

Statistical services in Europe have a long experience in applying material flow accounting (MFA) techniques. The demand for information on MFA has resulted in the appearance of high level political documents on the subject and the introduction of terms such as 'industrial metabolism' and 'eco-efficiency'. Initially material flows were used to provide insights into physical macro movements of materials (describing the extraction, production, transformation and consumption of chemical elements / materials) within the European Community. The emphasis has shifted to focus on developing detailed mass flow accounts for energy and strategic materials (including materials which have specific environmental importance). The chemical industry has a high profile due its generation of hazardous chemicals. Figure 1.1 presents a stylised model generated by Eurostat relating material flows to perceived environmental impact.

Figure 1.1: Stylised Map of the Materials of Particular Interest for Mass Flow Accounting



Source: Eurostat StBA 1995

The materials within the ellipse in Figure 1.1 have total environmental impacts of broadly the same order of magnitude. This total impact is estimated by multiplying the specific material impact (per ton) by the volume of the flow. Interpreting this model it could be said that the environmental impact of a small flow of a hazardous substance has an equivalent environmental impact as a high volume flow of a substance with a very low toxicity.

Table 1.1 demonstrates how this mapping technique has been applied to group materials into three overlapping clusters, which correspond to the main areas of current European interest and policy direction.

Table 1.1: Application of Mapping Technique

Cluster	Interest / Policy Direction	Examples of Materials
Low volume flows of hazardous substances	Characteristics of the individual substances Control of the individual substances	Heavy metals Pesticides CFCs
Basic industrial materials	Life cycle considerations: • Material management • Resource efficiency • Waste minimisation	Base metals Plastics Packaging materials
High volume flows of non-hazardous substances	General sustainability considerations	Water Sand Timber

Eurostat predicts that material flow analyses will become part of an integrated economic-accounting process and will be used to provide relevant information for the consideration of environmental issues or concerns.

1.5 Existing Reference Data in the UK

The consumption of resources by the UK chemical industry has, to some extent, been quantified by the CIA in its annual Responsible Care Indicators of Performance (IOP) survey.

The Indicators of Performance (IOP) record the chemical industry's progress in measuring, managing and improving its health, safety and environmental performance under the commitments made in its voluntary Responsible Care programme. The IOP programme started in 1990 and captures data from the CIA member sites. It is not intended to report on resource consumption or efficiency, but allows the CIA to give assurance that Responsible Care is delivering genuine health, safety and environmental performance improvement. Among the indicators covered in 1999 were the environment and energy.

1.5.1 Environment

- Emissions to water eg COD, elemental discharge, nitrogen and phosphorus compounds and Red List discharges which have an impact on the aquatic environment.

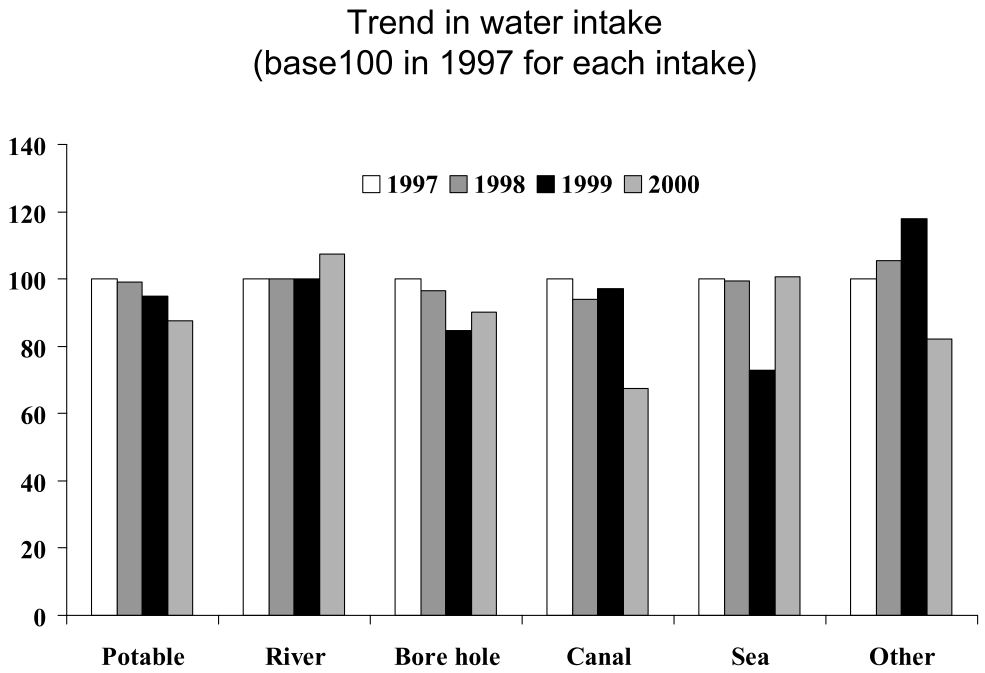
- The Red List comprises 27 substances or groups thereof defined by regulation which are of particular concern if discharged to water or to sewer e.g. mercury. There has been a continual decline to less than 4% of the 1990 baseline.

- Emissions to air eg of Volatile Organic Compounds (VOCs), sulphur and its compounds, compounds of oxygen and nitrogen, which contribute to atmospheric acidification and photochemical ozone creation.

- Disposal and fate of Special and non-Special Waste whether treated on or off site. In 1999, CIA members were responsible for 794,000 tonnes of Special Waste, which is estimated to account for approximately 20% of the UK total special waste arisings. Recycling by energy recovery or reprocessing was the method used for 34% of the industry arising, with 30% going to landfill.

- Water intake - in 1999 the chemical industry consumed 940,000 megalitres of water, 11% was from public (potable) water supplies and the rest from raw water sources with sea and river being the largest share. A lot of the raw water is used to simply cool processes and is then returned to its original source. A large part of the sea water abstraction is used for the extraction of certain products and then returned. Figure 1.2 presents a summary analysis of the consumption by water source and indicates the trends emerging.

Figure 1.2: Water Intake



1.5.2 Energy

- Energy consumption and CO_2 emissions **-** In 1999, CIA members' energy consumption was 383 million gigajoules on a primary fuel basis (direct consumption of primary fuels such as oil and gas) and indirect consumption, where steam and electricity are generated by others with efficiency factors for the their generation and transmission losses. Converting this energy consumption into CO_2 emissions (based on standard calculations) identifies that the industry is responsible for emissions of 6 million tonnes of CO_2 (as carbon) representing about 4 % of total UK emissions.

- Energy efficiency agreement - the CIA had a voluntary agreement with the Government on energy efficiency with a target to reduce the industry's specific energy consumption (energy efficiency as measured by energy consumed per tonne of product) by 20% of its 1990 level by 2005. With the implementation of the Climate Change Levy, there is now a chemical sector negotiated agreement where a target of 18% reduction for 2010 based on a 1998 baseline has been agreed with DEFRA.

1.6 Existing Mass Flow Indicators used to Define Study Boundaries

The chemical sector is extremely diverse, (Intrastat lists over 800 finished products from this sector and there are many thousands of intermediate materials) especially in comparison to many of the other sectors undergoing mass balance projects (e.g. paper). In addition official statistics estimate that there are currently around 3,500 companies trading within the chemical sector in the UK.

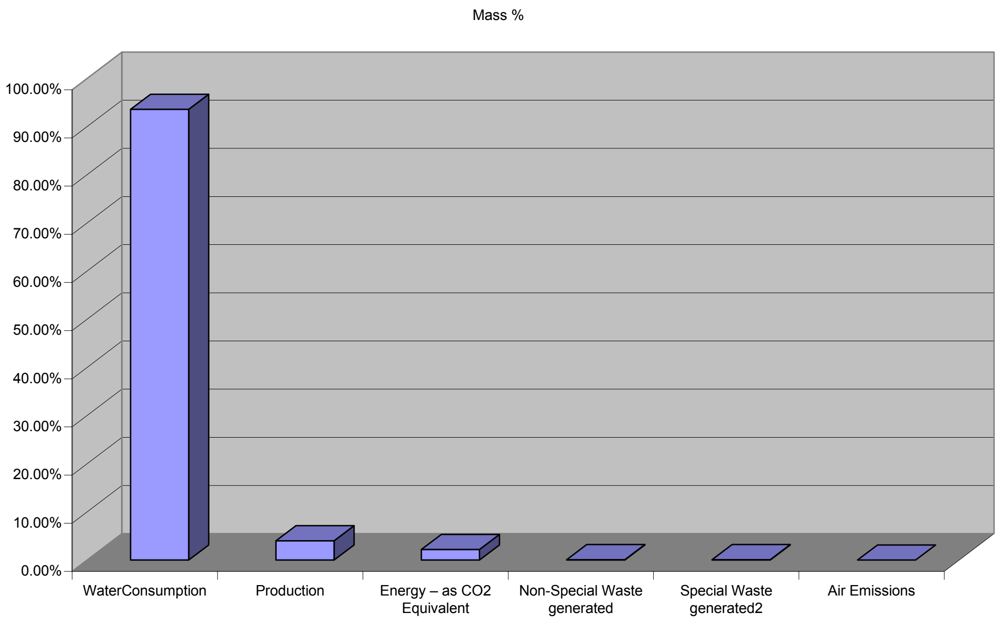
A study of the materials flow and mass balance within the chemicals sector needed to be very tightly focussed on the critical sub-sectors. To achieve this focus it is necessary to identify the key sub-sectors and associated companies responsible for the majority of mass flow within the industry.

The data gathered by the CIA does allow us to take an overview of resource consumption and efficiency in the chemical industry by gathering data on water consumption, production, energy consumption, waste disposal and certain key air emissions. Table 1.3 and Figure 1.3 provide an overview of total mass flow within the UK chemical industry from data gathered by the CIA in 1999.

Table 1.3 : Resource Consumption by Chemical Industry

	Mass (Mtonnes)	Mass %
Water Consumption	940	93.6
Production	40	4
Energy – as CO_2 Equivalent	22	2.2
Non-Special Waste generated	1.1	0.1
Special Waste generated	0.8	0.1
Air Emissions	0.06	0.01

Figure 1.3: Production & Resource Consumption



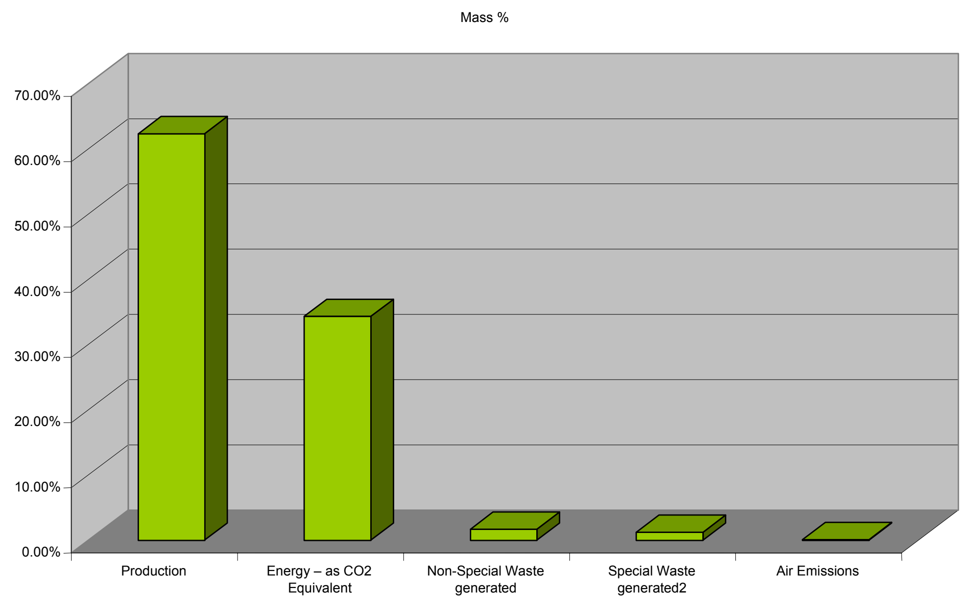
It can be seen that by far the largest mass flow in the industry is water. Initial indications suggested that most of this water is extracted and returned to natural sources with little or no change in water quality. A great deal of river-water is used for once-through-cooling systems, and in certain cases salts and other elements are extracted from sea water . This project has attempted to understand water consumption by the chemical industry in more detail.

Disregarding water consumption in the overview of the mass flow in the chemical industry gives a different picture, as illustrated in Table 1.4 and Figure 1.4.

Table 1.4 : Resource Consumption by Chemical Industry (excluding water)

	Mass (Mtonnes)	Mass %
Production	40	62.3
Energy – as CO_2 Equivalent	22	34.3
Non-Special Waste generated	1.1	1.7
Special Waste generated	0.8	1.2
Air Emissions	0.06	0.1

Figure 1.4: Production & Resource Consumption (excluding water)



Perhaps surprisingly, energy represents a third of mass flow, whilst waste represents only 3%. However it should be borne in mind that the ultimate fate of some of the products will be disposal as waste as the material filters down the supply chain into other industries who use chemicals. The ultimate fate of each product will be determined through the other mass balance studies and this is outside the scope of this study.

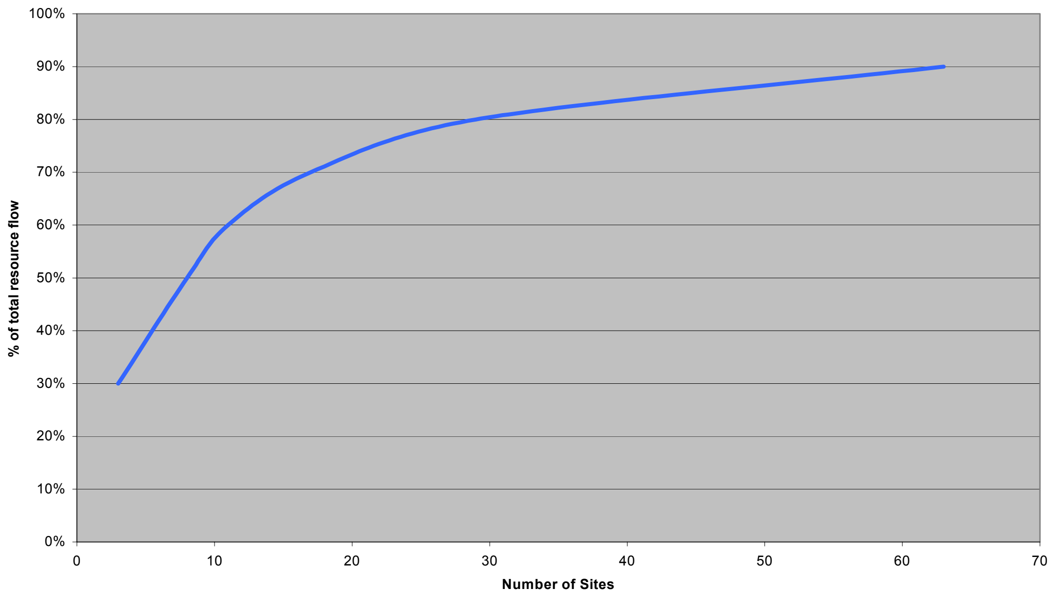
Disregarding water flows, the two major mass flows in the UK chemical sector are energy consumption and production (as an indicator of resource consumption - raw materials).

From the outset of the project it was recognised that a considerable quantity of detailed data was required from the chemical industry in order to undertake this project. Surveying all 3,500 companies in the sector in the UK was not practical and even surveying the 330 sites who are members of the CIA seemed daunting. One way of overcoming such a problem is to take a sample of the industry and survey that as a way of gaining a picture of the whole industry.

1.6.1 Sample Size

Figure 1.5 presents an analysis of the CIA IOP data for 1999 and reveals that of the 330 member sites for which they have information and other selected large chemical producers, 63 sites are responsible for 90% of the resource flow (as indicated by production + waste generation + air emissions).

Figure 1.5: Resource Utilisation by CIA Members' Sites



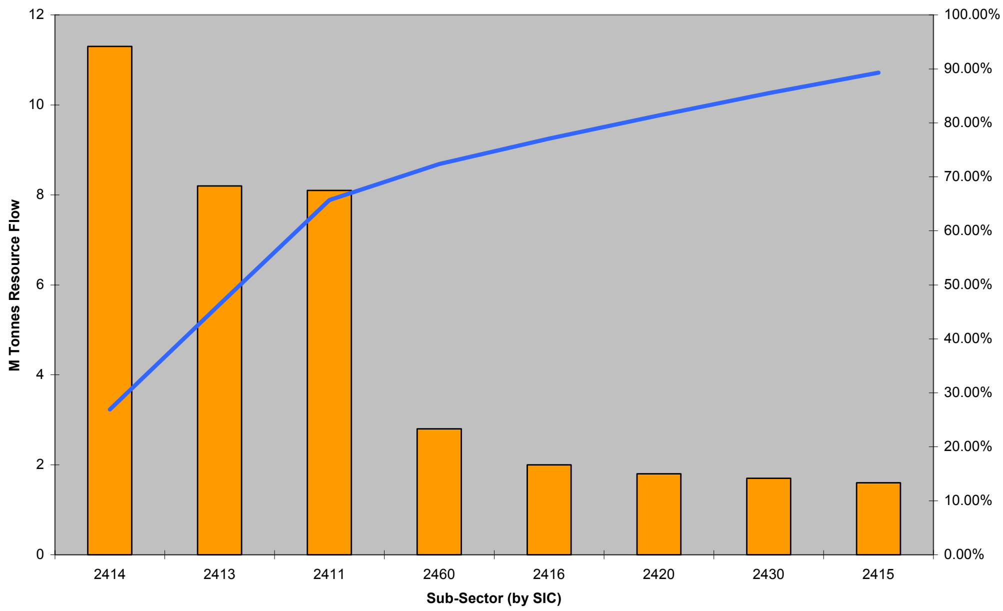
1.6.2 Sample Structure

The IOP data provides information on production, air emissions and special waste and non-special waste disposal. Summing these figures reveals an estimate of the relative sizes of the principal sub-sectors within the UK chemicals industry by mass of material output (ignoring at this stage the impact of water and energy usage). This is shown in Table 1.5 below against the Standard Industry Classification (SIC) codes that describe the primary sub-sectors of the industry. Together, these eight sub-sectors account for 89% of the total resource flow of the UK chemicals industry as illustrated in Table 1.5 and Figure 1.6. More information on the SIC sub-sectors is given in Appendix 3.

Table 1.5 : Chemical Industry Production Output

SIC	Description	Mtonnes p.a	% of total
2414	Other Organic Base Chemicals	11.3	26.9
2412 / 2413	Other Inorganic Base Chemicals	8.2	46.4
2411	Industrial Gases	8.1	65.7
2460	Other Chemical Products	2.8	72.4
2416	Plastics in Primary Form	2.0	77.1
2420	Pesticides and Other Agrochemical Products	1.8	81.4
2430	Paints Varnishes and Printing Inks	1.7	85.5
2415	Fertilisers and Nitrogen Compounds	1.6	89.3

Figure 1.6: Chemical Industry Sub-sector Resource Flow



The scope of this project was limited to companies within **SIC 24.1**. The production of pesticides, agrochemicals, paints and inks do not fit neatly into a definition of chemical manufacture, as many of the products produced by these industries are formulated or even finished products for the industrial or consumer markets.

Based on the analyses above we estimated that this focus would provide coverage of around 80-85% of the UK chemical industry total resource flow and captures data from all but 12 of the top 63 sites which represent 89% of the resource flow of the industry.

Important areas outside SIC sub-sector 24.1 such as speciality chemicals, paints and inks, pesticides/agrochemicals and pharmaceuticals could be covered in a later study.

The manufacturing sites to be studied were therefore defined as those companies within the five chosen sub-sectors of SIC 24.1 (Table 1.6) with particular emphasis on the top 51 sites (Presented in Appendix 1) as:

- They represent the most resource intensive production steps.
- They will highlight significant issues of material supply or downstream product flow, which could be analysed in follow-on projects.

Table 1.6 : SIC Sub-sectors used in this Study

SIC	Description	Mtonnes p.a
2414	Other Organic Base Chemicals	11.3
2412 / 2413	Other Inorganic Base Chemicals	8.2
2411	Industrial Gases	8.1
2416	Plastics in Primary Form	2.0
2415	Fertilisers and Nitrogen Compounds	1.6

2. PROFILE OF THE UK CHEMICAL INDUSTRY

2.1 Introduction

This section has been included to present a summary overview of the UK chemicals industry including those historical drivers (e.g. competitiveness and existing legislation) which have positioned the industry to date and those drivers (e.g. sustainable development policies) which will impact on the industry in the future.

2.2 Size, Segmentation, Location & Ownership

2.2.1 Size

The global production of chemicals has increased from 1 million tonnes in 1930 to 400 million tonnes today. In 1998 the European Union Chemical Industry was estimated to represent 31% of the global market in value terms and was the world's largest chemical industry, generating a trade surplus of 41 billion euros. The chemical industry is Europe's third largest manufacturing industry employing 1.7 million people directly and with up to 3 million jobs dependent on it.

The UK chemical industry is one of the UK's largest industries: it is in fact the fourth largest industry in terms of share of direct purchases in 1997 and share of total manufacturing Gross Value Added (GVA) in 1996 and the UK's number one exporting industry. Table 2.1 presents the key economic data for the Industry.

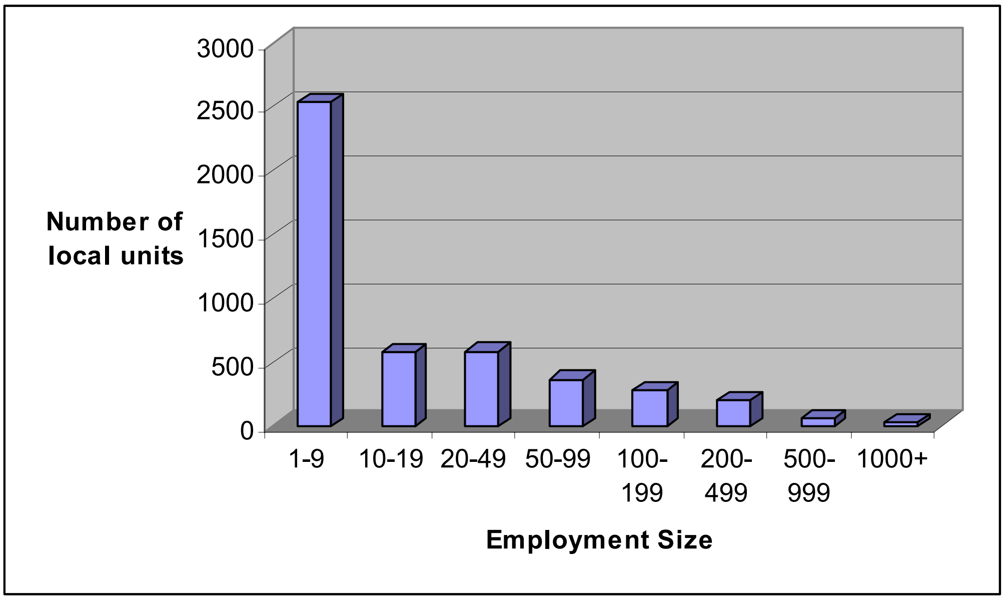
Table 2.1: The UK Chemical Industry – Key Data 2000

• **Gross Output** (*broadly equivalent to company turnover; including sales of all products including merchanting)*	**£49bn** (10% on UK manufacturing)
• **Sales** *(chemicals and chemical products only)*	**£34bn** (12% of EU chemical sales)
• **Exports**	**£25.8bn**
• **Imports**	**£21.2bn**
• **Trade Surplus**	**£4.6bn**
• **People Employed**	**239,000**
• **Capital Investment in UK**	**£2.8bn**
• **R&D Expenditure in 1999**	**£3.3bn**
• **Output Growth in 2000**	**4.1%**
• **Forecast Output Growth in 2001**	**2.5%**
• **Average Annual Output Growth: 1990-2000**	**3%**

Source: CIA

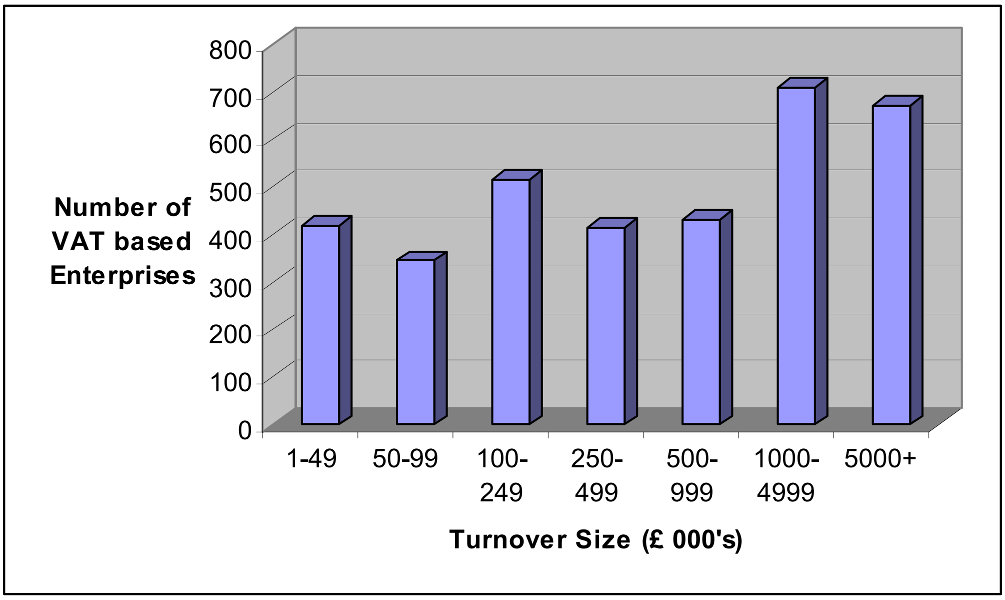
A breakdown of the numbers of sites by employment and turnover is given in the following charts (Figures 2.1 and 2.2 respectively).

Figure 2.1: Number of Sites by Employment Size - 1997



Source: PA 1002

Figure 2.2: Number of Vat based Enterprises by Turnover Size – 1997



Source: PA 1002

2.2.2 Segmentation

ONS statistics show that there were 3,500 VAT registered businesses in the UK chemical industry in 1999. The number of companies, registering an annual turnover of £5 million p.a. or more, was 230. Figure 2.3 presents the 1998 UK chemical industry share of Gross Value Added analysed by key sub-sectors.

Figure 2.3: UK Chemical Industry Sector Shares of Gross Value Added - 1998

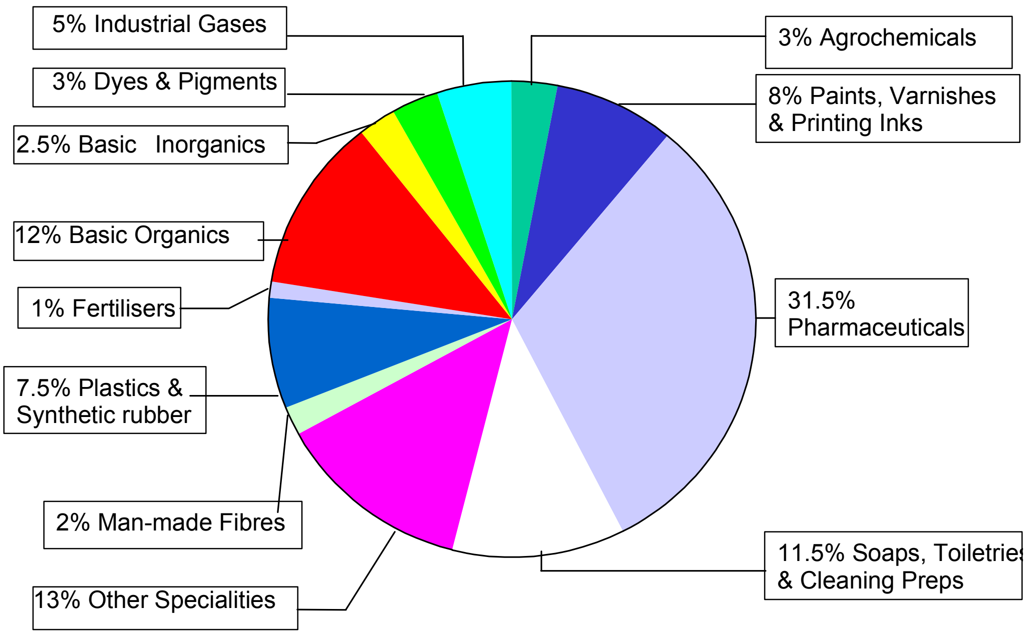
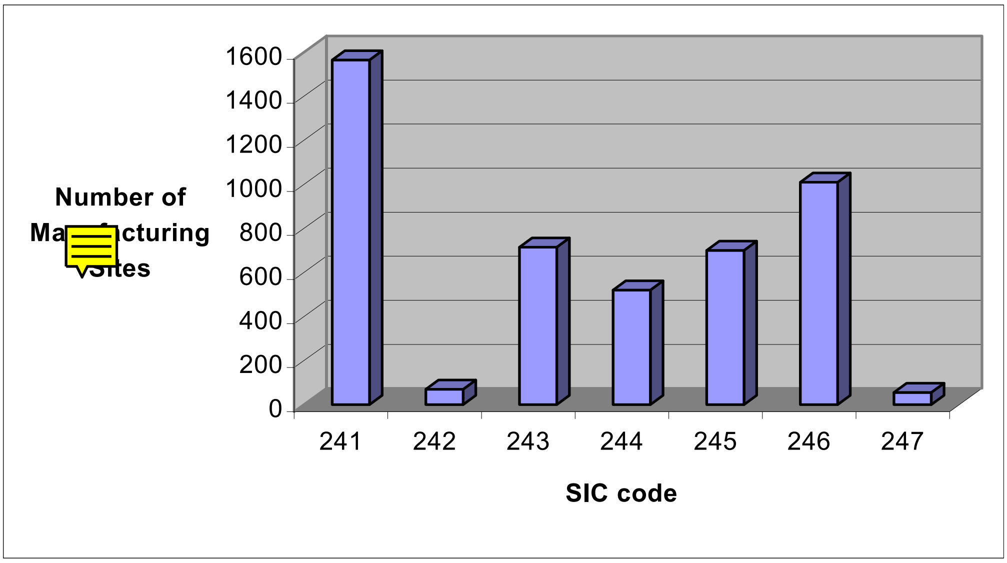


Figure 2.4 presents an analysis of the ONS employment statistics by SIC code and reveals that the SIC sector 24.1 – defined as the manufacture of basic chemicals, represents 34% of the total number of individual manufacturing sites in the industry.

Figure 2.4: Number of Manufacturing Sites by SIC Code

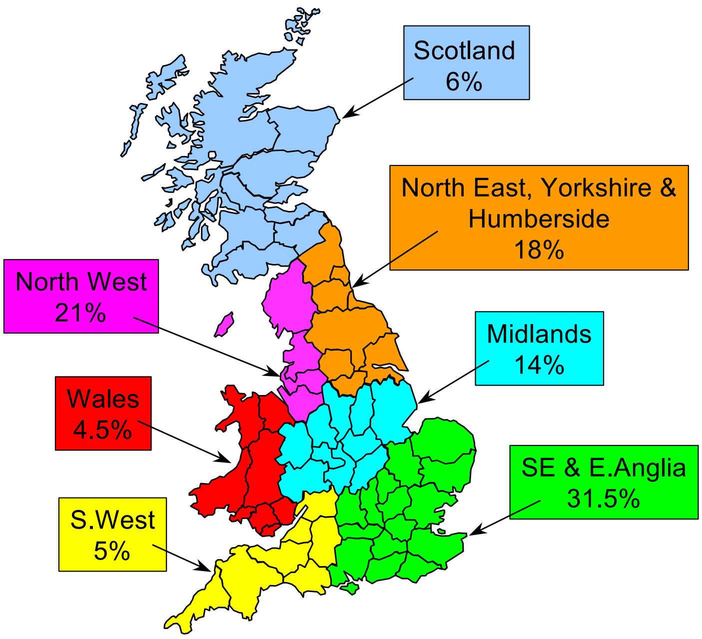


The vast majority of the sites in SIC 24.1 were in the five main sub-sectors presented in Table 1.5 i.e. 1,015 of total businesses and 190 of the larger businesses[1].

2.2.3 Location

The UK chemical industry has a long history dating back almost to the beginning of the industrial revolution in the late 1700's. The location of many of the UK chemical manufacturing sites is a legacy of history, i.e. cotton mills became chemical sites as market demands evolved. The locations are often less than ideal, in terms of receiving raw materials and reaching end markets, and have been described by the chemical producers themselves as "an accident of history". In other countries, where the chemicals industry is relatively new compared with the UK's, there is greater local supply chain integration with many manufacturing sites physically located next to their feedstock suppliers, close to customers and/or established transport systems. Figure 2.5 presents a regional breakdown of direct employment within the industry.

Figure 2.5: Employment by Percentage Share of Great Britain



2.2.4 Ownership

The UK chemical industry, once dominated by a few well-known UK owned companies, is now predominantly and increasingly owned by foreign based multinationals that are used to operating in a global economy. There has been a great deal of merger and acquisition activity within the industry in recent years and most bulk chemical production in the UK is now in US or

[1] It should be recognised that these statistics are based on the Inter-Department Business Review (IDBR) which surveys all enterprises with 250 or more employees but estimates the numbers of smaller firms based on a sample survey. In addition, it is recognised that a significant proportion of the small firms (less than 20 employees) are re-packers or blenders rather than manufacturers.

European ownership. This non-UK ownership has an impact on the extent to which key business decisions (e.g. investment, purchasing) affecting the sites and the region are made outside the region and the UK.

2.3 Industry's Products & Supply Chain

2.3.1 Feedstocks to the Industry

From the North Sea and other sources, oil and gas provide the basic feedstocks for the organic chemicals sector from which ethylene, propylene, benzene and methanol for example, are produced.

The UK also has natural mineral deposits such as salt and limestone, which are extracted to provide feedstocks for the inorganic chemicals sector to produce the basic inorganic chemicals such as sulphuric acid, chlorine, lime and caustic soda. However there is still a requirement for various feedstock imports such as phosphate rock.

2.3.2 Products and Applications

The products of the chemical industry provide the raw materials for further processing within the industry itself, in plastics manufacture, pharmaceuticals, agrochemicals, paints and toiletries and other allied industries, as well as for use in a wide variety of other unrelated industries, including the metal, glass, textile, paper, and food and drink manufacturing industries.

Almost all consumer products require the use of chemicals in their manufacture but there may be many steps between the sale of a chemical and the final consumer product. For example, car manufacturers make direct purchases of chemicals such as paints and industrial solvents but also buy plastic, textile and electronic components that rely on various chemicals for their manufacture. Table 2.2 presents the UK demand for chemicals.

Table 2.2: UK demand for chemicals – shares of direct purchases – 1998

Sector	%	Cumulative %
Agriculture		**2.5**
Food & drink (processing)	2.5	
Textiles & clothing	2.0	
Paper, printing & publishing	2.5	
Chemicals	**21.0**	
Plastic & rubber processing	7.5	
Electrical engineering	2.0	
Metal Products	2.0	
Transport equipment (including cars)	1.5	
Other production & construction industry	5.5	
Total Production & Construction Industry		**46.5**
Healthcare	12.5	
Other services	7.0	
Total Service Industries		**19.5**
Household Spend On Chemical Products		**31.5**

2.4 Industry Drivers

There are a range of driving forces which affect the chemical industry. For convenience, these have been classified as:

2.4.1 Social, Economic and Market Drivers

Globalisation of the chemicals industry is probably the most significant driver affecting the UK basic chemicals sector. Chemicals are, predominantly in mass terms, low added value products sold as commodities. Products are described as commodities when they are not easily differentiated from other competitive products available and are easily emulated or copied. Thus many basic chemicals, such as fertilisers, are sold as commodities. The main driving forces affecting businesses in a commodities market relate to:

- maintaining low cost production/reducing unit costs
- maximising economies of scale
- matching production to demand.

The globalisation of the chemical industry and the need to maintain low cost production has led to a shift in production of basic chemicals away from areas with high labour costs and energy costs. Investment in large petrochemical complexes and the manufacture of low added value chemical products has moved from the UK and Europe to India, the Far East, the Middle East and South America. These countries and regions benefit from financial incentives from their respective governments, have comparatively low fixed costs compared to Western European competition due to low labour and utility costs.

Whilst the emphasis in the UK and Europe has shifted to the production of higher added value speciality / fine chemicals for a diverse range of niche markets, there is increasing global competition here too. UK manufacturers are reporting that high quality, complex chemical intermediates can be sourced from developing countries at prices at or below below European levels. As a result of this competition there are very strong pressures on margins and hence a major emphasis on cost reduction.

Demand in Western Europe and North America is currently static or declining. Exports to Asia/Pacific and the Middle East are growing as the global manufacturing base moves to these regions.

If the globalisation trends continue, with the net decline in chemical manufacture in the UK, there will be a significant resulting shift of the chemical mass flows from exports of finished chemicals / goods from the UK to imports of finished goods. The trends will not been seen from looking at *Great Britain plc* in isolation and reinforces the importance of being able to link the mass balance studies within the UK to equivalent sectorial studies outside the UK.

The UK chemicals industry image is perceived to be poor principally associated with perceived hazardous activities both on-site and also affecting the local community. Reassurance is required principally on the levels of pollution and health effects. The lack of general public knowledge of the industry's activities, health and safety record, and probably more significantly, the impact that chemicals have on daily lives adds to this poor image. There is distrust of the credibility of the communication from companies and government.

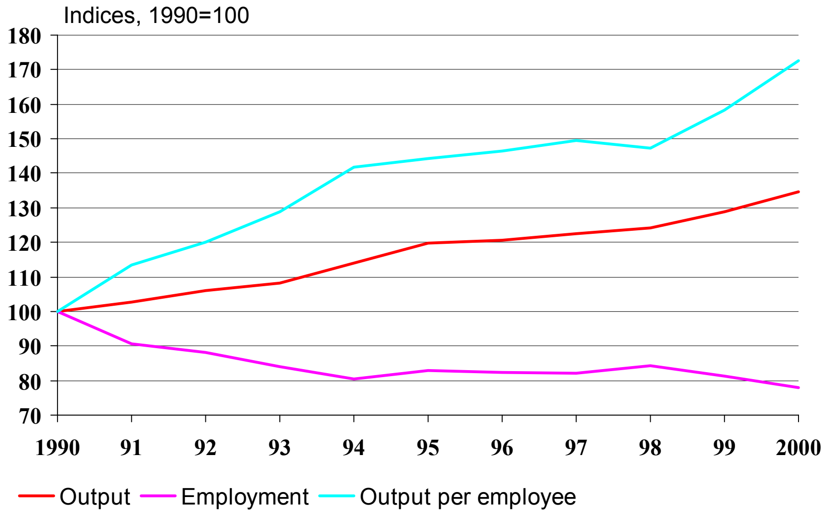
The CIA commissions Mori on an annual basis to review public perception of the chemical industry. The 2002 poll stated that communities where the industry is concentrated have high regard for the way that industry looks after its workforce but deep concern about the effects of long term exposure to chemicals for both employees and communities. These concerns have been increased by perceived erosion of the local employment and community involvement benefits that have long been seen by neighbours as the unwritten trade-off for local pollution and safety risks. There is still a low level of communication and trust between the industry and the public. The industry attempts to address these public perceptions in many ways including local initiatives e.g. links to schools and via national campaigns the CIA Responsible Care Programme – which reports in the public domain on health, safety and environmental issues, statistics and generic action plans.

2.4.2 Technological Drivers

The UK chemical industry enjoyed considerable growth in output during the late 1980s but then in 1990 there was an overall decline due to the worldwide recession. The impact was felt most keenly in the UK basic chemicals sector where there was significant over-capacity and price competition was very fierce. Both the basic chemicals and speciality chemicals industries have suffered in more recent years due to increasing globalisation factors with the decline of the domestic downstream manufacturing markets and the emergence of competition in developing countries such as China and India.

In response to global competitive pressures the industry has done much to increase process efficiencies and reduce costs over the past decade. Figure 2.6 presents a normalised analysis of the output per employee. This graph highlights that whilst employment trends in the industry are down are down, output is increasing and there has been a 70% increase in output per employee over the period 1990 to 2000.

Figure 2.6: Normalised Analysis of the Output per Employee



Source: CIA Indicators of Performance 2000

Recent regional studies (source DTI - CD) have identified that the majority of the large and medium sized chemical companies within those regions feel that there is a *'law of diminishing returns'* in terms of further cost-effective improvements that can be achieved on existing plants.

There are indications from other sources, however, that there is further scope for improvement. For example, the recent study on the *'Competitiveness of the Process Industries 2001'* by the Process Industry Centre for Manufacturing Excellence (PICME) concludes that there is potential to make significant improvements in capacity utilisation, inventory turns, customer service and quality based on comparisons with world class standards.

2.4.3 Safety, Health and Environmental Drivers

An important driver for change in industry in the developed world is the growing emphasis on sustainable development and environmental performance, especially in Europe.

The UK chemical industry, like its competitors in Europe and the rest of the developed world, is one of the most heavily regulated from a health, safety and environment point of view, perhaps second only to the nuclear industry. This is neither surprising nor unwarranted given the hazardous nature of many chemical products and processes. Almost all the regulation in force in the UK is aimed at reducing the risk of the impact of the chemical industry on the health of workers in the industry and the general public and its effect on the environment (both acute and chronic effects).

A typical chemical manufacturer in the UK is likely to have to ensure they comply with over 25 separate pieces of environmental regulation alone, and many more health and safety ones.

Responsible Care

Responsible Care is the chemical industry's commitment to continual improvement in all aspects of health, safety and environmental performance and its openness in communication about its activities and its achievements. It is a voluntary and rigorous programme of collective actions through systems of mutual aid, sharing of best practice, open channels of communication and commitment by all.

The majority of chemical manufacturers in the UK are committed to developing Environmental Management Systems (as well as the equivalent Quality and Health & Safety standards) to continually improving their impact on the environment. In 2000 77% of CIA sites had formal environmental management systems of which 29.5% were externally certified eg ISO14001.

The key existing and planned legislative and fiscal drivers which aim towards improving the environmental performance and/or resource efficiency of the UK chemical industry include:

Environmental Management Systems

Compliance with all environmental legislation is obviously a basic goal of all chemical manufacturers. Established environmental management systems have a key tenet of good environmental management practice. In addition many chemical manufacturers seek to improve their environmental impact and gain other benefits through:

- Improved resource efficiency and commensurate savings, for example by reducing waste, and using less energy and water.
- Effective risk control which will help to
  - reduce injury, ill health and lost time and substantial associated costs
  - avoid incidents which damage plant and equipment and can threaten the very existence of the facility due to lost business or lost stakeholder confidence, reduce process and supply chain disruption and help control insurance premiums.
- Greater customer and public confidence in the manufacturers.
- Better relationships with regulatory bodies, insurers and the local community

Landfill Tax

Landfill tax became operational on 1 October 1996 and is levied on the disposal of material to landfill sites throughout the UK. The tax applies the principle, ‘the polluter pays’, to promote a more sustainable approach to waste management by encouraging businesses and consumers to produce less waste, dispose of less waste in landfill sites and to recover more value from waste through recycling.

On a national basis the chemicals industry generates approximately 20% of the UK’s special waste. However, other hazardous wastes created by industries that use chemicals make up the vast majority of the hazardous wastes disposed of in the UK (eg strong aqueous wastes from the textile industries). The majority of hazardous wastes require treatment to reduce or eliminate the hazard (health or environmental) before they are ultimately sent to land fill.

The Landfill Directive

Forthcoming EU-led regulations that will effect the waste management industry are also causing concerns within the industry. The Landfill Directive restricts the co-disposal of hazardous wastes with general waste (e.g. household wastes) and will enforce the pre-treatment (thermal, physical, chemical or biological) of all wastes, including “liquid” wastes e.g. sludges, that will reduce volume, aid recovery or alter the hazardous properties. It is still not clear how this Directive will be applied in the UK, but it is thought that the end result will be that special landfills will be required for the disposal of hazardous wastes only. There is great fear in the waste management industry that these hazardous waste landfills will be very difficult to establish due to planning restrictions, licensing restrictions and opposition from people local to any proposed site. There is talk of there only being a handful of such landfills being licensed in the whole of the UK in 5 years time

This Directive will have major implications for the UK chemical industry. In the first instance the option to dispose of hazardous wastes locally may disappear altogether, requiring chemical companies to transport wastes over long distances (assuming facilities are available elsewhere in the UK). Secondly, the disposal of liquid wastes will probably have to be diverted to specialist waste treatment plants and most certainly will prove to be a more expensive option as IPPC will require investment on behalf of the waste management industry.

There could, however, be scope for the development of new technologies and processes to treat such wastes and to investigate the scope for waste recycling and reuse within the industry or by other industries.

IPPC (Integrated Pollution Prevention and Control)

Integrated Pollution Prevention and Control (IPPC) and its predecessor, Integrated Pollution Control (IPC) are regulatory regimes that engage an integrated approach to control the environmental impacts from certain industrial activities, including the chemical industry. The aim is to achieve a high level of environmental protection as a whole, by preventing or, where this is not practicable, reducing emissions to air, water and land. This is done by determining and enforcing conditions that represent the best available techniques (BAT).

It is necessary for facilities which are governed by IPPC to obtain an Authorisation from the Environment Agency, demonstrating that the following environmental issues have been satisfied:

- Satisfactory environmental management of the installation;
- Assessment of polluting releases to the environment and demonstration of BAT;
- Adequate compliance monitoring;
- Energy efficiency, waste minimisation and management;
- Compliance with Environmental Quality Standards (EQS);

- Prevention of accidents; and
- Assessment of the condition of the site at the time of the application (to determine the need for any restoration when the installation closes).

Climate Change Levy

At The Earth Summit in Rio in 1992, the developed countries of the world agreed voluntarily to reduce their emissions of greenhouse gases to 1990 levels. At Kyoto in 1997, the developed countries (excluding the USA) agreed a legally binding commitment to reduce emissions by 5.2% below 1990 levels between 2008-2012. The UK agreed to a 12.5% reduction, and set itself the more challenging domestic goal of a 20% reduction in CO_2 emissions by 2010.

Lord Marshall was asked to produce a report on economic instruments and the use of energy in business. The report recommended that there ‘probably is a role for a tax, if businesses of all sizes and from all sectors are to contribute to improved energy efficiency and help meet the UK’s emissions target’. This is another point based on the principle of ‘the polluter pays’.

The Climate Change Levy is a tax on the business use of energy and was introduced on 1 April 2001. The levy is chargeable on the industrial and commercial supply of taxable commodities (electricity, gas, coal, petroleum and hydrocarbon gas in a liquid state, coke, semi-coke and petroleum coke).

The supply of ‘good quality’ electricity from CHP (combined heat and power) is exempt from the levy, as is electricity supplied from a renewable source, such as wind, tidal, photovoltaic and hydropower.

Energy intensive industries falling within the Pollution Prevention & Control Regulations 2000 are eligible for an 80% discount on the levy. The discount is available if companies enter into a negotiated agreement to reduce energy usage by 2010.

3 MASS BALANCE MODEL OF THE UK CHEMICAL INDUSTRY

As previously explained, it is important before setting out to develop a mass balance of a particular industry sector to describe the system boundaries of the study. That is, to define what shall be included and excluded from the study. The following sections describe the approach taken by this study.

3.1 System Boundaries

As explained in section 1.6 of this report this study focused on chemical manufacturing operations within the specific sub-sectors of SIC 24.1. As identified in section 1, these sub-sectors represent the most significant mass flows within the UK Chemicals Industry. In addition to identifying these industrial sub-sectors and associated manufacturing sites, the input and output boundaries of movements of materials need to be specified, in order to fully define the system boundary which has been applied to this mass balance study.

3.1.1 Manufacturing Activities

The manufacturing activities on any particular site to be included in the study were defined as the manufacture of products as defined by SIC 24.1 (see Table 1.5) and specifically excluding:

- Mining, quarrying, extraction (as in oil and natural gas) of raw materials, such as limestone, coal, salt etc.
- Certain primary refining processes involving physical separation of raw materials such as oil refining and manufacture of coke. But chemical processing to produce chemical products within an integrated petrochemical/chemical works would be included.
- Downstream formulation of products such as plastics, paints, dyes and pharmaceuticals.

3.1.2 Input Boundary Definition

The input boundary encompasses all resources consumed by the industry, specifically:

- All inorganic and organic raw material inputs at the point of delivery to each chemical processor. Transfers of materials from one site to another within the study sample are excluded to ensure true resource consumption figures are reported (these are known as inter site/company transfers).
- All ancillary materials (e.g. solvents, filter aids, etc) at the point of delivery to each processor.
- Packaging, including both packaging used to deliver raw materials and that used to pack finish products.

- Recycled materials (e.g. solvents, packaging, etc) that may have been sent for recycling by the industry (or from elsewhere) and have been processed for recycling purposes outside the chemical industry and then returned to the chemical industry.

- All water imports, including that in raw materials (ie where water is a solvent) as well as mains water and other bulk water supplies such as the sea, rivers, canals etc.

- All energy imports such as electricity, gas, oil, coal as well as steam from adjacent operators and energy derived from waste disposal operations on site.

3.1.3 Output Boundary

The output boundary encompasses all products and wastes generated by the industry, specifically:

- All finished products destined for use by companies outside the chemical industry or to be exported are included. Transfers of products from one site to another within the study sample are excluded (inter-site/company transfers) to ensure true resource consumption figures are reported.

- All wastes sent for disposal (both on and off-site), effluents discharged to drain (or other water bodies), air emissions and materials sent for recycling.

3.2 The Mass Balance Model at Site Level

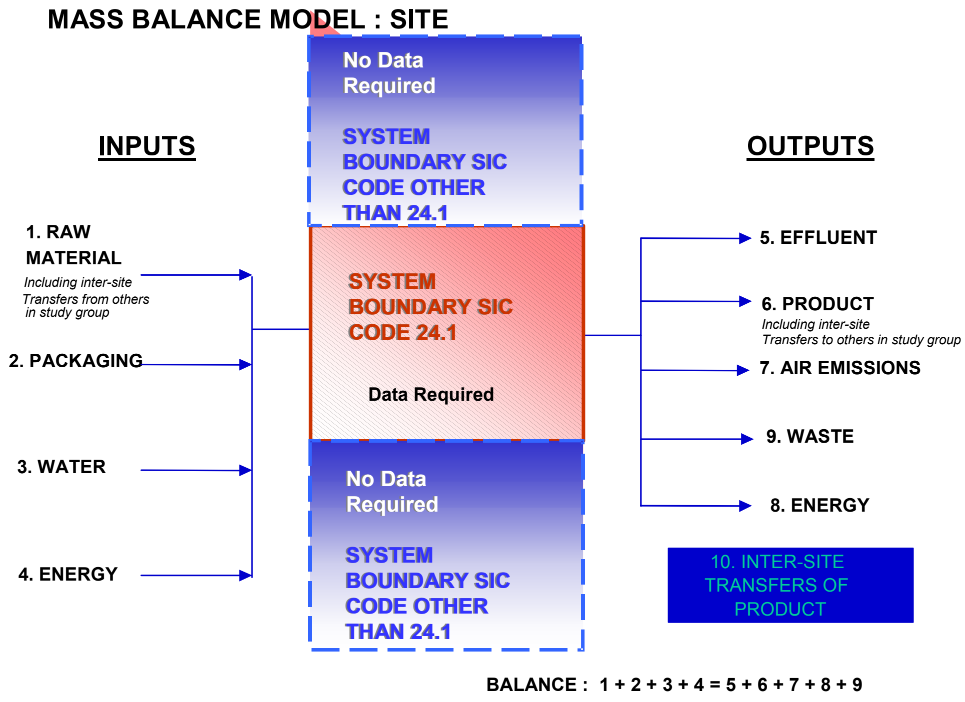
Figure 3.1 illustrates the mass balance model for a site in the study group. The dashed outline box is effectively the site boundary fence. The inputs and outputs to be measured can be viewed as having to cross this boundary fence to be included in the study. The only exception to this rule of thumb is the accumulation of wastes from landfilling of wastes on-site (which occurs in a very few instances).

The blue areas within the dashed line indicate processing activities that are excluded from the study, for which no data was required, in reality very few of the correspondents had such operations on their sites.

The red area is the processing activities for which data is required.

The lines into an out of the box indicate the various resource flows measured by the study.

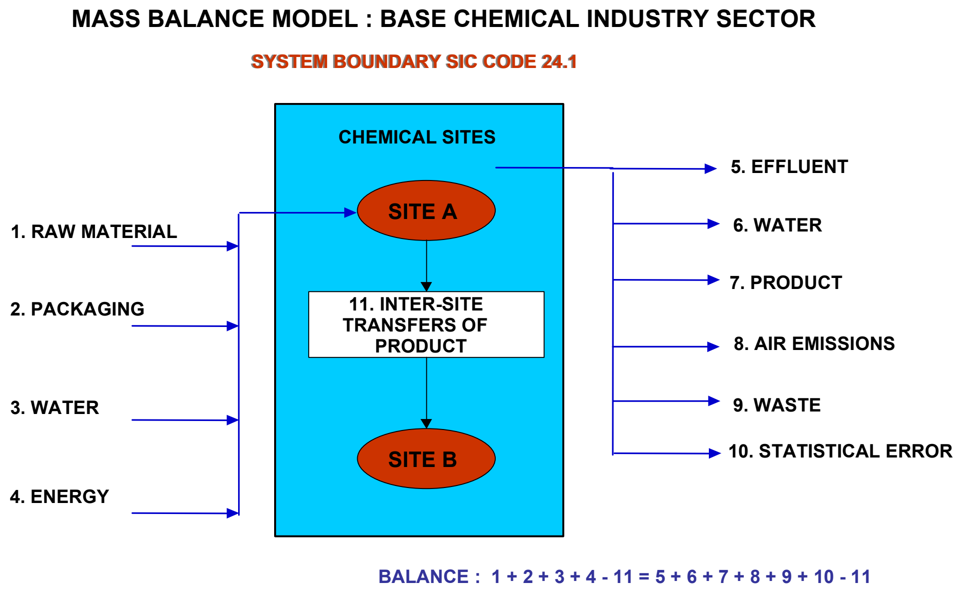
Figure 3.1: Site System Boundaries



3.3 Mass Balance Model for the Study Group

The model for a site can be extrapolated for the whole study group and the industry as a whole. Figure 3.2 illustrates the total system mass balance model – the upstream and downstream manufacturing activities that are outside the system boundary are omitted for clarity.

Figure 3.2: Study Boundaries



Inter-site transfers of materials (products sent from one site to another to use as a raw material) are excluded from the mass balance so that a truer representation of resource flows can be reported for the industry. Of course, at a site level actual raw material inputs and product outputs were gathered and reported.

3.4 Mass Balance Model: Inputs, Outputs and Balancing Equations

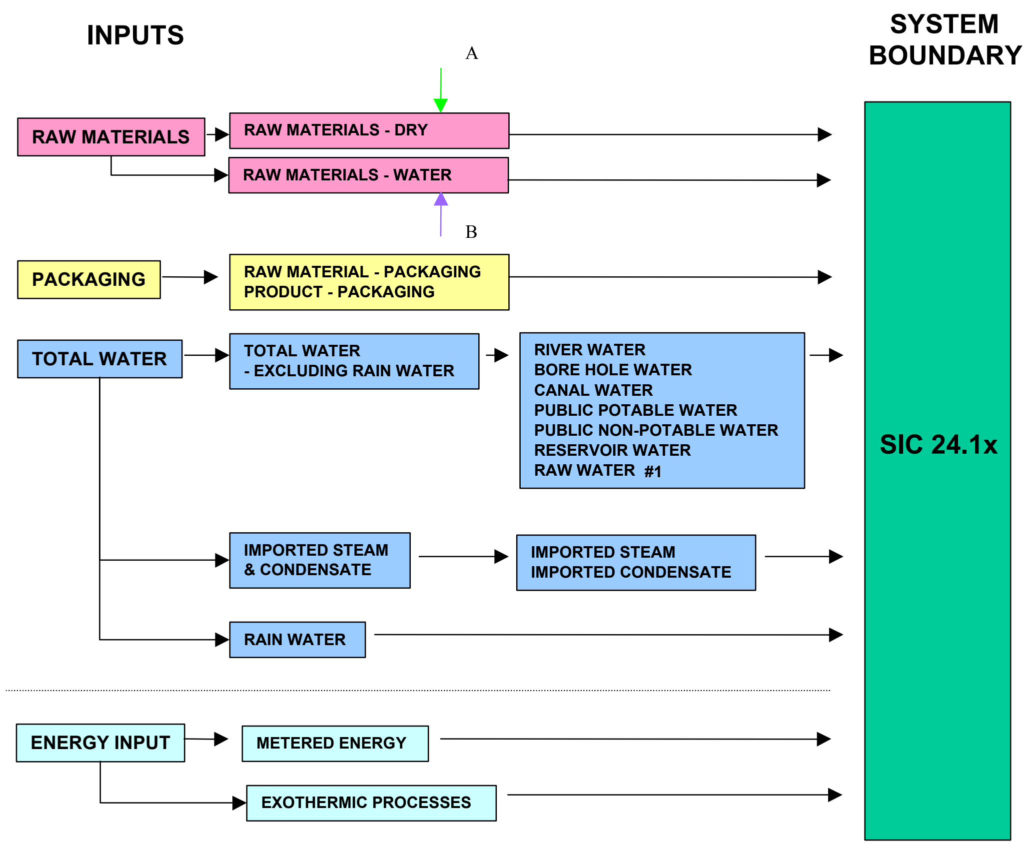
Figures 3.3 and 3.4 respectively present more detailed analyses of the mass balance inputs and outputs used to synthesise the summary model and to enable the mass balancing equations to be calculated for individual sites (for validation purposes), SIC sub-sectors and for the total study sample.

Inter-site transfers (the movement of product from one site to become raw materials for another site within the study boundary) are shown on the diagram as Dry Materials (A) and Water in Products (B). At an individual site level these are included in the figures for product or raw materials, but must be excluded from the total figures for the study (both as inputs and outputs) to avoid double counting, as this material is not leaving the industry.

Rain water falling on site and discharged off site has been excluded from the water inputs and outputs (for example in the effluent value).

Whilst recognising that certain chemical processes are either endothermic (energy absorbing) or exothermic (energy releasing), these have not been included in the presentation of energy data.

Figure 3.3: Study Inputs



3.4.1 Mass Balance Equations (Inputs)

1. Total Mass Balance

Total In = raw materials + packaging + total water – inter site transfers:water in product and dry products (A + B)

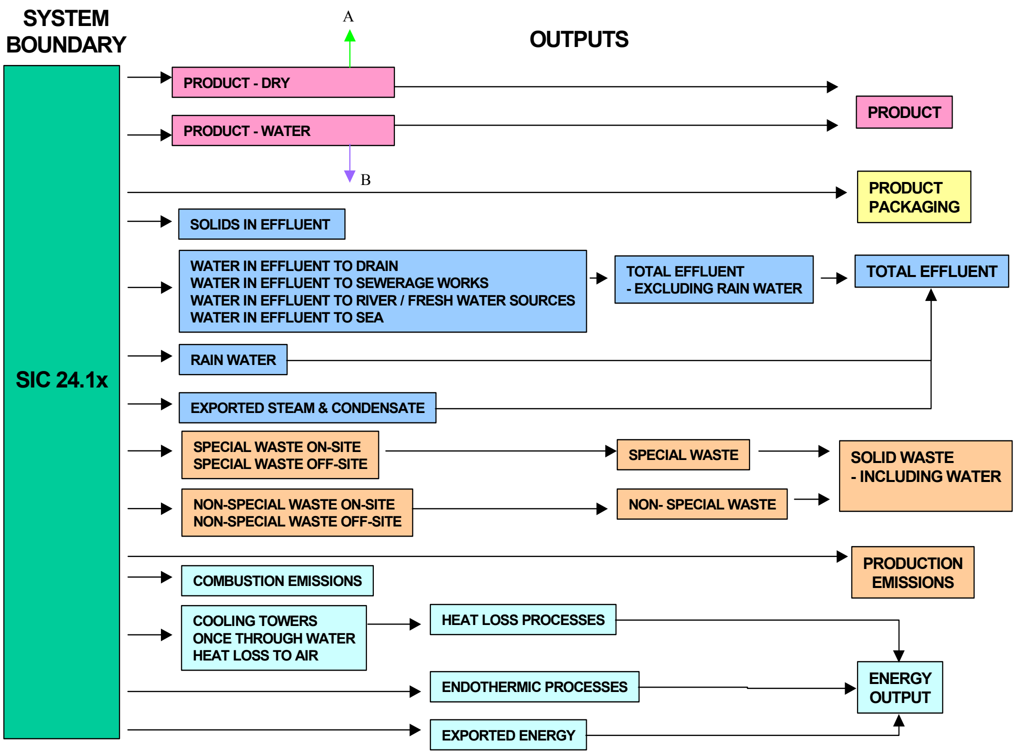
2. Dry Mass Balance

Total In = dry raw materials + packaging – inter site transfers:dry products (A)

3. Water Mass Balance

Total In = water in raw materials + total water – inter site transfers:water in products (B)

Figure 3.4: Study Outputs



3.4.2 Mass Balance Equations (Outputs)

1. Total Mass Balance

Total Out = product + product packaging + total effluent + solid waste + production emissions - inter site transfers:water in product and dry products (A + B)

2. Dry Mass Balance

Total Out = dry product + solids in effluent + product packaging + solid waste + production emissions - inter site transfers: dry products (A)

3. Water Mass Balance

Total Out = water in products + total effluent – inter site transfers:water in products (B)

3.5 Energy within the Mass Balance

Energy has no effective mass, however resources are consumed to convert energy from one source to another (eg generating electricity from coal/gas), in the utilisation of that energy. This results in the generation, one way or another, of carbon dioxide air emissions (associated with global warming), along with other important polluting emissions such as nitrogen and sulphur oxides.

The approach taken in this study has been to measure energy usage by the industry either from primary (eg gas) or secondary (eg electricity) sources on both their processes and in the transportation of materials from their point of manufacture/sale or importation into the UK.

This information is then reported in common units of energy consumption (as a measure of resource usage) and carbon dioxide emissions (as a measure of impact on the environment).

The impact of the transportation of products (with the exception of inter-site transfers) is excluded from the study. These impacts could be captured by other, downstream mass balance studies.

3.6 Capturing the Data

As has already been explained a sample of the companies in SIC 24.1 was chosen for the study. Each was sent an electronic (Microsoft Access database) questionnaire in order to gather the data required for the study. A copy of the questionnaire used can be found in Appendix 2.

The data submitted was validated by calculating the mass balance across each individual site and comparing some of the data with existing data sources (some owned by the CIA, but also publicly available data from the Environment Agency) and by querying problems with each site.

3.7 Data Validation

The returned data from each site has been validated and corrected as far as is possible. Two key indicators have been used to determine the level of confidence in the data. These are:

- The "dry" mass balance – the balance of raw materials into a site (excluding water) compared with the outputs from the site (products, air emissions, waste, etc), again excluding water.

- The water mass balance – the balance of the water consumed by the site (including water imported in raw materials) compared with the water discharges from the site.

These balance figures give a measure of the confidence, which can be given to the data provided. However, it is impossible to get a 100% match between inputs and outputs, or 0% loss/gain. This is due to a number of factors, which include:

3.7.1 For the "Dry" Mass Balance

- The level of accuracy of the measurement of material flows (raw materials, products, wastes, etc), bulk supplies are notoriously difficult to measure accurately.
- Stock differences over the study data gathering period have not been taken into account, although the data gathered did assess the level to which stock changes could effect the mass balance accuracy – in almost all cases this was less than 10%, and more typically less than 5% of the material flow. Gathering stock changes for every material flow was considered too onerous and would have made this project unworkable, so these inaccuracies have been accepted as inevitable.
- The allowable tolerances on weight in raw material supply contracts and product specifications can be as much as +/-3%.
- The accuracy of the measurement of air emissions, which are difficult to measure accurately in themselves and are seldom measured on a continuous basis.
- The fact that some sites are not required to measure air emission as they are below recordable thresholds for regulatory reasons means there is no reliable data for smaller air emissions.
- Dissolved inorganic solids in effluent discharges are not measured by the commonly used method of measuring Total Suspended Solids (TSS) for regulation of effluent emissions.

3.7.2 For the Water Balance

- The accuracy of water meters commonly used is no better than +/-3%.
- Some sites with significant water consumptions appear to have no reliable methods for measuring water usage.
- The accuracy to which effluent discharges can be measured is only +/-3%.
- Significant quantities of water can be discharged from a site as water vapour from cooling towers and steam leaks, this is not measured directly by any site and only indirectly by a few sites.

The degree to which individual site "dry" mass balances balance vary significantly, ranging from a 7% loss to a 13% gain. These figures are considered to be acceptable within the context of the study and do not in anyway indicate a lack of control by a site, merely the accuracy of the data provided. These inaccuracies also have to be put into the context of the overall mass balance for the study group and industry . The overall balance for the study group is a 1% loss, equating to 270,000 tonnes on a 20 million tonne throughput.

Water has proven to be far more difficult to "balance". As stated above the loss of water through evaporation is not measured by many sites, and then only partially. All sites were asked to report on rain water collected, however not all sites where able to provide this data. Individual sites water losses/gains range from +5% to –50%, the overall study group loss is 19% loss equating to 32 million tonnes. This loss may appear at first glance to be enormous, but it is likely that the majority of this loss is evaporated water used to dissipate waste heat from the sites via cooling towers.

4. MASS BALANCE OUTPUTS

4.1 Level of Confidence in the Data Presented

4.1.1 Dry Mass

The subsector and total SIC 24.1 mass balance has been synthesised from individual site data. A mass balance has been undertaken on each site's data and validated (confirmed as being accurate within an error of +/- 5% - based on dry mass) prior to accumulation within the sub-sector. The net error for all sample data was -1.2% based on dry mass, which is considered to be an acceptable statistical error.

There is a high level of confidence in the values presented for dry materials (raw materials, products, air emissions and waste values), as these inputs / outputs either have commercial value or are required by law to be measured.

4.1.2 Water Balance

The water inputs and outputs showed an error of –17%, equating to 30.8 million tonnes of water. This is probably due to unmeasured evaporative losses. There is a high level of confidence in the value presented for public supplies of water as this has commercial value. There is less confidence in the figures given for "private" water supplies, such as river / canal abstraction (which accounts for 46% of total water inputs) due to the relatively lower regulatory control over such water sources and the lower commercial value of this water.

4.1.3 Energy

Energy imports and exports as steam/electricity have a high degree of confidence associated with them due to the economic value of these resources (and the impact of the regulatory/fiscal controls brought about by the Climate Change Levy). However, the export of low-grade heat from sites was poorly reported. These exports are most usually achieved through evaporation of water from cooling towers or once through cooling using water from rivers/canals/etc. This is intimately linked to the poor reporting of water exports and hence attracts a low level of confidence in the reported data. As will be seen little can be deduced from the reported data on low-grade energy exports and water losses.

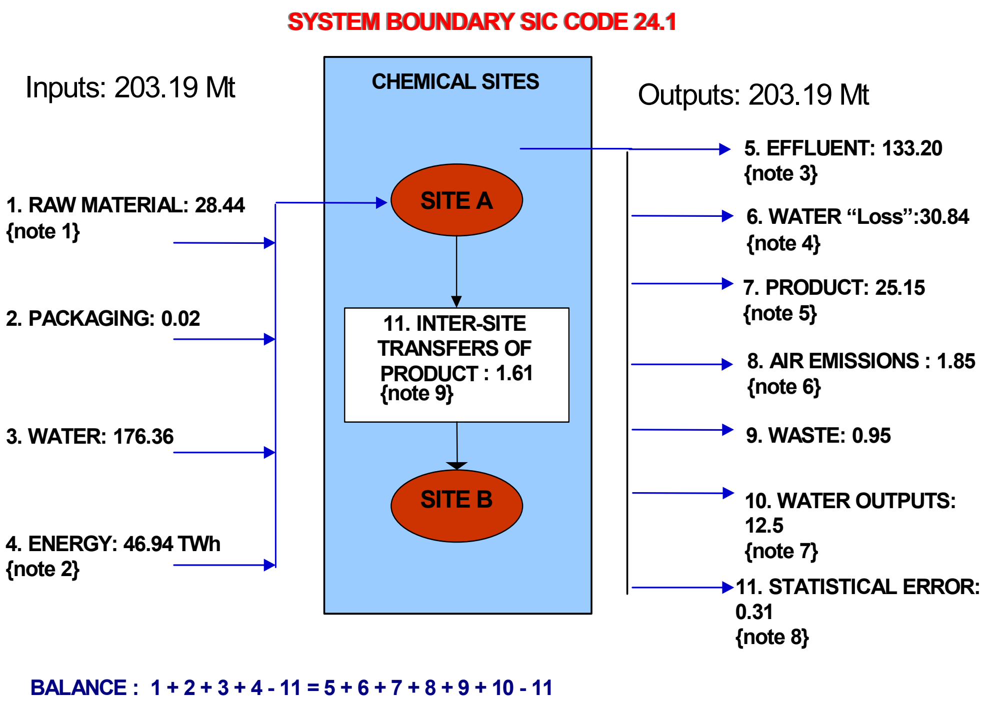
4.2 Summary Mass Balance

Figure 4.1 presents a summary mass balance model for those sites from the target sample which provided data that could be validated. 31 of the original target 52 sites provided such data, representing 83 % of the 1999 production output flow within SIC 24.1 based on CIA data. The CIA as an industry trade body represents the majority of the major chemical companies operating within the UK. Key exceptions from a mass flow perspective within SIC 24.1 are Brunner Mond, and EVC. Combining the production output data from these organisations plus other smaller sites to the CIA data expands the total industry production output for SIC 24.1 to 40 Mt (as presented in Tables 1.3

and 1.4). Using this value as a baseline the sample data production output value represents 63 % of the perceived total UK chemical industry SIC 24.1.

Figure 5.1 in section 5 of this report scales up the study outputs to estimate the mass flows for the total of the UK chemical industry (SIC 24.1).

Figure 4.1: Summary Mass Balance



Notes:

Note Number	Comment
1	Includes embodied water (such as water of crystallisation and water as a solvent) but excludes raw materials transferred from sites within the study group.
2	Net energy consumption (inputs-exported energy), not included as a mass.
3	Includes water and embodied material. Further explanation and analysis is presented in section 4.3 below.
4	Includes known evaporative losses, exported steam and calculated water losses (further explanation and analysis is presented in section 4.3 below). Excludes effluent.
5	Includes embodied water (such as water of crystallisation and water as a solvent). Excludes rain water, which has been removed from site effluent values.
6	Excludes emissions from combustion associated with on-site energy generation (such as CHP and steam generation).
7	Includes10.29 million tonnes of evaporative loss from cooling towers and 2.21 million tonnes of exported steam
8	Known statistical error in dry mass – see section 4.1.1 above
9	This value excludes inter-site transfer of gaseous materials – which was not presented in the site returns

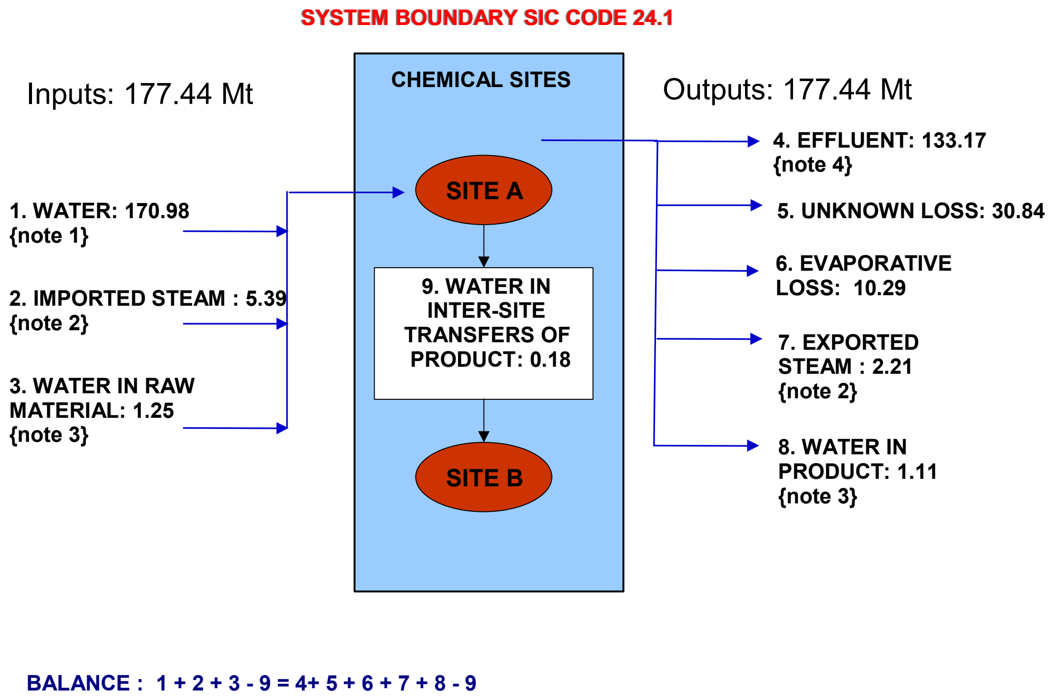
4.3 Water Mass Balance

4.3.1 Overview

Figure 4.2 presents a water mass balance model for the validated sample data. This model ignores all other materials and only reports movements of water in the model representing the industry.

The total amount of water consumed by the industry (177 Mt) is approximately 90% of the total material input of the industry – raw materials and water (ie excluding energy). This confirms the preliminary observation that water is an important resource to the chemical industry.

Figure 4.2: Water Balance



Notes:

Note Number	Comment
1	Includes water from all sources except rain water (raw, potable, etc).
2	Includes steam transfers from both sites within and outside the sample group.
3	Based on calculations of embodied water content in liquid raw materials and products only.
4	Excludes rainwater, which has been removed from site effluent values. Excludes organic materials dissolved or suspended in the effluent (measured as COD/BOD or TSS respectively).

4.3.2 Water Sources

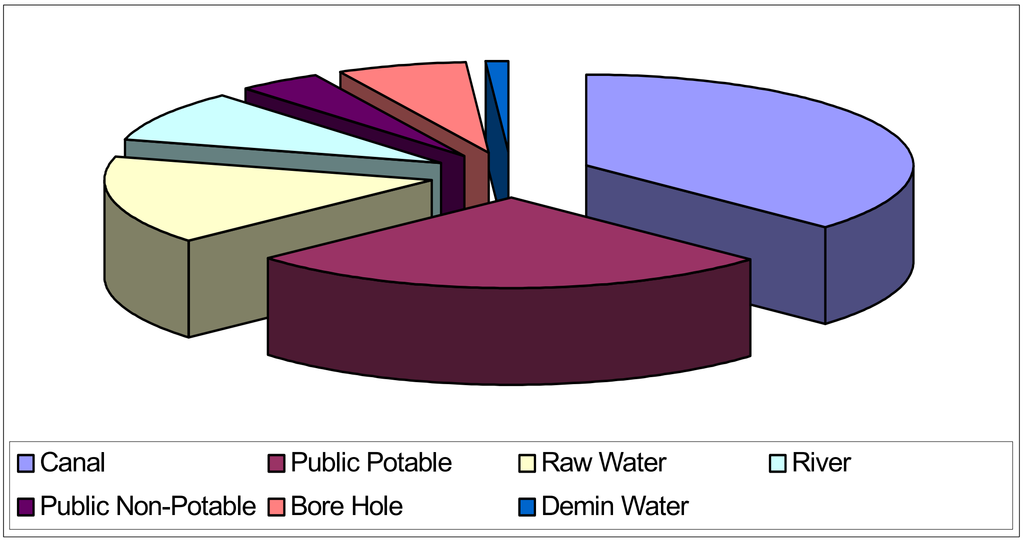
As presented previously in section 4.1 and illustrated in Figure 4.1, the mass of raw water consumed by all the validated sample data is 171 million tonnes. This excludes water imported in raw materials and imported as steam from other sites. Table 4.1 and Figure 4.3 illustrate the relative importance of various sources of water, as consumed by the validated sample of the sub-sector.

Table 4.1: Analysis of the Sources of Water

Source	% of Total
Canal	37.0
Public Potable	26.3
Raw Water #[1]	16.0
River	9.1
Bore Hole	6.5
Public Non-Potable	4.0
Demin Water	1.1
Total	**100.0**

Note: #[1] this description has been used where no other classification of water (as specified inTable 4.1) has been provided.

Figure 4.3: Analysis of the Sources of Water



As can be seen, significant amounts of high quality (public potable) mains water is used by the industry (26% of the total water consumed). However, the majority of the water comes from "untreated" water sources such as canals, rivers, reservoirs and bore holes (in excess of 70% of the total water consumed). Some of this water is treated on-site, usually by filtration and for particular applications a proportion of this treated water is further processed for special applications, such as boiler feed. It is estimated that at least 46% of the total water input is used for once-through cooling systems, where water is drawn from a source, used to cool processes by indirect heat-exchange and then discharged at a slightly higher temperature. This use of water has little to no environmental impact as the chemical quality of the water is not affected.

A very small quantity of very high quality water (demineralised) is imported by some sites from nearby sites.

4.3.3 Water Outputs

As presented in section 4.1 and illustrated in Figure 4.1 the mass of effluent leaving the validated sample sites is 133 million tonnes. In excess of 95% of this water is discharged back to the source from which it was taken for once-through cooling systems. The actual quantity of trade effluent, which is contaminated water discharges to sewer or treated effluent discharges to controlled waters is 415,000 tonnes , representing less than 5% of the total.

Material Losses to Water Discharges

Material losses to water discharges, in terms of products and/or raw materials discharged as contaminants of effluent are measured in two ways:

1. The organic content is measured by the quantity of oxygen required to oxidise the material to carbon dioxide and water (assuming it is a pure hydrocarbon) and other oxides of the constituent atoms of the waste material – this is usual measured as Chemical Oxygen Demand (COD) or Biochemical Oxygen Demand (BOD).

2. The solids suspended in the effluent measured as Total Suspended Solids (TSS) – muck, grit, etc carried in the effluent as a solid. It is usually assumed that this is the inorganic material in the effluent, although this can be inaccurate as some solids can be organic, if this were the case then the COD/TSS sum would be double counting in part the loss of material from a site. In addition, this method does not capture the *dissolved* inorganic materials in the effluent (such as salts) as the TSS method relies purely on filtering the effluent to gather the solids, where *dissolved* salts would pass right through the filter.

The values for average COD/BOD or TSS can be used to calculate the total loss of material from a site and hence for the study group. With TSS this is simply the product of the volume of effluent and the concentration of solids in the effluent. For COD/BOD an estimation that 1kg of COD is equivalent to 1kg of product has been used to make an estimate of the organic material discharged.

Table 4.2 below shows the average discharge concentrations for all the study group effluent discharges:

Table 4.2

Acronym	Description	Study Sample Average (mg/l)
BOD	Biochemical Oxygen Demand	170.6
COD	Chemical Oxygen Demand	35.5
TSS	Total Suspended Solids	63.7

The total COD and BOD equivalent mass loss to effluent reported by the validated sample sites is 28,200 tonnes. The TSS figure is 8,700 tonnes. Neither of these values represent a significant resource flow in the summary mass balance model. It must be noted that a more significant resource flow represented by dissolved inorganic salts in effluent may exist, but there is no reliable data available to support this.

Effluent discharges to both controlled waters and sewers are strictly regulated, and often consent limits are set on on specific chemicals and elements (such as copper, mercury, Red List substances etc) in addition to COD/BOD and TSS.

It can be concluded that, from a resource efficiency point of view, losses of materials to effluent would not be a priority area for action in general for the industry unless due to their environmental impact. However, for specific sites the loss of high value materials may alter this perception. Also the loss of dissolved inorganic salts may be important to specific sites.

4.4 Dry Mass Balance

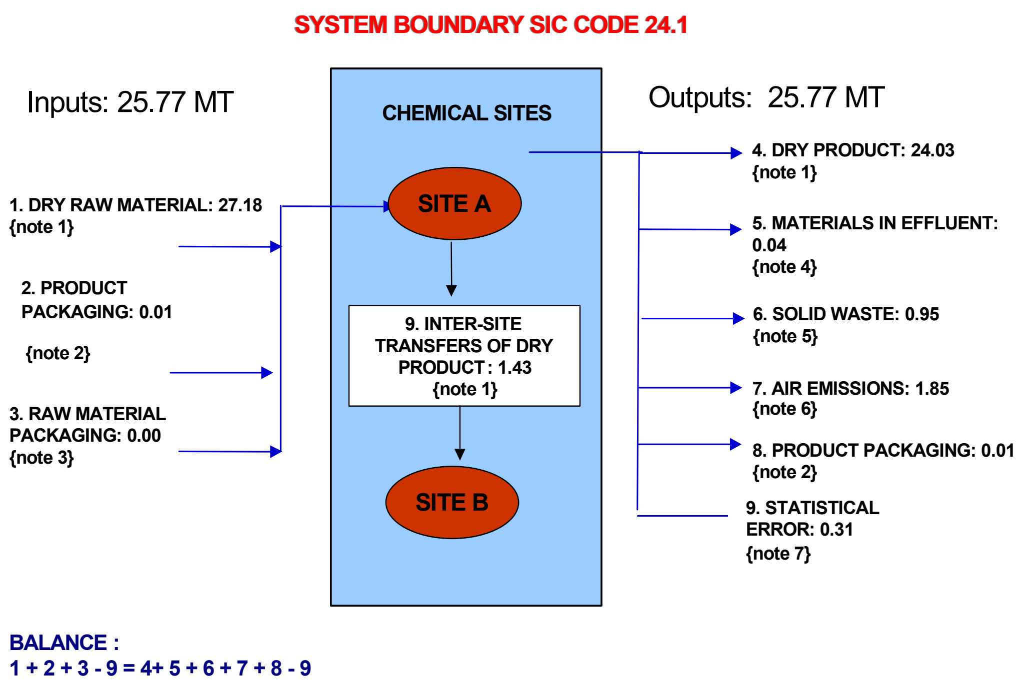
Figure 4.4 presents a dry mass balance model for the validated sample sites. This data has been derived by calculating the water content of raw materials and products from the data provided and excluding this from the data presented below. Water inputs and discharges have also been excluded from this model.

The material transferred between the sites in the study group has also been excluded from this model to show the true dry resource consumed and products exported to other industry sectors.

The resource flow of 19 Mt is only 10% of the total resource flow for the industry (179 MT including water, but excluding energy).

The data shows that roughly 20% of all raw materials imported by the industry are lost to air (as gaseous emissions), land (as waste) or water (as contamination in effluent – see Section 4.2) and that 80% is exported as finished products. This is an indicator of resource efficiency, which is discussed in more detail in Section 4.5 below.

Figure 4.4: Dry Mass Balance



Notes:

Note Number	Comment
1	Excludes calculated embodied water content in liquid raw materials, products and products transferred within the system boundary.
2	Based on total mass excluding recycled containers such as IBCs. Assumes losses in product packaging are negligible.
3	Actual value 873 tonnes. Based on total mass excluding recycled containers such as IBCs. Assumes all non-recycled raw material packaging leaves the system boundary as waste.
4	Based on calculations of materials dissolved or suspended in the effluent. Materials extracted via on-site treatment of effluent is recorded as waste.
5	Includes both on-site and off-site waste. Includes any water contained in the waste.
6	Includes only publicly reported product lost as air emissions. Includes water content within the emissions. Excludes emissions from combustion associated with on-site energy generation (such as CHP and steam generation).
7	Due to inaccuracies in measurement of waste (particularly on-site landfill), stock changes over the period of the study or estimates in the water content of raw materials or product.

4.5 Key Performance Indicators as Measures of Resource Efficiency

One of the key objectives of this study is the development of Key Performance Indicators (KPIs) that the UK basic chemical industry can use to benchmark future improvements in resource efficiency. No attempt has been made to derive a single KPI to define “overall resource efficiency”, rather a number of indicators of performance have been produced, few of these can be compared with other KPIs, each has to be viewed in isolation as one-of-many indicators of resource efficiency. In the following sections KPIs for various aspects of the resource flows in the basic chemical industry are presented and discussed. Where possible, these KPIs are presented for the constituent sub-sectors of the basic chemical industry (i.e. expressed by 4 figure Standard Industry Classification codes).

4.5.1 Overall Raw Material Efficiency

Overall raw material efficiency is defined as the total mass of products (including water) produced by the industry divided by the total mass of raw materials (including water) consumed by the industry. Table 4.3 presents an analysis of this KPI.

Table 4.3: Resource Efficiency

SIC Code	General Description of Manufacturing Activity	Overall Raw Material Efficiency %
24.11	Industrial gases	99.7
24.12	Pigments & dyes	32.4
24.13	Other inorganic basic chemicals	83.6
24.14	Other organic basic chemicals	89.0
24.15	Fertilizers & nitrogen compounds	71.4
24.16	Plastics in the primary form	94.9
Total		**88.8**

This indicator is interesting in itself, but is flawed in that comparison between the industry sub-sectors is meaningless without an understanding of the chemistry involved. For example;

- Manufacture of industrial gases (24.11) does not consume raw materials or produce products containing water, whereas all the other sectors do to a greater or lesser extent and in some cases actually consume significant quantities of water as a raw material (eg in the fertiliser industry) or produce water as a by-product.

- Manufacture of inorganic chemicals (SIC 24.12) often involves the extraction of specific metal salts from naturally occurring minerals - where the salt concentration in the mineral raw material determines the level of product and corresponding waste.

4.5.2 Dry Material Resource Efficiency

Dry material resource efficiency is defined as the mass of products (excluding water) produced by the industry divided by the mass of dry raw materials consumed. Table 4.4 presents an analysis of this KPI by SIC code.

Table 4.4: Dry Material Resource Efficiency

SIC Code	General Description of Manufacturing Activity	Dry Material Resource Efficiency %
24.11	Industrial gases	99.6
24.12	Pigments & dyes	32.5
24.13	Other inorganic basic chemicals	84.6
24.14	Other organic basic chemicals	88.7
24.15	Fertilizers & nitrogen compounds	68.4
24.16	Plastics in the primary form	99.7
Total		**88.4**

Here it can be seen that three of the industry sub-sectors are less resource efficient than industrial gases and primary plastic production. This can be explained in part by the nature of these two industries:

- The industrial gases industry primarily involves the physical separation of the constituent gases of air (mainly oxygen and nitrogen) and hence has no inherent waste built into raw materials or the processes themselves (any un-used air is put back into the atmosphere).

- The primary plastics industry utilises highly refined raw materials and mainly involves the joining of small molecules into long polymer chains. There is little or now refining of raw materials or products in this sub-sector.

The other three subsectors all include processes that involve to a greater or lesser extent the refining of raw materials before they are used or products, once they are produced. Many of the raw materials consumed contain inherent wastes (eg ores that contain unwanted chemicals or inert components), such as titanium ores used in the manufacture of titanium dioxide. .

Some of the chemistry used in the manufacture of products is also inherently wasteful, in that to win one element in a certain form it has to be separated from another, which may be discarded as waste in one form or another, an example here is the production of lime (calcium oxide) from limestone (calcium carbonate), where carbon dioxide is generated from the breakdown of the limestone and emitted to the atmosphere. These figures are also distorted when water is generated as a by-product of processes (eg in the production of nitric acid from ammonia, where considerable quantities of water are generated by the reaction and then excluded from this KPI by definition).

On a site by site basis these KPIs have to be used with care, comparison of individual sites KPIs with the sector or subsector KPI may be meaningless.

4.5.3 Other KPIs

The two important routes by which raw materials and products are lost or discharged from processes are as air emissions or wastes. As has already been discussed the loss of raw materials and products to effluent discharges are relatively insignificant and are not treated here.

Total Waste & Air Emissions

Tables 4.5 and 4.6 present analyses of waste and air emissions as KPIs. Table 4.5 presents the values divided by wet production mass (i.e. including water) and Table 4.6 presents the values divided by wet raw material mass (i.e. including water).

Table 4.5: Waste & Air Emissions (based on production)

SIC Code	General Description of Manufacturing Activity	Waste / Wet Products %	Air Emissions / Wet Products %
24.11	Industrial gases	<1	<1
24.12	Pigments & dyes	74.4	123.6
24.13	Other inorganic basic chemicals	7.9	7.9
24.14	Other organic basic chemicals	6.1	1.8
24.15	Fertilizers & nitrogen compounds	<1	45.3
24.16	Plastics in the primary form	5.4	<1
Weighted Ave		**3.8**	**7.8**

Table 4.6: Waste & Air Emissions (based on raw materials)

SIC Code	General Description of Manufacturing Activity	Waste / Wet Raw Materials %	Air Emissions / Wet Raw Materials %
24.11	Industrial gases	<1	<1
24.12	Pigments & dyes	24.1	40.0
24.13	Other inorganic basic chemicals	6.6	6.6
24.14	Other organic basic chemicals	5.4	1.6
24.15	Fertilizers & nitrogen compounds	<1	32.4
24.16	Plastics in the primary form	5.1	<1
Weighted Ave		**3.3**	**6.9**

Classification of Wastes

Further analysis of the waste figures, broken down into special and non-special waste by SIC code is presented in Table 4.7. It can be seen that roughly a quarter of all waste produced by the industry is classified as special waste and can be assumed to be hazardous in nature and potentially harmful to the environment. The remaining non-special waste is likely to be low in hazard or inert.

Table 4.7: Special & Non-Special Wastes

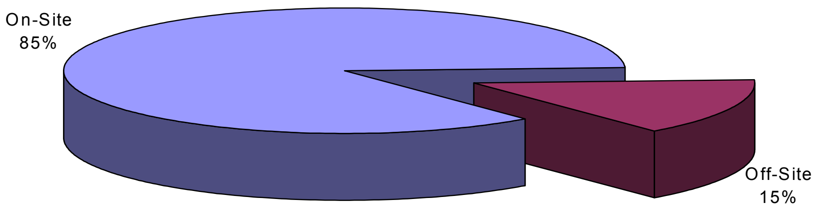
SIC Code	Total Waste (000 tonnes)	Non-special Waste (000 tonnes)	Special Waste (000 tonnes)	Special Waste / Total Waste (%)
24.11	2.6	1.4	1.2	46.3
24.12	150.7	150.7	0.0	0.0
24.13	277.8	191.4	86.4	31.1
24.14	458.1	25.9	432.2	94.3
24.15	3.7	3.5	0.2	6.9
24.16	59.3	3.1	56.2	94.8
Total / Ave	**952.5**	**376.0**	**576.3**	**60.5**

Waste Disposal Routes

About 448,000 tonnes of all the waste arising is disposed of via landfill representing approximately 47% of the total. The remainder is treated, recycled or incinerated.

Of this 448,000 tonnes sent to land fill 20%, equating to 87,700 tonnes, is classified as special waste, of which 76,700 tonnes is landfilled on-site – which can be assumed to be special landfills designed for particular site specific wastes (Figure 4.5):

Figure 4.5: Waste Disposal Routes

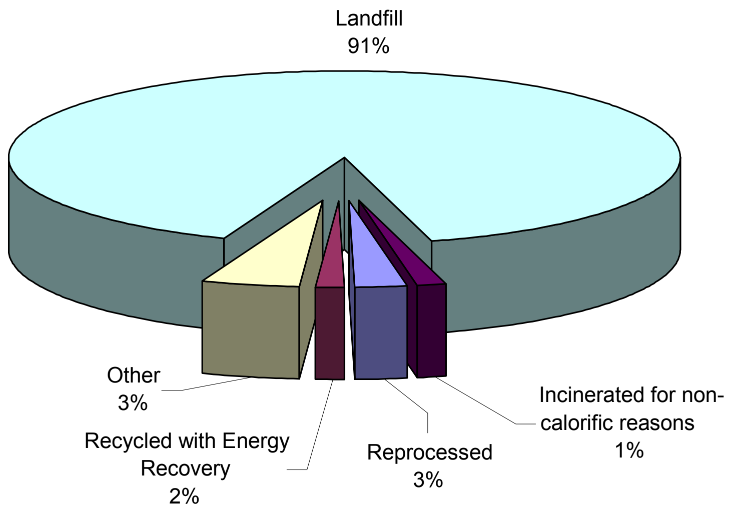


As can be seen from Table 4.7 the majority of the waste produced by the study group comes from two particular sub-sectors, these being the non-specific organic and inorganic base chemical sectors.

A few companies within these two sectors contribute significantly to waste that is landfilled. 84% of landfill off-site is generated by three sites and 89% of on-site landfill is carried out by 5 sites (two of which are in the previous group) from these sub-sectors – all of these sites are basic inorganic chemical manufacturers utilising primary raw materials as ores, the majority of the waste being inherent to the raw material and not within the control of the processor.

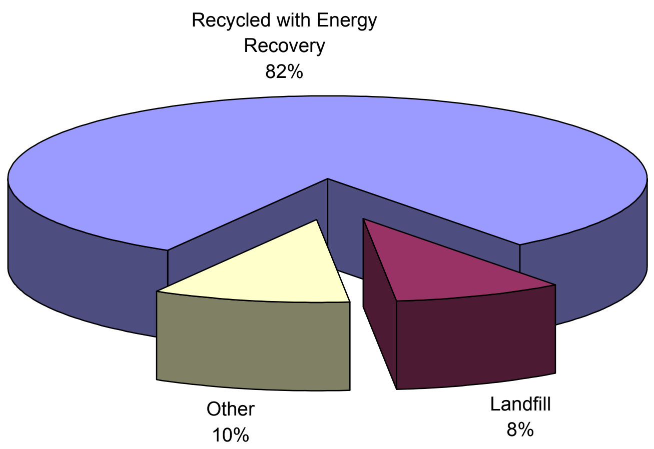
Figures 4.6 and 4.7 present the further analyses of the waste disposal routes, both on-site and off-site respectively.

Figure 4.6: Waste Disposal Off-Site



There are a number of companies in the base organics sector that take by-products/wastes from their processes and burn them to generate energy for their processes, around 66% of wastes disposed on-site are disposed in this manner.

Figure 4.7: Waste Disposal On-Site



4.5.4 Water Efficiency

The amount of water imported to all the sites in the study group embodied in raw materials is insignificant compared to the total raw water imported to the sites (1.3 million m^3 compared with 171 million m^3 respectively) and has not been included in the calculations for Table 4.8 below which presents an analysis of the water efficiency of the various sub-sectors of the industry:

Table 4.8: Water Consumption by Chemical Industry Sub-Sectors

SIC Code	General Description of Manufacturing Activity	Average Value Water Imported / Tonne Production (wet)	Range Water Imported / Tonne Production (wet)
24.11	Industrial gases	0.2	0.2 – 0.0
24.12	Pigments & dyes	40.5	47.4 – 31.5
24.13	Other inorganic basic chemicals	27.1	68.9 – 0.2
24.14	Other organic basic chemicals	6.6	32.1 – 3.9
24.15	Fertilizers & nitrogen compounds	5.6	11.1 – 4.0
24.16	Plastics in the primary form	4.8	7.7 – 0.7
Ave / Range		7.1	68.9 – 0.0

The industrial gas producers do not use significant quantities of water.

The base inorganic industry involves a great deal of water based-chemistry and processing so the high average figure is perhaps not surprising. There is a wide range in individual site performance, and even between sites carrying out the same chemical process. The same can be said of the remaining three sub-sectors, widely varying site performances are disguised by these seemingly similar averages.

4.6 Energy Consumption

4.6.1 Energy Inputs

The sites provided data on energy consumption, enabling energy inputs to be calculated and analysed. The sample of the industry uses 46.94 TWh of energy on-site in the production processes. Table 4.9 and Figure 4.9 present an analysis of this energy input by type and source. None of the study sample exported electricity or condensate. The only inter-site transfer of energy was in the form of steam.

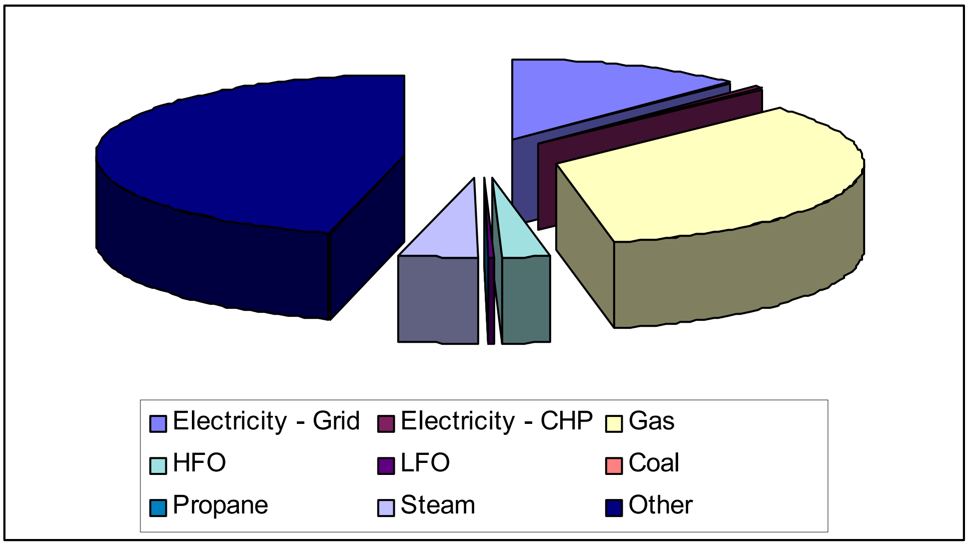
Table 4.9: Energy Input Types and Source for the Validated Sample Sites

Type	Source	% of Total
Electricity	Grid	15.8
	CHP	0.6
Gas		32.9
HFO		2.3
LFO		0.2
Coal		0.1
Propane		0.0
Steam (note 1)		3.9
Other (note 2)		44.1
Total		**100.0**

Notes:

Note Number	Comment
1	There is a transfer of energy, in the form of steam, between sites within the sample. The value presented represents the net consumption of this transferred steam (imported – exported).
2	Some sites have reported energy used from non-typical sources – defined as other in the questionnaire. The majority of this energy comes from the following two sources. ➢ Heat transfer from upstream and / or downstream activities within the system boundary (e.g. cracking of oil). ➢ Burning of production or waste materials.

Figure 4.9: Energy Input Types and Source for the Validated Sample Sites



4.6.2 Energy Outputs

The majority of sites that contributed to this study could not provide sufficient information on how energy is used or dissipated once used to enable reporting or analysis of an energy balance. The majority of the energy used in the chemical industry is ultimately degraded and discharged as low grade heat, normally via cooling towers or once-through water cooling systems.

4.6.3 Energy Consumption by Product

Using total energy input and when reported output figures the energy usage could be calculated across each of the sites in the validated study sample. This was then converted into the energy consumption per tonne of product for each of the SIC subsectors. Table 4.10 presents these results.

Table 4.10: Energy Consumption by Chemical Industry Sub-Sectors

SIC Code	General Description of Manufacturing Activity	Energy Use (MWh) / Production (tonnes)
24.11	Industrial gases	0.28
24.12	Pigments & dyes	6.77
24.13	Other inorganic basic chemicals	2.51
24.14	Other organic basic chemicals	3.8
24.15	Fertilizers & nitrogen compounds	1.49
24.16	Plastics in the primary form	0.88
Total		**1.87**

4.6.4 Transport Energy for Raw Material Receipt

The sample sites were asked to provide information on the site of origin of their raw materials (or port of entry for imported products) so that a calculation could be made of the energy used in transporting those products. 26 of the 31 sites provided data for this, equating to 55% of the total raw material input for the validated study sample (excluding material transported by pipe-line).

The transport energy calculated for those sites where information was available totals 33.5 GWh, which would equate to less than 1% of the total energy used in production processes, however, it is meaningless to scale this figure up to the complete sample group given the high level of uncertainty.

4.6.5 Carbon Dioxide Equivalence

The chemical industry produces carbon dioxide as a result of :

- **On-site combustion:** The combustion of fuels on-site to produce energy to drive the chemical reactions / processes (including on-site electricity generation via for example combined heat and power (CHP) plants).

- **Off-site electricity generation:** Indirectly via the combustion of fuels off-site (e.g national grid) to produce electricity which is used as an energy source on site. The CO_2 equivalence is calculated from primary fuel usage based on standard efficiencies of generation and transmission.

- **Chemical process:** The chemical process which may emit CO_2 as part of the reaction.

The actual carbon dioxide emitted by the study sample split down by type / source is presented in Table 4.11 below.

Table 4.11 : Source of CO_2 Emissions

Type / Source	CO_2 (million tonnes)
On-site combustion (A)	10.2
Off-site electricity generation (B)	3.4
Chemical process (C)	0.5
Total	**14.1**

The carbon dioxide emitted as a result of the movement of goods to site is very small by comparison at 117 tonnes (based on the validated sample data).

Table 4.12 presents an analysis of the carbon dioxide emissions by type / source.

Table 4.12: Source of CO_2 Emissions by SIC Sub-Sector

SIC Code	General Description of Manufacturing Activity	(A) % of Total	(B) % of Total	(C) % of Total
24.11	Industrial gases	0.9	35.3	0.0
24.12	Pigments & dyes	3.2	2.4	42.3
24.13	Other inorganic basic chemicals	11.8	30.9	57.7
24.14	Other organic basic chemicals	73.5	20.8	0.0
24.15	Fertilizers & nitrogen compounds	9.8	6.7	0.0
24.16	Plastics in the primary form	0.8	3.9	0.0
Total		**100**	**100**	**100**

4.7 Inter Site Transfers

4.7.1 Mass Flow

1.6 million tonnes of product is moved from one site to become raw materials for another site within the sample. This represents 13.4% of the total product, demonstrating the interdependence of the sites within the SIC 24.1.

4.7.2 Transport Energy

The energy consumption associated with this inter-site transfer is 12.6 GWh, equivalent to 44.3 tonnes of carbon dioxide.

It should be noted that the transport energy for the validated study sample was comprehensive for inter-site transfers which was not the case for the receipt of raw materials and therefore these two figures should not be compared.

4.8 Raw Materials

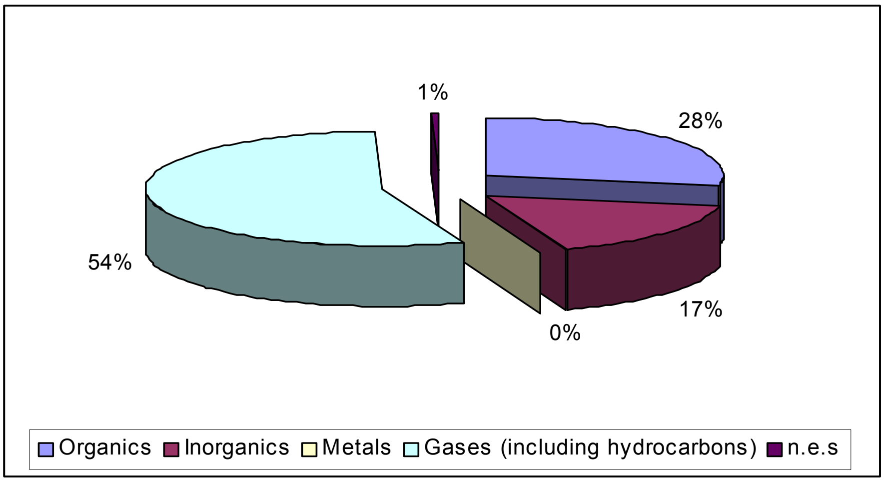
4.8.1 Overview

The validated study sample of the industry subsector consumes 28.4 million tonnes of raw materials (wet mass - excluding water as a process aid). Table 4.13 and Figure 4.10 present a primary level analysis of the raw materials.

Table 4.13 : Primary Analysis of the Raw Materials Consumed

Group	Mass (000' tonnes)	% Total
Organics	7,871.7	27.6
Gases - including hydrocarbons	15,595.8	54.8
Inorganics	4,753.2	16.7
Metals - in metallic form	45.7	0.2
Raw Materials n.e.s (not elsewhere specified)	172.5	0.6
Total	**28,438.9**	**100**

Figure 4.10: Primary Analysis of the Raw Materials Consumed



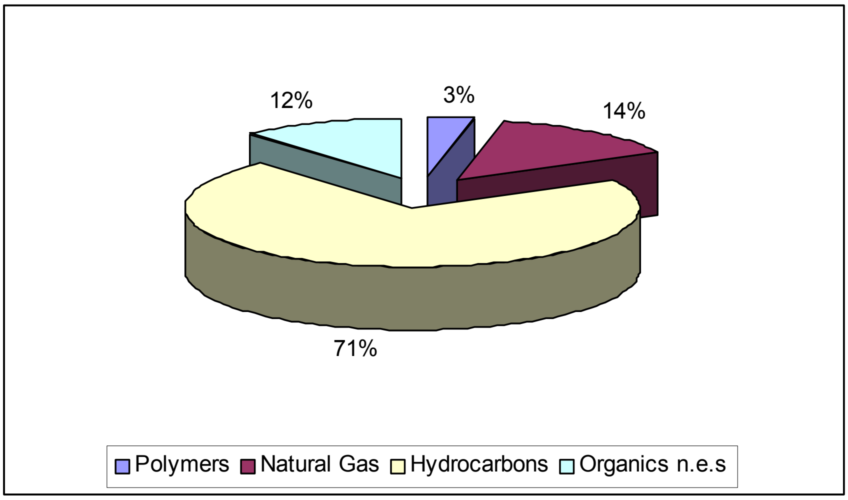
4.8.2 Organics

Further analysis of the organics group, including organic gases, as presented in Table 4.14 and Figure 4.11, reveals that hydrocarbons make up in excess of 70 % of this group. These are chemicals produced by the upstream oil and gas extraction and refining industries.

Table 4.14: Analysis of the Organic Raw Materials Consumed

Group	Mass (000 tonnes)	% Total of Organics
Polymers	308.1	3.4
Hydrocarbons – excluding natural gas	6492.5	71.1
Natural Gas	1,254.8	13.7
Organics n.e.s	1070.9	11.7
Total **Organics: 7,871.7** **Natural Gas: 1,254.8**	**9,126.3**	**100.0**

Figure 4.11: Analysis of the Organic Raw Materials Consumed



4.8.3 Polymers

Tiering down the analysis of Polymers, as presented in Table 4.15, reveals that polypropylene / polyethylene make up the majority of the polymers consumed.

Table 4.15: Analysis of the Polymers Raw Materials Consumed

Group	Mass (000 tonnes)	% Total of Polymers
PP/PE	291.7	94.7
Styrenics	8.2	2.7
Speciality	7.7	2.5
Chlorinated	0.5	0.1
Total	**308.1**	**100**

4.8.4 Gases

A major raw material for this industry is air, which is a mixture of gases including oxygen and nitrogen, both of which are used in the manufacture of a wide range of chemical products. Unseparated air makes up approximately 40 % of the raw material mass for the industry sector.

Due the nature of the UK market, for confidentiality reasons, further analysis of gaseous raw materials consumed is not presented.

4.8.5 Inorganics

There is a diverse range of inorganic chemicals consumed by the industry.

Sodium chloride represents nearly 50% of the inorganic material input, showing the degree of importance of this basic material to the chemical industry.

From a metallic perspective the pure metals and metallic ores can be grouped, and represent 3.9 million tonnes (13.7% of the total raw materials).

Table 4.16 presents the key inorganic raw materials consumed on a mass basis.

Table 4.16: Analysis of the Inorganic Raw Materials Consumed

Class	Mass (000 tonnes)	% Total of Inorganics
Primary - including Ti ores, NaCl, $CaCO_3$ and sulphur	3,443.2	72.4
Manufactured – Including NaOH, KOH and H_2SO_4	373.1	7.9
Inorganics	936.7	19.7
Total	**4,753**	**100.0**

4.9 Products

4.9.1 Overview

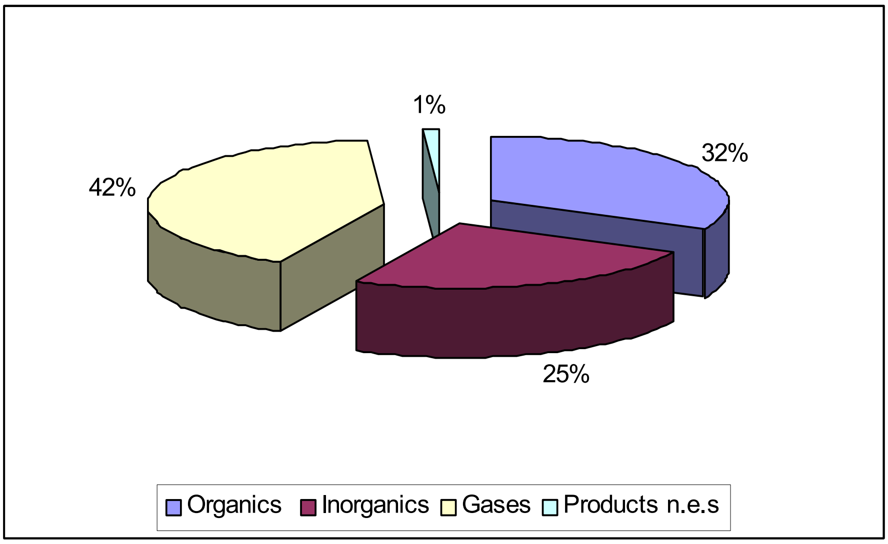
The sample of the industry subsector produces 17.5 million tonnes of products (wet mass) of which 1.6 million tonnes is transferred within the system boundary and used by other companies in the sector to manufacture other chemicals. Table 4.17 and Figure 4.12 present an initial grouped analysis of the products.

Figure 4.17: Primary Analysis of the Products Produced

Group	Mass (000' tonnes)	% Total
Organics	8,127.4	32.3
Gases - excluding organic gases	10,463.0	41.6
Inorganics	6,275.0	24.9
Other Products n.e.s	279.9	1.1
Total	**25,145.3**	**100**
Transferred Materials	-1,600[#1]	- 6.4

#[1] – Excludes air gases.
Note: The percentages presented above relate to the total mass minus transferred material.

Figure 4.12: Primary Analysis of the Products Produced



4.9.2 Organics

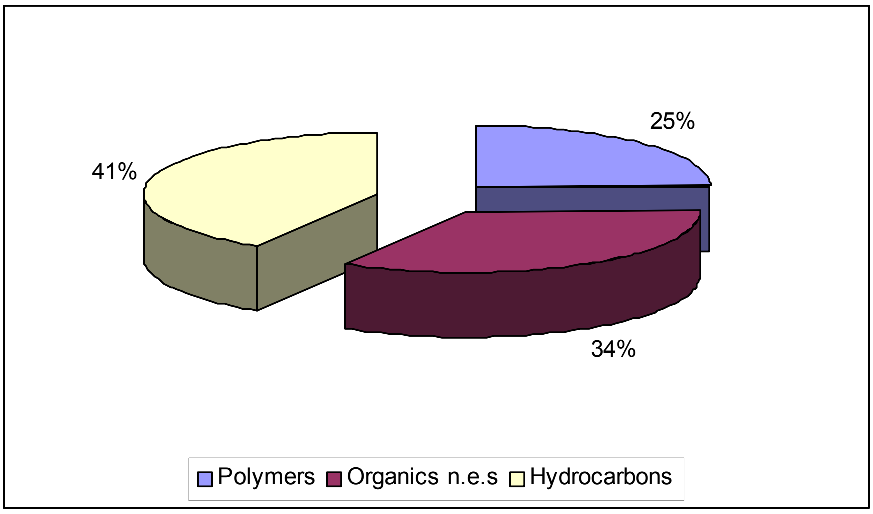
Further analysis of the organics products produced, including organic gases, is presented below in Table 4.18 and Figure 4.13.

Table 4.18: Analysis of the Organic Products Produced

Group	Mass (000 tonnes)	% Total of Organics
Hydrocarbons	3,355.7	41.3
Organics n.e.s	2,770.0	34.1
Polymers	2,001.7	24.6
Total	**8,127.4**	**100**

Note: values include the transferred products

Figure 4.13: Analysis of the Organic Products Produced



4.9.3 Polymers

Tiering down the analysis of Polymers, as presented in Table 4.19, reveals that polypropylene / polyethylene make up the majority of the polymers produced.

Table 4.19: Analysis of the Polymeric Products Produced

Group	Mass (000 tonnes)	% Total of Polymers
PP/PE	1,538.4	76.9
Speciality	271.4	13.6
Styrenics	191.8	9.6
Total	**2,001.7**	**100**

4.9.4 Inorganics

Table 4.20 presents an analysis of the key metal salts produced on a mass basis.

Table 4.20: Analysis of the Key Metal Salts Produced

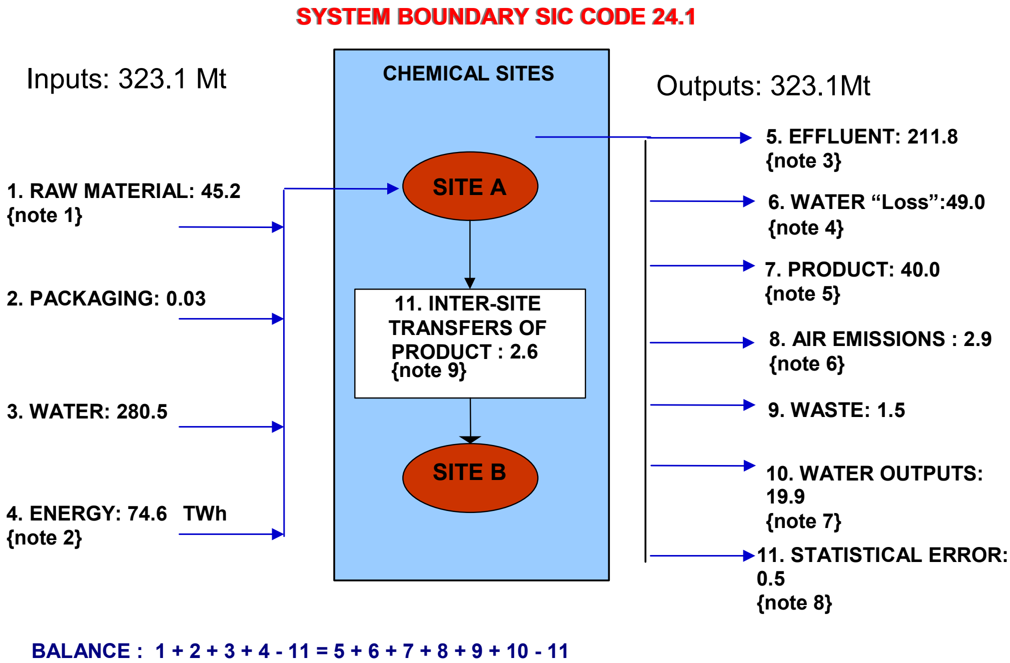
Natural Product Groups / Metal Salts	Mass (000 tonnes)	% of Inorganics Total
Na	1,580.0	25.2
Ca	544.5	8.7
Transition Metals including Ti and Cr	344.3	5.5
Total of Above	**2,468.8**	**39.4**

5. CONCLUSIONS & RECOMMENDATIONS

5.1 Total Industry Mass Balance (SIC 24.1)

Figure 5.1 presents a scale up of the study outputs, using the best available estimates of production output of the industry[2], to estimate the mass flows for the total of the UK chemical industry (SIC 24.1).

Figure 5.1: SIC 24.1 Mass Balance



[2] Estimate of Chemical Industry production output calculated from the CIA 1999 – production output figures combined with inputs from non CIA UK chemical companies.

Notes:

Note Number	Comment
1	Includes embodied water (such as water of crystallisation and water as a solvent) but excludes raw materials transferred from sites within the study group.
2	Net energy consumption (inputs-exported energy), not included as a mass.
3	Includes water and embodied material.
4	Includes known evaporative losses, exported steam and calculated water. Excludes effluent.
5	Includes embodied water (such as water of crystallisation and water as a solvent). Excludes rain water, which has been removed from site effluent values.
6	Excludes emissions from combustion associated with on-site energy generation (such as CHP and steam generation).
7	Includes evaporative loss from cooling towers and exported steam.
8	Known statistical error in dry mass.
9	This value excludes inter-site transfer of gaseous materials.

5.2 Resource Consumption

5.2.1 Water

Water is the largest single resource consumed by the UK chemical industry. This water is supplied from both public and private sources. Public potable water consumption is well measured, probably due to the fact that this is paid for. Other water consumed, such as bore hole or canal, is less accurately measured.

There is little measurement of water usage and output, with the exception of effluent discharges due to regulation. It has been impossible to present in detail the quantities of water output via cooling processes (cooling towers or once through water cooling) or steam loss, however this water has a low environmental impact.

Some sites have significant rainwater intakes, however there is little analysis or measurement of how this water leaves the sites.

5.2.2 Energy

Energy is a significant resource consumed by the industry. As with other major UK industries there are strong fiscal controls already in place, such as the Climate Change Levy, to incentivise the industry to monitor and improve energy efficiency.

It has proven difficult to balance energy inputs and outputs as only high value energy outputs are measured (eg steam) and low energy outputs have little to no value and are therefore have not traditionally been measured.

5.2.3 Raw Materials

The study data outputs suggest that overall raw material efficiency (ie that converted to useful product) is approximately 80%. Material losses to air and land seem to be approximately equal. The mass of materials lost to effluent is small. Losses to air are dominated by process CO_2 and water of reaction.

5.3 Recommendations

The industry could consider establishing a water minimisation programme, along the lines of the voluntary energy efficiency programme to improve its consumption of water and discharge of contaminated water.

The industry could consider including some of the key performance indicators from this report in its annual reporting programmes to enable the monitoring of resource flows to continue.

There could be value in further investigation of whether process integration and or networking could use some waste energy currently disposed of by the industry.

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APPENDIX 1

STUDY - MAIN SAMPLE COMPANIES AND SITES

STUDY - MAIN SAMPLE COMPANIES AND SITES

Air Product Group	Multiple sites[#1]	Huntsman Polyurethanes UK.Ltd	Wilton
Air Products (Chemicals)	Clayton	Hydro Polymers Ltd	Newton Aycliffe
Associated Octel	Ellesmere Port	Ineos Acrylics UK Ltd	Billingham
Atofina	Stalybridge	Ineos Chlor Ltd	Runcorn
Basell Polyolefins	Carrington	Ineos Chlor Ltd	Northwich
Basell Polyolefins	Wilton	Ineos Silicas	Warrington
BASF	Middlesborough	Kemira Agro Ltd	Ince
BOC Gases	Multiple sites[#1]	Laporte Performance Chemicals	Knottinghley
Borden Chemicals	Peterlee	Millennium Chemicals Ltd	Grimsby
BP Chemicals Ltd	Grangemouth	Rhodia Consumer Specialities	Oldbury
BP Chemicals Ltd	Hull	Rhodia Consumer Specialities	Whitehaven
British Salt Ltd	Middlewich	Rhodia Eco Services Ltd	Chesterfield
Coalite Smokeless Fuels	Chesterfield	Rhodia Organique Fine Ltd	Avonmouth
Dow Chemical Company Ltd	Middlesborough	Rockwood Specialities	Widnes
Dow Chemical Company Ltd	Sully	Sevalco Ltd	Bristol
Dow Chemical Company Ltd	Wilton	Shell Chemicals UK	Stanlow
Dow Corning	Barry	Singleton Birch Ltd	Barnetby
DuPont Sabanci Polyester	Wilton	Solutia UK	Newport
Eastman Company UK	Workington	Solvay Interox	Warrington
Elementis Chromium	Eaglescliffe	Terra Nitrogen (UK) Ltd	Billingham
Enichem UK.Ltd	Hythe	Terra Nitrogen	Severnside
Exxon Mobil Chemicals	Fife	Tioxide Europe Ltd	Grimsby
Exxon Mobil Chemicals	Hythe	Tioxide Europe Ltd	Hartlepool
Albion Chemicals (formerly Hays Chemicals Ltd)	Sandbach	Uniqema Chemicals	Wilton
Huntsman Petrochemicals UK Ltd	Wilton	Vinamul Ltd	Warrington

Note: Multiple sites[#1]

Due to the nature of the organizational structure of the gas producing chemical companies (SIC 24.11) the data for these companies were collected and validated on a multi-site basis. Whilst the Air Products data relates to 30 operating sites and the BOC data relates to 10 operating sites, for the purposes of this study the companies are presented as single entries.

APPENDIX 2

STUDY QUESTIONNAIRE

BIFFAWARD

PROJECT FOR A MASS BALANCE STUDY
CHEMICAL INDUSTRY

QUESTIONNAIRE

2001

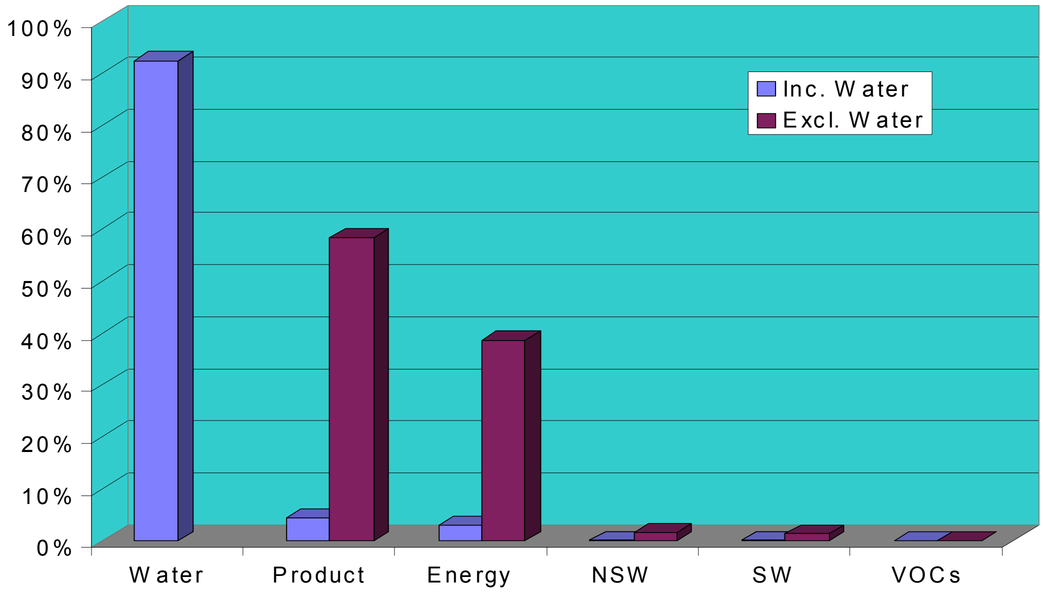
INTRODUCTION TO CHEMICAL INDUSTRY MASS BALANCE STUDY

This project is sponsored by the Chemical Industries Association (CIA) and funded by a multi-million pound environment fund, which utilises landfill tax credits donated by Biffa Waste Services.

The aim of the study is to quantify material flows and to provide further insight into more sustainable resource use and sustainable waste management practices within the industry. This project will build strongly on the data already available from the CIA. It will seek to provide a significant reference source and methodology towards the sustainability initiative launched by the CIA. In outline it will provide:

- Quantification of raw materials usage in the industry as a whole, and for the principal sub-sectors of which it is comprised;
- Identification of the relationships between resource inputs, product outputs, losses, emissions and waste streams, again at the industry and sector levels;
- Identification of the extent to which the industry's waste streams are currently reliant on landfill for their ultimate disposal and the type of material so disposed;
- Quantification of the tonnages of recycled material being used within the industry, and the importance of such materials in the different sectors relative to the use of virgin material
- Identification of areas where waste materials can be substituted for virgin materials
- Prioritisation of the areas where further action can be taken to minimise wastes and divert materials from landfill;

A first look at the mass flow through the industry, based on water use and production and emissions to air and land (waste), as reported by CIA members in the annual Responsible Care Indicators of Performance (IoP) survey, shows that around 90% of the industry's mass flow comprises water:



NSW and SW are Non-Special Waste and Special Waste respectively. Further examination of the IoP data shows that roughly 50 out of the CIA's 300 members contribute more than 90% of the industries total mass flow (indicated by production).

An analysis of the various industry sub-sectors that make up the chemical industry shows that those sites classified under the Standard Industry Code (SIC) 24.1 make up nearly 90% of the industry's mass flow:

SIC	Description	Mtonnes	Cumulative % of Total
24.14	Other Organic Base chemicals	11.0	32%
24.11	Industrial Gases	8.1	56%
24.13	Other Inorganic Base Chemicals	5.8	73%
24.16	Plastics in Primary Form	2.4	80%
24.15	Fertilisers and Nitrogen Compounds	2.3	87%
	Other Chemical Products	2.9	13%
	Total Chemical Production	**34.0**	

This study is therefore limited to the CIA members in SIC 24.1 and the data gathered will be used to characterise this sector of the industry. The aim is to collect data from all the sites which make up 90% of the total mass flow and to get information from the other sites on a voluntary basis.

If possible the collated data will be used to comment on the characteristics of the basic chemicals sector, although it is expected that further study would be required to complete the study for the remainder of the industry.

System Boundary

Figure 1, on the following page illustrates the principles behind the mass balance approach to this project. The system boundary prescribes those companies in SIC 24.1.

However, we have to recognise that some larger sites may have significant operations within their boundary that are outside SIC 24.1 (eg a primary plastics producer with formulation operations).

To overcome this problem we are asking correspondents to provide information about their site" operations **excluding** operations outside SIC 24.1 – see Figure 2.

Inter-Site Transfers

A second potential problem that has to be overcome is inter-site transfers within the target group, which will cause double counting errors unless measured (ie the product from one target site being the raw material of another - see Figure 1). Correspondents are asked to provide data on these movements.

What will you get out of this?

First, you will be contributing to an overall ecological footprint for the whole chemical industry, which the CIA will be able to use to assist in setting a sustainable development strategy for the industry.

Second, the data you provide will be fed back to you in the form of an overall mass balance for your site along with a commentary on how this fits into the overall ecological footprint (mass balance) of the basic chemicals sector. Where possible we will also comment on sustainable development issues for your site (eg waste minimisation, resource efficiency etc). Hopefully, you will be able to use this information in setting environmental improvement and sustainable development goals for your site.

Confidentiality

All information provided will be treated in strict confidence under a Confidentiality Agreement signed between Enviros and the CIA. No information provided for this project will be passed to any other person or company outside the Enviros or CIA project teams.

Any analysis of the information provided will be presented in such a way that no single company's data can be extrapolated from the presented data.

Enviros Contact Details & Help Line

In the event that you require assistance in completing this questionnaire please initially contact the Enviros help line:

Helen Fairclough
Enviros March
Telegraphic House,Waterfront Quay
Salford Quays
Manchester
M5 2XW

Tel : 0161 874 3630
Fax: 0161 874 0181
e-mail: chemicalmb@enviros.com

Figure 1

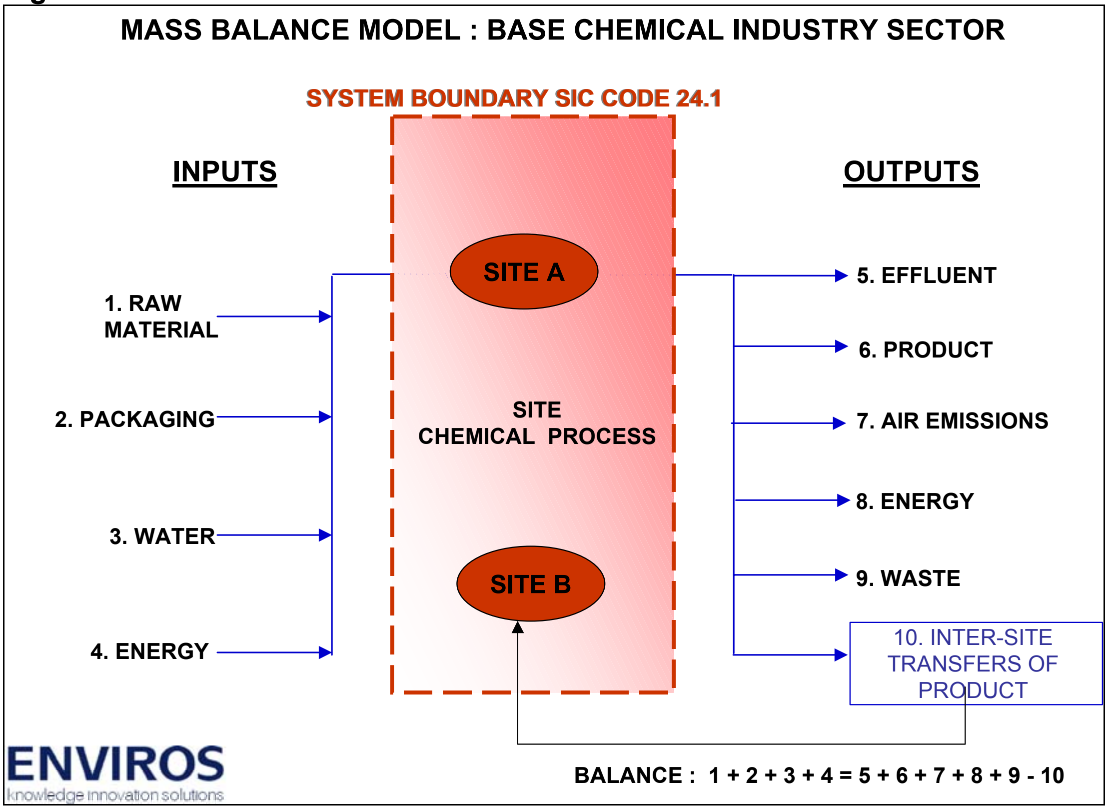
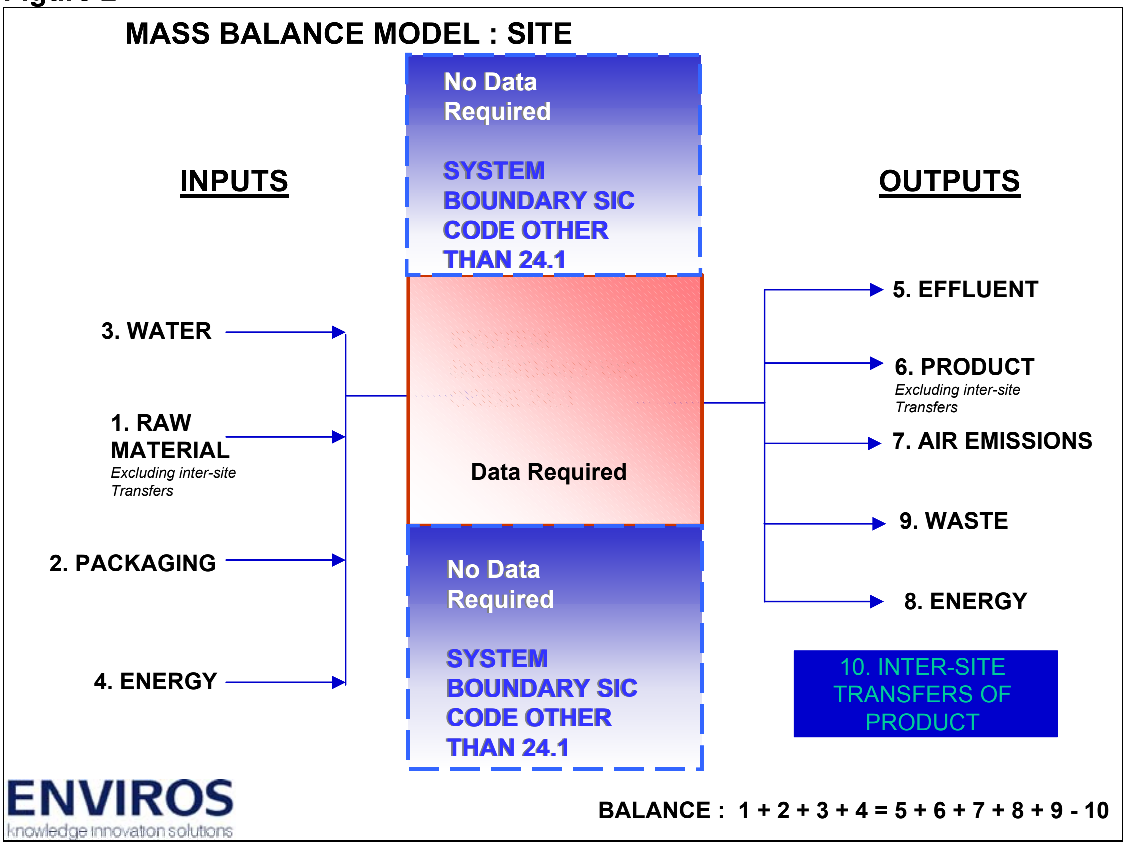


Figure 2



CONTENTS

1. INTRODUCTION TO QUESTIONNAIRE

1.1 Concept & General Instructions

This study aims to produce a mass balance of the basic chemical industry (those companies who produce basic chemicals, plastics and so on). The questionnaire is aims to gather all the information required to generate this mass balance.

We aim to have the questionnaire completed by all the companies in Table A : Mass Balance Company List (on the following page).

- All quantifiable data should be for the period ***Jan 1999 – Dec 1999*** inclusive (chosen as we expect that the sites will have this data available and complete)
    - **or otherwise specified h**
- Please indicate zero (NIL), not collected (NC) and not applicable (NA) for all entries.
- Please include additional comments were applicable.
- This questionnaire has been designed to readily incorporate the 1999 CIA Indicators of Performance (IoP) data in an effort to reduce effort – please copy the data you provided to the CIA in the 1999 IoP questionnaire or supply a copy.
- All shaded boxes are for internal use only and not required to be completed.

Abbreviations Used

Abbreviation	Description	Abbreviation	Description
SIC	Standard Industry Code	M^3	Cubic metres
gm	gramme	kWh	Kilowatt hours
Kg	kilogramme	BOD	Biological oxygen demand
MT	Metric tonne	TSS	Total suspended solids
pa	Per annum	PIR2	Pollution Inventory Report Form 2 – as issued by the Environmental Agency
W/V	Weight per unit volume	Qty	Quantity
C&E	UK Customs & Excise Code	BtU/lb	British thermal units per pound weight
COD	Critical oxygen demand	“Once-through” Water	The use of mains river or other water supplies to cool a process without recirculation (ie water leaving any heat exchanger which is discharged to effluent / river etc)
IBC	Intermediate bulk container	“Special Waste” & “Non Special Waste”	Please use the CIA IoP definition that was applicable for the year that you complete the questionnaire

1.2 Mass Balance Study – Companies Involved

Table A: Mass Balance Study Company List : Extracts from SIC: 24.1 and Relevant Sub-Sections

Mass Balance Site Ref.	Company Name	Site Locations	Post Code
1.	Air Product Group	multiple	N/A
2.	Air Products (Chemicals)	Clayton	M11 4SR
3.	Associated Octel	Ellesmere Port	CH65 4HF
4.	Atofina	Stalybridge	SK15 1PY
5.	Basell Polyolefins	Carrington	M31 4AJ
6.	Basell Polyolefins	Wilton	TS90 8JA
7.	BASF	Middlesborough	TS2 1TX
8.	BOC Gases	multiple	N/A
9.	Borden Chemicals	Peterlee	SR8 2HR
10.	BP Chemicals Ltd	Grangemouth	FK3 9XH
11.	BP Chemicals Ltd	Hull	HU12 8DS
12.	British Salt Ltd	Middlewich	CW10 0JP
13.	Coalite Smokeless Fuels,	Chesterfield	S44 6AB
14.	Dow Chemical Company Ltd	Middlesborough	TS2 1UD
15.	Dow Chemical Company Ltd	Sully	CF64 5YB
16.	Dow Chemical Company Ltd	Wilton	TS90 8JA
17.	Dow Corning*	Barry	CF63 2YL
18.	DuPont Sabanci Polyester	Wilton	TS90 8JW
19.	Eastman Chemical Ectonia Ltd	Workington	CA141LG
20.	Elementis Chromium,	Eaglescliffe	TS16 0QG
21.	Enichem UK.Ltd	Hythe	SO45 3YY
22.	Exxon Mobil Chemicals	Fife	KY4 8EP
23.	Exxon Mobil Chemicals	Hythe	SO45 3NP
24.	Hays Chemicals Ltd	Sandbach	CW11 3PZ
25.	Huntsman Petrochemicals UK Ltd	Wilton	TS90 8JE
26.	Huntsman Polyurethanes UK.Ltd	Wilton	TS90 8JA
27.	Hydro Polymers Ltd	Newton Aycliffe	DL5 6EA
28.	Ineos Acrylics UK Ltd	Billingham	TS23 1PR
29.	Ineos Chlor Ltd	Runcorn	WA7 4JE
30.	Ineos Chlor Ltd	Northwich	CW8 4DJ
31.	Ineos Silicas	Warrington	WA5 1AB
32.	Kemira Agro Ltd	Ince	CH2 4LB
33.	Laporte Performance Chemicals	Knottinghley	WF11 8BN
34.	Millennium Inorganic Chemicals Ltd	Grimsby	DN41 8DP

Mass Balance Site Ref.	Company Name	Site Locations	Post Code
35.	Rhodia Consumer Specialities	Oldbury	B69 4LN
36.	Rhodia Consumer Specialities	Whitehaven	CA28 9BD
37.	Rhodia Eco Services Ltd	Chesterfield	S43 2PB
38.	Rhodia Organique Fine Ltd	Avonmouth	BS11 9YF
39.	Rockwood Specialities	Widnes	WA8 0JU
40.	Sevalco Ltd	Bristol	BS11 0YL
41.	Shell Chemicals UK	Stanlow	L65 4HB
42.	Singleton Birch Ltd	Barnetby, Lincs	DN38 6AE
43.	Solutia UK	Newport	NP19 4XF
44.	Solvay Interox	Warrington	WA4 6HB
45.	Terra Nitrogen (UK) Ltd	Billingham	TS23 1XT
46.	Terra Nitrogen	Severnside	BS10 7SJ
47.	Tioxide Europe Ltd	Grimsby	DN31 2SW
48.	Tioxide Europe Ltd	Hartlepool	TS25 2DD
49.	Uniqema Chemicals	Wilton	TS90 8JA
50.	Vinamul Ltd	Warrington	WA4 6HG

This list of UK base chemical manufacturing companies represents the key companies operating within the Standard Industry Code 24.1 which have been selected for this study.

1.3 Company & Site Details

Please fill in or correct this section.

Company Name:

Mass Balance Site Reference No:

Site Location:

Address:	
Postcode:	

Contacts & Details:

Primary		Secondary	
Title:		Title:	
First Name:		First Name:	
Surname:		Surname:	
Position:		Position:	
Tel:		Tel:	
Fax		Fax	
Email:		Email:	

Mailing Address (if difference to above):

Number of Personnel:

Own Employees:	
Contractors:	

COMPANY & SITE DETAILS – CONTINUED

PLANTS & PROCESSES

ACTION: Describe all processing plants on site including a brief description of processes and record IPC / IPPC authorisation number if applicable.

NOTES: The site manufacturing plant column has been included to support the presentation of information and if not applicable should be ignored. Please present brief descriptions of plant processes and activities.

EXAMPLE **PLANT:** 3 **PLANT PROCESS:** Electrolysis **ACTIVITY:** Electrolysis of brine to produce Chlorine, Hypochlorite & HCl.

Site Manufacturing Plant	Plant Processes	Activity	IPC / IPPC Authorisation Number (if applicable)	Within Scope Y / N

COMPANY & SITE DETAILS – CONTINUED

ACTION: For each activity listed below record the 1999 (or relevant years) output from your site and any additional comments as applicable.

NOTES: The aim of this section is to clarify the boundary of the mass balance study for your site - differentiating between those activities performed on your site which fall within the scope of this study & those which will not be included at this time.

INCLUSIONS: Site Activities that are within the Scope of the Study

SIC Code	Site Manufacturing Activity Classification	1999 Output	Unit of Measure (e.g. T pa)	Comments
24.11	**Industrial Gases** excluding methane / ethane / propane / butane			
24.12	**Dyes & Pigments** excludes manufacture of prepared dyes and pigments eg paints, varnishes and similar coatings			
24.13	**Other Inorganic Basic Chemicals** excludes chemical substances used in the manufacture of pharmaceuticals and aluminium oxide			
24.14	**Other Organic Basic Chemicals** excludes ethyl alcohol / salicyclic acids and derivatives / crude glycerol / essential oils			
24.15	**Fertilisers and Nitrogen Compounds** excludes agro-chemical products eg pesticides			
24.16	**Plastics in Primary Form** Excludes plastics recycling			
24.17	**Synthetic Rubber in Primary Form** Includes mixtures of synthetic and natural rubbers			
	Other – please state:			
	Other – please state:			

COMPANY & SITE DETAILS – CONTINUED

EXCLUSIONS: Site activities that are outside of the Scope of the Study

SIC Code	Site Manufacturing Activity Classification	1999 Output	Unit of Measure (e.g. T pa)	Comments
14.5	Mining, quarrying and related activities			
11.10 / 23.2	Petrochemical Crude Production & Refining : catalytic cracking, distillation & hydrogenation			
24.2	Pesticides			
24.31 / 32	Paints, Varnishes and Inks			
24.33	Mastics & Sealants			
24.4	Pharmaceuticals – Basic and Preparations			
24.5	Soaps & Detergents			
24.61	Explosives			
24.62	Glues & Gelatine			
24.63	Essential Oils & Perfumes			
24.64	Photographic Chemicals			
24.66	Chemically modified Fats and Oils			
24.7	Man Made Fibres			

IMPORTANT NOTICE

All subsequent data on the following pages (egs raw materials, energy consumption, waste, etc) should relate solely to the activities classified as inclusions on the page before and not relate to the exclusions listed above.

2. INPUTS

PLEASE COPY THIS PAGE IF YOU REQUIRE MORE SPACE

2.1 Raw Materials : Classification,Sourcing & Consumption

ACTIONS: Please complete one row for each raw material consumed on site with an annual consumption of **greater than 100 MT/pa.**

Ensure list is comprehensive: include ancillary items, such as solvents, maintenance materials, filter aid, filter bags, effluent treatment chemicals, boiler chemicals, softeners, catalysts etc.

NOTES: Source of raw material will be used to calculate energy consumed in receiving material onto site which is included within the system boundary of this Study
(If you consider the source of any raw material as company confidential then please estimate the distance in miles from your source to your site)

For each source of material please record a maximum of 4 sources only: For materials sourced domestically: UK source location -Town & County. For imported materials: UK port of entry.

No.	Material*	Form (Solid/ Liquid/ Gas)	Liquid or Gas Concentration (gm/Litre, %)	Solvent Used (if any)	Bulk Density (e.g. Kg/ Litre)	Quantity Consumed on Site	Unit (e.g. Kg, T)	Packaging Unit (e.g. Pipe, "Bulk", 205 Litre drum)	Number of Units	Mass Equivalent (T)	Maximum Storage Capacity	Unit (e.g. Kg, T)	No. of Sources	Source Of Material			
														UK		Imported	
														%	Location	%	UK Port
1	*Hydrochloric Acid*	*L*	*27% w/v*	*Water*	*1.05*	*5,678*	*MT*	*Bulk*	*N/a*		*1000*	*MT*	*3*	*40*	*Chesterfield, Derbyshire*	*30*	*70 Miles*
														30	*Runcorn, Cheshire*		
	Total																

*** Key:** Material" means chemical (eg hydrochloric Acid), species (eg aromatic hydrocarbons, aliphatic ketones, etc) or generic name (eg silicone,surfactant,catalyst, filter-aid, etc) – please give as much detail as applicable to enable the material be readily identified)

If possible we would appreciate a comprehensive list of raw materials. Tick here if a is provided ☐

2.2 Packaging

ACTION: Are you obligated under the Producer Responsibility Obligations (Packaging Waste) Regulations?

Please tick appropriate box: Yes □ No □

If you are not obligated under the regulations please not do not fill this section in and proceed to Section 2.3: Water Inputs

NOTES: Please include and record additional items if not listed below.

Type	Description (e.g. 205 Litre)	Number of units consumed on Site	Weight per Unit (e.g. T / Kg)	Mass Equivalent (T)
Drums				
Cylinders				
IBC'S				
Shrink Wrap				
Pallets				
Cardboard Boxes				
Wooden Crates				
Plastic Bags				
Paper Sacs				
Total				

2.3 Water Inputs

ACTION: Please indicate below the sources of water for your site and volume consumed.

NOTES: This data (with the exception of rainwater) should be readily available from the CIA IoP data.

Please include and record additional items if not listed below.

Supply	✔	Volume Used on Site (M^3 pa)	Additional Information / Comments
Public Potable		113073	
Public Non-Potable			
Raw Water			
River			
Bore Hole			
Canal			
Rainwater [3]			
Private Reservoir			
Sea			
Other – Specify			
TOTAL			

[3] Please estimate the volume collected on site that ends up in your effluent discharge only. Any rainwater that is discharged via surface water drains, other natural drainage systems should not be included.

2.4 Energy Inputs

A. Consumption of Metered Energy

ACTION: Record all energy consumed on site to undertake manufacturing processes included within the scope and all other non-manufacturing activities (eg research & development, office administration) occurring on site.

NOTES: Please include and record additional items if not listed below.

Energy Source	Qty	Units (e.g. T, kWh)	Conversion to kWh	Mass Equivalent (T)	Comments / Additional Information
Electricity					
Gas					
Steam Imported On Site					
Liquid Nitrogen Used as Cooling Agent					
Coal					
Propane					
Light Fuel Oil (eg diesel)					
Heavy Fuel Oil					
Other - Specify					
Other - Specify					
Other - Specify					
Total					

ENERGY INPUTS (CONTINUED)

B. Additional on site energy generation through conversion processes.

ACTION: Record all energy generated on-site through conversion using as the energy source either raw material (e.g. methane) or waste.

EXAMPLE: Fuel Type 1 - Methane Gas. Fuel Type 2: Waste Filter Aid. Fuel Type 3 – Oil.

NOTES: Please include and record additional items if not listed below.

Type	Indicate On-Site or 3rd Party	Qty	Units (e.g. M pa, kWh)	Conversion to kWh	Mass Equivalence (T)	Fuel Sources Used									Comments
						Fuel Type 1	% of Total	Calorific Value of Fuel / Waste[1]	Fuel Type 2	% of Total	Calorific Value of Fuel / Waste[1]	Fuel Type 3	% of Total	Calorific Value of Fuel / Waste[1]	
Boiler Steam															
Combined Heat & Power (CHP) – electricity															
Combined Heat & Power (CHP) - Steam							+								
Other - Specify															
Total															

Key: Please state units for calorific values of fuel or waste (eg kW/kg or BTU/lb)

On Site Incineration

Do you have an incinerator on site ? ❑ - (please tick in the affirmative).

Is it fitted with heat recovery ? ❑ - (If Yes, please include this as "Other" in the table above).

3. OUTPUTS

3.1 Effluent

A. Effluent Discharge Quantity

ACTION: Please describe effluent disposal routes used on site and quantities discharged.

NOTES: Additional contributing sources key:
A. rain & storm
B. fire
C. spillage & incident
D. ground water
E. other (please specify)

Discharge Route Off-Site	Volume Discharged From Site (M^3 pa) (Column B)	Additional Contribution Sources		Comments / Additional Information
		Source (use Key A – E above)	Volume Estimate[1] (M^3 pa)	
Direct to sewerage works				
Public sewer via drains				
Freshwater Body / River				
Sea / Estuary				
Other – specify				
Other - specify				
Total				

Key: [1] Please state volume as a component of the volume discharged from site (Column B).

3.1 Effluent

B. Effluent Discharge Quality

Please copy this page if you have more than one discharge point

ACTION: Please describe final effluent discharge quality from site.

NOTES: Record either COD ***or*** BOD as applicable

	Volume Weighted Average (mg/Litre)	**Volume Discharged (m^3 pa)**	**Annual Quantity (mg/Litre) x (m^3 pa)**
Chemical Oxygen demand (COD)			
Biological Oxygen Demand (BOD)			
Total Suspended Solids (TSS)			
Total	**-**	**-**	

Additional Comments (if applicable):

....
....
....
....
....
....

.

3.2 Product (*Please copy this page if you require more space)*

ACTION: Please record data for each product group of manufactured on site by processes that have been identified as being within the scope of the study.

NOTES: Definition of product: All products or bi-products taken off site and not classified as waste, i.e. materials which are sold / transported to another site / exchanged for goods or services.

C & E Code	Chemical Group	Physical Form (Solid / Liquid / Gas)	Liquid or Gas Concentration (gm/Litre) For products with water based solvents only.	Solvent	Packaging Type (Use key from Column 1 of Packaging Section)	Quantity Sent Off Site as Finished Product	Unit of Measure (Column H)	Mass Equivalent (T)	Maximum Storage Capacity (in unit of measure of Column H)
	Surfactants	L	N/A	None	205 Lt Drum	500	MT		50
	Total								

3.3 Air Emissions

ACTION: Please present a copy of each Environment Agency inventory of sources and releases reporting form (PIR2) that your company submitted for the year 1999 for each process authorisation that is covered under the Inclusions as listed on page 6.

Please indicate below whether carbon dioxide emmisions from combustion plant are included in your PIR2 returns for each combustion plant.

Authorisation Number	Combustion Emissions included in PIR2 Return ✔	Comments (e.g. boiler house, hot oil heater within unit)

3.4 Energy Outputs

ACTION: Please record all site energy exports in the form of plant cooling.

NOTES: Cooling tower outputs can be recorded in tonnes of water consumed per annum.

Where possible cooling loads should be expressed in kWh otherwise state cooling media throughput and temperature difference across cooler.

Please ignore minor cooling loads (less than 5% of total heat input to site).

Type	Qty	Units (e.g. kwh)	Conversion to kWh	Mass Equivalent (T)	Comments / Additional Information
Cooling Tower					
Refrigeration / Chiller Units					
Direct Air					
"Once Through " Water					
Electricity					
Steam					
Other - Specify					
Other - Specify					
Total					

3.5 Waste

ACTION: Please record all mass leaving the site with the exception of finished products / air emissions / effluent.

NOTES: This data should be available from your 1999 IoP return.The definitions of "Special" and "Non-Special" waste to be applied are those as described in the IoP return.

Location	Type	Destination	Qty	Units (e.g. T)	Comments / Additional Information
On Site	"Special Waste"	Recycled with Energy Recovery			
		Incinerated for Non-Calorific Reasons			
		Landfill			
	SUB TOTAL				
On Site	"Non Special Waste"	Recycled with Energy Recovery			
		Incinerated for Non-Calorific Reasons			
		Landfill			
	SUB TOTAL				
Off Site	"Special Waste"	Recycled with Energy Recovery			
		Reprocessed			
		Incinerated for Non-Calorific Reasons			
		Landfill			
		Other			
	SUB TOTAL				
Off Site	"Non Special Waste"	Recycled with Energy Recovery			
		Reprocessed			
		Incinerated for Non-Calorific Reasons			
		Landfill			
		Other			
	SUB TOTAL				
TOTAL					

4. ADDITIONAL INFORMATION

(PLEASE COPY THIS FORM IF MORE SPACE IS REQUIRED)

4.1 Product Recycled within the System Boundary

ACTION: Record all inter-site transfer data for all products listed in Section 3.2 Products.

DEFINITION: Products taken off your site and transferred to another site listed in Table A: The Mass Balance Study Company List.

C & E Code	Chemical Product	Delivery Location (company number from Table A)	Quantity Per Year	Unit (e.g. T)	Comments/ Additional Information	Transport Energy	Mass Equivalent (MT)
TOTAL							

4.2 Summary

This page is illustrative of the data that will be returned to you which will include the summary of the data collated for the exercise enabling you to in some degree "bench-mark" your site against the industry standard.

Inputs

Input Source	Mass Equivalence (T)	Comments
Raw Materials		
Packaging		
Water		
Energy Inputs		
TOTAL		

Outputs

Output Source	Mass Equivalence (T)	Comments
Effluent		
Products		
Product Recycled (-)		
Air Emissions		
Energy Outputs		
Waste		
TOTAL		

Thank you for completing this questionnaire. Please return it plus associated documentation in the pre-paid envelope to:

David Lyon
Enviros March
Telegraphic House
Waterfront Quay,Salford Quays
Manchester
M5 2XW

Tel : 0161 874 3600

APPENDIX 3

SIC 24.1 CHEMICAL PROCESSES

SIC 24.1 CHEMICAL PROCESSES

The following table presents examples of the types of chemical processes undertaken by companies within SIC 24.1

Chemical / Physical Process	Description / Study Examples
Air separation and purification	Separation of air into constituent gases including purification and liquefaction of the extracted gases
Alkoxylation	Reaction of ethylene oxide with a) methanol, b) butanol and c) ammonia to produce methyl & butyl glycol ethers and ethanolamines
Batch organic chemical synthesis	Batch reaction of organic amines for the manufacture of additives/curing agents for epoxide resins
Carbonisation	Manufacture of smokeless fuels and derivatives from coal
Carbonylation, oxidations, synthesis, esterifications, condensation	Carbonylation of methanol to produce acetic acid and acetic anhydride. Oxidation of naphtha to produce formic, acetic and propionic acids and acetone. Synthesis of nitrogen and hydrogen to produce ammonia. Esterification of acetic acid to produce ethyl, propyl and butyl acetate. Oxidation of ortho-xylene to produce phthalic anhydride. Esterification of phthalic anhydride with higher alcohols to produce phthalate esters. Condensation of acetone to produce isophone. Production of polypropylene and ethyl bezene
Chlorination ,oxidation	Chlorination of titanium ore to produce titanium tetrachloride. Oxidation of titanium tetrachloride to produce titanium dioxide
Electrolysis	Electrolysis of brine to produce chlorine, hydrogen, sodium hydroxide, sodium hypochlorite
Manufacture of Ethylene oxide and ethylene glycol	Oxidation of ethylene to produce ethylene oxide and ethylene glycols (mono-ethylene glycol: MEG, di-ethylene glycol: DEG, etc).
Haber Process	Production of ammonia from natural gas/steam/air
Hydrocarbon oxidation	Oxidation of paraxylene to produce terephthalic acid (PTA)
Extraction of hydrogen	Electrolysis of water into hydrogen and oxygen
Manufacture of nitric acid	Oxidation of ammonia and absorption in water
Manufacture of chromate salts	Manufacture of sodium dichromate and sodium sulphate from chromite ore. Manufacture of chromic acid from sodium dichromate. Manufacture of potassium dichromate from sodium dichromate. Manufacture of ammonium dichromate from sodium dichromate. Manufacture of chromic oxide from sodium dichromate. Manufacture of chromic sulphate from sodium dichromate
Manufacture of hydrochloric acid	Combustion of hydrogen and chlorine to produce hydrochloric acid
Manufacture of precipitated silicas	Reaction of diluted sodium silicate with dilute sulphuric acid. The products are filtered, dried and milled.
Manufacture of silica gells	Reaction of sulphuric acid with silicate solution to form a hydrosol which solidifies and is washed , slurried or dried.
Nitration and hydrogenations	Nitration of benzene (using nitric acid) to produce nitrobenzene and water. Hydrogenation of nitrobenzene using hydrogen to produce aniline and water. Hydrogenation of Aniline using hydrogen to produce crude cyclohexylamine.
Production of fertilizers	Steam-reforming of natural gas to produce ammonia and CO2. Conversion of ammonia into nitric acid and sodium salts. Conversion of ammonia and nitric acid into fertilizers
Polymerisation	Polymerisation of ethylene for production of polyethylene nibs. Polymerisation of terephthalic acid (PTA) and monoethylene glycol to produce polyethylene terephthalate (PET).
Production of speciality catalysts	Preparation of a dry silicaceous substrate in a solvent upon which are absorbed a variety of metal alkyls, alkoxides or metal salts.
Production of higher olefins, alcohols, solvents, sulphane, additives and resin	Hydroformulation process using olefins and synthesis gas. Production of straight chain olefins from ethylene. Production of C3 alcohol and ketone using polypropylene and sulphuric acid. Production of solvent for primary use as a solvent for extraction of aromatics. Production of specialist additives for lube oils. Production of epoxy resin. Production of polypropylene and ethyl benzene