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Guidance for the Speciality Organic Chemicals Sector



Commissioning Organisation

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Table 0.1: Record of changes

Version	Date	Change	Template Version
Issue 1	24 Jul 2002	Initial draft	v2
Issue 2	29 Jul 2002	Section 2.2.2 added, Section 3.3 removed	v2
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Executive summary

Status of this Guidance	This guidance has been produced by the Environment Agency for England and Wales with the Scottish Environment Protection Agency (SEPA) and the Northern Ireland Environment and Heritage Service (EHS) - each referred to as “the Regulator” throughout this document. Its publication follows consultation with industry, government departments and non-governmental organisations.
What is IPPC	Integrated Pollution Prevention and Control (IPPC) is a regulatory system that employs an integrated approach to control all environmental impacts of certain listed industrial activities. In the UK, the IPPC Directive is implemented through the English and Welsh, the Scottish, and the Northern Irish versions of the Pollution Prevention and Control (PPC) Regulations. It involves determination by the Regulator of the appropriate controls for those industries to protect all environmental media, through a single permitting process. To gain a PPC Permit, Operators have to demonstrate in their Applications, in a systematic way, that the techniques they are using or are proposing to use, do represent the use of Best Available Techniques (BAT) and meet certain other requirements, taking account of relevant local factors.
This Guidance and the BREFs	Much UK Technical Guidance on what is BAT is based on the “BAT Reference documents” (“BREFs”) produced by the European Commission. BREFs are the result of exchanges of information between member states and industry, with most covering individual industrial sectors, and some (“horizontal” BREFs) covering cross-sectoral subjects. UK Technical Guidance Notes are designed to complement BREFs, and take into account information contained in relevant BREFs in setting out indicative BAT standards and expectations for England and Wales, Scotland and Northern Ireland.
The aims of this Guidance	<p>The aim of this Guidance is to provide Operators and officers of the Regulator with advice on indicative standards of operation and environmental performance, relevant to the industrial sector concerned. It also aims (through linkage with the Permit Application Form template) to provide a clear structure and methodology for Operators to follow to ensure they address adequately all aspects of the PPC Regulations and relevant aspects of other environmental Regulations. Also, by expressing BAT techniques as clear indicative standards wherever possible, it aims to minimise the effort involved in the permitting of an installation (by both Operator and Regulator).</p> <p>To further assist Operators in making Applications, separate, horizontal guidance is available on a range of topics such as noise, odour, waste minimisation, monitoring, calculating stack heights and so on. Most of this guidance is available free through the Environment Agency, SEPA or EHS (Northern Ireland) websites (see References).</p>
key environmental issues	<p>The key environmental issues for this sector are:</p> <ul style="list-style-type: none">• Optimisation of the reaction stage - to improve reaction specificity and efficiency, raw material usage, and reduce the ultimate generation of both waste waters and waste organic liquids or solids.• Point source emissions of organics to water - from the mixtures of aqueous and organic phases in post-reaction extraction, separation or purification stages. These are often relatively large in volume or may contain intractable pollutants such as complex organics, chlorinated hydrocarbons or heavy metals.• Waste minimisation - by optimisation of reaction arrangements, and better Waste disposal routes - to minimise disposals to landfill.• Point source emissions to air - in particular, reductions in the release of VOCs through better reaction arrangements and techniques for removal and recovery of VOCs from vent streams.• Fugitive emissions of VOCs to air - although small in relation to Large Volume organics plants, there can be considerable potential for leakage of VOCs from joint and vessel openings, and from solvents in aqueous waste streams, etc.• Odour - from the handling of inherently malodorous substances and also from fugitive releases of organic solvents.• Energy efficiency - as speciality chemical installations tend to have significant energy use per tonne of output.

- **Chemical analysis and monitoring of emissions** - to improve consistency of emissions monitoring and comparability of reporting.
- **Accident prevention and control** - to reduce the occurrence of spillages and other similar environmental accidents.

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1 Introduction

The status and aims of this Guidance

This Guidance has been produced by the Environment Agency for England and Wales, with the Scottish Environment Protection Agency (SEPA) and the Environment and Heritage Service (EHS) in Northern Ireland - each referred to as “the Regulator” in this document. Its publication follows consultation with industry, Government departments and non-governmental organisations.

It aims to provide Operators and the Regulator’s officers with advice on indicative standards of operation and environmental performance relevant to the industrial sector concerned, to assist the former in the preparation of applications for PPC Permits and to assist the latter in the assessment of those Applications (and the setting of a subsequent compliance regime). The use of techniques quoted in the guidance and the setting of emission limit values at the benchmark values quoted in the guidance are not mandatory, except where there are statutory requirements from other legislation. However, the Regulator will carefully consider the relevance and relative importance of the information in the Guidance to the installation concerned when making technical judgments about the installation and when setting Conditions in the Permit, any departures from indicative standards being justified on a site-specific basis.

The Guidance also aims (through linkage with the Application Form or template) to provide a clear structure and methodology for Operators to follow to ensure they address all aspects of the PPC Regulations and other relevant Regulations, that are in force at the time of writing. Also, by expressing the Best Available Techniques (BAT) as clear indicative standards wherever possible, it aims to minimise the effort required to permit an installation (by both Operator and Regulator).

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1.1 Understanding IPPC

IPPC and the Regulations

Integrated Pollution Prevention and Control (IPPC) is a regulatory system that employs an integrated approach to control the environmental impacts of certain listed industrial activities. It involves determination by the Regulator of the appropriate controls for those industries to protect the environment, through a single permitting process. To gain a Permit, Operators have to demonstrate in their Applications, in a systematic way, that the techniques they are using or are proposing to use, are the Best Available Techniques (BAT) for their installation, and meet certain other requirements, taking account of relevant local factors.

The essence of BAT is that the techniques selected to protect the environment should achieve an appropriate balance between environmental benefits and the costs incurred by Operators. However, whatever the costs involved, no installation may be permitted where its operation would cause significant pollution.

IPPC operates under [The Pollution Prevention and Control Regulations](#) (for equivalent legislation in Scotland and N Ireland see [Appendix 2](#)). The three regional versions of the PPC Regulations implement in the UK the EC Directive on IPPC (96/61/EC). Further information on the application of IPPC/PPC, together with Government policy and advice on the interpretation of the English & Welsh Regulations, can be found in [IPPC: A Practical Guide](#) published by the Department for Environment, Food and Rural Affairs (Defra). Equivalent guidance on the Scottish Regulations is provided in [PPC Regulations: A Practical Guide \(Part A Activities\)](#), published by the Scottish Executive and SEPA. The Department of the Environment, Northern Ireland has published equivalent guidance on the N Ireland Regulations.

Installation based, NOT national emission limits

The BAT approach of IPPC differs from regulatory approaches based on fixed national emission limits (except where General Binding Rules or Standard Permits are issued). The legal instrument that ultimately defines BAT is the Permit, and Permits can only be issued at the installation level.

Indicative BAT Standards

Indicative BAT standards are laid out in national guidance (such as this) and, where relevant, should be applied unless a different standard can be justified for a particular installation. BAT includes the technical components, process control, and management of the installation given in Section 2, and the benchmark levels for emissions identified in Section 3. Departures from those benchmark levels can be justified at the installation level by taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions. If any mandatory EU emission limits or conditions are applicable, they must be met, but BAT may go further (see “BAT and EQS” below).

Some industrial sectors for which national guidance is issued are narrow and tightly defined, whilst other sectors are wide and diffuse. This means that where the guidance covers a wide variety of processes, and individual techniques are not described in detail, the techniques (and their associated emission levels) which might constitute BAT for a particular operation, are more likely to differ, with justification, from the indicative BAT standards than would be the case for a narrow, tightly-defined sector.

BAT and EQS

The BAT approach complements, but differs fundamentally from, regulatory approaches based on Environmental Quality Standards (EQS). Essentially, BAT requires measures to be taken to prevent emissions - and measures that simply reduce emissions are acceptable only where prevention is not practicable. Thus, if it is economically and technically viable to reduce emissions further, or prevent them altogether, then this should be done irrespective of whether or not EQSs are already being met. The BAT approach requires us not to consider the environment as a recipient of pollutants and waste, which can be filled up to a given level, but to do all that is practicable to minimise emissions from industrial activities and their impact. The BAT approach first considers what emission prevention can reasonably be achieved (covered by Sections 2 and 3 of this Guidance) and then checks to ensure that

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the local environmental conditions are secure (see [Section 4](#) of this Guidance and also Guidance Note [Environmental Assessment and Appraisal of BAT](#)). The BAT approach is therefore the more precautionary one because the release level achieved may be better than that simply required to meet an EQS.

Conversely, if the application of indicative BAT might lead to a situation in which an EQS is still threatened, a more effective technique is required to be BAT for that installation. The Regulations allow for expenditure beyond indicative BAT where necessary, and, ultimately, an installation will only be permitted to operate if it does not cause significant pollution.

Further advice on the relationship between BAT, EQSs and other related standards and obligations is given in [IPPC: A Practical Guide](#), its Scottish equivalent, and also in Section 3.

Assessing BAT at the sector level

The assessment of indicative BAT takes place at a number of levels. At the European level, the European Commission issues a “BAT reference document” (BREF) for each main IPPC sector. It also issues “horizontal” BREFs for a number of general techniques which are relevant across a series of industrial sectors. The BREFs are the result of an exchange of information between regulators, industry and other interested parties in Member States. Member States should take them into account when determining BAT, but they are allowed flexibility in their application. UK Sector Guidance Notes like this one take account of information contained in relevant BREFs and set out current indicative standards and expectations in the UK. At national level, techniques that are considered to be BAT should represent an appropriate balance of costs and benefits for a typical, well-performing installation in the sector concerned. They should also be affordable without making the sector as a whole uncompetitive, either within Europe or world-wide.

The BREF production programme is in progress, but is not yet complete. The BREF for the Speciality Organics sector is expected to be published in 2005 but the “horizontal” BREF for the Treatment of Waste Water and Waste Gas has been published. The indicative standards laid down in this Note are therefore based on Best Available Techniques Not Entailing Excessive Cost (“BATNEEC”) standards from the IPC Technical Guidance Note for the Speciality Organic Chemicals sector, together with information from other BREFs [Ref 1](#), where relevant. When the BREF for this sector is published, this Guidance Note will be revised.

Assessing BAT at the installation level

When assessing applicability of sectoral indicative BAT standards at the installation level, departures may be justified in either direction. Selection of the technique which is most appropriate may depend on local factors and, where the answer is not self-evident, an installation-specific assessment of the costs and benefits of the available options will be needed. The Regulator’s guidance [Environmental Assessment and Appraisal of BAT](#) and its associated software tool may help with the assessment. Individual installation or company profitability (as opposed to profitability of the relevant sector as a whole) is not a factor to be considered, however.

In the assessment of BAT at the installation level, the cost of improvements and the timing or phasing of that expenditure, are always factors to be taken into account. However, they should only be major or decisive factors in decisions about adopting indicative BAT where:

- the installation’s technical characteristics or local environmental conditions can be shown to be so different from those assumed in the sectoral assessment of BAT described in this guidance, that the indicative BAT standards may not be appropriate:
- or the BAT cost/benefit balance of an improvement only becomes favourable when the relevant item of plant is due for renewal/renovation (eg. change to a different design of furnace when the existing furnace is due for a rebuild). In effect, these are cases where BAT for the sector can be expressed in terms of local investment cycles.
- or a number of expensive improvements are needed. In these cases, a phasing programme may be appropriate - as long as it is not so drawn out that it appears to be rewarding a poorly performing installation.

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In summary, departures by an individual installation from indicative BAT for its sector may be justified on the grounds of the technical characteristics of the installation concerned, its geographical location and the local environmental conditions - but not on the basis of individual company profitability, or if significant pollution would result. Further information on this can be found in [IPPC: A Practical Guide](#) and [IPPC Part A\(1\) Installations: Guide for Applicants](#), or the equivalent Scottish Guidance.

Innovation

The Regulators encourage the development and introduction of innovative techniques that advance indicative BAT standards criteria, ie. techniques which have been developed on a scale which reasonably allows implementation in the relevant sector, which are technically and economically viable and which further reduce emissions and their impact on the environment as a whole. One of the main aims of the PPC legislation is continuous improvement in the overall environmental performance of installations as a part of progressive sustainable development. This Sector Guidance Note describes the indicative BAT standards at the time of writing but Operators should keep up-to-date with improvements in technology - and this Guidance note cannot be cited as a reason for not introducing better available techniques. The technical characteristics of a particular installation may also provide opportunities not foreseen in the Guidance, and as BAT is determined at the installation level (except in the case of General Binding Rules (GBRs)), it is a requirement to consider these even where they go beyond the indicative Standards.

New installations

Indicative BAT standards apply, where relevant, to both new and existing installations, but it will be more difficult to justify departures in the case of new installations (or new activities in existing installations) - and for new activities, techniques which meet or exceed indicative BAT requirements should normally be in place before operations start.

Existing installations - standards

For an existing installation, it may not be reasonable to expect compliance with indicative BAT standards immediately if the cost of doing so is disproportionate to the environmental benefit to be achieved. In such circumstances, operating techniques that are not at the relevant indicative BAT standard may be acceptable, provided that they represent what is considered BAT for that installation and otherwise comply with the requirements of the Regulations. The determination of BAT for the installation will involve assessment of the technical characteristics of the installation and local environmental considerations, but where there is a significant difference between relevant indicative BAT and BAT for an installation, the Permit may require further improvements on a reasonably short timescale.

Existing installations - upgrading timescales

Where there are departures from relevant indicative BAT standards, Operators of existing installations will be expected to have upgrading plans and timetables. Formal timescales for upgrading will be set as Improvement Conditions in the Permits. See [Section 1.4.2](#) for more details.

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1.2 Making an application

A satisfactory Application is made by:

- addressing the issues in Sections 2 and 3 of this guidance;
- assessing the environmental impact described in Section 4 (and in England and Wales [Environmental Assessment and Appraisal of BAT \(IPPC H1\)](#));
- demonstrating that the proposed techniques are BAT for the installation.

In practice, some Applicants have submitted far more information than was needed, yet without addressing the areas that are most important - and this has led to extensive requests for further information. In an attempt to focus application responses to the areas of concern to the Regulator, Application forms (templates) have been produced by the Environment Agency, by SEPA and by EHS in N Ireland. In addition, as the dates for application have approached, the operators in most industrial sectors in England and Wales have been provided with Compact Discs (CDs) which contain all relevant Application Forms, technical and administrative guidance, BREFs and Assessment tools, hyper-linked together for ease of use.

There is such a CD for Operators in the Speciality Organic Chemicals sector in England and Wales. The tools and advice on the CD help to steer the operator through the Application process, define much more closely the level of detail required in the Application and aim to make the process of calculating impact assessment much simpler.

For Applicants with existing IPC Authorisations or Waste Management Licences, the previous applications may provide much of the information for the PPC application. However, where the submitted Application refers to information supplied with a previous application the Operator will need to send fresh copies - though for many issues where there is a tendency for frequent changes of detail (for example, information about the management systems), it will be more appropriate simply to refer to the information in the Application and keep available for inspection on site, up-to-date versions of the documents.

For further advice see [IPPC Part A\(1\) Installations: Guide for Applicants \(for England and Wales\)](#) or [PPC Part A Installations: Guide for Applicants \(for Scotland\)](#) or the equivalent Northern Ireland guide for Applicants.

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1.3 Installations covered

This Note mainly covers installations for the manufacture of organic chemicals on a small or medium scale, principally by batch operations. It covers the manufacture of fine organic chemicals, the chemical production of explosives, pharmaceuticals and plant health products, the formulation of pharmaceuticals and plant health products. It is also intended to cover some activities that may be undertaken outside of chemical installations - ie. those involving the polymerisation of unsaturated hydrocarbons or vinyl chloride, or the use of isocyanate-containing materials. However, because the sector is very diverse not all relevant activities operating in the UK can be described. Furthermore, the Note is not intended to coincide precisely with all the "organic chemical" sections of the Regulations - particularly as large volume organic chemical production is covered in its own IPPC Guidance Note and associated BREF document (see [References](#)).

This Guidance relates to installations containing the activities listed below, as described in Part A(1) of Schedule 1 to the [The Pollution Prevention and Control Regulations](#). The schedules of listed activities are slightly different in Scotland and Northern Ireland so for their equivalent Regulations see [Appendix 2](#)

Section 4.1 - Organic Chemicals

(a) Producing organic chemicals such as:

- (i) hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic)
- (ii) organic compounds containing oxygen, such as alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, peroxides, phenols, epoxy resins
- (iii) organic compounds containing sulphur, such as sulphides, mercaptans, sulphononic acids, sulphonates, sulphates and sulphones and sulphur heterocyclics
- (iv) organic compounds containing nitrogen, such as amines, amides, nitrous-, nitro- or azo-compounds, nitrates, nitriles, nitrogen heterocyclics, cyanates, isocyanates, di-isocyanates and di-isocyanate prepolymers
- (v) organic compounds containing phosphorus, such as substituted phosphines and phosphate esters
- (vi) organic compounds containing halogens, such as halocarbons, halogenated aromatic compounds and acid halides
- (vii) organometallic compounds, such as lead alkyls, Grignard reagents and lithium alkyls
- (viii) plastic materials, such as polymers, synthetic fibres and cellulose-based fibres
- (ix) synthetic rubbers
- (x) dyes and pigments
- (xi) surface-active agents

(b) Producing any other organic compounds not described in paragraph (a).

(c) Polymerising or co-polymerising any unsaturated hydrocarbon or vinyl chloride (other than a pre-formulated resin or pre-formulated gel coat which contains any unsaturated hydrocarbon) which is likely to involve, in any period of 12 months, the polymerisation or co-polymerisation of 50 tonnes or more of any of those materials or, in aggregate, of any combination of those materials.

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(d) Any activity involving the use in any period of 12 months of one tonne or more of toluene di-isocyanate or other di-isocyanate of comparable volatility or, where partly polymerised, the use of partly polymerised di-isocyanates or prepolymers containing one tonne or more of those monomers, if the activity may result in a release into the air which contains such a di-isocyanate monomer.

(e) The flame bonding of polyurethane foams or polyurethane elastomers.

(f) Recovering:

(i) carbon disulphide

(ii) pyridine or any substituted pyridine

(g) Recovering or purifying acrylic acid, substituted acrylic acid or any ester of acrylic acid or of substituted acrylic acid.

Section 4.4 - Plant Health Products and Biocides

Producing plant health products or biocides.

Section 4.5 - Pharmaceutical Production

(a) Producing pharmaceutical products using a chemical or biological process.

(b) Formulating such products if this may result in the release into water of any substance listed in paragraph 13 of Part 2 of this Schedule in a quantity which, in any period of 12 months, is greater than the background quantity by more than the amount specified in that paragraph for that substance.

Section 4.6 - Explosives Production

(a) Producing explosives.

The installation will also include **associated activities** which have a technical connection with the main activities and which may have an effect on emissions and pollution, as well as the main activities described above. These may involve activities such as:

- the storage and handling of raw materials;
- the storage and despatch of finished products, waste and other materials;
- the control and abatement systems for emissions to all media;
- waste treatment or recycling.

Environment Agency advice on the composition of English or Welsh installations and which on-site activities are to be included within it (or them) is given in its guidance document [PPC Part A\(1\) Installations: Guide for Applicants \(England and Wales\)](#). Operators are advised to discuss the composition of their installations with the Regulator before preparing their Applications.

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1.4 Timescales

1.4.1 Permit review periods

Permits are likely to be reviewed as follows:

- for individual activities not previously subject to regulation under IPC or Waste Management Licensing, a review should be carried out within four years of the issue of the PPC Permit
- for individual activities previously subject to regulation under IPC or Waste Management Licensing, a review should be carried out within six years of the issue of the IPPC Permit

However, where discharges of Groundwater List I or List II substances have been permitted, or where there is disposal of any matter that might lead to an indirect discharge of any Groundwater List I or II substance, a review must be carried out within four years as a requirement of the Groundwater Regulations.

These periods will be kept under review and, if any of the above factors change significantly, they may be shortened or extended.

1.4.2 Upgrading timescales for existing plant

Existing installation timescales

Unless subject to specific conditions elsewhere in the Permit, upgrading timescales will be set in the Improvement Programme of the Permit, having regard to the criteria for improvements in the following two categories:

- 1 *Standard “good-practice” requirements, such as, management systems, waste, water and energy audits, bunding, housekeeping measures to prevent fugitive or accidental emissions, good waste-handling facilities, and adequate monitoring equipment.* Many of these require relatively modest capital expenditure and so, with studies aimed at improving environmental performance, they should be implemented as soon as possible and generally well within 3 years of issue of the Permit.
- 2 *Larger, more capital-intensive improvements, such as major changes to reaction systems or the installation of significant abatement equipment.* Ideally these improvements should also be completed within 3 years of Permit issue, particularly where there is considerable divergence from relevant indicative BAT standards, but where justified in objective terms, longer time-scales may be allowed by the Regulator.

Local environmental impacts may require action to be taken more quickly than the indicative timescales above, and requirements still outstanding from any upgrading programme in a previous permit should be completed to the original time-scale or sooner. On the other hand, where an activity already operates to a standard that is close to an indicative requirement a more extended time-scale may be acceptable. Unless there are statutory deadlines for compliance with national or international requirements, the requirement by the Regulator for capital expenditure on improvements and the rate at which those improvements have to be made, should be proportionate to the divergence of the installation from indicative standards and to the environmental benefits that will be gained.

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The Operator should include in the Application a proposed programme in which all identified improvements (and rectification of clear deficiencies) are undertaken at the earliest practicable opportunities. The Regulator will assess BAT for the installation and the improvements that need to be made, compare them with the Operator's proposals, and then set appropriate Improvement Conditions in the Permit

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1.5 Key issues

Key environmental issues The key environmental issues for the speciality organic chemical manufacturing sector are:

1.5.1 Optimisation of the reaction stage

At the present time, the speciality chemicals manufacturing sector overwhelmingly uses stirred tank reactors (STRs) in batch mode at the reaction stages because this offers wide flexibility in the types of reactions that can be carried out. However, this flexibility can sometimes be at the expense of reaction specificity and efficiency, and raw material usage - and may necessitate substantial downstream separation and purification stages which generate both waste waters and waste organic solids or liquids. Low inventory "fast" reactors and other "process intensification" techniques have the potential to improve all these aspects, so the use of alternative reaction techniques should be considered where there is significant scope for improving raw material or energy efficiencies, and particularly where multiple batches of near-identical syntheses are planned. In-process controls (ie. waste/pollution minimisation at source) are covered in [Section 2.1](#) of this Guidance Note.

Reaction optimisation tends to be a particular problem on multi-product toll-conversion plants. BAT for the whole range of preparations is less likely to be considered to have been met where just a few (different) STRs are used.

The real key issue is:- where general-purpose reactors are in use (or are proposed for use), and raw material/energy inefficiencies and pollution/waste generation impacts been assessed and found to be significant, alternative reaction arrangements should be considered and investigated to see if there is a better technique that can be described as BAT for the medium to longer term.

1.5.2 Point source emissions of organics to water

Many organic preparative stages involve mixed volumes of aqueous and organic phases, either in the stirred-tank reactor itself (if used) or in subsequent extraction, separation or purification stages. This often leads to considerable amounts of aqueous effluent containing organics. Some of these effluent streams are easily treatable by in-house biological treatment plant or by a Sewage Treatment Works but many contain more intractable pollutants such as complex organics, chlorinated hydrocarbons or heavy metals. These place great demands on Treatment Works and can lead ultimately to unacceptable discharges to controlled waters or unacceptable pollutant loadings in sewage sludge.

The key issue is to avoid, as far as is practicable, the generation of these contaminated aqueous streams and to minimise the volume when generation is impossible. In-process controls are covered in [Section 2.1](#), and treatment techniques in [Section 2.2.2](#) and also in the Waste Water and Waste Gas Treatment BREF ([Ref 1](#)).

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1.5.3 Waste minimisation and waste disposal routes

As with waste water generation, reaction specificity, kinetics, yield, etc are major factors in the generation of waste - and for many syntheses the ratio of waste: product is high - so the key issue again is the avoidance of waste generation in the first place. In-process controls are covered in [Section 2.1](#) and BAT criteria for efficient material use and waste handling, recovery and disposal are laid out in [Section 2.4](#), [Section 2.5](#) and [Section 2.6](#) of this Note.

1.5.4 Point source emissions to air

Emissions to air from point sources on batch chemical plants have improved steadily since the introduction of the IPC regime across the sector in 1992-1995, but considerable improvements can still be made. In particular, whilst emissions of most inorganic gases are generally well controlled now, there is scope for reductions in the release of VOCs - particularly in terms of mass flow. Whilst reaction arrangements can be influential in reducing VOC emissions, techniques for removal and recovery of VOCs from vent streams are also likely to be required (see [Section 2.2.1](#) and corresponding sections in the Waste Water and Waste Gas Treatment BREF ([Ref 1](#))).

1.5.5 Fugitive emissions of VOCs to air

Although small in relation to Large Volume Organics plants, there are a considerable numbers of plant items, flanges, pumps and valves with seals, storage tanks, tanker connections, sample points, etc. All have the potential for leakage of VOCs - and a significant number of joints and vessels are opened on a regular basis between batches or to change the chemistry. In addition, solvents and other VOCs in aqueous waste streams can escape to air from open drains or be released in water treatment facilities. There is scope for reducing emissions of VOCs from all these sources.

1.5.6 Odour

Many of the substances produced or used in the batch organics sector have the odour potential to cause offence to neighbouring communities. This arises not only from the handling of inherently malodorous substances but also from fugitive releases of organic solvents. This is a major concern for some installations, and the issues are covered in more detail in [Section 2.2.6](#) in this Guidance Note, and also in the Horizontal Guidance Note for Odour - IPPC H4 (Parts 1 and 2).

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1.5.7 Energy efficiency

Speciality chemical installations tend to have significant energy use per tonne of output but most will be participants to a Climate Change Agreement or a Direct Participant Agreement (which are deemed to satisfy the BAT requirement for energy efficiency). However, even at these installations there may be some issues which could be considered in the PPC application and permitting process (eg. the use in the medium to longer term of appropriate “process intensification” techniques). For general energy efficiency issues, see [Section 2.7](#) in this Guidance Note, and the Interim Horizontal Guidance Note for Energy Efficiency - IPPC H2 ([Ref 12](#)).

1.5.8 Chemical analysis and monitoring of emissions

Emissions monitoring has, to date, been variable within the sector - particularly where continuous monitoring throughout the batch is concerned. With national reporting and comparisons via databases like the Pollution Inventory (PI) or the European Pollutant Emission Register (EPER), becoming the norm, it is imperative that more consistency is applied to streams from batch processes, to the substances that are monitored, and to the methods of analysis used. Further guidance on emissions monitoring is being developed but interim guidance is provided in [Section 2.10](#) in this Note.

1.5.9 Accident prevention and control

Over the last few years there have been a number of spillages of organic liquids from plants within the sector that have contaminated land, groundwater or surface water. Whilst major accident hazards and associated environmental risks are likely to be covered by the requirements of the COMAH Regulations there is a need for operators to demonstrate that they have lesser risks well controlled. [Section 2.8](#) in this Guidance Note covers indicative BAT requirements for environmental accident prevention.

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1.6 Summary of releases

The Speciality Organics sector is so wide that almost any substance might conceivably be a potential release to any medium - so a releases summary of the type used in some other sectoral Guidance Notes is not really appropriate for this Note.

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1.7 Technical overview

Activities covered by this Note are to be found in Sections 4.1, 4.4, 4.5, and 4.6 of Schedule 1 to the PPC Regulations . They include approximately 750 processes previously authorised under IPC in England and Wales (which was around one-third of all processes regulated under that legislative regime).

The sector is characterised by a wide range of raw materials, reaction chemistries, products and releases but despite this diversity there are areas of commonality. These areas are outlined below. Guidance is then provided in [Section 1.7.2](#) on issues specific to each of the sub-sectors.

1.7.1 Main unit processes used

Most of the processes covered by this Guidance Note may be expected to have a structure based on the following unit operations or processes:

- storage and handling of raw materials, products and wastes
- plant systems and equipment
- reaction
- separation and isolation
- purification and/or final product preparation

The sections below provide a brief description of these unit operations, but although this unit operation approach provides a good means of identifying the key issues, it may not cover all situations or identify all significant issues.

Once the chemistry to be used has been established by preliminary consideration of the economics plus the safety, health and environmental issues involved (by the initial stages of a Hazard and Operability Study), it is often helpful to distinguish clearly between the **process** design (which addresses the essential chemical and physical transformations required) and the **plant** design (which selects appropriate hardware to carry out the transformations identified). Time and short-term cost pressures commonly force a project into the plant design phase without adequate consideration of the process design, the consequence being that the plant may not be ideal for its intended purpose and any operational shortcomings then necessitate additional work throughout its operational life. If proper attention is paid to the process design at the design stage (and this is considered to be BAT for chemical plant design) - using experience and knowledge that is readily available (in universities and consultancies, if not in-house) - most of these difficulties can be avoided.

In this Sector there cannot be uniform application of BAT because each chemical process and each site will have its own specific characteristics, and a technique that is BAT for one chemical process may not be BAT for another which appears superficially to be similar.

1.7.1.1 Storage and handling of raw materials, products and

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wastes

The sector is characterised by the storage and handling of a broad range of raw materials and products, usually in relatively small quantities. The importance of batch operations in the sector means that flexibility in storage and handling arrangements may be particularly important. Issues of relevance include:

- **Storage.** This covers solids, liquids and gases. The storage of solids will tend to involve dedicated buildings. Liquid storage will involve both bulk (IBCs or dedicated tanks) and drum storage - and the use of drums is particularly prevalent for batch operations. Gases may be stored in cylinders or in liquid form, often involving a packaged unit.
- **Handling.** Batch operations often require the handling of small quantities of accurately measured amounts of reagents, and this usually necessitates the use of pre-measuring equipment prior to the reagents being fed to the reactor.

1.7.1.2 Plant systems and equipment

A wide range of ancillary equipment is required throughout the process. This may include the following systems - ventilation, pressure relief, vacuum raising, pumps, compressors, agitators, valves, purging and heating/cooling. Some of these systems give rise to a waste stream, for example wet vacuum systems or dust extraction equipment, and all of them have the potential to give rise to fugitive emissions.

1.7.1.3 Reaction

Reactors are the key component of batch operations; they have to provide flexibility to vary production cycles in terms of products, volumes and manufacturing time-spans. Reactions have conventionally been undertaken, batch-wise, in stirred-tank reactors (STRs) - and usually still are - but for small-scale batch production STRs often involve relatively large inventories of materials in non-stoichiometric proportions and this can lead to the generation of unnecessarily large quantities of waste - both as solids or liquids and in the form of aqueous effluent.

Newer techniques involving small, low-inventory "fast" reactors have the potential to achieve better yields whilst generating considerably lower quantities of organic waste and waste-water contaminated by organics. These usually operate continuously (allowing a steady state to be attained with obvious simplification of control and improved product consistency/quality) or semi-continuously where a batch of reactants is prepared before being processed through the reactor. Individual fast reactors are usually custom-built for each reaction in order to optimise reaction specificity and maximise yields - and though they may appear to offer less flexibility than conventional reactor systems, in many cases the equipment is so small that individual pieces can be constructed cheaply and installed easily whenever a reaction change is required. This is a good illustration of why proper attention to process design before starting plant design pays dividends.

A clear understanding of the reaction scheme to be followed is required, including knowledge of side reactions and by-products. The yields for the reactions provide essential information about the quantities and nature of anticipated wastes. The application of physical chemistry principles at the process design stage is important to achieving the correct processing conditions, eg.:

- Are the reactions irreversible or subject to equilibrium constraints?

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- What are the rates of the reactions involved (detailed kinetics are usually unavailable but even qualitative views such as "instantaneous" for reaction complete in under 1 second, "fast" for reactions complete in a few seconds, "moderately fast" for reactions taking a few tens of seconds, etc, will suffice). Where there are both desired and undesired reactions are there sufficient differences in the rates to allow the former to be encouraged at the expense of the latter by appropriate choice of contacting time? Do the orders of the reactions with respect to the various species involved provide clues to the best contacting pattern or addition profile for the promotion of the desired reaction(s), whilst discouraging unwanted ones?
- How much heat has to be removed or supplied during the reaction(s)?
- Can a desired reaction be encouraged relative to undesired ones by appropriate choice of the phase in which it is carried out?
- Would the use of a catalyst improve the rate and selectivity of a conversion?

Once the chemistry has been explored sufficiently it is then time to apply chemical engineering principles to the selection of appropriate equipment in which to carry it out. The choice of contacting pattern (batch or continuous, plug flow or backmixed, all in one stage or separated into several stages if the latter is beneficial) and the associated issues of transfer processes impacting upon the rates of reaction (heat removal/addition, mixing requirements, mass transfer) plus process control needs. Scale up from the laboratory recipe is fraught with problems arising from the facts that not all of the important parameters can be increased proportionately together and the inherent variability in processing conditions increases with scale. The leap from the classical stirred flask in the laboratory to a much bigger version on the plant (the ubiquitous STR) invariably introduces wider distributions in the chemical and physical conditions experienced by the reactants, leading to different (usually worse) performance at full scale. Optimisation of reaction conditions and the reduced need for subsequent separation, purification and waste treatment or disposal will usually balance the economics when compared to conventional batch-reactor systems whilst having the potential for:

- improved product quality and reduced costs of production (arising from better yields, less work up and maybe lower capital costs) offering competitive advantage, and
- marked environmental benefits.

All reactor systems must have the ability to allow the following operations:

- addition of reagents, often in pre-quantified amounts
- removal of product
- removal of waste streams, both during (usually volatiles, which may be condensed and returned as useful material to the reactor system) and after the reaction (usually solids and liquids)
- variation and control of temperature
- variation and control of pressure
- measurement and control of reaction conditions
- insertion of an inert reaction atmosphere
- emergency venting when reaction conditions deviate from the norm
- maintenance activities

Whilst conventional stirred-tank reactors can accommodate all these requirements, operators who intend to use them should demonstrate to the Regulator that their reactor systems compare favourably with individually-tailored small "fast" reactors, in terms of the requirement to use BAT (typically in terms of raw material-to-desired product efficiency and/or waste production). This is particularly important for operators who make many batches of near-identical product, but multi-product/multi-use installations must also demonstrate that their reaction arrangements are BAT for the whole range of operations they propose to undertake within the "envelopes" of their Permits.

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1.7.1.4 Separation

When the reaction is complete, the product(s) need to be separated from the waste(s). This is facilitated by a separation process, a wide range of which are available. These include the following:

- Extraction. This takes advantage of any difference in solubility between the product and waste. A solvent is added to the product/waste mix and preferentially solubilises one of the components. The solvent can then be removed and the product recovered.
- Decanting. This process can be used when the product and the waste are present as immiscible liquids or as solid and liquid (e.g after a crystallisation step).
- Filtration. In this process the reaction mix is passed through a filter medium, with the product being preferentially allowed through or retained.
- Centrifuging. Centrifugal force is applied to the mix to separate phases of differing density, one of which will contain the product.

1.7.1.5 Purification and/or final product preparation

Although separation will partition the product from the bulk of the waste streams, it is unlikely to produce the product in the final form. Instead some form of final purification/finishing step will usually be required.

There is a considerable degree of diversity in terms of this step but it may include, eg. for purification::

- re-application of separation steps
- washing or solvent extraction
- drying
- distillation
- membrane separation processes
- recrystallisation

and for final product preparation:

- size adjustment of solids (e.g. reduction by grinding or enlargement by granulation or tableting)
- formulation

1.7.2 Sub-sector examples - specific issues

The unit operations approach which forms the basis on which this Guidance is structured has limitations as well as strengths. The following sub-sectors of the Speciality Organic Chemicals sector are used as examples to demonstrate that variety of specific issues that may arise as well as those that are common. The chosen sub-sector examples are:

- organo-metallics
- sulphonation and nitration (including explosives nitrations)
- halogenation
- pesticides
- pharmaceuticals

The sub-sectors are not mutually exclusive; for example a pharmaceutical process may also involve sulphonation.

1.7.2.1 Organo-metallics

This Guidance Note does not cover the manufacture of all organo-metallic compounds, but concentrates instead on organo-lead, -lithium and -magnesium compounds. Whilst the production of each of these three types of organo-metallic compound requires a unique approach, there are also a number of issues common to them all. These include:

- strongly exothermic reactions which if not properly controlled can result in overpressurisation and the need to vent the contents of reactors
- the sensitivity of the reactions to the presence of atmospheric oxygen and moisture, which can compromise product quality and in certain cases can give rise to pyrophoric reactions
- the extensive use of organic solvents due to the widespread potential for water to adversely affect the reactions
- the presence of both organic and metal-based pollutants in waste streams
- the potential for side-reactions that can reduce reaction yields and increase the quantity and complexity of the waste produced

In addition to these general issues, the production of each type of compound gives rise to a number of specific issues. These are covered in the following subsections.

Lead alkyls

Lead alkyl production was the most significant activity in the organo-metallics sector but with the use of lead additives in petrol having ceased in Western Europe, North America and other industrialised countries and about to be phased-out in the rest of the World, output in the UK is now limited just to tetra-ethyl lead (TEL), and that in declining quantities. Despite the temporary nature of TEL production, it has been included in this Guidance to demonstrate some of the issues which can arise.

The existing process is based on the batchwise reaction of lead/sodium alloy with ethyl chloride. The main issues to note with this process are as follows:

- A large excess of lead is used in the reaction, with the result that up to 75% is not incorporated into the product and so needs to be recovered from the process. Unreacted ethyl chloride also has to be recovered.
- The reaction is conducted under pressure to ensure that the ethyl chloride reactant remains liquid.
- TEL is scrubbed from tail-gas by mineral oil circulated through packed tower absorbers; the TEL is then recovered from the oil by heating and stripping under vacuum.
- Waste waters receive pH adjustment followed by settlement to remove inorganic lead compounds and the lead-rich sludges are collected and sent for recovery. Soluble organo-lead compounds are removed by reduction with sodium borohydride or zinc, or, as an alternative, chemical precipitation can be used, followed by adsorption and ozone treatment.

The key operations and releases associated with the reaction are summarised in [Table 1.1](#).

Table 1.1: Production of lead alkyls

Unit operation	Activity	Main Release(s)
Reaction (in an autoclave)	- Reactants are charged to reactor with catalyst where they are reacted under reflux at 6 barg and approx. 65°C.	- Hydrocarbons and ethyl chloride are vented from reflux. - Excess ethyl chloride vented off at completion of reaction.
Batch still	- Reaction mass from autoclave is transferred to a batch still pre-charged with water. - TEL is then steam-distilled off and condensed and collected in a separation vessel.	- Remaining ethyl chloride is driven off as batch still is heated. - Still residues (primarily lead, sodium chloride, sodium hydroxide and alkyl chloride).

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Table 1.1: Production of lead alkyls

Unit operation	Activity	Main Release(s)
Phase separation	- Remaining water and impurities are removed from the TEL by phase-separation.	- Lead and other impurities in aqueous stream.
Blending	- TEL is blended with a variety of materials to form final product.	- Dibromo- and dichloroethane from blending process.
Effluent collection	- Effluents from the various stages in the process are directed to collection pits for the recovery of lead.	- TEL vapour.

Lithium alkyls

The most important lithium alkyl is n-butyl lithium, which is used extensively as an initiator in polymerisation reactions. All commercial production of n-butyl lithium is based on the reaction of lithium metal with n-butyl chloride, and important issues in its production are:

- Lithium and the product react exothermically with water to form butane or hydrogen gas; the product is also pyrophoric. The process therefore takes place in a hydrocarbon solvent that excludes moisture and air (usually pentane, hexane or cyclohexane).
- Large volumes of inert gas (nitrogen and argon) are used during parts of the process and these will carry away volatiles.
- Vents are fitted with oil bubblers to prevent the ingress of air/moisture into the process and oil from these bubblers may be volatilised and lost to atmosphere.
- Lithium is expensive, and therefore considerable attention is paid to its recovery during the process and from subsequent waste-water treatment.

The main process steps, release points and substances released are outlined in [Table 1.2](#).

Table 1.2: Production of n-butyl lithium

Unit operation	Activity	Main Release(s)
Pre-reaction	- Lithium ingots are melted in mineral oil at 180-190°C and then cooled to form 'clean' finely-divided lithium. The mineral oil is drained from the reactor and a hydrocarbon solvent added to wash the lithium. This too is drained from the reactor to form a lithium dispersion.	- Mineral oil drained from the reactor and hydrocarbon wash contaminated with lithium. - Hydrocarbon solvent emissions to air.
Reaction	- Lithium dispersion is charged to reactor and butyl chloride added at a constant rate.	- Hydrogen. - Hydrocarbon solvent emissions.
Filtration	- Reaction mass is filtered twice. The resulting filtrate is the product.	- Filter cake sent for recovery.

Organo-magnesium compounds

Organo-magnesium compounds are used extensively as Grignard reagents. A wide variety of reactions have been developed to produce specific compounds, but typically these can be viewed as the displacement of a halogen by magnesium from the desired organic group. The most important element of the production of organo-magnesium compounds is that they are always made and used in an organic solvent, typically ethers (eg tetrahydrofuran) which provide good solubility.

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Given the wide variety of reactions that can be used to form Grignard reagents, it is difficult to generalise about the process steps involved, but a typical reaction may consist of the unit operations, releases and substances outlined in [Table 1.3](#).

Table 1.3: Production of organo-magnesium compounds

Unit operations	Activity	Main Release(s)
Pre-reaction	- Solvent and magnesium metal are charged to reactor before the controlled addition of an organo-halide.	- Alkyl halide and solvent emissions to air.
Reaction	- Reaction mass is transferred to another reactor for the addition of a second organic compound.	- Solvent emissions to air.
Distillation	- To recover solvent.	- Solvent emissions to air. - Distillation column 'bottoms'.
Phase separation	- Reaction mass is acidified, with the result that magnesium salts are driven into aqueous phase. Product concentrates in organic phase.	- Aqueous phase for effluent treatment.

Sulphonation and nitration

Three common types of sulphonation or nitration reactions are:

- sulphonation and nitration of aromatics
- aliphatic sulphonation or sulphonation
- explosives nitrations

There are a number of issues that are likely to arise, whichever combination of agent or reaction is used. These are as follows:

- There is a great diversity of products and of raw materials utilised.
- Large amounts of acid gas are evolved from the process.
- Large excesses of acid are used to drive the reaction.
- Nitration will lead to the formation of streams rich in oxides of nitrogen (NO_x). These may be diluted with air to convert the NO into NO₂ and this can be treated in a scrubber containing weak caustic soda. Alternatively recovery via absorption in nitric acid can be used.
- Sulphonation often generates a sulphur trioxide (SO₃)-rich gas stream, which can be treated in a ceramic-packed scrubber containing 98% sulphuric acid, followed by a candle filter to eliminate mist.
- Cyclones are often used to remove surplus liquid.

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Each of these reactions and the main releases associated with them are summarised in [Table 1.4](#) to [Table 1.6](#)

Table 1.4: Aromatic sulphonation and nitration

Unit operations	Activity	Main Release(s)
Reaction	<ul style="list-style-type: none"> - Aromatic reactant plus sulphonating or nitrating agent (usually sulphuric acid or oleum for the former, or a mixture of sulphuric acid/nitric acid, commonly known as mixed acid, for the latter) is charged to reactor. A wide range of operating conditions may be used but typically atmospheric pressure and 100°C. - On completion of the reaction, the mixture is quenched in water or an ice slurry (which may take place in a separate vessel). 	<ul style="list-style-type: none"> - Acid vapours from the reaction and quenching stages. - Unreacted sulphonating/nitrating agent arising from the use of an excess to drive the reaction. - Organic emissions. - Acidic waste waters.
Separation	<ul style="list-style-type: none"> - Quenched mixture is separated using pressure filtration. 	<ul style="list-style-type: none"> - Filtrate contaminated with unreacted raw material and acid. Some may be recycled, most is neutralised with lime. - The product is washed on the filter and the resulting dilute acidic wash waters are neutralised.

Table 1.5: Sulphonation and sulphation of aliphatics

Unit operations	Activity	Main Release(s)
Reaction	<ul style="list-style-type: none"> - Sulphur trioxide is often used as the sulphonation/sulphation agent and reacted with an aliphatic organic compound. The SO₃ is often produced in-plant from sulphur. 	<ul style="list-style-type: none"> - Acidic vapours from the reaction and the sulphur trioxide production process. - VOC emissions. - Acidic waste waters.
Neutralisation	<ul style="list-style-type: none"> - The acid reaction product is neutralised and sent for storage. 	Vapours from the neutralisation.

Table 1.6: Explosives nitrations

Unit operations	Activity	Main Release(s)
Reaction	<ul style="list-style-type: none"> - Organics like glycerol or cellulose are nitrated with mixed acid at about 0°C. 	<ul style="list-style-type: none"> - Nitrogen oxide off-gases.
Separation	<ul style="list-style-type: none"> - The chilled emulsion is separated and washed with water and sodium carbonate; - Spent acid from separation is distilled to obtain the nitric and sulphuric acid components. 	<ul style="list-style-type: none"> - Nitric acid and sulphuric acid from distillation. - Acidic product waste waters.

Halogenation

Halogenation is characterised by a very wide variety of reaction options, although a number of environmental issues are associated with virtually all options. These include the following:

- The potential for release of organo-halogens.
- The potential for small quantities of dioxins to be formed.
- The need in many cases for fairly complex storage and handling techniques for the halogenating agent.
- The release of inorganic halogenating agent, hydrogen halides or halogens (which are usually abated by scrubbing with water or caustic soda).

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The main process units and releases associated with halogenation processes are summarised in [Table 1.7](#).

Table 1.7: Halogenation processes

Unit operation	Activity	Main Release(s)
Reaction	- Organic feed is reacted with halogenating agent.	- VOCs (including halo-organics). - Inorganic halides and halogens. - Aqueous solution of reaction medium (HCl or inorganic salts).
Separation	- A wide choice of techniques may be available.	- Wash waters from filtration and VOCs from evaporation.

A wide range of halogenating agents is available and some of the strengths and weaknesses of their use are summarised in [Table 1.8](#).

Table 1.8: Halogenating agents

Halogenating agent	Advantage(s)	Disadvantage(s)
Chlorine	- Many reactions will generate only gaseous by-product streams, which are easily removed from the off-gas. - On completion of the reaction, only small amounts of chlorine usually remain.	- Sophisticated storage and handling facilities are normally required.
Bromine	- As for chlorine. - Can be contained in small, easily handled containers.	- As for chlorine.
Iodine	- Readily available. - Does not require sophisticated storage facilities.	- Charging of solids to the reaction vessel may require special solids handling equipment. - Difficulties with certain waste disposal routes.
Thionyl chloride or Sulphuryl chloride	- Many reactions generate a gaseous by-product stream, which is separated from the product and easily removed from the tail-gas. - Readily available in small containers as well as in bulk. - Does not usually require complex storage facilities.	- Can react violently with water, alcohols, etc. - On completion of the reaction, considerable excess quantities can remain and these have to be removed by distillation.
Phosphorus tri- or pentachloride	- Readily available in small containers as well as in bulk. - On completion of the reaction, the inorganic component may be removable by filtration.	- Effluent containing phosphorus compounds may require specialist treatment. - Can react violently with water and fumes on contact with moist air.
Aluminium chloride	- Readily available. - Does not require sophisticated storage facilities. - Can be used to carry out chemical reactions to produce substances that would be difficult to make using other approaches.	- Fumes in contact with moist air (though not as vigorously as S- or P-containing chlorides). - Generates a considerable volume of acidic effluent containing aluminium salts. - Charging of solids to the reaction vessel may require special solids handling equipment.
Hydrogen halides	- Readily available in anhydrous form or aqueous solution. - May generate no gaseous by-product.	- Sophisticated storage and handling facilities may be required for anhydrous forms.

Pesticides

Common issues specific to the manufacture of pesticides include the following:

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- Interaction of the pesticide approval system with environmental and workplace health/safety regulatory systems, although not to the same extent as for pharmaceuticals.
- The storage and handling and hazardous substances, and disposal of hazardous wastes.
- The use of high integrity packaging and materials handling equipment.
- The need for comprehensive cleaning between batches;
- Two-stage production:
 - a primary production step in which the active ingredient is manufactured;
 - a secondary formulation step in which the active ingredient is mixed with other materials to form the final product.
- Dust generation that may contain active ingredients (requiring abatement to the levels of high-efficiency particulate arrester (HEPA) filtration).

The main releases to the environment associated with the primary and secondary manufacture of pesticides are summarised in [Table 1.9](#) and [Table 1.10](#).

Table 1.9: Primary manufacture of pesticides

Unit operation	Activity	Main release(s)
Reaction	- Raw materials are usually reacted in a solvent.	- Dusts from vessel charging with dry raw materials. - VOCs from the use of solvents, etc. - Aqueous organics-containing effluents. - Wash-down effluent.
Separation	A wide variety of separation techniques is may be used.	- Distillation column 'bottoms'. - VOCs from distillation "overheads".

Table 1.10: Secondary manufacture (formulation) of pesticides

Unit operation	Activity	Main release(s)
Size reduction	Raw materials are crushed or pulverised to get them into the correct physical form.	- Dusts from crushing/pulverising and handling operations..
Blending	The active ingredient may be blended with a number of other materials, inert or active, to produce the final product.	- Dusts and VOCs. - Effluent or liquid wastes containing organics
Milling	- The final product may require milling to ensure that it is in the correct physical form.	- Dusts from milling.
Packaging	- High standards of packaging are required to prevent inadvertent release of the pesticide, as well as to preserve product quality.	- Dusts where dry materials are handled..

Pharmaceuticals

The manufacture of pharmaceuticals raises a number of particular environmental issues, including the following:

- Interaction between the approval system for manufacturing a particular pharmaceutical and environmental and workplace health/safety regulatory systems. This interaction can make proposed changes to the manufacturing process very time-consuming and costly to implement.
- Prevention of cross-contamination between product and environment. Modern installations tend to be designed on the basis of containment (eg. collection and treatment of workplace air as well as process gas streams) and island systems (ie. separation of processing units from each other and from support services).
- Long timescales for the development of products.
- The use of some production techniques that are uncommon in other parts of the chemical industry, eg natural separation or fermentation.

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- Formulation of the product into forms (eg. tablet, capsule, ointment) that are rarely used elsewhere in the chemical industry.
- Operation at extremely high levels of cleanliness and product quality.
- Limited opportunities to recycle materials, particularly solvents, because of mandatory raw material traceability and product quality requirements.
- Dust generation that may contain active ingredients (requiring abatement to the levels of high-efficiency particulate arrester (HEPA) filtration).

The main releases to the environment associated with the primary and secondary manufacture of pharmaceuticals are summarised in [Table 1.11](#) and [Table 1.12](#).

Table 1.11: Primary manufacture of pharmaceuticals

Unit operation	Activity	Main release(s)
Reaction	- Raw materials are usually reacted in a solvent.	- Dusts from vessel charging with dry raw materials. - VOCs from the use of solvents, etc. - Aqueous organics-containing effluents. - Wash-down effluent.
Separation	- The active ingredient is separated from by-products and waste.	- VOCs. - Effluent containing organics.
Natural extraction	- This is an alternative to chemical synthesis; it involves extraction of the active ingredient from natural materials, eg. vegetation.	- Large amounts of waste from the naturally-occurring source material.
Fermentation	- This involves the inoculation of micro-organisms in a liquid broth in the presence of nutrients.	- Waste liquid broth from centrifuging, etc. - Solvents, filter residues and wash materials from product recovery.
Drying	- May be required to remove excess solvent.	- VOC emissions to air.

Table 1.12: Secondary manufacture of pharmaceuticals

Process unit	Activity	Main release(s)
Sieving, milling or micronizing	May be required to ensure that no foreign matter is present and that the raw materials/active ingredients are present in the correct physical form.	- Particulates or dust.
Weighing	- Very accurate weighing procedures may be needed. - Cleaning of weighing equipment between batches will be required.	- Particulates or dust.
Mixing or blending	- May need to add fillers (eg. sugar or starch), etc, to the active ingredient and then ensure that they are well mixed. - Wet or dry blending may be used.	- Particulates or dust.
Granulation	- This ensures that the active ingredient is present in the correct physical form prior to encapsulation, tablet-forming, etc.	- Particulates (dry process). - Solvent (wet process).
Drying	- Drying is often required to remove any excess solvent. - Tray ovens, fluidised beds, vacuum dryers, tumble dryers, spray dryers and freeze dryers may be used. - Where flammable, solvent concentrations within the dryer must be carefully controlled to avoid potential explosion problems. If this is accomplished by dilution with air, VOC abatement becomes more difficult.	- VOCs.

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Table 1.12: Secondary manufacture of pharmaceuticals

Process unit	Activity	Main release(s)
Tablet pressing, printing and coating	<ul style="list-style-type: none"> - After blending the active ingredient with a binder and/or lubricant, it is pressed into a tablet. - Collection of tablets in containers may result in dust problems. - Printing is used to apply a brand or manufacturer's name. The ink is usually butanol/ethanol-based. - Coating imparts physical strength to the tablet. Water-based coatings are increasingly replacing solvent based ones, except where water-insoluble (slow-release) tablets are being produced. 	<ul style="list-style-type: none"> - Particulates or dust. - VOCs
Filling and packing	<ul style="list-style-type: none"> - High standards of packaging are required to prevent inadvertent release of the pharmaceutical, as well as to preserve product quality. 	<ul style="list-style-type: none"> - Dusts where dry materials are handled.
Aerosol preparation	<ul style="list-style-type: none"> - Aerosols are filled, capped, tested and weighed in specialist equipment. 	<ul style="list-style-type: none"> - VOCs from propellant leaks.

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1.8 Economics

1.8.1 Introduction

In determining an Application, the Regulator must assess what is BAT and translate it into conditions to be included in the Permit. The BAT philosophy requires that judgments are made, balancing cost against environmental harm; the cost of pollution control should not be disproportionate to the environmental benefits delivered.

BAT is not concerned with the financial health or resources of a particular operator, and costs are viewed in the context of the process and the industry sector. While techniques and achievable release levels may vary between industry sectors, the same principles apply to all sectors. For existing processes, the timing of improvement programmes may be a factor in the determination of BAT.

The information contained in this section gives background on the economics of the industry and the ability of operators to raise funds for investment as well as an indication of possible abatement costs. In the absence of the EC's BREF for the Speciality Organic Chemicals sector, which has still to be completed, the information below has been taken from IPC Technical Guidance Note, IPC S2 4.02 - Speciality Organic Chemicals ([Ref 20](#)) - which was published in 1999. Some cross-sectoral economics information is included in the BREF entitled Reference Document on Economics and Cross-Media Effects (see [Ref 1](#)), and this should also be consulted.

1.8.2 The Speciality Chemicals sector

The wider speciality chemicals sector is composed of around 350 companies with total employment in the region of 70-80,000. The majority of companies manufacture or wholesale chemicals as their primary business activity, but rubber and plastic product manufacture is also important. Apart from these major groupings, companies with existing IPC Authorisations or PPC Permits are spread amongst a diverse set of industries including the manufacture of food and beverages, textiles, fuel, construction, transport and sanitary services - the only common feature in many cases being that they operate a process for the batch manufacture of fine or speciality organic chemicals. For some companies this is the ultimate function of the business operations, whereas for others the chemicals produced are simply a stage in a further production process.

The core of the sector is approximately 150 dedicated speciality chemicals manufacturers, many of which are affiliated to SOCSA - the Specialised Organic Chemicals Sector Association.

The sector is dominated by small and medium-sized enterprises (SMEs - less than 250 employees), but manufacturers in this sector include stand-alone operators, divisions of larger companies or in-house divisions supplying other functions within the same company. In many cases the divisional and in-house operators conduct business like stand-alone operators, acting as separate profit centres, although being forward - and back - integrated to varying degrees.

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Product values range from £4/kg upwards, although some products can reach the £20/kg plus range. The range of annual product volumes is estimated to be between 500 g-1 kg (for laboratory chemicals) and 900 - 1000 tonnes at the top end. Anything above 1000 tonnes per annum is more likely to be undertaken by commodity organic chemicals producers.

The market prospects for the sectors covered are largely determined by the level of general economic activity. Speciality chemicals have such wide application throughout other markets that there is a strong link between general demand and sector activity. There are exceptions, however, notably for the agrochemical intermediates sector, which is highly dependent on agricultural policy and is forecast to decline relative to general economic growth.

The markets in which the companies operate are global in nature and are influenced by conditions in other countries (notably the US for product sales and the Far East for competition). There will be further globalisation as a result of ongoing reductions in world trade barriers, and all markets are expected to increase substantially with the largest growth in China, the Far East and the Indian subcontinent.

The prospects for the sector depends upon product innovation which, in general, is unlikely to be curtailed as economic growth proceeds. Most business is generated when new products are introduced by a customer or upstream division of an in-house operation. Product innovation by customers is thus of primary importance in determining sector growth.

Investment and growth tends to be stepwise with much growth achieved through merger and acquisition. As a result, new plant developments are rare. Investment cycles tend to be long (eg 25 years) and significant peaks in capital investment activity were seen in the late 1970s and the early 1990s.

Major product groupings include intermediate chemicals for the pharmaceutical and agrochemical industries, pigment and dyestuff intermediates, fluorescent brightening agents, biocides, plastic additives and flame retardants. UK companies are involved in all these sectors, but in the face of competition from low-cost overseas producers have largely moved out of the low-value end of the market into higher-value products aimed at fulfilling niche customer needs.

1.8.3 Financial resources

The availability of financial resources for capital investment is a function of the level of debt in the industry, the liquidity of the companies and their profitability. Financial data of a subset of companies (approximately 50% of the total) have been analysed to examine the financial resourcing characteristics of the sector. This analysis reflects the performance of the sector in 1997; conditions in subsequent years may be different. The performance of individual companies may also deviate significantly from the sector average.

High levels of debt constrain a company's ability to finance further investment and jeopardise future prospects because interest repayments need to be made in both good and bad times. Analysis of debt and equity rates for the companies suggests that the sector as a whole does not have a significant debt constraint. Debt rates in general are above those seen in UK industry as a whole, but few companies appear to have unacceptable levels. Lower than average rates of debt are seen in the pharmaceutical and agrochemical sectors, while relatively high rates are seen in other chemical products manufacture.

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Liquidity in the sector is generally reasonably high and considerably higher than the averages for UK enterprises and manufacturing in general. Liquidity measures the short-term availability of funds and is an accurate predictor of financial difficulties. The majority of companies appear to be relatively liquid, although a portion of the sector can be regarded as having an unacceptable liquidity position. These companies could face short-term difficulties if required to invest heavily in pollution control.

Financial resources available for investment will be dependent upon the level of profitability in the sector, as retained profits are often the source of financing. Historically, profitability has generally been relatively high, on the bases of return on capital employed and return on assets. Returns in the majority of companies are higher than the comparable figures for UK manufacturing and related sectors, as a whole. There is a 19% return on capital (in 1997) for the sector as a whole compared to the average of 12% for industry in general, with higher than average rates of return seen in most sub-sectors - the exceptions being soaps and detergents and chemicals wholesaling. In general, companies in the sector have been reasonably profitable, which increases their ability to finance pollution control improvements from internal sources, but the situation more recently has not been as good.

1.8.4 Sector affordability

The sector, and individual companies within the sector, have the choice of one or more of the following strategies for financing increased investment in pollution prevention, minimisation and control:

- pass-through - whereby costs are passed through to the consumer
- pass-back - whereby costs are passed back to suppliers or met by internal improvements in efficiency
- absorption - whereby costs are absorbed by the process operator in the form of lower margins

The potential for utilising these strategies is summarised below.

1.8.4.1 Cost pass-through

There are rigidities in the market which mean that price competition, although important, may not be fundamental in all markets - quality, reliability and flexibility are also key aspects of competition. The use of preferred supplier lists and long-term contracting are common and there is a large degree of niche marketing. This suggests that there is some scope (on a case-by-case basis) for cost pass-through. This is reflected in generally high levels of profit margins within the sector, 7% across all the companies compared to 4% for the UK as a whole. Much higher profit margins are being earned in some sectors.

The ability to pass through costs will be curtailed by the degree of foreign competition. The UK's traditional competitors have been Germany, Switzerland and the US, with India, Korea, Taiwan and China comprising a new and increasingly important wave. The sector has witnessed both increasing import penetration by foreign firms and rising exports - highlighting the continued globalisation of the market. Globalisation means that currency fluctuations are increasingly important for the sector. The high value of products mean that transportation costs are frequently not an issue. The UK has to a large extent already moved out of the low-value end of the market where price issues dominate. The new wave of competition comes from companies which although benefiting from a lower environmental cost base, have in many cases the skills, initiative and flexibility to compete with the best UK firms.

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Understanding IPPC	Making an application	Installations covered	Timescales	Key issues	Summary of releases	Technical overview	Economics	

The global nature of the market means that there is large-scale ownership of foreign companies by UK firms and vice versa. Much of the inward investment in the UK is from North America (70%) and this will often represent a foothold into European markets - encouraged by the UK's traditional attractiveness as a site for foreign direct investment. The UK's investment overseas are three times the level of foreign investment here and is evenly spread amongst the major markets. This global nature of investment links means that many companies will be sensitive to cost increases in one country relative to another.

1.8.4.2 Cost pass-back

Efficiency measured in terms of the sales generated from investment is generally low in comparison to other UK companies although profit per employee is high. There have been rapid increases in productivity for the chemical sector as a whole, but it is now slower, suggesting limited scope for further efficiency gains. The sector does, however, have leading and lagged company characteristics, and many companies could benefit from the chance to catch up through an increased awareness of leading technologies and operating strategies.

1.8.4.3 Cost absorption

Profitability in the sector has been relatively high and simulated cost increases indicate that few companies would see a significant reduction in profitability as a result of small to moderate cost increases - though this is less clearly the case now than it was in 1997 when the review for IPC was undertaken. A 1% increase in operating costs across all companies analysed would raise £50m of expenditure for investment in pollution control.

1.8.5 Case-by-case issues

The variability of companies within this sector makes prescriptive approaches to the identification of what is BAT difficult. However, a number of issues related to the industry structure, the product market and the operating conditions of the sector can be highlighted.

As individual installations are frequently part of a much larger operation, there needs to be careful consideration of the whole range of associated operations when assessing or allocating costs. The particular difficulties of assessing financial impacts on in-house operators may require the use of comparisons from stand-alone operators.

The importance of SMEs in the sector means that careful consideration needs to be given to making environmental improvements cost effective in relation to the environmental benefits to be gained and to avoiding over-burdening small companies. At the other end, the potential impact of foreign ownership in the sector may also need to be considered because foreign ownership increases the choices that companies have regarding investment.

New installations are likely to be few and far between and most developments have been, and will continue to be, extensions to existing plants. Combined with the relatively long investment cycles, this means the maximum use should be made of opportunities for change as and when they arise. The

Introduction			Techniques			Emissions		Impact
Understanding IPPC	Making an application	Installations covered	Timescales	Key issues	Summary of releases	Technical overview	Economics	

recent high level of acquisitions and divestments has led to frequent changes in management structures and attitudes to environmental performance - both positive and negative - and these present opportunities for review of environmental performance by both operators and Regulators.

1.8.6 Cost information for abatement techniques

The costs of abatement techniques vary widely according to process duty and site-specific factors. The following examples are provided as illustrations and relate to data generally collected in 1997. It is the operator's responsibility to develop robust cost estimates that correspond to its own specific processes and circumstances.

Where possible, the examples provide annualised capital and operating costs, the annualised capital charge being calculated using an assumed discount rate of 10% over ten years. This approximates to the typical cost of capital in the late 1990s rather than to the opportunity cost to the company.

1.8.6.1 Volatile organic compounds

The capital costs of VOC abatement are affected by gas flowrate, the nature and concentration of the VOCs and by particular items relating to individual techniques and specific sites. The capital costs given in Table 1.8.1 are for non-halogenated VOCs. Equipment to treat halogenated VOCs is generally more expensive owing to the larger sizing of equipment required by some of the technologies or to the materials of construction required by others.

Table 1.13: Examples of VOC Abatement techniques - approximate costs

Technique	Flow (m ³ /hr)	Capital costs (£)	Operating costs (£/annum)	Annualised Total costs (£/annum)
Adsorption - canister	200	1000	100	260
Adsorption - regenerable fixed bed	10000	900000	26000	173000
Absorption	5000	550000	17000	107000
Condensation - refrigerant	1000	400000	13000	7800
Condensation - cryogenic	200	200000	--	--
Thermal oxidiser	25500	750000	278000	400000
Catalytic oxidiser	34000	750000	300000	420000
Biological oxidiser	3600	300000	5000	54000

1.8.6.2 Particulate matter

The cost of particulate matter abatement is highly dependent on the flowrate ([Figure 1.1](#)), but much less dependent on the loading.

Figure 1.1: Particulate matter abatement costs

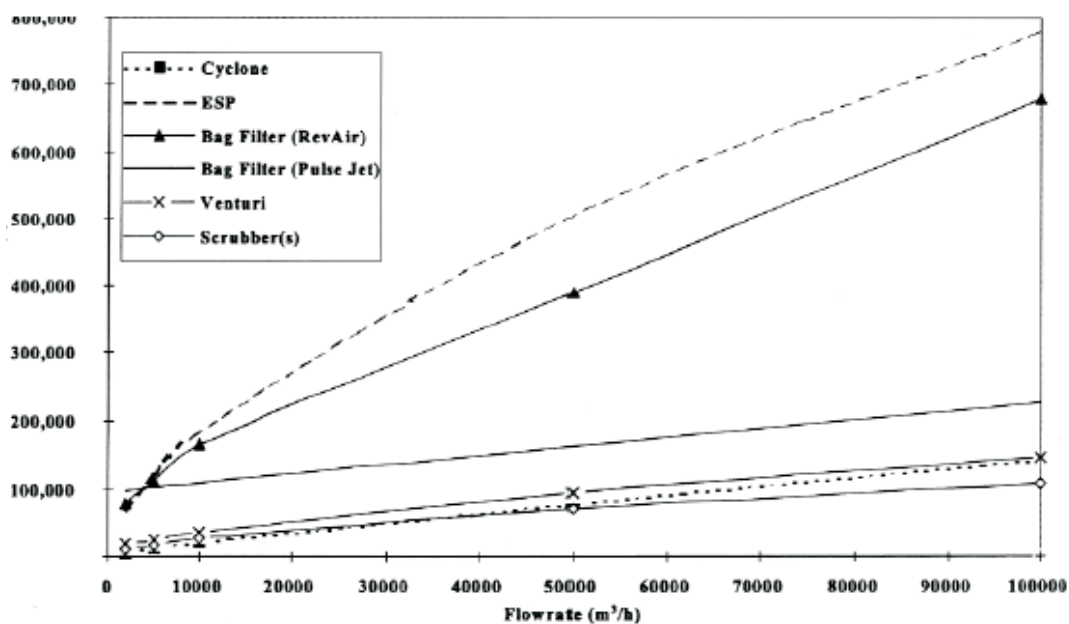
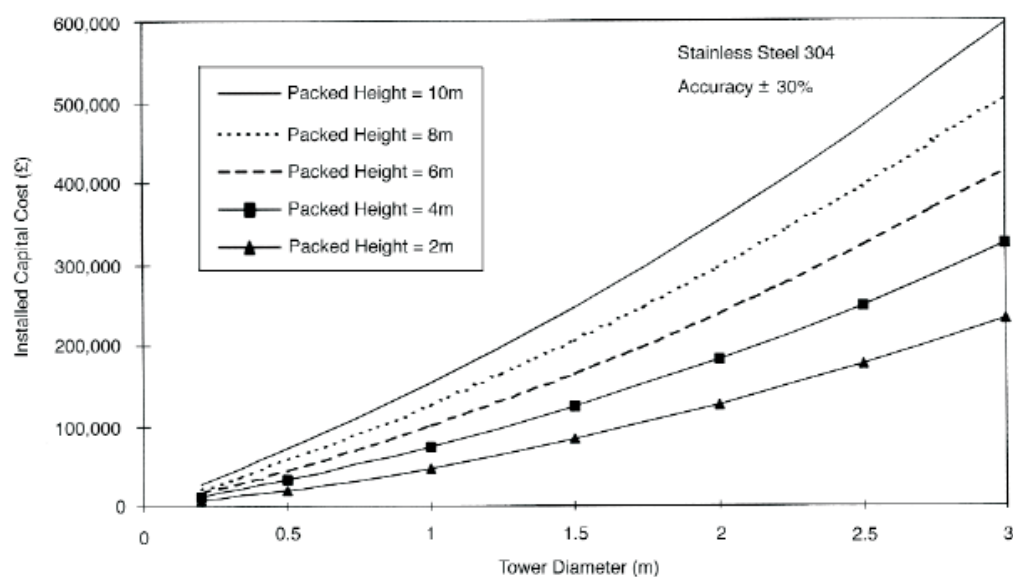


Figure 1.2: Installed cost of acid scrubbers



1.8.6.3 Gas scrubbing

Scrubbing techniques are widely used in the sector for gaseous pollutants. However, the diverse nature of the pollutants, the scrubbing medium and operating conditions make it impracticable to give average annualised costs.

Figure 1.2 shows installed capital costs only for a common type of scrubbing equipment constructed in stainless steel.

1.8.7 Cost information for waste water techniques

1.8.7.1 General

The capital costs for removal of organic or inorganic pollutants from waste waters are affected by flowrate, the nature and concentration of the pollutants in the waste water, and issues peculiar to specific pollutants, treatment techniques and individual sites. Table 1.14 and Table 1.15 show approximate costs for typical techniques.

Table 1.14: Examples of specialised waste-water treatment - approximate costs (a).

Technique	Capital costs (£)	Operating costs (£/annum)	Annualised total cost (£/annum)
PAC	3500	800	1300
GAC	1900	3000	6200
Chemical coagulation	120000	2500	22300
Ozone	150000	5800	30000
Air stripping	10500	--	17000

Costs are based on a waste-water flow of 100 m³/day; maintenance and operating labour are excluded. (Data from Environment Agency Research Report No P.163, 1998, entitled "Best Available Techniques for the control of Pollution in Batch and Fine Chemicals".)

Table 1.15: Cost of treatment of a high-organic effluent - approximate costs

Technique	Capital costs (£000)	Operating costs (£000/annum)	Annualised cost (£000/annum)	Unit cost (£/m ³)
Incineration	4000	1750	2400	60
Wet air oxidation	5000	360	1170	29
Supercritical water oxidation	7000	690	1830	46

1.8.7.2 Biological treatment

Biological treatment is the most widely used technique in the sector, yet it defies all but the most broad cost estimates because of the large number of interdependent factors.

At the very simplest level, a basic reed bed may cost as little as £30,000 for a low-volume, low-strength, biodegradable effluent. Conversely, an activated sludge plant installed at a pharmaceutical plant may cost as much as £20 million.

Introduction		Techniques for pollution control			Emissions			Impact			
Economics	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2 Techniques for pollution control

To assist Operators and the Regulator's officers in respectively making and determining applications for PPC Permits, this section summarises the indicative BAT requirements (i.e. what is considered to represent BAT for a reasonably efficiently operating installation in the sector). The indicative BAT requirements may not always be absolutely relevant or applicable to an individual installation, when taking into account site-specific factors, but will always provide a benchmark against which individual Applications can be assessed.

Summarised indicative BAT requirements are shown in the "BAT boxes", the heading of each BAT box indicating which BAT issues are being addressed. In addition, the sections immediately prior to the BAT boxes cover the background and detail on which those summary requirements have been based. Together these reflect the requirements for information laid out in the Regulations, **so issues raised in the BAT box or in the introductory section ahead of the BAT box both need to be addressed in any assessment of BAT.**

Although referred to as indicative BAT requirements, they also cover the other requirements of the PPC Regulations and those of other Regulations such as the Waste Management Licensing Regulations (see Appendix 2 for equivalent legislation in Scotland and Northern Ireland) and the Groundwater Regulations, insofar as they are relevant to PPC permitting.

For further information on the status of indicative BAT requirements, see [Section 1.1](#) of this guidance or [Guidance for applicants](#).

It is intended that all of the requirements identified in the BAT sections, both the explicit ones in the BAT boxes and the less explicit ones in the descriptive sections, should be considered and addressed by the Operator in the Application. Where particular indicative standards are not relevant to the installation in question, a brief explanation should be given and alternative proposals provided. Where the required information is not available, the reason should be discussed with the Regulator before the Application is finalised. Where information is missing from the Application, the Regulator may, by formal notice, require its provision before the Application is determined.

When making an Application, the Operator should address the indicative BAT requirements in this Guidance Note, but also use the Note to provide evidence that the following basic principles of PPC have been addressed:

- The possibility of preventing the release of harmful substances by changing materials or processes (see [Section 2.1](#)), preventing releases of water altogether (see [Section 2.2.2](#)), and preventing waste emissions by reuse or recovery, have all been considered, and
- Where prevention is not practicable, that emissions that may cause harm have been reduced and no significant pollution will result.

This approach should assist Applicants to meet the requirements of the Regulations to describe in the Applications techniques and measures to prevent and reduce waste arisings and emissions of substances and heat - including during periods of start-up or shut-down, momentary stoppage, leakage or malfunction.

Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.1 In-process controls

Pollution prevention and minimisation at source is the subject of this chapter - and, as in Chapter 1.7 - Technical overview - suitable techniques are discussed under the headings of the following unit processes:

- storage and handling of raw materials, products and wastes
- plant systems and equipment
- reaction
- separation and isolation
- purification and/or final product preparation

However, the diversity of this sector is such that it is not possible to include all techniques which could be classed as “clean technology”.

2.1.1 Storage and handling of raw materials, products and wastes

The design of storage facilities depends upon the properties, such as toxicity, environmental persistence and flammability, of the raw materials, products and wastes that are being stored. It also depends upon the quantities involved and their proximity to sensitive environmental receptors. Much information exists on the properties of materials (eg. Hazard Datasheets) and this, together with hazard and operability (HAZOP) studies, can be used for prioritisation of areas of concern.

Storage areas are subject to the same risks of overpressure, leakage, equipment failure and fire as the main processing areas - but the material inventories are generally greater and the level of surveillance is generally lower.

Additional guidance on the storage of chemicals is provided in the BREF entitled Emissions from Storage (see [Ref 1](#)).

Indicative BAT requirements for storage and handling of chemicals and wastes

- 1 All operations involving the storage and handling of chemicals and wastes should be subjected to a systematic HAZOP study to identify areas of risk to the environment. Plans and timetables for improvements should be in place where the risks are identified as significant.

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In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.1.2 Plant systems and equipment

2.1.2.1 Ventilation systems

Plant ventilation systems are primarily installed for occupational health reasons and the exhaust gases usually contain lower concentrations of pollutants than process streams. However, consideration should still be given to:

- the concentration, mass-flow and air impact of the substances vented to atmosphere
- the potential for contamination by extract air of rain-water run-off from the roof
- whether the ventilation system should be fed to an abatement unit
- noise levels and adequate silencing arrangements.

Indicative BAT requirements for ventilation systems

- 1 All the issues above should have been formally considered. Where the potential for substance or noise pollution has been identified, plans and timetables for improvements should be in place.

2.1.2.2 Over-pressure protection systems

A comprehensive design procedure should be followed to protect against overpressure of equipment. This requires the identification of all conceivable over-pressure situations, calculation of relief rates, selection of relief method, design of the vent system, discharge and disposal considerations, and dispersion calculations. In some cases careful design can provide intrinsic protection against all conceivable over-pressure scenarios, so relief systems and their consequential emissions can be avoided.

Most pressurised vessels will use relief valves or bursting discs, or a combination of the two, to provide emergency pressure relief. Emergency venting may be through an absorption system, to a dump tank or directly to atmosphere, and the need for equipment to collect and treat the release will depend on the likely impact of a discharge. It is imperative that the relief system is designed to cope with all conceivable conditions, because under some emergency situations the vented stream might be liquid or a two-phase foaming mixture, which would impose a different set of design constraints from simple gas relief. All equipment installed in the venting system should be maintained in a state of readiness even though the system is rarely used.

Relief valves may be mounted downstream of bursting discs or between pairs of bursting discs to protect the valve seats from corrosion, with pressure gauges and alarms installed between the discs and valve to warn of perforation of a disc or operation of the relief device. Sometimes a small-capacity relief valve is installed, discharging to an abatement system, with, in parallel and at a slightly higher pressure setting and discharging directly to atmosphere, a large-capacity device to deal with fire-induced relief.

Indicative BAT requirements for over-pressure protection systems

- 1 The examples above represent BAT for different circumstances. All relief systems should be subjected to a systematic HAZOP study to identify and quantify significant risks to the environment from the technique chosen for the activity in question.

Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.1.2.3 Vacuum systems

The load on vacuum systems and releases to the environment from them depend upon the degree of cooling and condensation achieved upstream, and on the quantity of gas the vacuum system has to handle. The environmental impacts can be minimised by careful design and choice of equipment, and good maintenance can reduce substantially the ingress of air at seals.

Sufficient instrumentation should be installed to detect reduced performance and to warn that remedial action should be taken. The main types of vacuum systems are as follows:

- **Steam jet ejectors.** These are simple, reliable and widely used in the chemical industry. In most cases, indirect cooling rather than direct quenching should be used for steam jet condensation so that discharges of contaminated effluent are minimised.
- **Liquid ring pumps.** The degree of vacuum is limited in this technique by the vapour pressure of the sealing fluid. The liquid seal fluid will often become contaminated but the contaminants may be amenable to recovery, and in the ideal case, one of the process liquids may be used as the sealing fluid.
- **Dry vacuum pumps.** These are rotary pumps which rely on high rotation speeds and close tolerances to effect a seal. These pumps do not normally produce an effluent but condensing or entrained liquids and solids can result in breakdowns or increased maintenance.

Both steam jet ejectors and liquid ring pumps have the potential to cause severe noise problems. The Envirowise Programme has published a guide (GG101) on Reducing Vacuum Costs. ([Ref 7](#))

Indicative BAT requirements for vacuum systems

- 1 The examples above represent BAT for different circumstances. Options should be compared and subjected to a systematic HAZOP study as part of the BAT assessment for the activity in question.

2.1.2.4 Pumps

Pumps driven by a shaft require a seal to prevent the pumped fluid escaping to the environment - but all seals depend for lubrication on a low leakage of fluid passing over the sealing surfaces.

The mechanical seal is an advance on the packed gland for rotating shafts and is widely used. Mechanical seals are generally reliable and have minimal leakage provided that the seal unit is properly assembled and aligned to the correct tolerances, and there is no lateral movement or vibration of the shaft.

Double mechanical seals arranged in a back-to-back arrangement are often used to prevent leakage of process fluids by pressurising the space between the seals with a sealing fluid. This arrangement is often used where abrasive solids are present in the pumped fluid.

For duties where no leakage can be tolerated, pumps are available which do not require glands or seals. Types in general use include:

- **Magnetic drive centrifugal pumps.** The impeller is inside a sealed casing and driven through a magnetic coupling so there is no likelihood of leakage under normal operating conditions. However, bearing lubrication is entirely dependent on a recirculated flow of pumped liquid and catastrophic failure of the casing can occur if solids are allowed to enter the lubrication channels and restrict the flow to the bearings. Following bearing failure the moving part of the pump can contact the casing and wear through it.

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- **'Canned' centrifugal pumps.** The rotating part of the drive motor is inside a sealed "can" which, with the attached impeller, is located inside the liquid-filled casing. The part of the casing containing the "canned" rotor is, in turn, surrounded by the stator coils of the motor. As with magnetic-drive pumps, the pumped fluid lubricates the impeller bearings, so canned pumps are not suitable for liquids containing solids or liquids with poor lubrication properties - though bearing failure in canned pumps rarely results in damage to the casing and subsequent leakage.
- **Diaphragm pumps.** These are reciprocating pumps in which the shaft movement is transmitted to the liquid by a flexible diaphragm, which also seals-in the liquid being pumped. To prevent leakage in the event of diaphragm failure, two diaphragms with the small space between filled hydraulically full with an inert liquid, are often used. Problems can arise in the pumping of slurries if the solids interfere with the operation of the non-return valves or settling of solids takes place inside the pump during an interruption of production.
- **Peristaltic pumps.** The fluid is forced along a flexible elastomeric tube by an external impeller. They are in common use for slurries as well as clean liquids.

Indicative BAT requirements for pump systems

- 1 The examples above represent BAT for a wide variety of different circumstances. Options should be compared and subjected to a systematic HAZOP study as part of the BAT assessment for the activity in question.

2.1.2.5 Gas fans, blowers and compressors

Many designs of fans, blowers and compressors are available, with particular designs appropriate for different pressure/volume/substance requirements.

Axial- and centrifugal-flow fans and compressors need a shaft seal to minimise leakage. Positive displacement compressors can be rotary - like screw, sliding vane, liquid-piston or straight-lobe designs - or reciprocating, but all require appropriate sealing or packing arrangements to prevent leakage. High standards of installation and maintenance, and careful attention to lubrication arrangements, are required to minimise fugitive losses (as well as to ensure high reliability).

Common types of seal used are labyrinth seals (two sets of interlocking teeth, one rotating, one stationary), restrictive ring seals (multiple stationary carbon rings in place of gland packing), mechanical seals (similar to those used in pumps), liquid film seals (in which liquid is injected into the space between close-tolerance bushes), and magnetic liquid seals (which provide effective sealing for low-pressure gases). For some compressor designs the seal arrangements are an integral part of the basic design.

Indicative BAT requirements for gas compression systems

- 1 The examples above represent BAT for a wide variety of different circumstances. Where alternatives are available, options should be compared and subjected to a systematic HAZOP study as part of the BAT assessment for the activity in question.

2.1.2.6 Agitator systems

Where a tank reactor is used the standard method of agitating the contents is with a rotating impeller, so a seal is required where the impeller enters the vessel.

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The sealing methods used for pumps are also used for agitators and, as with pumps, double mechanical seals are the most commonly used technique. Care must be taken to suppress lateral movements in the shaft as this will increase wear on the seal and, as with all glands and seals on rotating shafts, losses through leakage are also highly dependent on the standards of the installation work and of routine operation and maintenance.

Indicative BAT requirements for agitators

- 1 Any of the standard seal arrangements are potential candidates for being described as BAT. Which is actually BAT will depend upon the specific duty involved.

2.1.2.7 Valves

Types of valves commonly used in the chemical industry include: gate valves, globe valves, 90-degree ball- or plug- valves, and control valves, - all of which have potential leakage paths and therefore glands or seals to prevent or minimise leakage. Glandless valves in which the actuating mechanism is isolated from the process liquid by bellows arrangements or by flexible diaphragms, are also in common use. These glandless valves do not leak in normal use but on failure of the diaphragm or bellows-seal there can be the potential for high leakage rates. Valve leakage performance is significant in minimising plant fugitive losses and should be a major factor in valve selection.

Indicative BAT requirements for valves

- 1 The examples above represent BAT for different circumstances. The duties and conditions in each vessel and section of piping should be subjected to a systematic HAZOP study to identify and quantify significant risks to the environment from the valves chosen for those parts of the plant activity in question. Plans and timetables for replacement by higher integrity designs should be in place where the risks are identified as significant.

2.1.2.8 Heat exchangers and cooling systems

All heat exchange systems have the potential for process streams to leak into the heating/cooling fluid, or vice versa. If corrosion is likely, methods for rapid detection of leaks should be in place and a regime of corrosion monitoring at critical points should be in operation. Alternatively, materials of construction that are inert to the process and heating/cooling fluids under the conditions of operation should be substituted.

The BREF note entitled Industrial Cooling Systems (see [Ref 1](#)) provides detailed information on BAT for water-cooled heat exchangers and cooling-tower systems.

Indicative BAT requirements for heat exchangers and cooling systems

- 1 The issues of leak detection, corrosion monitoring and materials of construction noted above should have been considered, preferably in a formal HAZOP study. Plans and timetables for improved procedures or replacement by higher integrity designs should be in place where the risks are identified as significant.
- 2 For cooling water systems, the techniques in use should compare favourably with relevant techniques described in the Industrial Cooling Systems BREF.

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2.1.2.9 Purging facilities

Plant will normally require purging with air between batches and campaigns, and prior to maintenance activities; similarly, prior to start-up, air is often displaced from the system by an inert gas to ensure that a flammable atmosphere does not form. Purging leads to non-condensable gases carrying organic vapours being vented from the system, and the release of pollutants through these activities needs to be assessed and abatement applied if necessary.

Indicative BAT requirements for purging activities

- 1 The potential for the release to air of VOCs and other pollutants along with discharged purge gas should have been assessed - and abatement applied where necessary.

2.1.3 Reaction stage

2.1.3.1 Process design and plant selection for the Reaction stage

Understanding the chemistry of the reaction:

As outlined in Section 1.7.1, it is important to consider how the chemistry and engineering options available may contribute to releases to the environment from the reaction stage, both directly and as a consequence later in the process. It is also important that these considerations are made at the process design stage - before plant design and equipment selection is commenced:

The first thing that is required is a clear understanding of the basic reaction scheme, including knowledge of yields, side reactions and by-products under a variety of conditions. The application of physical chemistry principles at the process design stage is very important to achieving the optimum processing conditions, for example:

- Are the reactions irreversible or subject to equilibrium constraints?
- What are the rates of the reactions involved? Detailed kinetics are usually unavailable but even qualitative views such as "instantaneous" for reaction complete in under 1 second, "fast" for reactions complete in a few seconds, or "moderately fast" for reactions taking a few tens of seconds, etc, will suffice.
- Where there are undesired side-reactions that reduce yields and increase waste reduction, are there sufficient differences in the rates to allow the desired reaction to be encouraged at the expense of the side-reactions?
- Would the use of a catalyst (heterogeneous, homogeneous or enzyme) improve the rate and selectivity of the conversion?
- How much heat has to be removed or supplied during the reaction(s)?
- Can a desired reaction be encouraged relative to undesired ones by appropriate choice of the phase in which it is carried out, be it single-phase, multi-phase or membrane-separated phases?
- Does the order of the reaction with respect to the various species involved (ie. the reaction mechanism) help the promotion of the desired reaction(s) whilst discouraging unwanted ones?
- What are the best combinations of contacting pattern, raw material addition profile, concentrations, temperatures and pressures?

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Where the feed materials are not pure there may be additional inefficiencies so potential problems of this type should also be identified and considered before moving to the plant design and selection stage, ie:

- Can reaction yields be improved by better quality control of raw materials?
- What impurities in the reactor feeds may contribute to purification problems later in the process?

Chemical engineering design of the reactor:

Once the reaction chemistry has been explored sufficiently it is then time to apply chemical engineering principles to the selection of the optimum reactor type and configuration to minimise side reactions and waste generation. Heat removal or addition, mixing arrangements and mass transfer characteristics, together with process control options, will all have an impact on the reaction(s). The extensive library of chemical engineering literature on the pros and cons of the various types of reactors should be consulted for advice on how to choose the best combination for the reaction scheme involved

Scale-up from the laboratory recipe is not a simple process because not all of the important parameters can be increased proportionately together, and the inherent variability in processing conditions increases with size. Thus, simply changing from the laboratory flask to a much bigger plant version (the STR) invariably introduces wider distributions in the chemical and physical conditions experienced by the reactants, and the performance of a full size STR usually falls short of that seen at the laboratory scale - leading to lower yields and increased production of waste products to be removed in the purification stages. Some reaction schemes are robust enough to tolerate the range of conditions experienced within a STR but many would be better performed in other devices. At this stage, choosing a reactor system which optimises reaction conditions and thereby reduces subsequent (often costly) separation, purification and waste disposal stages, will usually balance the economics when compared to using an STR for reactions whose ideal conditions STRs cannot approach. Whatever the outcome (and sometimes the choice will be an STR) choosing a reactor system on the basis of optimisation of reaction conditions has the potential for:

- competitive advantage - through improved product quality and reduced costs of production (arising from inherently better yields, less work up and maybe lower capital costs), and
- marked environmental benefits.

It is difficult to overstate the importance of an adequate understanding of the physical chemistry involved in the reaction scheme, followed by sound application of reactor engineering principles at the process design stage. For example, heat transfer capability in STRs is only modest if jackets or coils are used, though it is better if the reactor contents are vigorously circulated through an external heat exchanger. Similarly, though liquid/liquid, liquid/gas and liquid/solid reaction systems can be handled in STRs, agitator power input (and therefore mixing efficiency) is limited in normal shear-thinning non-Newtonian systems by the creation of cavities of low viscosity material adjacent to the agitator(s).

Design considerations to be taken into account include:

- Would small-scale continuous reaction technology be feasible and more appropriate?

The answer to this question requires an understanding of the business drivers, as well as the chemical and physical transformations required in the process and the factors controlling their rates. There is the potential for lower inventories of hazardous materials, for smaller minimum campaign size, for faster and cheaper clean-outs and changeovers between products, and for reduced working capital (as well as the raw material efficiency and environmental advantages noted above) but do the potential business benefits outweigh the business risks inherent in trying something new? Similarly, can continuous processing provide business advantages through improved product quality or consistency resulting from better process control?

Continuous reactor types to consider include jet or T-piece mixers, pulsatile flow reactors, spinning cone reactors, spinning disk reactors, static mixers and vortex mixers. Residence times in some of the above devices can be as low as a few milliseconds, making them well suited for rapid reactions.

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Pulsatile flow reactors have been used for liquid/liquid, liquid/gas and liquid/solid reactions; they achieve thorough mixing with low energy inputs, the design being effectively a plug flow reactor achieved via the equivalent of a chain of STRs in series. The rotating devices referred to operate using thin films of liquid. Increasingly numbers of reactor types and their applications are being published in the literature. For spinning disk reactors, published examples include liquid phase reactions, polymerisations, manufacture of nanoparticles and synthesis of pharmaceutical intermediates with very “clean” chemistry reported.

Small-scale continuous reactors are often designed for a specific task - but their small size and modest cost can make it possible to change the reactor quickly between campaigns on multiple-product plant. Other designs are modular and have built-in flexibility to accommodate campaign changes.

- Are novel reaction techniques available to activate the desired chemistry, either alone or in combination? Examples include:
 - *Biological methods*. These can be extremely specific but tend not to be very compact. Examples include the use of captive enzymes.
 - **Use of supercritical fluids**. These have very low viscosities and surface tensions, and offer very high solvating potential and the ability to wet solids very easily. Among their novel applications, they can be used to manufacture small particles of solids with special properties by rapid expansion of their solutions.
 - **Electrochemical**. These can be very selective and of interest for redox and synthesis reactions.
 - **Ultrasonics**. Reaction rates can be enhanced through the intense temperatures (several thousand degrees) and pressures (over one thousand atmospheres) generated during the formation and violent collapse of cavitation bubbles generated using power ultrasonics. Enhancement of reaction rates through the increase in mass-transfer area arising from thorough phase mixing can also be obtained in cases where mass-transfer area is limiting.
 - **Radiation-induced reactions (microwave/radio frequency, lasers, photochemistry)**. These can increase reaction rates selectively by being tuned to the correct frequency to stimulate particular reactions. Microwave generators are commonly available at a small number of frequencies; used alone they can be an expensive form of heating but in combination with other more conventional methods of thermal energy input they are able to achieve rapid yet uniform heating economically.
 - *Use of membranes*. These can be used, for example, to remove products as they are formed, thereby discouraging side reactions or avoiding the reduction of reaction rate by equilibrium constraints. The selective passage of raw materials or products through membranes can be driven by pressure or by the combination of relative diffusivities and solubilities.

- Does the reaction require a solvent and, if so, which particular solvent is the most appropriate?
 - Can the use of a solvent be eliminated (eg. by using one of the reactants or products as a solvent)?
 - Can a solvent of lower volatility or water pollution-potential be used?
 - Can the solvent be readily recovered for re-use?
 - Is the solvent purely to slow down the reaction by dilution so that heat removal can be achieved, for example, or can a more intensive, continuous reactor be used to advantage instead?

- If a catalyst is used, can its removal be achieved more easily, and can it be re-used or recycled?
- Is the order in which the reactants are added optimal for limiting vapour losses and waste production?
- What is required to minimise demand on pressure relief systems, and what are the most appropriate arrangements for pressure control and for over-pressure relief?

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- Can computer control be used to improve yields and consistency between batches or campaigns, whilst minimising routine and non-routine releases?

If expertise in reaction chemistry and/or related chemical engineering is not available in-house for reearch into and selection of candidate processes, the requisite knowledge and experience is available from a variety of engineering consultancies and university departments. Some background papers on novel techniques are included in the References section (see [Ref 21](#)) and simple on-line searches will provide lists of commercial suppliers of reaction/heat-exchange equipment and process know-how.

Indicative BAT requirements for Reactor process design and plant selection

- 1 The physical chemistry of the desired reaction and potential side-reactions should have been characterised and understood, and then chemical engineering principles used to evaluate options for suitable reactor types.
- 2 The reactor system should be selected from a number of potentially suitable reactor designs - conventional STR, process-intensive or novel-technology - by formal comparison of costs and business risks against the assessment of raw material efficiencies and environmental impacts for each of the options.
- 3 Where the activity is an existing activity and achieved raw material efficiencies and waste generation suggest there is significant potential for improvement, studies should be undertaken to review reactor design options based on process-optimisation. The studies should formally compare the costs and business risks, and raw material efficiencies and environmental impacts of the alternative systems with those of the existing system. The scope and depth of the studies should be in proportion to the potential for environmental improvement over the existing reaction system.
- 4 Process yields from the selected reactor design should be maximised, and losses and emissions minimised, by the formalised use of optimised process control and management procedures (both manual and computerised where appropriate).
- 5 The potential for the release of vapours to air from pressure relief systems and the potential for emissions of organic solvents into air or water, should be minimised by formal consideration at the design stage - or formal review of the existing arrangements if that stage has passed.

2.1.3.2 Minimisation of liquid losses from reaction systems

Different products are often made in successive campaigns, and at the end of each campaign it is important to remove as much potential contamination by the preceding batch as possible. The following features may contribute to a reduction in waste arisings from clean-outs:

- Use of low-inventory continuous throughput reactors with minimum surface area for cleaning, where possible.
- Minimum use of internals such as baffles and coils in the reactor.
- Smooth reactor walls, no crevices.
- Flush bottom outlet on reaction vessels.
- All associated piping to slope back to the reactor or to a drain point.
- Sufficient headroom under the reactor for collection of all concentrated drainings in drums or other suitable vessel, if necessary.
- Pipework minimised, and designed to eliminate hold-up and to assist drainage.
- Pipework designed to allow air or nitrogen blowing.
- System kept warm during emptying to facilitate draining.

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- HAZOP studies used to assess the potential for the choking of lines by high-melting-point material.
- Campaigns sequenced so that cleaning between batches is minimised.
- Campaigns made as long as possible to reduce the number of product change-overs.
- Where a complete clean is necessary, cleaning methods used that minimise the use of cleaning agents, (eg. steam-cleaning, rotating spray jets or high-pressure cleaning) or use a solvent which can be re-used. HAZOP studies carried out to minimise the generation of wastes and to examine their treatment/disposal.
- Use of disposable plastic pipe-liners considered.
- Locations for solids to settle-out eliminated or minimised.
- Duplicate or dedicated equipment considered where it can reduce the need for cleaning that is difficult.

Indicative BAT requirements for minimising liquid losses from reaction systems

- 1 The examples above represent good practices which are BAT for some or all reaction systems. The reaction systems should be subjected to a systematic HAZOP study to identify where any improvements can be made, and plans and timetables for modifications should be in place where significant losses can be avoided.

2.1.3.3 Minimisation of vapour losses

During the charging of vessels, vapour losses can be reduced by using dip-pipe or bottom-filling instead of splash-filling from the top. This also reduces the risks of static-induced explosion.

Organics evaporated from reactor systems can be collected ahead of an abatement system in order to achieve direct recovery of the material, the most common method being condensation. Opportunities to enhance the performance of abatement systems, eg. by increasing the heat transfer area or chilling the coolant medium for condensation, or by changing the packing or absorbent in absorption towers, should always be considered.

Indicative BAT requirements for minimising vapour losses from reaction systems

- 1 There are many techniques for minimising the potential for vapour losses and for collection and abatement of vapour displaced into vent lines. Operating practices and vent flows should be formally reviewed to see if improvements need to be made.

2.1.4 Separation stages

On completion of the reaction it is usually necessary to separate the desired product from the other components in the reaction system. Environmental issues can arise because:

- complete separation is rarely achieved and there will be a loss with the reject stream; and
- many separations introduce additional materials to the process, such as solvents or wash water, which ultimately require recovery or disposal.

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2.1.4.1 Liquid-vapour separations

The most widely used vapour-liquid separation techniques are evaporation, steam- or gas-stripping and distillation. The operations need to be carefully designed, and design conditions such as heat input, reflux flows and ratios, etc, must be adhered to for effective separation and minimisation of losses. Contaminants in the liquid phase can cause excessive foaming and the presence of inert non-condensable gases can depress the performance of condensers. Instrumentation needs to be in place to warn of faults in the system, such as a temperature, pressure or low coolant-flow alarms..

Indicative BAT requirements for vapour-liquid separations

- 1 The chosen separation technique should be the result of a detailed process design and HAZOP study (which included consideration of the points above). It should be operated according to formal operating instructions designed to achieve effective separation and minimisation of losses.

2.1.4.2 Liquid-liquid separations

The most widely used liquid-liquid separation techniques are 2-phase extraction with water or solvent, decantation, centrifuging and multi-stage contacting.

Small quantities of surfactant substances can affect dispersion and coalescence, and even with good separation there is usually a secondary haze which, typically, accounts for up to 1% of the required substance remaining in the wrong phase and ending up in the waste stream.

In batch operations, a common problem which results in loss of organics to drain is detection of the interface between the aqueous phase and the organics phase and stopping the flow in time. When a separation is done by hand, a "dead man's handle", backed-up by good management, can be used to improve the chance of the flow being properly controlled as the phase-boundary approaches. Operators should also consider if automatic detection of the interface is practicable - and if discharge to drain without the use of an intermediate holding or "guard" tank to protect against accidental losses from the organics phase, is an acceptable risk.

Indicative BAT requirements for liquid-liquid separations

- 1 Techniques which maximise physical separation of the phases (and also aim to minimise mutual solubility) should be used where practicable.
- 2 When the phases are separated, techniques should be used which prevent (or minimise the probability and size of) breakthrough of the organics phase into a waste-water stream. This is particularly important where the environmental consequences of subsequent releases of organics to air or into controlled waters may be significant (eg. where the effluent is treated in a DAF unit or some of the organic components are resistant to biological treatment).

2.1.4.3 Solid-liquid separations

The main solid-liquid techniques are centrifuging, filtration, sedimentation, clarification, drying and ion-exchange. Most solid-liquid separations involve washing stages and thus have the potential to produce significant quantities of waste water - so recycling possibilities need to be considered. Many filtrations

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require the use of added solid filter aid to improve filtration, and this increases the solid load ultimately requiring disposal. Countercurrent washing where multiple stages are involved allows a significant reduction in the volume of wash water used.

All of the techniques are vulnerable to solids breakthrough so instrumentation or other means of detecting malfunction should be installed. "Guard" filters of smaller capacity are often installed downstream which, in the event of breakthrough, rapidly 'clog' and prevent further losses. Good management procedures are required to minimise loss of solids, escape of volatiles to air and excessive production of waste water.

Indicative BAT requirements for solid-liquid separations

- 1 Different separation techniques will be BAT for different applications, with factors like solubility, crystallisation rate and granular size being important. However, techniques to minimise, re-use and/or recycle rinse water, and techniques to prevent breakthrough of solids should be used.

2.1.5 Purification stage

Waste associated with the purification stage may arise from:

- Impurities in the raw materials - so a change in the raw material specifications may reduce waste arisings.
- By-products generated by the process - so a change in reaction conditions, catalyst, solvent, etc may improve the selectivity of the reaction and reduce or eliminate by-product formation (see Section 2.1.3.1)

Indicative BAT requirements for Purification stages

- 1 There are many techniques which will qualify as BAT for different purification activities. Standard chemical engineering principles should be applied to minimise losses and the production of waste and waste-waters - with particular consideration being given to the points noted in Sections 2.1.5.1 and 2.1.5.2 below.

2.1.5.1 Purification of liquid products

Liquid products are usually refined by distillation, with filtration used to remove solid contaminants. Sources of loss are:

- **Gas entrainment.** Gas or vapour flow will carry away volatile material either as vapour or as entrained droplets. Additional condenser heat-exchange area or colder heat-exchange fluid can improve the recovery rate, and coalescing demisters are relatively cheap and easy to install.
- **Ineffective separation.** A better separation in the distillation column can be achieved by using more stages (theoretical plates) or more reflux. Modern types of packing or high-efficiency trays can often produce a marked improvement for a modest capital investment.
- **Filtration.** Enclosed filtration is usually used and this is not normally a source of great vapour loss to air. Liquid discharged during cleaning or changing of filters should be returned to the process.

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2.1.5.2 Purification of solid products

Washing and crystallising activities have the potential to produce large volumes of dilute liquors so counter-current systems of operation should be used wherever possible.

During drying, the aim should be to produce the maximum concentration of solvent in the gas to allow recovery of the solvent. The use of vacuum during drying can improve both solvent recovery and energy efficiency.

2.1.6 Design of a new process

During new project development, environmental issues should be an integral part of discussion at every stage of the design, beginning with the initial concepts. Section 2.1.3.1 explained in some detail the need in reactor design to distinguish between process design (where the science underpinning the essential chemical and physical transformations to be achieved is explored and understood) and the plant design (which selects appropriate hardware in which to perform the operations on the full scale), with the former to be essentially complete before hardware selection starts. The same philosophy is relevant to other unit operations and should be applied to the design of the rest of the installation.

At the initial stage of the development of the process there should be a formal and comprehensive study - the first stage in a formal HAZOP study - of the likely environmental consequences from:

- the use of all raw materials, and production of all intermediates and products;
- all routine emissions, discharges and solid/liquid waste streams; and
- non-routine or unplanned releases and disposals from, for example:
 - start-ups and shutdowns;
 - off-specification products;
 - spillages; and
 - pressure relief.

Every emission, discharge and waste stream from the process should be considered as another product whose quantity and quality are measured, controlled and recorded. This includes releases generated from non-routine cleaning or maintenance operations.

All realistic options for minimising pollution should have been considered from the outset, and where end-of-pipe techniques are proposed, the costs of abatement, waste treatment and waste disposal should be formally compared with alternatives for waste minimisation at source.

The whole study should use formal HAZOP techniques, and the quality and effectiveness of the study will depend upon the calibre and the commitment of the members of the team involved - which should include process engineers, design engineers, operational staff (including those who operate shared facilities like waste-water treatment plants, etc) and it is vital that environmental specialists are also members of the team.

A key purpose of the first part of the HAZOP study is the production of a preliminary environmental statement for the proposed operation, and this should cover the following points:

- **Identification and characterisation.** This should identify all potential releases.
- **Segregation of all releases.** This allows measurement and diagnosis; it also retains the flexibility to pursue recovery, recycling and other waste minimisation opportunities.

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- **Treatment of waste streams at source.** Most segregated waste streams are more concentrated, of lower volume, and less complex mixtures than combined flows so separate treatment should be considered.
- **Containment of spills.** It is important to ensure that all potential spillages are contained, the potential for recovery considered and, where this is not feasible, suitable disposal routes developed.
- *Fugitive emissions.* Specification of equipment should take into account the likelihood of fugitive emissions, and the positions of piping and of vessels should allow rapid detection and rectification of leaks.
- **Provision for effluent flow equalisation and for emergency discharges.** If effluent treatment is on-site the installation must be capable of dealing with fluctuations in flow, composition and concentration - which usually means the provision of holding and balancing tanks. Emergency effluent storage may be required to cope with unusual events such as fire-fighting water. Further guidance is provided in PPG18 (Reference 10)
- *Abatement system reliability.* If, in the event of primary system failure, the process cannot be stopped quickly enough to prevent an emission then strong consideration should be given to the provision of a secondary back-up system.

Indicative BAT requirements for the design of a new chemical production process

- 1 Any new project for manufacturing chemicals should include consideration of all potential environmental impacts from the outset, with appropriate stages of a formal HAZOP study being undertaken as the project progresses through the process design and plant design phases. The HAZOP studies should consider, amongst other things, the points noted above.

2.1.7 Environmental Performance Indicators

Benchmark values in this guidance are typically presented as concentrations (e.g. mg/l, mg/Nm³). Concentrations are the traditional basis for setting emission limits in permits as they are good indicators of unit operation performance but they have limitations. Thus, for England and Wales, the Environment Agency is developing complementary “Environmental Performance Indicators” that could help to target regulatory effort on the most important environmental issues.

Environmental Performance Indicators involve using emission data to:

- Normalise for the scale of process operation - to benchmark the emissions from installations that have different sizes and product mixes (e.g. quantity of emitted pollutant per unit of production).
- Calculate “Environmental Burdens” - using equivalency factors to determine the significance of emissions in terms of recognised environmental impacts.

Consideration is being given to a range of Environmental Performance Indicators, including:

For Air:

Stratospheric Ozone Depletion,
 Global Warming (both from the installation and from imported power),
 Photochemical Ozone Creation,
 Airborne Acidification.

For Water:

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Acidification,
Oxygen Demand,
Eutrophication.

For Waste:

Waste Hazard Score (from H1),
Waste Disposal Score (from H1).

For raw materials:

Water use (potable and non-potable).

For hazardous substances:

Environmental Health,
Human Health.

In the absence of any guidelines for the calculation of Environmental Performance Indicators, there are no indicative BAT requirements. However, Operators in England or Wales should demonstrate to the Environment Agency that they have their own methods of monitoring and benchmarking their environmental performance and show how these are used to drive environmental improvements.

The choice of Environmental Performance Indicators is left to Operators but they should give consideration to the issues that are listed above. The H1 database tool is advocated as providing a simple solution.

In future the Environment Agency may recommend specific methodologies for calculating Environmental Burden and/or normalising for scale. Research projects are currently under way to develop these systems.

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In-process controls	Emissions control	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.2 Emissions control

2.2.1 Point source emissions to air

The nature and source of the emissions expected from each activity is given in previous sections and the inventory of emissions should be confirmed in detail in the Application.

A wide variety of techniques are available for the control of releases to air, and the BREF on Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector (see [Ref 1](#)) should be consulted. Section 3.5 of the BREF has details of available air abatement techniques and Section 4.3.2 contains recommendations on what might constitute BAT for a variety of abatement techniques for releases to air.

The abatement of releases of volatile organic compounds (VOCs) is probably the primary concern for this sector so the following section in this Note concentrates on VOC control. Some guidance is also provided, however, for the control of particulate emissions and cooling tower emissions as these are common in the sector.

For a diverse sector like Speciality Organics, none of the abatement techniques described in the following sub-sections for controlling emissions to air can be described as BAT for all situations; the particular circumstances of the installation will effect assessments of which is best. There are however a few general requirements which should be considered as being part of BAT for control of emissions to air from point sources, and these are included in the following BAT box.

Indicative BAT requirements for the control of point-source emissions to air (Sheet 1 of 2)

- 1 In conjunction with information in this Guidance Note, information and recommendations in the BREF on Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector (see Reference 1) should be formally considered as part of the assessment of BAT for point-source releases to air.
- 2 The benchmark values for point source emissions to air listed in [Section 3.2.1](#) should be achieved unless alternative values are justified and agreed with the Regulator.
- 3 The main chemical constituents of the emissions should be identified, including VOC speciation where practicable.
- 4 Vent and chimney heights should be assessed for dispersion capability and an assessment made of the fate of the substances emitted to the environment (see [Section 4](#)).

Control of visible particulate plumes

- 5 Even where particulate benchmarks are already met, the aim should be to avoid visible emissions. However, because plume visibility is extremely dependent on the particle size and reflectivity, the angle of the light, and the sky background, it is accepted that, even when BAT is employed and very low emissions are being achieved, some plumes may still be visible under particular conditions.

Introduction		Techniques for pollution control			Emissions			Impact			
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Indicative BAT requirements for the control of point-source emissions to air (Sheet 2 of 2)

Control of visible condensed water plumes

- 6 The need to minimise water vapour plumes should always be considered as, in addition to possible local visual amenity issues, in severe cases, plumes can cause loss of light, fogging, icing of roads, etc. High moisture content can also adversely affect plume dispersion so, where practicable, water content of the exhaust stream should be reduced. Ideally, the exhaust should be discharged at conditions of temperature and moisture content that avoid saturation under a wide range of meteorological conditions, including cold damp conditions.
- 7 The use of **primary energy** to reduce a plume simply because it is visible is not considered BAT. However, it may be appropriate to use **waste or recovered heat**, for example, heat in a gas stream prior to wet scrubbing can be used for re-heating the exhaust stream after scrubbing by means of a gas-gas heat exchanger. The use of energy for exhaust gas re-heat should be balanced against the benefits gained.
- 8 For cooling towers, plume abatement may be achieved by combining conductive heat exchange and evaporative cooling in the design of the tower. The degree of abatement required will depend upon local conditions and the distance from the towers to the nearest sensitive area. Plume modelling should be employed by an applicant to confirm that the visible (condensed) plume will not ground beyond the boundary fence nor reach areas of habitation at a height that will cause significant loss of light. As a guide, the width of the plume should not fill an arc which subtends an angle greater than 10° when viewed vertically from the ground.

2.2.1.1 Control of emissions of volatile organic compounds (VOCs)

Releases of VOCs may be broadly characterised as those from:

- fugitive sources (leaking valves, pumps, etc)
- point sources (reactor, separator release points, etc, as well as situations where fugitive emissions are collected and sent for end-of-pipe abatement)

Techniques for the abatement of the former are process-related and are discussed in [Section 2.2.4](#) of this Note. The main issues that influence the selection and cost of VOC abatement techniques for this sector are:

- the intermittent nature of releases from batch processes
- and the complex nature of the gas streams involved, with many different VOCs often being present as well as moisture, particulates and acid gases

Both of these issues have a profound influence on the selection of abatement techniques. The Environment Agency (or its predecessor) has issued guidance on abatement techniques to deal with:

- particulates – Technical Guidance Note (Abatement) A3
- acid gases – Technical Guidance Note (Abatement) A3
- combustion by-products - IPC Guidance Notes on Combustion Processes (S2 1.01) and Incineration (S2 5.01) respectively

These documents should be referred to where these pollutants are of relevance. (See [Ref 9](#) and [Ref 20](#))

Before selecting the appropriate technique(s) it is important to quantify systematically flows, chemical compounds and concentrations over all potential operating conditions.

Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions control	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

Quantification allows opportunities for in-process minimisation to be considered as well as aiding in the selection of the appropriate abatement techniques. Particular attention may have to be given to vent header systems that receive gas streams from a number of different sources.

Techniques for the abatement of VOCs may be broadly characterised as those that:

- recover the VOC and offer the potential for recycle/re-use (adsorption, absorption and condensation)
- destroy the VOC (thermal, catalytic, flameless and biological oxidation, respectively)

Unless a viable recycle/re-use route is available for the former techniques, then there will still be a need for disposal. All of these techniques have been and will continue to be widely applied in the sector.

2.2.1.1.1 Recovery versus destruction for VOCs

Recovery followed by re-use/recycling is generally preferable compared to destruction. A number of issues need to be considered when deciding if this is a viable option. These include:

- Composition of the gas stream. Generally the more complex the mixture of VOCs, the harder it will be to justify recovery technically or economically unless recovery is to be followed by energy recovery rather than re-use/recycle.
- Quality requirements. It may not be possible to recover the target VOC(s) with a quality sufficient to satisfy the requirements of re-use/recycle.
- Economics. The economics of recovery will reflect the complexities associated with the gas stream's composition and the quality requirements of the process as well as such considerations as the cost of the VOC and the volume that can be recovered.
- Release levels. In certain situations recovery techniques may not provide sufficiently good release levels.

2.2.1.1.2 Adsorption of VOCs

Adsorption requires a consideration of the following factors:

Arrangement of adsorption system

There are five ways of supporting the adsorbent in adsorption systems:

- *Canister capture systems* can be fitted readily to sources of low flow and concentration. The operator should have a procedure that anticipates or detects breakthrough in the system. Spent canisters need to be disposed of.
- *Skid-mounted capture systems* are larger than canister systems (typically containing 1000 kg of adsorbent compared to 75 kg in a canister) but they are still mobile and can be retrofitted with relative ease. Skid-mounted systems are usually returned to the supplier for regeneration.
- *Fixed-bed systems* consist of two or more fixed adsorption beds. At any given time, one bed will be operating on-line, whilst the other bed is regenerated. Three beds may be used, where one bed is kept on stand-by in case of primary bed failure.
- *Fluidised beds* use a fluidised rather than solid bed of adsorbent. They tend to be more complex than fixed-bed systems but their smaller size may be an advantage. Attrition may require new adsorbent to be added periodically and may also cause entrainment of particulates in the exhaust gas stream.
- *Continuous adsorption-desorption* is not widely used in this sector, being more complex and expensive to operate and usually more appropriately applied to continuous processes.

Adsorbent

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A number of adsorbents are available. The main ones are summarised in [Table 2.1](#) together with some of their strengths and weaknesses.

Table 2.1: Main Adsorbents

Adsorbent	Strengths	Weaknesses
Granular activated carbon (GAC)	<ul style="list-style-type: none"> -Good for non-polar compounds. -Extensive experience of their application in a wide range of situations. -Wide range of grades available at different costs to deal with a diversity of operating conditions, VOCs and desired release levels. 	<ul style="list-style-type: none"> -Poor for polar compounds; -Poor for high VOC concentrations (above 10000 ppm). -Poor for very high or low molecular masses (only effective in the range 45–130). -Poor for mixtures of high- and low-boiling point VOCs. -Poor for relative humidities above 50%. -Poor for reactive compounds (organic acids, aldehydes, ketones and monomers). -Poor for high-boiling-point compounds (plasticisers, resins, long-chain hydrocarbons (C14 and above), phenols, glycols and amines).
Activated carbon mat	<ul style="list-style-type: none"> -Good for non-polar compounds and can be used for the removal of VOCs. -Compared to GAC, they have a relatively large number of adsorption points per unit volume, which reduces the number of regenerations required. 	<ul style="list-style-type: none"> -As for GAC. -Significantly more expensive than GAC.
Macroporous polymer particles	<ul style="list-style-type: none"> -Good for non-polar compounds and can be used for the removal of VOCs. -Good for continuous adsorption/desorption processes. -Durable. -Unaffected by high humidity, does not catalyse degradation of unstable VOCs. -High-purity VOCs recovered. - 	<ul style="list-style-type: none"> -Significantly more expensive than GAC. -Cannot be used for very polar compounds. -Cannot be used for low boiling compounds.
Molecular sieve zeolites;	<ul style="list-style-type: none"> -Can be used for the removal of VOCs, although not widely applied for this purpose. -Good for dehydrating gas streams. -Hydrophobic zeolites are available that have a higher capacity than GAC at low VOC inlet concentrations and a higher capacity at high relative humidities (above 50%). -Non-flammable, therefore good with VOCs that may present a fire risk. -Uniform size of pores means they can be used to separate compounds on the basis of molecular mass and shape. 	<ul style="list-style-type: none"> -Expensive. -If dehydration is not desired, can preferentially adsorb water and allow pollutant to pass through.
Silica gel.	<ul style="list-style-type: none"> -Good for dehydrating gas streams. 	<ul style="list-style-type: none"> -Generally not effective for VOCs. -Ineffective above 260oC.
Sodium aluminium silicates	<ul style="list-style-type: none"> -Good for the removal of carbon dioxide, hydrogen sulphide, sulphur dioxide. 	<ul style="list-style-type: none"> -Generally not effective for VOCs. -Ineffective above 260oC.

Adsorption/desorption properties of VOCs

Introduction		Techniques for pollution control			Emissions			Impact			
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As it is the most widely used adsorbent in the chemical industry, this section relates to the use of GAC. Activated carbon mat and macroporous polymers will have broadly similar strengths and weaknesses, whilst zeolites, silica gel and silicates will be more appropriately used for polar compounds. Certain types of substance are particularly amenable to adsorption by GAC. These include those with the following properties:

- relatively high molecular mass and/or boiling point (mass 45–130)
- low polarity
- cyclic rather than linear molecules
- unsaturated rather than saturated compounds
- compounds with a low volatility

However, not all substances that are readily adsorbed are as easy to desorb and thus recover. This may be because:

- the energy requirements to separate the pollutant from the adsorbent are excessive, eg. high boiling point VOCs
- the adsorbent may catalyse the decomposition of the pollutant, eg. cyclohexanone tends to polymerise on GAC
- certain compounds, in particular ketones, may present a combustion risk because of the large amounts of heat that they liberate during the adsorption process
- the wider the variety of VOCs that are present in the gas stream, the more likely that non-uniform adsorption will take place

Physical characteristics of gas stream

Good adsorption is promoted by:

- low flow rates and low temperatures, both of which increase residence time in the bed
- increased pressure
- minimising moisture and particles in the gas stream, both of which may blind, and thus reduce the availability of, adsorption points
- uniform airflow distribution so that the full capacity of the adsorbent is utilised
- sufficient adsorbent capacity to deal with projected airflows and concentrations

Pre-treatment of the gas stream may be necessary to ensure that these requirements are achieved. This usually adds to the overall cost and complexity of the system.

Regeneration of adsorbents

Regeneration is required for all but canister systems. The main options are as follows.

- **Regeneration of fixed beds.** A number of options exist for regenerating saturated fixed beds. These include:
 - *Thermal swing.* The temperature of the bed is elevated, usually using saturated steam to desorb the VOCs. An effluent is generated that will require either treatment then disposal or the use of a separation technique to allow re-use/recycle.
 - *Inert gas.* Hot inert gas (usually nitrogen at 200–300°C) is passed through the saturated bed. Once any moisture is removed, the inert gas strips out the pollutant, which is then recovered by condensation.
 - *Vacuum.* A vacuum is applied to the bed, which allows the pollutant to be re-vaporised. The pollutant is then removed from the system by back-purging and subsequently recovered by condensation.
 - *Displacement cycle.* This is an infrequently used approach whereby the adsorbed material is preferentially displaced by another material. It will only be applied when the adsorbate is both temperature-sensitive and valuable, and vacuum desorption is ineffective.

Introduction		Techniques for pollution control			Emissions			Impact			
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- *Regeneration by continuous adsorption and desorption.* In rotating systems the desorption stage may be based on either steam or hot, inert gas and the comments made above are generally applicable. In tower systems the desorption system is usually based on hot, inert gas.
- *Control of adsorption techniques.* Instrumentation has been developed that allows fixed beds to be switched when the concentration of the pollutant in the exit gas reaches a pre-determined level. There is a risk that VOCs adsorbed onto the bed whilst the process is operating may be desorbed when the bed is out of use. To prevent this happening the gas flow should be diverted away from the bed during intervals when no production is occurring

2.2.1.1.3 Condensation of VOCs

Condensation can in theory be applied to any pollutant in any gas stream. In practice the main constraint on its use is the condensation temperature that has to be achieved. Particularly low temperatures will be required for gas streams containing:

- low-boiling-point pollutants
- low concentrations of pollutants
- high concentrations of non-condensable material

The main condensation systems are:

- coolant/refrigeration
- cryogenic nitrogen

The main difference between the systems is the temperature that they can achieve.

VOC Condensation by air, water or refrigeration coolant

These systems have been widely applied in the sector. A diverse range of coolants/refrigerants are available to cover the temperature range of ambient to about -70°C. Either indirect cooling or direct cooling of the gas stream can be used. Direct cooling requires the coolant to be separated from the VOC and is rarely used. For low-volatility substances that condense with relative ease, air or water systems may be appropriate. For lower temperatures chilled water/air or brine may be used, whilst glycol may offer opportunities for further temperatures reductions. A series of condensers at progressively lower temperatures may be required to prevent process blockage.

VOC Condensation by Cryogenic nitrogen

Cryogenic nitrogen systems have only recently been applied on an industrial basis. They can achieve significantly lower temperatures than coolant/refrigerant systems, can be applied to a wider range of compounds and achieve better removal rates.

Cryogenic nitrogen condensation systems use the evaporation of liquid nitrogen to form nitrogen gas to provide cooling. They may be particularly appropriate for processes or sites that already utilise liquid nitrogen in amounts similar to the requirements of the cryogenic abatement system.

If liquid nitrogen is used on-site and the correct balance can be achieved, there appear to be a number of advantages in applying cryogenic nitrogen techniques. These include:

- all VOCs can theoretically be removed from a gas stream to better than 99%
- there is considerable future-proofing built into the technique, ie. operating temperatures can be varied for new pollutants and/or tighter release levels
- systems can be designed to deal with the fluctuations in flow and concentration
- the condensed VOCs are not contaminated with other materials

A dual system of condensers alternately cooling and warming may be necessary to handle materials that freeze (eg. traces of water vapour).

Control of condensation techniques

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Condensers are generally easier to control than other techniques, with the outlet gas temperature being the main indicator of removal efficiency.

2.2.1.1.4 Absorption of VOCs

The main variables in selecting an absorption system are the following:

- physical characteristics of the gas stream
- chemical characteristics of the VOC and the scrubber liquid
- process unit design for contacting VOC with scrubber liquid

Physical characteristics of gas stream

The lower the temperature of the gas stream, the better will be the transfer between the gas and liquid phases. Lower temperatures also reduce the risk of losses of scrubber liquids due to evaporation.

Chemical characteristics of pollutant and scrubber liquid

In selecting scrubber liquids, operators need to be aware of the following issues:

- If a non-water-based scrubbing liquid is to be used, there is the potential for it to be volatilised and lost to atmosphere.
- The scrubber liquid needs to have an effective life in the system and therefore should not be susceptible to thermal or chemical degradation.
- Flammable, toxic and odorous scrubbing liquids should generally be avoided.
- The VOC needs to be at least partially soluble in the scrubbing liquid.
- Mass transfer may be enhanced by the use of appropriate surfactants.

Process unit design for contacting VOC with scrubber liquid

- The process unit used will depend upon the chemical and physical characteristics of the gas stream to be treated as well as the desired removal efficiency. A wide range of process units are available. These include:
 - packed towers
 - moving or fluidised beds
 - plate towers
 - impingement plates
 - spray towers
 - wet mop scrubbers and rotacloves
 - void towers

Control of absorption systems

A number of variables can be varied to optimise performance. These variables include:

- temperature of gas and scrubber liquid
- circulation rate of the scrubber liquid
- design of column

The gas stream may be cooled to its saturation temperature and cause a visible plume to be formed. Potential controls include fitting a demister, a knock out pot or reheating.

2.2.1.1.5 Thermal destruction of VOCs

Thermal processes rely on the thermally induced breakdown (oxidation) of pollutants. The main thermal processes are:

- (high-temperature) thermal oxidation
- (low-temperature) catalytic oxidation
- flameless thermal oxidation
- flares

Thermal oxidation

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The use of thermal oxidisers is discussed in the IPC Guidance Note on Waste Incineration (S2 5.01). The main issues of relevance to this sector are as follows:

- Compared to other techniques it can achieve very good removal efficiencies under a wide variety of conditions.
- A supplementary energy source may be required to support the oxidation of VOCs with a low heat content or dilute flows (ie. below autothermal conditions).
- The heat generated from oxidation can often be used beneficially.
- Highly variable flows may reduce the efficiency of oxidation. The use of pre-concentrators may allow the flow to be evened out over time.
- Safety devices will be required, for example flame arresters, to provide a screen between the process and the abatement technique.
- Oxidation may give rise to secondary pollutants such as acid gases that require subsequent treatment.
- There is potential for the formation of dioxins in the presence of halogens. Correct design and operation should prevent this problem occurring

Catalytic oxidation

Catalytic oxidation uses a catalyst bed to promote the oxidation process at a lower temperature than is required by thermal oxidation. This has the advantage of reducing:

- auxiliary fuel requirements
- the need for the oxidiser to be constructed out of expensive and heavy high-temperature-proof materials
- the chance of secondary pollutants such as NO_x being formed

However, they have certain disadvantages. In particular, they are susceptible to poisoning and/or blinding by constituents of the gas stream. Metals (arsenic, antimony, lead, mercury, etc) and chlorine- and sulphur-containing compounds have traditionally been the main catalyst poisons

Chrome/alumina, cobalt oxide, and copper oxide/manganese oxides have been developed for the control of chlorinated compounds. Platinum-based catalysts have been developed to deal with sulphur-containing compounds, although these catalysts are still susceptible to poisoning by chlorinated compounds. Compounds containing lead, arsenic and phosphorus are still fast-acting catalyst poisons under most conditions.

Fluidised-bed systems allow catalyst to be constantly replaced, thus reducing the impact of poisons. Attrition of the catalyst in the fluidised bed may result in particulates being entrained in the exhaust stream. Particulates may not only blind but also abrade the surface of the catalyst. Excessive temperatures, concentrations and concentration fluctuations may also damage the catalyst bed.

Recovery of energy in VOC destruction systems

An important consideration in utilising a thermal technique is the potential it provides for the recovery of useful heat energy. The main ways of recovering heat energy are the following:

- Recuperative systems use a shell and tube or other type of heat exchanger to recover heat from the hot exhaust gas and use it to preheat the incoming gas.
- Regenerative systems utilise two or more ceramic beds. Hot exhaust gas is used to heat one bed, whilst the other bed heats the inlet gas. The beds are periodically switched, leading to a net exchange of heat from exhaust to inlet gas. Purge systems, which have a third bed, ensure that the small volume of inlet gas left in a bed on swapping is not lost, unabated, in the exhaust gas.

The decision as to which energy recovery system should be utilised will be site-specific.

Gas stream characteristics of VOC destruction systems

The following gas stream characteristics may influence the use of oxidation techniques:

- The presence of moisture tends to increase secondary fuel requirements.

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- Certain pollutants may need to be removed from the gas stream prior to incineration, in particular those that may foul/corrode the system or poison catalytic beds.
- An excess of air is required to provide sufficient oxygen to allow complete oxidation.

Control of thermal and catalytic oxidation techniques

The main issues to be considered in operating an oxidiser are:

- the residence time of the gas stream in the combustion chamber
- the oxygen content in the combustion chamber
- the operating temperature in the combustion chamber
- turbulence in the combustion chamber
- the use of a flame detector

Many problems associated with thermal oxidisers have arisen from poor burner operation and poor start up/shut-down procedures. An operator should be able to demonstrate that robust operating procedures, including good monitoring and maintenance programmes, are being utilised.

Flameless thermal oxidation

Flameless thermal oxidation uses an inert, hot ceramic matrix to support oxidation. Once oxidation has been initiated, radiation and convection transfer heat to the incoming gas stream, raising its temperature to the ignition point. Unlike other types of oxidiser no flame is present and so the potential for the formation of NO_x is reduced. They may be particularly suitable for the variations in flow and concentration characteristic of this sector. Similar benefits may be achieved in a regenerative system operating under autothermal conditions.

Flares

Flaring should be confined to emergency use. It is not widely practised in the sector and HMIP Technical Guidance Note A1 should be referred to for information on its use. Flaring of halogenated compounds should be avoided.

2.2.1.1.6 Biological oxidation of VOCs

This is a destructive technique that relies on the biologically induced oxidation of VOCs to form water and carbon dioxide. The main biological systems are:

- biofiltration, where the gas stream is passed through a moist substrate (peat, heather, etc), which supports the micro-organisms;
- bioscrubbing, where the gas stream is passed through a trickling filter or column; and bioreactors, where micro-organisms are supported on an artificial substrate in a reactor

All three systems operate on the same basic premiss, that certain organic compounds can be readily biodegraded by micro-organisms. The respective strengths and weaknesses of the three systems have been summarised by the DTI's BMB Initiative(34) and are reproduced in [Table 2.2](#)

Table 2.2: Summary of strengths and weaknesses of biological systems

System	Application	Strengths	Weaknesses
Biofilter	<0.5 g/m ³	High gas/liquid surface area. Works for VOCs and odours of medium solubility. Easy operation and start-p. Low operation costs.	Poor control of reaction conditions. Slow adaptation to fluctuating concentrations in gas stream. Large area required.

Introduction		Techniques for pollution control			Emissions			Impact			
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Table 2.2: Summary of strengths and weaknesses of biological systems

System	Application	Strengths	Weaknesses
Biotrickling filters	<0.5 g/m ³	Comparable to bioscrubbing. Better retention of slow-growing micro-organisms. Single reactor.	Low surface area for mass transfer. Higher operational costs than biofilters. Potential clogging.
Bioscrubbers	<3.0 g/m ³	Better control of reaction conditions (pH, nutrients). Possibilities to avoid accumulation of products. Compact equipment. Low pressure drop.	Low surface area for mass transfer. Disposal of excess sludge. Extra air supply needed at high degradation rates Higher investment and operational costs

VOCs that can be destroyed by Biological oxidation

In theory any VOC can be biologically oxidised, but in practice the time taken to oxidise certain compounds (the residence time) precludes their control by this method. [Table 2.3](#) summarises the biodegradability of some VOCs.

Table 2.3: Biodegradability of VOCs

Relative speed of biodegradation	VOC
Rapid	Alcohols Aldehydes Amines Organic acids
Good	Esters Ketones Phenols Mercaptans
Slow	Aliphatic hydrocarbons
Very slow	Halogenated hydrocarbons Polyaromatic hydrocarbons

Operating conditions applicable to Biological oxidation

A number of factors need to be considered when operating biological techniques:

- The water content and temperature of biological systems are critical.
- Poor solubility of the target VOC in water slows this mass transfer and reduces the viability of biological oxidation.
- Biological systems are susceptible to inhibition, particle blinding and excess temperature, all of which can reduce the effectiveness of the biological population in the system. Inhibition may be caused by certain toxic gases (hydrogen sulphide, carbon monoxide), acid gases, heavy metals and high concentrations of cyanide.
- Systems usually need a fairly constant throughput (in terms of both flow and concentration), although recent innovations have seen the introduction of activated carbon substrates that can buffer the system against 'spikes' in concentration.
- Nutrients, oxygen and a neutral pH are required.
- Biological systems can be particularly effective with large volumes of gas containing low concentrations of VOC.
- Systems can be 'switched off' between batches, but for longer downtimes, typically over 1–2 weeks, an artificial feed may have to be dosed to the system.
- Trials will be required before the installation of any system to identify the optimum microbiological community and operating conditions.

Introduction		Techniques for pollution control			Emissions			Impact			
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- The system will need to be acclimatised to the target VOC(s). Changes in the VOCs in the gas stream may necessitate a re-acclimatisation period or even a change in the biological community.
- Biofilter beds tend to consolidate and may need periodic reworking

2.2.1.1.7 Polymer membranes to separate VOCs

Polymer membranes allow certain molecules preferentially to pass through them. If the concentration of the VOC in the gas stream is low, then a high vacuum will be required to draw the VOC molecules through the membrane. Polymer membranes have not been demonstrated as abatement techniques in this sector because of their:

- low transmission fluxes, which means that very large membranes are needed to deal with the flows typical of the sector
- poor selectivity for the most commonly used solvents

Envirowise has published a solvent recovery guide which provides a useful overview of the respective merits of the techniques ([Ref 7](#)), and its summary is the basis of [Table 2.4](#).

[Figure 2.1](#) summarises the concentration/flow ranges for which individual techniques may be particularly suitable and provides broad estimates of the removal efficiencies they can achieve.

Table 2.4: Summary of the strengths and weaknesses of VOC control techniques

Issue	Recovery and re-use techniques			Destructive techniques		
	Adsorption	Condensation	Absorption	Thermal oxidation	Catalytic oxidation	Biological
Low flow/low concentration	A	B	A	B	D	A
High flow/low concentration	A	C	C	B	A	A
Low flow/high concentration	D	A	A	A	D	B-D
High flow/high concentration	D	A	B	A	D	E
Hydrocarbon gases	D	E	B-D	A	A	A-C
Halogenated or sulphonated organic gases	D	E	A	B	D	C-E
Aminated organic gases	D	E	C-D	C	C	B-C
Hydrocarbon condensables	A	A	B-C	A	A	A-C
Halogenated or sulphonated organic condensables	A	A	A-B	B	D	C-E
Aminated organic condensables	A	A	B	C	C	A-C
Continuous	A	A	A	A	A	A
Batch or variable	A	A	A	D	D	A

Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions control	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

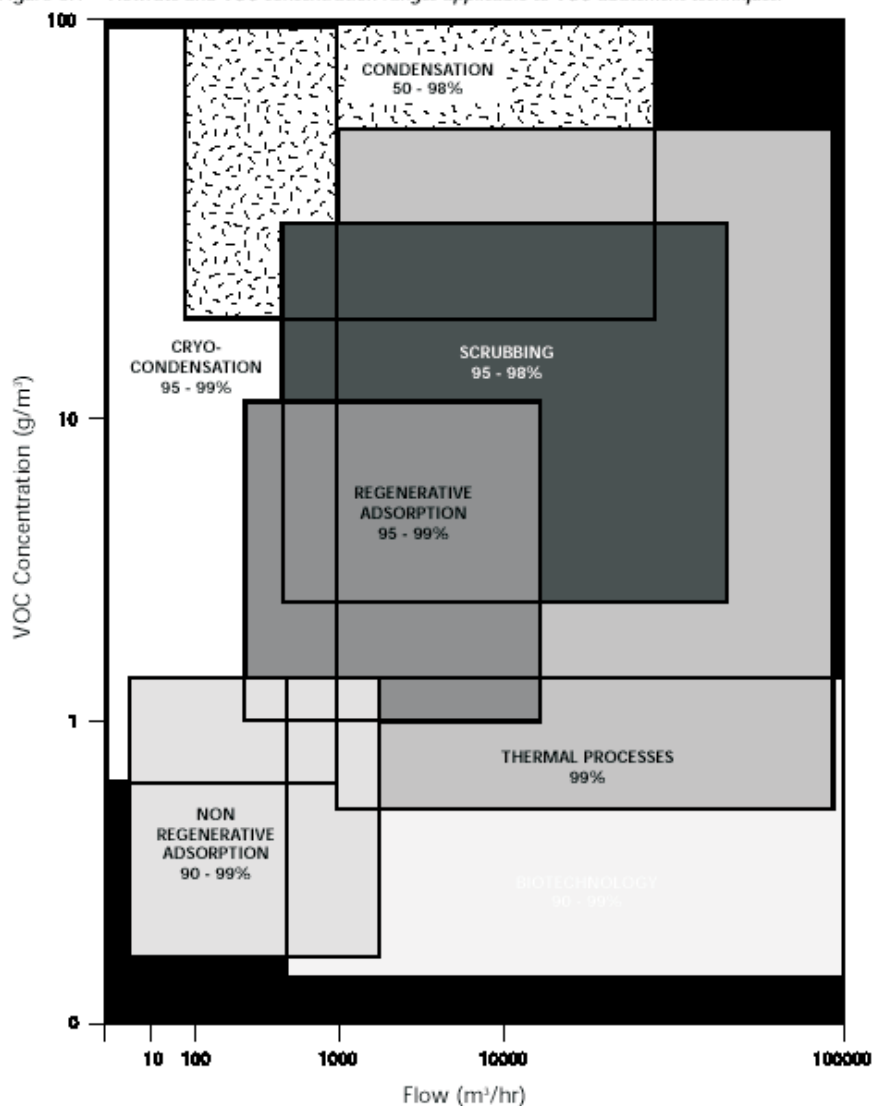
Table 2.4: Summary of the strengths and weaknesses of VOC control techniques

Issue	Recovery and re-use techniques			Destructive techniques		
Removal efficiency	B	C	A	B	C	A-B
Pressure drop	C	B	B	A	C	A
VOC recovery	B	A	B	E	E	E

Key: A = Excellent B = Good C = Satisfactory D = Poor E = Unacceptable

Figure 2.1: Flowrate and VOC concentration ranges applicable to VOC abatement techniques

Figure 3.1 Flowrate and VOC concentration ranges applicable to VOC abatement techniques.



Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions control	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.2.1.2 Control of emissions of particulates

In addition to the Waste Water and Waste Gas Treatment BREF ([Ref 1](#)), HMIP Technical Guidance Note (A3) is a useful source of information on BAT in this sector ([Ref 9](#)). The main techniques that are available for the control of particulates are:

- scrubbing
- cyclones
- filters
- electrostatic precipitators

2.2.1.2.1 Scrubbing

Scrubbing operates on the principle that particulates can be removed from the gas stream by dissipating their momentum. This dissipation can be achieved either by impacting the particulate on to the scrubbing liquid or by impacting a solid surface, which is then washed.

The main delivery systems for contacting the scrubbing liquid with the gas stream are broadly similar to those used for VOCs. Scrubbing systems tend to be less effective than other alternatives for the control of particles <10 micrometres. They also generate an effluent that will require treatment.

2.2.1.2.2 Cyclones

Cyclones are particularly effective for the removal of particles with a diameter >10 micrometres and are often used as a secondary device for the protection of more expensive abatement equipment that can achieve better release levels.

There are two basic types of cyclone:

- reverse flow
- straight through

These are differentiated by the geometry with which the gas stream enters the cyclone. The design of a cyclone will depend upon the particular gas stream that is being dealt with. Recent innovations have seen the development of cyclones containing a rotating impeller to improve removal efficiencies.

2.2.1.2.3 Filters

Filters are widely used for the collection of particulates > 1 micrometre and can usually achieve efficiencies of greater than 99%. The main variables that are available in designing filters are:

- the filter medium
- the manner in which the filter is periodically cleaned

Filter Media

A number of filter media are available to deal with a wide range of variables such as temperature, corrosiveness, composition, particle size, etc. The most commonly used filter medium is fabric.

[Table 2.5](#) summarises some of the more important fabrics that are used as filter media.

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Filters can cope with a wide range of substances and operating conditions but there are limitations to their use. Very high temperatures and large, instantaneous temperature changes are often most usefully dealt with by the use of ceramic cartridges. Moisture and sticky particles can also reduce the effectiveness of fabric filters.

Table 2.5: Materials utilised in fabric filters

Common Name	Generic Name	Chemically resistant to:		Operating temp. (oC)	Max temp.(oC)	Fire resistance
		Acids	Alkalis			
Cotton	Natural fibre cellulose	Poor	Excellent	80	105	Poor
Polypropylene	Polyolefin	Excellent	Excellent	87	87	Poor
Glass	Glass	Good	Poor	260	287	Good
Nylon	Polyamide	Poor	Excellent	93	121	Poor
Nomex	Aromatic polyamide	Fair	Very good	204	218	Poor
Teflon	Fluorocarbon	Excellent	Excellent	232	260	Poor
PBI	Polybenzimidazole	Good	Fair	537	649	Poor
Goretex	Polytetrafluoro-ethylene	Excellent	Excellent	230	260	Poor
Dralon T	Homopolymer acrylic	Good	Excellent	140		Poor
Bekipor	Stainless steel	Good	Good	454	538	Good

Filter cleaning mechanisms

As particles build up on the surface of the filter they initially aid the filtration mechanism but they eventually begin to reduce gas stream throughput and reduce the removal efficiency. To address this problem fabric filters are fitted with cleaning mechanisms that allow the periodic removal of the build-up of particles. There are three main mechanisms for this particle removal, which may be summarised as:

- pulse jet – whereby a pulse of compressed air is applied to the filter in the reverse direction to the normal flow of the gas stream
- shaker – the bag is shaken to dislodge the particulates
- reverse flow – clean air is passed through the filter medium in the reverse direction to the normal flow of the gas stream

Two- and three- filter systems allow cleaning to be undertaken whilst at least one filter is left on-line, improving average performance.

Control of fabric filters

The main issues involved in the control of fabric filters are:

- ensuring that procedures are in place to clean the filter before operating efficiency is compromised by excessive build-up of captured particulates
- managing the operating temperature of the gas stream
- the risk of fire caused by particles that are extremely hot or explosion from explosive dusts

Introduction		Techniques for pollution control			Emissions			Impact			
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2.2.1.2.4 Electrostatic precipitators

Electrostatic precipitators use an electrostatic field to charge the particles in a gas stream. The charged particles are then attracted to a grounded surface from which they are periodically dislodged into a collection system. Because of the risks of fire and explosion associated with their use for flammable materials, electrostatic precipitators are not widely applied in the sector.

2.2.1.3 Control of plumes from Vents and Cooling towers

Cooling Tower Plumes

Several types of cooling tower are in common use. These include:

- air cooling
- natural-draught cooling towers
- low-level mechanically assisted cooling towers

Information related to BAT for cooling tower systems is contained in the BREF on Industrial Cooling Systems (see [Ref 1](#)).

Condensed plumes that come down to ground level can bring droplets containing biocides, or organisms that could be harmful, and can also cause loss of light, poor visibility and icing of roads. Such plumes should not be permitted.

Where plumes need to be abated, the temperature and the humidity need to be controlled. This may be achieved by combining conductive heat exchange and evaporative cooling in the design of the cooling tower. The degree of abatement required will depend upon local conditions and the distance from the towers to the nearest sensitive area. Where there is reasonable cause for doubt, plume modelling should be undertaken by the operator to confirm that the visible (condensed) plume is unlikely to ground beyond the boundary fence or reach areas of habitation at a height that will cause significant loss of light. (As a guide, the width of the plume should not fill an arc that subtends an angle greater than 10 degrees when viewed vertically upwards from the ground.) Performance curves should be provided to enable the plume abatement to be demonstrated under a wide range of ambient conditions.

Vent plumes

Releases from vents generally should be hot enough to avoid visible plume formation in the vicinity of the vent. This is to prevent the condensation or absorption of environmentally harmful substances by the condensing water vapour. Exhaust gases from a wet scrubber can be heated by the use of waste process heat to raise the exit temperature of the exhaust gases and prevent immediate condensation on exit from the vent. This procedure also assists the thermal buoyancy of the plume. Where there is no available waste heat and the vent contains no significant environmentally harmful substances, the applicant may be able to demonstrate that the BAT criteria have nonetheless been met.

2.2.2 Point source emissions to surface water and sewer

The nature and source of the emissions to surface water or sewer expected from each activity is given in previous sections and the inventory of emissions should be confirmed in detail in the Application.

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As noted before, the primary consideration should always be to prevent releases of harmful substances to the aquatic environment, whether releases are direct or via a sewage treatment works, and only where prevention is not practicable should the release be minimised or reduced to the point where the emission is incapable of causing significant harm.

A wide variety of techniques are available for the control of releases to water or sewer, and the BREF on Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector (see [Ref 1](#)) should be consulted. Section 3.3 of the BREF has details of available water treatment techniques and Section 4.3.1 contains recommendations on what might constitute BAT for a variety of treatment techniques for releases to water.

In addition to the BREF and the techniques noted below, guidance on cost-effective effluent treatment techniques can be found in [Releases to water references](#). This includes IPC Technical Guidance Note A4 which summarises techniques of particular relevance to the batch organic chemicals sector.

Waste water can arise from the process, from storm water, from cooling water, from accidental releases of raw materials, products or waste materials, and from fire-fighting. These should all be taken into account when determining the Application.

The sector is characterised by significant variations in waste-water quantity and quality. This variability has to be taken into account in the selection of techniques. The initial definition of waste-water issues is thus particularly important.

For a diverse sector like Speciality Organics, none of the water treatment techniques described in the following sub-sections (Section 2.2.2.1 to 2.2.2.9) can be described as BAT for all situations; the particular circumstances of the installation will effect assessments of which is best. There are however a few general requirements which should be considered as being part of BAT for control of emissions to water or sewer from point sources, and these are summarised in the following BAT box.

Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions control	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

Indicative BAT requirements for effluent treatment and the control of emissions to water

- In conjunction with information in the following sections of this Guidance Note (Sections 2.2.2.1-2.2.2.9), information and recommendations in the BREF on Common Waste Water and Waste Gas Treatment/ Management Systems in the Chemical Sector (see [Ref 1](#)) should be formally considered as part of the assessment of BAT for point-source releases to surface water or sewer.
- The following general principles should be applied in sequence to control emissions to water:
 - water use should be minimised and wastewater reused or recycled (see [Section 2.4.3](#))
 - contamination risk of process or surface water should be minimised (see [Section 2.2.5](#))
 - wherever possible, closed loop cooling systems should be used and procedures in place to ensure blow down is minimised
 - where any potentially harmful materials are used measures should be taken to prevent them entering the water circuit
- Consideration should be given to the use of filtration/osmosis or other techniques which allow the effluent water to be cleaned for release or, preferably, for return to the process. Particular consideration should be given to the fate of the concentrated residues of such techniques. These can often be returned to furnaces, evaporated, solidified, sent for incineration etc. Tankering of such residues off the site as waste, simply transfers the problem to another place unless they are sent to a facility with the genuine ability to recycle the materials.
- If the pollutants in the wastewater are all readily biodegradable or the effluent contains only materials which are naturally occurring in much larger quantities in the receiving water, there may be justification for filtration/osmosis or similar techniques not being considered appropriate.
- Where prevention is not possible, the emissions benchmarks given in [Section 3](#), should be achieved.
- Where effluent is treated off-site at a sewage treatment works the above factors still apply. In particular, it should be demonstrated:
 - the treatment provided at the sewage treatment works is as good as would be achieved if the emission were treated on-site, based on reduction of load (not concentration) of each substance to the receiving water. (The [IPPC Environmental Assessments for BAT](#) software tool will assist in making this assessment.)
 - that action plans are appropriate to prevent direct discharge of the waste-waters in the event of sewer bypass, (via storm/emergency overflows or at intermediate sewage pumping stations) - for example, knowing when bypass is occurring, rescheduling activities such as cleaning or even shutting down when bypass is occurring.
 - that a suitable monitoring programme is in place for emissions to sewer.
- There must be an understanding of the main chemical constituents of the treated effluent (including the make-up of the COD and the presence of any substances of particular concern to the aqueous environment). The fate of these chemicals in the environment should be assessed.
- As a minimum, all emissions should be controlled to avoid a breach of water quality standards (see [Section 3.2](#) and [Section 4.1](#)), but where another technique can deliver better results at reasonable cost it will be considered BAT and should be used (see [Section 1.1](#)). Unless self-evident, calculations and/or modelling to demonstrate this should be carried out as part of the Application (in response to its Section 4.1 questions)..

Introduction		Techniques for pollution control			Emissions			Impact			
In-process controls	Emissions control	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.2.2.1 Identification and definition of waste-water issues

The definition of waste-water issues for a particular process should cover:

- *Site-specific issues.* These can be represented by the use of plans for sewage, process waste water and surface water run-off systems. The plans should show the interactions between the various systems.
- *Characterisation of all waste streams.* In general this should cover monitoring the main process waste-water streams for flow, pH, temperature, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and potentially inhibitory or toxic pollutants.
- *Defining water use requirements.* This is a necessary step if the re-use/recycle of water is to be maximised and should cover quantity and quality requirements.
- *Listing the chemicals used on the site and any potential contaminants.* This allows the identification of those materials which, whilst not routinely released in waste water, may enter systems during incidents.
- *Worst-case scenarios.* This involves the derivation of potential 'worst-case' combination flow and loads under routine and non-routine conditions.
- *Future changes.* The assessment of the impact of likely future production changes on the measured effluent flow and loads.

Opportunities for changes in production processes or waste-stream modification should be considered. This accords with the principles of preventing and minimising pollution as well as making subsequent treatment cheaper and easier to apply. Very detailed attention should be given to preventing process releases of substances such as pesticides, pharmaceuticals and endocrine disruptors. Waste-stream modification may include:

- *Stream segregation.* Certain waste-water streams may require segregation from the bulk of the process waste water. This may be because they are particularly toxic, odorous, non-biodegradable or contain constituents (eg solvents) that can be recovered.
- *Blending.* This may provide nutrients for subsequent biological treatment or optimise pH for metals removal. Blending requires compatibility issues to be considered, for example:
 - pH changes may make the stream more corrosive
 - temperature increases could lead to the liberation of VOCs or sulphides and may also facilitate reactions between chemicals
 - potential microbial or chemical reactions

It is important to identify opportunities for waste-water modification as soon as possible.

2.2.2.2 Water use

The understanding of water use has significant implications for the management of waste water and should be assigned a high priority by the operator. Typical techniques for reducing water use include:

- management practices such as process unit water-use targets, audits and publication of water use/product ratios may be appropriate
- the use of closed-loop cooling systems
- process changes to reduce the use of water-intensive process equipment
- batch scheduling to reduce the need for wash-down
- re-use or recycling of water within or between process units – the use of recycle/re-use loops should also be considered for their potential to taint products, change odour potential, cause corrosion and increase concentrations

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- substitution of wash water by solvent wash with the solvent being subsequently re-used
- regular checks of pipes and valves for leaks, and maintenance where required
- awareness raising and training of staff

2.2.2.3 Abatement technique selection

Once the waste-water issues have been defined and opportunities for pollution prevention/minimisation implemented, consideration will need to be given to the options for treating (abating) the waste water.

There are four potential stages in waste-water treatment. These are:

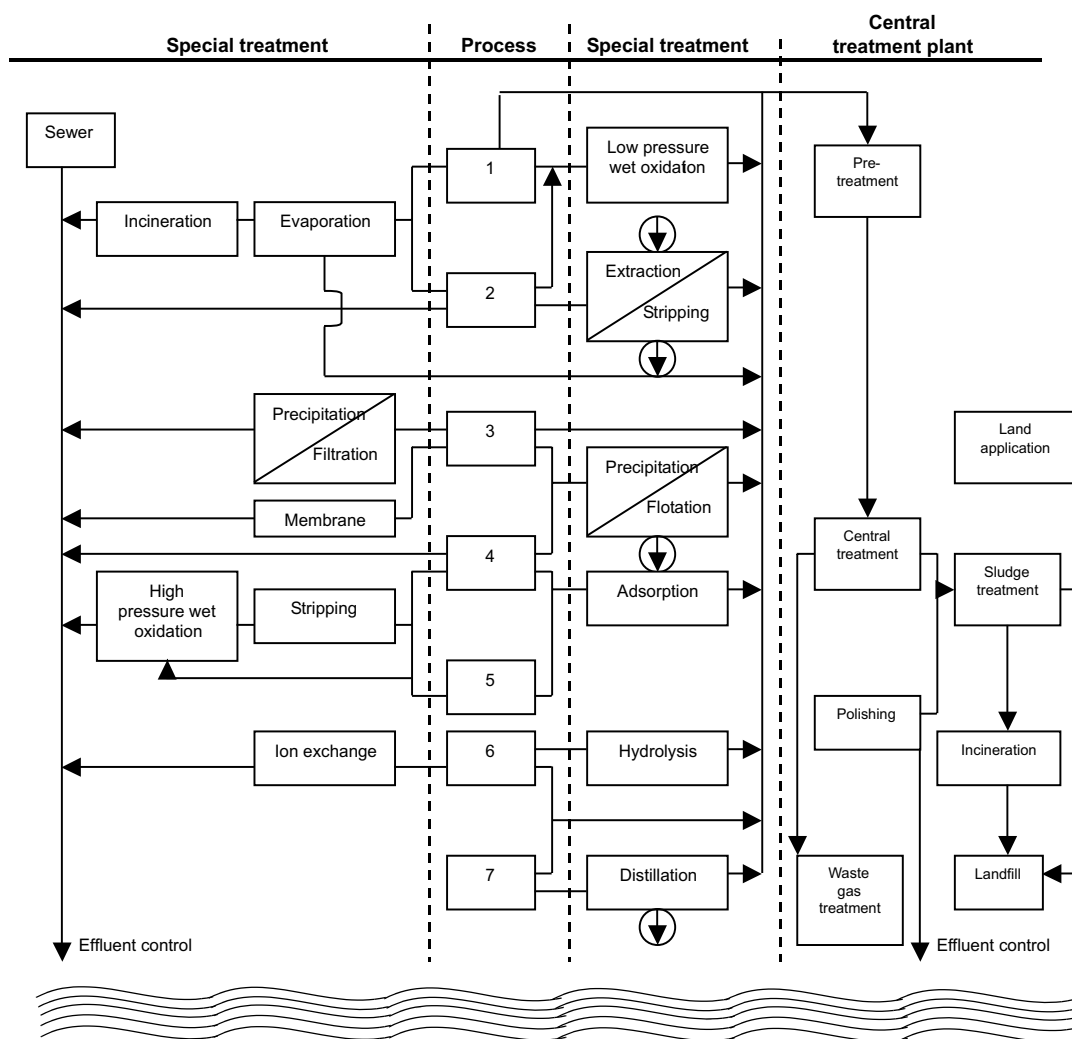
- special treatment of segregated streams
- pre-treatment before central treatment
- central treatment
- polishing treatment

In practice processes will often combine two or more of these stages. The combination adopted will be process-specific and will reflect considerations such as waste-water characteristics and the receiving medium (ie sewer or surface water). Figures 2.2 and 2.3, respectively, illustrate the potential interactions between the four stages and the potential techniques which may be applied depending on the waste-water characteristics. Certain techniques may be applied at both the special and polishing stages.

Figure 2.2 depicts a hypothetical site consisting of seven PPC activities, some of which are interlinked. The Figure is used to show, in particular, the diversity of special treatment techniques that may be applied to individual process streams prior to discharge to central treatment or direct to sewer. It does not cover all potential combinations. Figure 2.3 provides a summary of some of the questions that a process operator could reasonably be expected to address when considering options for waste water treatment.

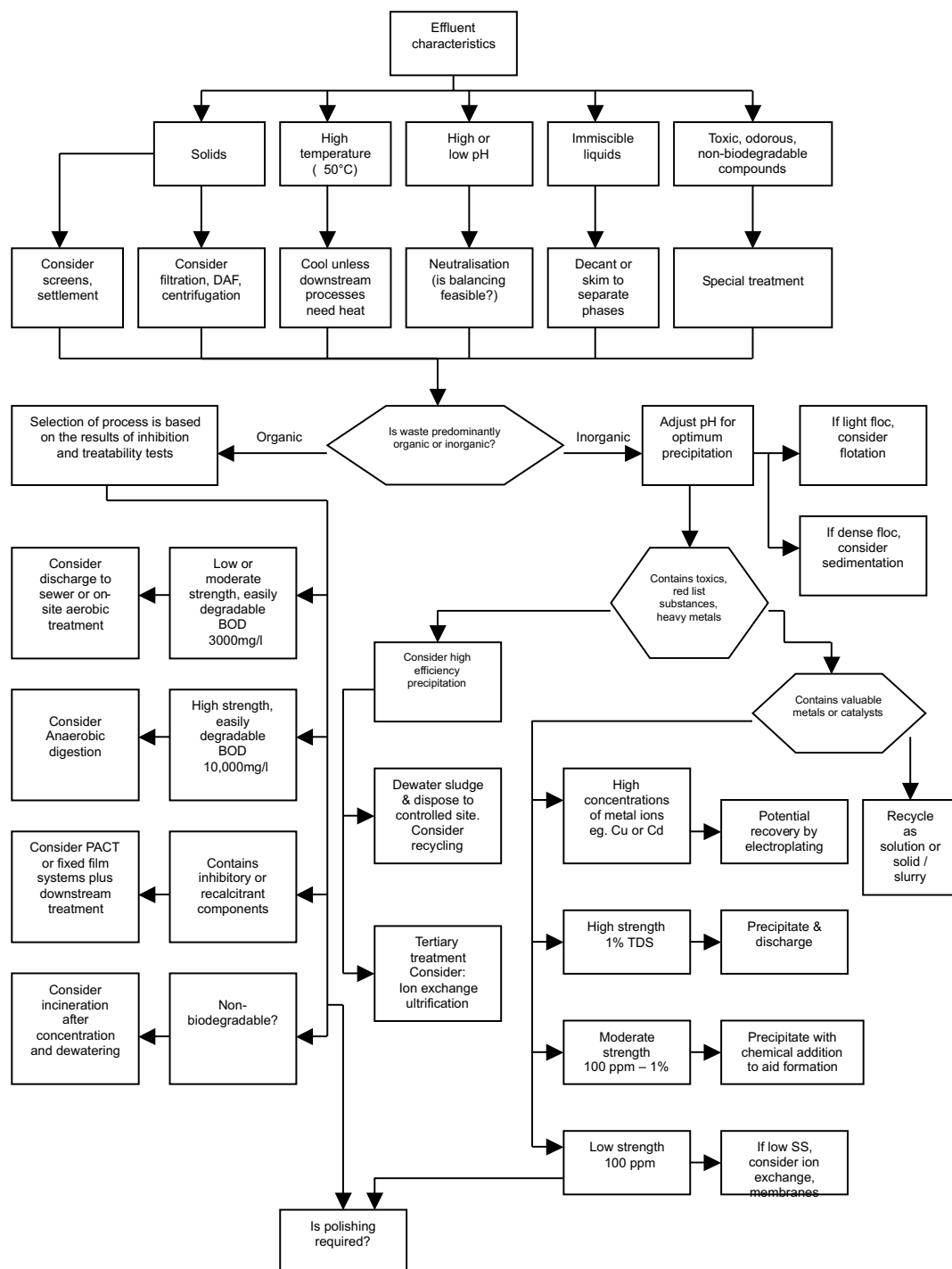
Introduction		Techniques for pollution control			Emissions			Impact			
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Figure 2.2: Potential special and pre-treatment waste-water techniques



Introduction		Techniques for pollution control			Emissions			Impact			
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Figure 2.3: Decision tree for selection of waste-water treatment techniques



2.2.2.4 Technique screening

A large number of techniques are available and a preliminary screen of the options may be necessary to identify the few that merit detailed consideration. Screening factors may include:

- whether the technique can actually abate the constituents of the waste stream
- mechanical and operational reliability

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- containment of waste streams
- cross-media transfer of pollutants
- downstream sewerage systems and sewerage treatment works
- downstream combined sewer overflows
- quality and quantity requirements for receiving waters
- secondary environmental impacts such as noise, odour, visual impairment, etc
- risk of accidents
- space requirements
- capital and operating costs
- energy consumption
- automation and control

Pilot trials or evaluation studies may need to be performed on the short-listed treatment options to provide data for the final selection. It would be expected that the selection procedure is documented for future reference.

2.2.2.5 Pre-treatment

Many waste waters require pre-treatment (conditioning) prior to the main treatment step (whether on-site or at a sewage treatment works), and in some cases this may be sufficient to preclude the need for further treatment prior to disposal, especially if the effluent is discharged to sewer. The main pre-treatment techniques are:

- *Oil removal* - eg. in a separator, electrostatic coalescer, hydrocyclone, ultrafilter, surface-modified cellulose filter, or by air flotation or by the use of (acceptable) physical coalescing agents.
- *Solids removal* - can occur at several points in a treatment sequence and may include screening, filtration, sedimentation, flotation, clarification, and evaporation.
- *Control of pH* - is not simple as the relationship between pH and acid/base concentration is highly non-linear. Multi-stage treatment/dosing is better than single stage, and a better response profile, and hence control of pH, is achieved where there is in-built buffering - an example being the injection of carbon dioxide. Automatic control by pH meters should be monitored by regular manual pH measurements and the pH meters should be calibrated frequently.
- *Equalisation (balancing)* - may address pH and/or temperature problems and it will also reduce peak loads. Balancing tanks may require continuous mixing to prevent settlement, and if the water contains organics or other reducible compounds, there may also be septicity problems.

2.2.2.6 Special treatment

Some waste waters may require special treatment before they can be sent for central treatment or discharged to the receiving medium - because they are particularly toxic, odorous or non-biodegradable or because they are amenable to recovery. Techniques may include:

- *Solids removal* - as noted in the pre-treatment section above, this can occur at several points in a treatment sequence and may include screening, filtration, sedimentation, flotation, clarification and evaporation, eg. for removal of heavy metal compounds.
- *Steam stripping* - involves the contacting of steam with the waste water to evaporate volatile compounds. It may be used for VOC or solvent recovery but consideration should be given to the collection and treatment of all volatiles that may be released. Steam stripping also removes dissolved carbon dioxide, thereby tending to increasing the pH of the effluent stream.

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- *Air stripping* - involves the contacting of the waste water with a current of air. As with steam-stripping, air (or nitrogen) stripping may be used for VOC or solvent recovery but consideration needs to be given to flammability issues and to the treatment of volatiles that may be released.
- *Distillation* - may be used to separate organic compounds from waste water, either on-or off-site, (but associated energy requirements should be assessed).
- *Decantation* - is feasible for 2-phase systems containing immiscible liquids.
- *Evaporation, followed by incineration of the residue* - may be appropriate for odorous or particularly toxic substances but there may be significant energy requirements.
- *Wet air oxidation* - involves the oxidation of aqueous wastes (particularly organics-containing) at temperatures in the range of 177 - 315°C and pressures between 7 and 200 bar. The degree of oxidation is dependent upon the temperature, pressure, residence time and nature of the chemical substances present. The oxidation process is autothermal at COD values greater than around 10,000 mg/l (below this concentration auxiliary oxidant may have to be added to the system), and waste waters with greater than 100,000 mg/l COD can be handled if diluted. Waste waters containing high levels of chlorine-containing compounds (or similar potential corrosives) will require the use of corrosion-resistant materials of construction. A variant of the wet air oxidation process uses temperatures lower than 200°C and pressures of 20 bar by utilising an iron-based catalyst and acidification stage at the front end of the process. Wet air oxidation can be particularly suitable for the pre-treatment of specific high, non-biodegradable COD waste waters prior to conventional biological treatment.
- *Supercritical water oxidation* - is a high-pressure (>221bar), high-temperature (>374°C) oxidation process that destroys all organic matter dispersed or dissolved in water. Under these supercritical conditions total miscibility occurs and this facilitates the decomposition of organic chemicals. It can be utilised for the removal of organic compounds from wastes containing between 3% and 20% solids, and is particularly suited to the destruction of organic molecules that are not amenable to biological treatment.
- *Chemical oxidation* - is usually used as pre-treatment for segregated aqueous streams containing hazardous substances or for removing residual traces of contaminants after biological treatment. Removal efficiencies may be severely affected by suspended solids or other organics which will 'use up' the redox potential provided by the oxidation chemicals. The reactions may be exothermic and require a cooling system, and pH may also have to be controlled to maximise the redox reactions.

2.2.2.7 Central treatment

The type of central treatment required will depend on the characteristics of the waste water. [Figure 2.3](#) illustrates the approaches that can be adopted for predominantly inorganic and organic waste waters, respectively. The former are usually treated using chemical coagulation followed by one or more solid/liquid separation steps (eg flotation, sedimentation, filtration), the latter using some form of biological technique.

Chemical coagulation

Dissolved iron or aluminium salt is added to the waste water and rapidly dispersed and mixed. The pH of the dosed water is adjusted to a level at which the dissolved metal precipitates, usually in the form of a hydrated hydroxide. This pH adjustment is typically achieved by the addition of acid or lime. In some instances a further flocculant aid is added to improve solid-liquid separation. The coagulated and flocculated particles (floc) attract and adsorb other dissolved and suspended matter. The floc can then

Introduction		Techniques for pollution control			Emissions			Impact			
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be separated from the water by settlement or flotation. The technique can be used for the removal of suspended solids, metals, some dissolved organic compounds and phosphate, and to reduce the concentration of micro-organisms.

Biological treatment

This option is usually considered where the waste water is predominantly organic, biodegradable and present in large volumes. A wide range of options is available.

Aerobic techniques

There are many variants on this technique. It has been used extensively in the sector, particularly the activated sludge technique. It is generally the most cost-effective, safe and reliable method of removing biodegradable organics in waste water.

Control of pH to approximately neutral, equalisation and suspended solids removal, if the concentration is too high, should precede the activated sludge system. Activated sludge treatment involves an aeration step, followed by solid–liquid separation, with recycle of a portion of the solids (activated sludge). The basic system consists of an open tank for the mixing of the biomass with the waste water and air, followed by a clarifier. The aeration step encourages the growth of bacteria that perform the hydrolysis and oxidation reactions.

The traditional activated sludge plant requires a relatively large area. In some industrial applications this may limit its application. Some variants have been designed to overcome this problem, eg the deep tank system, aerated filters. use of oxygen

A number of issues need to be considered when applying aerobic techniques. These include:

- *Volatile emissions* - volatilised organics may contribute to cross media contamination, odours may arise and health risks be posed to plant operators.
- *Inhibition*. Some chemicals can inhibit the growth or respiration of the biomass that forms the basis for aerobic techniques. This may reduce the efficiency of treatment. The possibility or extent of inhibition for any given waste water is usually only predictable using inhibition tests. Such methods for assessing the treatability of industrial waste waters have been published.
- *Acclimatisation*. The biomass is a living and often changing entity. Slow increases in the concentration of a contaminant in the waste water may allow the biomass to adapt but shock concentrations may not be treated effectively and may even threaten the biological system.
- *Solids*. The residual sludge may be contaminated with metals, pathogens and toxic chemicals. This gives potential for cross-media contamination and the sludge may require special disposal.
- *Recalcitrant organics*. These are organic chemicals that are resistant to biological treatment and which may have an adverse impact on the receiving waters.
- *Odour*. Volatilisation of chemicals, digestion by-products, septicity of sludges and poor sludge management procedures can generate odour.
- *Nutrients*. The biomass needs a suitable level of nutrients (carbon, nitrogen, oxygen, phosphorus, sulphur, etc) to survive. If the waste water does not contain the correct balance, dosing of nutrients to the treatment plant may be required

Constructed wetlands

Constructed wetlands (reed beds) may be used in situations where space is available to build them and the waste water contains predominantly organic or biodegradable wastes of a relatively low strength <2000 mg/l (BOD₅).

They have the advantages of low operating and capital costs, being easy to operate and facilitating regeneration of natural habitats. However, VOCs may be lost to the atmosphere from the surface of the reed bed, and solids or non-biodegradable substances may accumulate in the bed, reducing removal efficiency.

Introduction		Techniques for pollution control			Emissions			Impact			
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Anaerobic techniques

Anaerobic digestion is a biological treatment technique for the degradation of organics in an oxygen-free environment. The microbiology is complex and conditions such as pH and loading must be closely controlled. The technique is preferred for very strong organic streams but certain organic compounds may have an inhibitory effect on the process and some are only poorly removed. Anaerobic treatment is only likely to be used in this sector for specialist purposes.

Enhanced biological treatment

A number of techniques have been developed to enhance aerobic and anaerobic biological treatment, particularly for those substances which are difficult to remove in the standard treatment process. These include:

- Fixed film processes use a solid medium to support the micro-organisms. The use of this medium may make the process more tolerant to fluctuations in load because of the large biomass available.
- Bio-augmentation uses supplementary bacteria or immobilised enzymes to deal with specific compounds that are resistant to normal biological treatment.
- Biological treatment with adsorption uses a suspended growth system supplemented by dosing of powdered activated carbon (PAC). The PAC adsorbs toxic chemicals to protect the biological system, thereby increasing its robustness, stability and performance, and similarly protects the receiving waters by removing those toxic substances.

These techniques can often be applied to upgrade the performance of central, biological treatment at relatively low cost.

2.2.2.8 Polishing

Polishing may be required as the final treatment stage.

It will usually be applied to remove substances that, whilst not interfering with other treatment stages, may have an adverse impact on the receiving water. Some polishing techniques may occasionally be applied as special treatment upstream of central treatment, but this is relatively rare as polishing techniques are relatively costly and there is always the potential for competition between general pollutants and the polishing technique's target pollutants. If central treatment is applied first the bulk of the load in the waste water is removed before the polishing stage.

Ozone-based system

Ozone-based systems are particularly useful for dealing with recalcitrant COD. Ozone (O₃) is usually generated by discharging a high-voltage electrical current through dry air or pure oxygen. Dry air must be used or else nitric acid is formed. Efficient cooling of the ozone production elements is required. Recent developments in ozone generation use medium-rather than high-frequency electric currents, and oxygen rather than air. This reduces energy consumption and increases the ozone concentration, thus improving removal efficiencies substantially. The ozone is added to the waste water in specially designed contact tanks. A number of variations exist. These include:

- *Ozone* on its own can be used for the removal of recalcitrant COD or to convert it to biodegradable COD. It can also be used for the removal of colour and odour as well as for disinfection.
- *Ozone with ultraviolet irradiation* uses reactors fitted with UV lights and run under pressure to keep the ozone in solution. The use of combined UV/ozone systems allows a wider range of organic substrates to be treated in a shorter reaction time. The use of this technique may be limited by turbidity, which results in poor transmission of UV through waste water and hence limits removal efficiencies.

Introduction		Techniques for pollution control			Emissions			Impact			
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- *Ozone with ultraviolet irradiation and hydrogen peroxide* uses in addition hydrogen peroxide to enhance oxidation by generating more hydroxyl radicals. The system may be especially useful for the oxidation of aromatic halides, which readily adsorb UV. This system appears to give the highest oxidation rates with lowest ozone usage, although its use has yet to be widely demonstrated. Ammonia competes with the target organic pollutants for the hydroxyl radicals and thus the technique is best applied to well-nitrified or low- ammonia-containing effluents.
- *Ozone with adsorption pre-concentration* is used to deal with specific high-toxicity compounds that may be present in relatively low concentrations in effluents with a high COD loading. The waste water is mixed with a metal hydroxide, which adsorbs the target substance(s). This forms a slurry, which is then mixed with ozone and the target substances destroyed. The ozonation is catalysed by the metal hydroxide.

The capital and operating costs of ozone treatment are high. The high capital cost is mainly due to the cost of ozone generation equipment, and the high operating costs are mainly due to electricity usage. Each of the variants on the basic ozone system will increase overall costs.

Activated carbon adsorption

Activated carbon adsorption is available in two forms:

- *Granular activated carbon (GAC)* is usually used in fixed-bed reactors with the waste water being passed through it. The bed periodically has to be removed for, usually, specialist off-site regeneration. Problems can arise due to the presence of other substances that preferentially adsorb to the bed, which can lead to the bed being exhausted rapidly.
- *Powdered activated carbon (PAC)* is superior to GAC in terms of its specific capacity for adsorbing organics but usually offers few opportunities for recycling and its capacity depends on the other organics present. The removal of PAC from the waste water requires a sedimentation stage and PAC is therefore usually applied before the main treatment stage (see enhanced biological treatment in [Section 2.2.2.7](#)). The PAC-adsorbed organics are usually disposed of with the sludge generated by the biological treatment plant.

Zeolites

Zeolites adsorb ammonia or toxic metals such as cadmium from waste waters.

Membrane processes

Membrane processes include: ultrafiltration, reverse osmosis, membrane filtration and pervaporation. The efficiency of the filtration processes depends upon the difference in size between the pore and the particle to be removed or retained; whilst in reverse osmosis the efficiency depends on how well the membrane rejects the flow of solute whilst allowing the flow of solvent.

These types of process can be used either to clean up the waste water for re-use, or to recover material for recycling. They tend to be used in specialist applications where the membrane technology has been developed to overcome membrane life and fouling problems.

Pervaporation is a process that uses polymeric membranes for the removal of organic compounds from water. It is suitable for the treatment of waste water containing VOCs and chlorinated solvents. The component to be separated is 'evaporated' from a liquid waste, through a membrane, under vacuum. The separated component is recovered by condensation. A wide variety of organic polymers can be used to remove specific target contaminants. Pervaporation is a technically feasible and economically attractive method for treating waste water contaminated with VOCs, and compares favourably with steam stripping and carbon adsorption.

Pervaporation has been successfully adopted in the following applications:

- pollution control of dilute solutions of hydrophobic solvents (eg 1000 ppm benzene in water)
- solvent recovery from process waste waters
- volume reduction of mixed solvent hazardous waste

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Pervaporation is particularly suited to waste water containing relatively hydrophobic volatile organics such as chlorinated solvents, naphthas, toluene and benzene.

Ultrafiltration, in which the effluent is passed across a semipermeable membrane at elevated pressures, may be used for the removal of organo-halogen and other pesticides. Efficiencies of removal of 95 to 99% have been achieved from effluent containing 500 to 5000 µg/l of total pesticides. After concentration, the pesticides should be incinerated if recycling is not practicable.

Reverse osmosis is capable of removing hexachlorocyclohexane and malathion from waste waters at 99% efficiency.

Membranes can be classified according to their molecular weight cut-off point (MWCO), ie the approximate molecular weight above which molecules cannot pass through the membrane. [Table 2.6](#) shows situations in which such techniques can be applied

Fouling of the membrane can occur. This can be reduced primarily by designing the plant to maintain high velocities and turbulence at the membrane surface, but may sometimes require the dosing of anti-scaling compounds to the waste water or physical cleaning. Some compounds may adsorb to the membrane, reducing its effectiveness, whilst others, particularly those containing chlorine, may damage it. Membranes produce a highly concentrated waste stream that requires incineration or other specialist disposal technique.

Table 2.6: Technique application ranges for a number of different types of membrane

	Pore size (micrometres)	Molecular weight cut-off (MWCO)	Application
Microfiltration	0.1 to 1	>100,000	Particles
Ultrafiltration	0.001 to 0.1	50,000 to 100,000	Particles + large dissolved molecules
Nanofiltration	0.001 to 0.01	200 to 10,000	Dissolved medium molecules
Reverse Osmosis	<0.001	<200	Most dissolved molecules

Ceramic membranes

These consist of a rigid structure, produced from sintered alumina or zirconia. The waste water is fed down the centre of the sintered tubes and the filtrate collected on the outside. Compared to polymer membranes, ceramic-based systems can be heated, back-washed and cleaned using solvents. Furthermore they exhibit a much greater resistance to chemicals and are much less susceptible to blocking by suspended solids.

The major disadvantages are that ceramic membranes cannot be made with the same low ratios of volume to surface area, consequently the space required for the filter units is much larger. They are also much more brittle, thus vibration may cause problems.

Ion exchange

Ion exchange units consist of a resin bed or beds designed to remove cations or anions from a waste stream. The waste water flows through ion exchange beds, the target ions bind to the bed material, displacing (exchanging) comparatively innocuous ions. Advantages of ion exchange are that energy consumption is relatively low and the technique works well on dilute waste streams. The main disadvantages are the relatively high cost of regenerant chemicals and, because it is a batch process, two parallel streams or more are required for continuous operation, thus increasing the capital cost.

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The regeneration technique produces a fixed volume batch of effluent per ion exchange exhaustion cycle and this needs treatment before discharge.

2.2.2.9 Summary

Table 2.7 summarises the types of technique that are available to deal with specific chemical compounds or families.

In this sector it is more common for processes to be upgraded rather than new ones constructed. The main issue is therefore the identification of techniques that can improve the performance of existing waste-water treatment stages. The use of PAC and bioaugmentation, in particular, offer opportunities for enhanced performance at relatively low cost.

Table 2.7: Waste-water abatement techniques

Contaminant	Abatement techniques
Suspended solids	Coagulation/flocculation Sedimentation Flotation Filtration
pH	Neutralisation
Insoluble organics	Separators
Biodegradable organics	Aerobic Anaerobic
Volatile organics	Air stripping Steam stripping Distillation Activated carbon Evaporation
Metals	Chemical coagulation Ion exchange
Ammonia	Ammonia stripping
Nutrients (N)	Suspended-growth nitrification and denitrification variations Fixed-film nitrification and denitrification variations Ion exchange Breakpoint chlorination Natural systems
Nutrients (P)	Metal-salt addition Lime coagulation Biological phosphorus removal Biological-chemical phosphorus removal
Nutrients (N+P)	Biological removal

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Table 2.7: Waste-water abatement techniques

Contaminant	Abatement techniques
Refractory organics	Carbon adsorption Ozonation Supercritical water oxidation Wet air/oxygen oxidation Chemical oxidation
Dissolved organic solids	Ion exchange Membranes Carbon adsorption

2.2.3 Point source emissions to groundwater

Groundwater protection legislation

The Groundwater Regulations for the UK came into force on 1 April 1999, and an IPPC Permit will be subject to the following requirements under these Regulations.

- i. The Permit shall not be granted at all if it would allow the *direct discharge* of a List I substance (Regulation 4(1)) - except in very limited circumstances (see Notes 1 and 2, below).
- ii. If the Permit allows the disposal of a List I substance or any activity that might lead to an *indirect discharge* of a List I substance then *prior investigation* (as defined in Regulation 7) is required and the Permit shall not be granted if this reveals that indirect discharges of List I substances would occur. In any event, conditions to secure the prevention of such discharges must be imposed (Regulation 4(2) and (3)).
- iii. In the case of List II substances, Permits allowing direct discharges or possible indirect discharges, cannot be granted unless there has been a prior investigation and conditions must be imposed to prevent groundwater pollution (Regulation 5).
- iv. The Regulations contain further detailed provisions covering *surveillance* of groundwater (Regulation 8); conditions required when direct discharges are permitted (Regulation 9); when indirect discharges are permitted (Regulation 10); and review periods and compliance (Regulation 11).

The principles, powers and responsibilities for groundwater protection in England and Wales, together with the Environment Agency's policies on this, are outlined in the Environment Agency's document [Policy and Practice for the Protection of Groundwater](#). This outlines the concepts of vulnerability and risk and the likely acceptability from the Regulator's viewpoint of certain activities within groundwater protection zones. These are categorised as:

- A Prior investigation** of the potential effect on groundwater of on-site disposal activities or discharges to groundwater. Such investigations will vary from case to case, but the Regulator is likely to require a map of the proposed disposal area; a description of the underlying geology, hydrogeology and soil type, including the depth of saturated zone and quality of groundwater; the proximity of the site to any surface waters and abstraction points, and the relationship between ground and surface waters; and the composition and volume of waste to be disposed of; and the rate of planned disposal.

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The Environment Agency has produced a series of maps for England and Wales, which provide a guide to potential groundwater vulnerability. Source Protection Zones are intended to aid protection by defining annular zones around each major potable source, including springs, boreholes and wells, based on travel times.

B Surveillance - This will also vary from case to case, but will include monitoring of groundwater quality and ensuring the necessary precautions to prevent groundwater pollution are being undertaken.

Note 1 The Regulations state that, subject to certain conditions, the discharges of List I substances to groundwater may be authorised if the groundwater is “permanently unsuitable for other uses”. Advice must be sought from the Regulator where this is being considered as a justification for such discharges.

Note 2 List I and List II refer to the list in the Groundwater Regulations and should not be confused with the similar lists in the Dangerous Substances Directive (see [Appendix 4](#))

Indicative BAT requirements for point source emissions to groundwater

Identify if there may be a discharge of any List I or List II substances and if any are identified, explain how the requirements of the Groundwater Regulations 1998 have been addressed.

- 1 In general, there should be no permitted releases to groundwater of either a direct or indirect nature.
- 2 If there are releases to groundwater and they are to continue, the requirements of the Regulations, as summarised above, must be complied with.

2.2.4 Control of fugitive emissions to air

On many installations fugitive or diffuse emissions may be more significant than point source emissions, and common examples of sources and causes are given in the BAT box below.

As part of the Application the Operator should identify and, where possible quantify, significant fugitive emissions to air from all the specific relevant sources listed above, estimating the proportion of total emissions that are attributable to fugitive releases for each substance. Where there are opportunities for reductions, the Permit may require the updated inventory of fugitive emissions to be submitted.

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Indicative BAT requirements for fugitive emissions to air

- 1 **Dust** - The following general techniques should be employed where appropriate:
 - Covering of skips and vessels
 - Avoidance of outdoor or uncovered stockpiles (where possible)
 - Where unavoidable, use of sprays, binders, stockpile management techniques, windbreaks and so on
 - Regular wheel and road cleaning (avoiding transfer of pollution to water and wind blow)
 - Closed conveyors, pneumatic or screw conveying (noting the higher energy needs), minimising drops. Filters on the conveyors to clean the transport air prior to release
 - Regular housekeeping
 - Enclosed silos (for storage of bulk powder materials) vented to fabric filters. The recycling of collected material should be considered under Section 2.6.
 - Enclosed containers or sealed bags used for smaller quantities of fine materials
- 2 **VOCs**
 - When transferring volatile liquids, the following techniques should be employed – subsurface filling via (anti-syphon) filling pipes extended to the bottom of the container, the use of vapour balance lines that transfer the vapour from the container being filled to the one being emptied, or an enclosed system with extraction to suitable abatement plant.
 - Vent systems should be chosen to minimise breathing emissions (for example pressure/ vacuum valves) and, where relevant, should be fitted with knock-out pots and appropriate abatement equipment.
 - Maintenance of bulk storage temperatures as low as practicable, taking into account changes due to solar heating etc.
 - The following techniques should be used (together or in any combination) to reduce losses from storage tanks at atmospheric pressure:
 - Tank paint with low solar absorbency
 - Temperature control
 - Tank insulation
 - Inventory management
 - Floating roof tanks
 - Bladder roof tanks
 - Pressure/vacuum valves, where tanks are designed to withstand pressure fluctuations
 - Specific release treatment (such as adsorption condensation)
- 3 For Information on Odour, see [Section 2.2.6](#).
- 4 Fugitive VOC emissions are very likely from this sector - from phase-separations, valve glands and STR cleaning or charging, for example. Operators should identify all potential sources and develop and maintain procedures for monitoring and eliminating or minimising leaks and releases of VOCs from all non-process stream sources.

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2.2.5 Fugitive emissions to surface water, sewer and groundwater

As part of the Application, the Operator should identify and, where possible, quantify significant fugitive emissions to water, sewer or ground from all relevant sources, and estimate the proportion of total emissions that are attributable to fugitive releases for each of the main substances releases.

Some common examples of sources of fugitive releases to waters and their preventive measures are given in the BAT box below.

Indicative BAT requirements for fugitive emissions to water (Sheet 1 of 2)

- For **subsurface structures**:
 - establish and record the routing of all installation drains and subsurface pipework;
 - identify all sub-surface sumps and storage vessels;
 - engineer systems to minimise leakages from pipes and ensure swift detection if they do occur, particularly where hazardous (ie. Groundwater-listed) substances are involved;
 - provide secondary containment and/or leakage detection for sub-surface pipework, sumps and storage vessels;
 - establish an inspection and maintenance programme for all subsurface structures, eg. pressure tests, leak tests, material thickness checks or CCTV

All sumps should:

 - be impermeable and resistant to stored materials;
 - be subject to regular visual inspection and any contents pumped out or otherwise removed after checking for contamination;
 - where not frequently inspected, be fitted with a high level probe and alarm, as appropriate;
 - be subject to programmed engineering inspection (normally visual, but extending to water testing where structural integrity is in doubt).

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Indicative BAT requirements for fugitive emissions to water (Sheet 2 of 2)

2 For surfacing:

- design appropriate surfacing and containment or drainage facilities for all operational areas, taking into consideration collection capacities, surface thicknesses, strength/reinforcement; falls, materials of construction, permeability, resistance to chemical attack, and inspection and maintenance procedures;
- have an inspection and maintenance programme for impervious surfaces and containment facilities;
- unless the risk is negligible, have improvement plans in place where operational areas have not been equipped with:
 - an impervious surface
 - spill containment kerbs
 - sealed construction joints
 - connection to a sealed drainage system

3 All above-ground tanks containing liquids whose spillage could be harmful to the environment should be banded. For further information on bund sizing and design, see the [Releases to water references](#). Bunds should:

- be impermeable and resistant to the stored materials;
- have no outlet (that is, no drains or taps) and drain to a blind collection point;
- have pipework routed within banded areas with no penetration of contained surfaces;
- be designed to catch leaks from tanks or fittings;
- have a capacity greater than 110 percent of the largest tank or 25 percent of the total tankage;
- be subject to regular visual inspection and any contents pumped out or otherwise removed under manual control after checking for contamination;
- where not frequently inspected, be fitted with a high-level probe and an alarm, as appropriate;
- where possible, have tanker connection points within the bund, otherwise provide adequate containment;
- be subject to programmed engineering inspection (normally visual, but extending to water testing where structural integrity is in doubt).

4 Storage areas for IBCs, drums, bags, etc, should be designed and operated to minimise the risk of releases to the environment. In particular:

- Storage areas should be located away from watercourses and sensitive boundaries, (eg. those with public access) and should be protected against vandalism.
- Storage areas should have appropriate signs and notices and be clearly marked-out, and all containers and packages should be clearly labelled.
- The maximum storage capacity of storage areas should be stated and not exceeded, and the maximum storage period for containers should be specified and adhered to.
- Appropriate storage facilities should be provided for substances with special requirements (eg. flammable, sensitive to heat or light) and formal arrangements should be in hand to keep separate packages containing incompatible substances (both “pure” and waste).
- Containers should be stored with lids, caps and valves secured and in place - and this also applies to emptied containers.
- All stocks of containers, drums and small packages should be regularly inspected (at least weekly).
- Procedures should be in place to deal with damaged or leaking containers.

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2.2.6 Odour

The level of detail supplied should be in keeping with the risk of causing odour-related annoyance at sensitive receptors.

Where an installation poses no risk of odour-related environmental impact because the activities undertaken are inherently non-odorous, this should be justified and no further information relating to odour need normally be supplied.

Where odour could be a problem, the Operator will be required in the Application to supply the information as indicated below:

- Information relating to sensitive receptors, in particular the type of receptor, location relative to the odour sources and an assessment of the impact of odorous emissions on the receptors. Where detailed information is required the Operator may be able to secure an agreement to supply this as part of an Improvement Programme.
- An overview of any complaints received, what they relate to (source/operation) and remedial action taken.
- The types and source of odorous substances used or generated, intentional and fugitive (unintentional) release points and monitoring undertaken.
- Actions taken to prevent or minimise
 - A description of the actions taken to prevent and/or minimise odour annoyance for each odour source.
 - A demonstration that the indicative BAT requirements are being complied with.
 - Identification of any circumstances or conditions which might compromise the ability to prevent or minimise odour annoyance, and a description of the actions that will be taken to minimise the impact.

There may be a requirement placed upon the Operator to provide some or all of this information in the form of an odour management statement. See the [Odour management statement](#) for a typical log book.

Indicative BAT requirements for odour control (Sheet 1 of 2)

- 1 The requirements for odour control will be installation-specific and depend on the sources and nature of the potential odour. In general:
- 2 Where odour can be contained, for example within buildings, the Operator should maintain the containment and manage the operations to prevent its release at all times.
- 3 Where odour releases are expected to be acknowledged in the Permit, (i.e. contained and treated prior to discharge or discharged for atmospheric dispersion):
 - For existing installations, the releases should be modelled to demonstrate the odour impact at sensitive receptors. The target should be to minimise the frequency of exposure to ground level concentrations that are likely to cause annoyance.
 - For new installations, or for significant changes, the releases should be modelled and it is expected that the Operator will achieve the highest level of protection that is achievable with BAT from the outset.
 - Where there is no history of odour problems then modelling may not be required although it should be remembered that there can still be an underlying level of annoyance without complaints being made.

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Indicative BAT requirements for odour control (Sheet 2 of 2)

- Where, despite all reasonable steps in the design of the plant, extreme weather or other incidents are liable, in the view of the Regulator, to increase the odour impact at receptors, the Operator should take appropriate and timely action, as agreed with the Regulator, to prevent further annoyance (these agreed actions will be defined either in the Permit or in an odour management statement).
- 4 Where odour generating activities take place in the open, (or potentially odorous materials are stored outside) a high level of management control and use of best practice will be expected.
 - 5 Where an installation releases odours but has a low environmental impact by virtue of its remoteness from sensitive receptors, it is expected that the Operator will work towards achieving the standards described in this Note, but the timescales allowed to achieve this might be adjusted according to the perceived risk.

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2.3 Management

Within IPPC, an effective system of management is a key technique for ensuring that all appropriate pollution prevention and control techniques are delivered reliably and on an integrated basis.

The Regulators strongly support the operation of formal environmental management systems (EMSs). An Operator with such a system will not only find it easier to meet the BAT requirements for management of the installation but also many of the technical/regulatory requirements listed in other Sections of this Guidance.

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The Regulators recommend either certification to the ISO 14001 standard or registration under EMAS (EC Eco Management and Audit Scheme) (OJ L114, 24/04/01). Both certification and registration provide independent verification that the EMS conforms to an auditable standard. EMAS now incorporates ISO 14001 as the specification for the EMS element, and the Regulators consider that overall EMAS has a number of other benefits over ISO14001 - including a greater focus on environmental performance, a greater emphasis on legal compliance, and a public environmental statement. For further details about ISO 14001 and EMAS contact British Standards Institute (BSI) or the Institute of Environmental Management and Assessment (IEMA), respectively.

Whilst an effective EMS will help the Operator to maintain compliance with specific regulatory requirements and manage all significant environmental impacts, this section of the Guidance identifies only those EMS requirements that are not specifically covered elsewhere in the document. This Section should not, therefore, be taken to describe all of the elements of an effective environmental management system. The requirements below are considered to be BAT for IPPC, but they are the same techniques required by a formal EMS and so should be capable of delivering wide environmental benefits.

The European Commission has also set out its views on BAT and Environmental Management Systems in the form of standard text which will be included in all new and updated BREFs.

Indicative BAT requirements for management techniques (Sheet 1 of 3)

Operations and maintenance

- 1 Effective operational and maintenance systems should be employed on all aspects of the process whose failure could impact on the environment, in particular there should be:
 - documented procedures to control operations that may have an adverse impact on the environment
 - a defined procedure for identifying, reviewing and prioritising items of plant for which a preventative maintenance regime is appropriate
 - documented procedures for monitoring emissions or impacts
 - a preventative maintenance programme covering all plant, whose failure could lead to impact on the environment, including regular inspection of major 'non productive' items such as tanks, pipework, retaining walls, bunds ducts and filters
- 2 The maintenance system should include auditing of performance against requirements arising from the above and reporting the result of audits to top management.

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Indicative BAT requirements for management techniques (Sheet 2 of 3)

Competence and training

- 3 Training systems, covering the following items, should be in place for all relevant staff which cover
 - awareness of the regulatory implications of the Permit for the activity and their work activities;
 - awareness of all potential environmental effects from operation under normal and abnormal circumstances
 - awareness of the need to report deviation from the Permit
 - prevention of accidental emissions and action to be taken when accidental emissions occur
- 4 The skills and competencies necessary for key posts should be documented and records of training needs and training received for these post maintained.
- 5 The key posts should include contractors and those purchasing equipment and materials;
- 6 The potential environmental risks posed by the work of contractors should be assessed and instructions provided to contractors about protecting the environment while working on site.
- 7 Where industry standards or codes of practice for training exist (e.g. WAMITAB) they should be complied with.

Accidents/incidents/non-conformance

- 8 There should be an accident plan as described in [Section 2.8](#) which:
 - identifies the likelihood and consequence of accidents
 - identifies actions to prevent accidents and mitigate any consequences
- 9 There should be written procedures for handling, investigating, communicating and reporting actual or potential non-compliance with operating procedures or emission limits.
- 10 There should be written procedures for handling, investigating, communicating and reporting environmental complaints and implementation of appropriate actions.
- 11 There should be written procedures for investigating incidents, (and near misses) including identifying suitable corrective action and following up
- 12 The company should conduct audits, at least annually, to check that all activities are being carried out in conformity with the above requirements. Preferably, these should be independent.
- 13 The company should report annually on environmental performance, objectives and targets, and future planned improvements. Preferably, these should be published environmental statements.

Organisation

- 14 The following are indicators of good performance which may impact on the Regulator's resources, but not all will necessarily be insisted upon as Permit conditions:
- 15 The company should adopt an environmental policy and programme which:
 - includes a commitment to continual improvement and prevention of pollution;
 - includes a commitment to comply with relevant legislation and other requirements to which the organisation subscribes; and
 - identifies, sets, monitors and reviews environmental objectives and key performance indicators independently of the Permit.

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Indicative BAT requirements for management techniques (Sheet 3 of 3)

- 16 The company should have demonstrable procedures (eg. written instructions) which incorporate environmental considerations into the following areas:
- the control of process and engineering change on the installation;
 - design, construction and review of new facilities and other capital projects (including provision for their decommissioning);
 - capital approval; and
 - purchasing policy.
- 17 The company should operate a formal Environmental Management System. Preferably, this should be a registered or certified EMAS/ISO 14001 system (issued and audited by an accredited certification body).
- 18 The company should have a clear and logical system for keeping records of, amongst others:
- policies
 - roles and responsibilities
 - targets
 - procedures
 - results of audits
 - results of reviews

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2.4 Raw Materials

This section covers the use of raw materials and water, and the techniques for both minimising their use and minimising their impact by selection. (Energy and fuels are covered under [Section 2.7](#), Energy).

As a general principle, the Operator will need to demonstrate the measures taken to:

- reduce the usage of all raw materials and intermediates ([Section 2.4.2](#))
- substitute less harmful materials, or those which can be more readily abated and when abated lead to substances that are more readily dealt with
- understand the fate of by-products and contaminants and their environmental impact ([Section 2.4.2](#))

2.4.1 Raw materials selection

This section looks at the selection and substitution of raw materials and [Section 2.4.2](#) describes the techniques to minimise their use.

It should be recognised that the process of selecting raw materials can present an opportunity to control emissions at source. In this regard it is suggested that Operators closely examine the range of possible raw material options available to them.

The Operator should supply in the Application a list of the materials used which have potential for significant environmental impact, together with the following associated information:

- the chemical composition of the materials, where relevant;
- the quantities used;
- the fate of the material in the installation (ie. approximate percentages to each environmental medium and to the products);
- the environmental impact potential, where known (eg. degradability, bioaccumulation potential, toxicity to relevant species);
- any reasonably practicable alternative raw materials that may have a lower environmental impact (including, but not limited to any alternatives described in the BAT requirements below) on the substitution principle;
- and justification for the continued use of any substance for which there is a less hazardous alternative (eg. on the basis of impact on product quality) to show that the proposed raw materials are therefore BAT.

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Indicative BAT requirements for raw materials selection

- 1 The Operator should maintain a list of raw materials and their properties as noted above.
- 2 The Operator should have procedures for the regular review of new developments in raw materials and for the implementation of any suitable ones with an improved environmental profile.
- 3 The Operator should have quality-assurance procedures for controlling the impurity content of raw materials.
- 4 The Operator should complete any longer-term studies needed into the less polluting options and should make any material substitutions identified.

2.4.2 Waste minimisation audit (minimising the use of raw materials)

The options for waste recovery and recycling are covered in [Section 2.6](#). Waste avoidance/minimisation, and the use of clean technologies, is a theme which runs throughout [Section 2.1](#) and [Section 2.2](#). This section deals with the systematic approach to look for other opportunities.

Waste minimisation can be defined simply as: *“a systematic approach to the reduction of waste at source, by understanding and changing processes and activities to prevent and reduce waste”*.

A variety of techniques can be classified under the term waste minimisation, from basic housekeeping through statistical measurement, to application of clean technologies.

In the context of waste minimisation and this Guidance, waste relates to the inefficient use of raw materials and other substances at an installation. A consequence of waste minimisation will be the reduction of gaseous, liquid and solid emissions.

Key operational features of waste minimisation will be:

- the ongoing identification and implementation of waste prevention opportunities
- the active participation and commitment of staff at all levels including, for example staff suggestion schemes
- monitoring of materials' usage and reporting against key performance measures

For the primary inputs to activities which are themselves waste activities, eg. incineration, the requirements of this section may have been met “upstream” of the installation. However, there may still be arisings that are relevant.

See the [Waste minimisation and raw materials efficiency references](#) for detailed information, guides and case studies on waste minimisation techniques.

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Indicative BAT requirements for waste minimisation audits

1 The Operator should carry out a waste minimisation audit at least every 4 years. If an audit has not been carried out in the 2 years prior to submission of the application and the details made known at the time of the application, then the first audit shall take place within 2 years of the issue of the Permit. The methodology used and an action plan for reducing the use of raw materials should be submitted to the Regulator within 2 months of completion of the audit. The audit should be carried out as follows:

The Operator should analyse the use of raw materials, assess the opportunities for reductions and provide an action plan for improvements using the following three essential steps

- process mapping
- materials mass balance
- action plan

The use and fate of raw materials and other materials, including by-products, solvents and other support materials, such as fuels, catalysts and abatement agents, should be mapped onto a process flow diagram (see the [Waste minimisation and raw materials efficiency references](#)). This should be achieved by using data from the raw materials inventory and other company data as appropriate. Data should be incorporated for each principal stage of the operation in order to construct a mass balance for the installation.

2 Using this information, opportunities for improved efficiency, changes in process and waste reduction should be generated and assessed. An action plan should then be prepared for implementing improvements to a timescale approved by the Regulator.

2.4.3 Water use

Reasons for reducing water use

Water use should be minimised within the BAT criteria for the prevention or reduction of emissions and be commensurate with the prudent use of water as a natural resource.

Reducing water use is usually a valid environmental (and economic) aim in itself, but any water passing through an industrial process is degraded by the addition of pollutants so there is generally an increase in pollutant load. The benefits to be gained from reducing water input include:

- reducing the size of (a new) treatment plant, thereby supporting the BAT cost-benefit justification of better treatment;
- cost savings where water is purchased from or disposed of to another party;
- associated benefits within the process such as reduced energy requirements for heating and pumping, and reduced dissolution of pollutants leading in turn to reduced sludge generation in the effluent treatment plant (and consequent disposal costs).

The use of a simple mass balance for water use should help to reveal where reductions can be made.

Advice on cost-effective measures for minimising water can be found in the [Water efficiency references](#).

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Indicative BAT requirements for minimisation of water use (Sheet 1 of 2)

1 The Operator should carry out a regular review of water use (water efficiency audit) at least every 4 years. If an audit has not been carried out in the 2 years prior to submission of the application and the details made known at the time of the application, then the first audit should take place within 2 years of the issue of the Permit.

- Flow diagrams and water mass balances for the activities should be produced.
- Water-efficiency objectives should be established, with constraints on reducing water use beyond a certain level being identified (which usually will be usually installation-specific).
- Water pinch techniques should be used in the more complex situations such as chemical plant, to identify the opportunities for maximising reuse and minimising use of water (see the [Water efficiency references](#)).

Within 2 months of completion of the audit, the methodology used should be submitted to the Regulator, together with proposals for a time-tabled plan for implementing water reduction improvements for approval by the Regulator.

2 The following general principles should be applied in sequence to reduce emissions to water:

- Water-efficient techniques should be used at source where possible
- Water should be recycled within the process from which it issues, by treating it first if necessary. Where this is not practicable, it should be recycled to another part of the process that has a lower water-quality requirement
- In particular, if uncontaminated roof and surface water cannot be used in the process, it should be kept separate from other discharge streams, at least until after the contaminated streams have been treated in an effluent treatment system and been subject to final monitoring.

3 Measures should be in place to minimise the risk of contamination of surface waters or ground-water by fugitive releases of liquids or solids (see [Section 2.2.5](#)).

4 The water-quality requirements associated with each use should be established, and the scope for substituting water from recycled sources identified and input into the improvement plan.

Less contaminated water streams, such as cooling waters, should be kept separate from more contaminated streams where there is scope for reuse - though possibly after some form of treatment.

Most wastewater streams will however need some form of treatment (see [Section 2.2.2](#) for techniques) but for many applications, the best conventional effluent treatment can produce a water that is usable in the process directly or when mixed with fresh water. Though treated effluent quality can vary, it can often be recycled selectively - used when the quality is adequate, discharged when the quality falls below that which the system can tolerate.

5 In particular, the cost of membrane technology continues to reduce, and they can be applied to individual process streams or to the final effluent from the effluent treatment plant, as appropriate. In some applications in some Sectors, they can supplement (or possibly completely replace) the ETP plant so that most water is recyclable and there is a greatly reduced effluent volume. Where the remaining, possibly concentrated, effluent stream is sufficiently small - and particularly where waste heat is available - further treatment by evaporation can lead to zero aqueous effluent. Where appropriate, the Operator should assess the costs and benefits of using membrane techniques to minimise water usage and effluent discharge.

6 Water usage for cleaning and washing down should be minimised by:

- vacuuming, scraping or mopping in preference to hosing down;
- reusing wash water (or recycled water) where practicable;
- using trigger controls on all hoses, hand lances and washing equipment.

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Indicative BAT requirements for minimisation of water use (Sheet 2 of 2)

- Fresh water consumption should be directly measured and recorded regularly at every significant usage point - ideally on a daily basis.

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2.5 Waste handling

The Operator should list in detail the nature and source of the waste from each activity as the response to the emissions inventory requirement of the Application - though where there are a very large number of relatively small streams, some aggregation of similar and relatively insignificant waste streams may be appropriate.

Indicative BAT requirements for waste handling

Characterisation and quantification of each waste stream, and description of measures for waste management, storage and handling.

- 1 A system should be in place and maintained which records the quantity, nature and origin of any waste that is disposed of or recovered - and also, where relevant, the destination, frequency of collection, mode of transport and treatment method for those wastes.
- 2 Wastes should be segregated wherever practicable, and the disposal routes identified. Disposal should be as near to the point of generation as is practicable.
- 3 Records should be maintained of any waste sent off-site (Duty of Care).
- 4 All appropriate steps should be taken to prevent emissions from waste storage or handling (eg. liquid or solid spillage, dust or VOC emission, and odour) (see [Section 2.2.4](#), [Section 2.2.5](#) and [Section 2.2.6](#)).

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2.6 Waste recovery or disposal

The Regulations require the Regulator, in setting Permit conditions, to take account of certain general principles, including that the installation in question should be operated in such a way that “waste production is avoided in accordance with Council Directive 75/442/EEC on waste; and where waste is produced it is recovered, or where this is technically or economically impossible it is disposed of, while avoiding or reducing the impact on the environment”. The objectives of the National Waste Strategies should also be considered.

Waste avoidance (minimisation) at source is addressed in detail in [Section 2.1](#) and related issues are addressed in the sections on abatement techniques (see [Section 2.2](#)). The specific requirement for a waste minimisation audit is noted in [Section 2.4.2](#).

To meet these requirements, Operators should provide the Regulator with the information requested in point 2 below.

Indicative BAT requirements for waste recovery or disposal

Description of the way each waste stream is recovered or disposed of.

- 1 Waste should be recovered, unless it is technically or economically impractical to do so.
- 2 Where waste must be disposed of, the Operator should provide a detailed assessment identifying the best environmental options for waste disposal - unless the Regulator agrees that this is unnecessary. For existing disposal activities, this assessment may be carried out as an improvement condition to a timescale to be approved by the Regulator.

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2.7 Energy

BAT for energy efficiency under the PPC Regulations will be satisfied provided the Operator meets the following conditions:

either

- the Operator meets the basic energy requirements in Section 2.7.1 and Section 2.7.2 below and is a participant to a Climate Change Agreement (CCA) or a Direct Participant Agreement (DPA) within the Emissions Trading Scheme.

or

- the Operator meets the basic energy requirements in Section 2.7.1 and Section 2.7.2 below and the further sector-specific energy requirements in Section 2.7.3 below.

Note that even where a Climate Change Agreement or Direct Participant Agreement is in place, this does not preclude the consideration of energy efficiency (including those identified in Section 2.7.3) as part of an integrated assessment of BAT where they impact on other emissions, e.g. where:

- the choice of fuel impacts upon emissions other than carbon, e.g. sulphur in fuel
- the minimisation of waste by waste-to-energy does not maximise energy efficiency, e.g. by Combined Heat and Power (CHP)
- the most energy-intensive abatement leads to the greatest reduction in other emissions

Further guidance is given in the guidance note [H2 Energy efficiency for IPPC](#).

2.7.1 Basic energy requirements (1)

The BAT requirements of this section are basic low-cost energy standards that apply whether or not a CCA or DPA is in force for the installation.

Indicative BAT requirements for basic energy requirements (1):

Provide a breakdown of the energy consumption and generation by source, and the associated environmental emissions.

- 1 The Operator should provide annually the energy consumption information, shown in the table below, in terms of delivered energy and also, in the case of electricity, converted to primary energy consumption. For the public electricity supply, a conversion factor of 2.6 should be used. Where applicable, the use of factors derived from on-site heat and/or power generation, or from direct (non-grid) suppliers should be used. In the latter cases, the Operator should provide details of such factors. Where energy is exported from the installation, the Operator should also provide this information. In the application this information should be submitted in the inventory in the H1 software tool and should also supplement this with energy flow information (such as “Sankey” diagrams or energy balances) showing how the energy is used throughout the process.
- 2 The Operator should provide the following Specific Energy Consumption (SEC) information. Define and calculate the SEC of the activity (or activities) based on primary energy consumption for the products or raw material inputs that most closely match the main purpose or production capacity of the installation. Provide a comparison of SEC against any relevant benchmarks available for the sector. (See BREF and Energy Efficiency Guidance)

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Indicative BAT requirements for basic energy requirements (1):

Provide a breakdown of the energy consumption and generation by source, and the associated environmental emissions.

- 3 The Operator should provide associated environmental emissions. This is dealt with in the Operator's response to the emissions inventory using the H1 software tool.

Table 2.8: Example breakdown of delivered and primary energy consumption

Energy source	Energy consumption		
	Delivered, MWh	Primary, MWh	% of total
Electricity*			
Gas			
Oil			
Other (Operator to specify)			

* specify source.

2.7.2 Basic energy requirements (2)

The BAT requirements of this section are basic low-cost energy standards that apply whether or not a CCA or DPA is in force for the installation.

Indicative BAT requirements for basic energy requirements (2) (Sheet 1 of 2)

Describe the proposed measures for improvement of energy efficiency.

- Operating, maintenance and housekeeping measures** should be in place in the following areas, where relevant: (Indicative checklists of appropriate measures are provided in Appendix 2 of the guidance note [H2 Energy efficiency for IPPC](#).)

 - air conditioning, process refrigeration and cooling systems (leaks, seals, temperature control, evaporator/condenser maintenance)
 - operation of motors and drives
 - compressed gas systems (leaks, procedures for use)
 - steam distribution systems (leaks, traps, insulation)
 - space heating and hot-water systems
 - lubrication to avoid high-friction losses
 - boiler operation and maintenance, e.g. optimising excess air
 - other maintenance relevant to the activities within the installation
- Basic low-cost physical techniques** should be in place to avoid gross inefficiencies. These should include insulation, containment methods, (such as seals and self-closing doors), and avoidance of unnecessary discharge of heated water or air (e.g. by fitting simple control systems such as timers and sensors).

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Indicative BAT requirements for basic energy requirements (2) (Sheet 2 of 2)

Describe the proposed measures for improvement of energy efficiency.

- 3 **Energy-efficient building services** should be in place to deliver the requirements of the Building Services section of the guidance note **H2 Energy efficiency for IPPC**. For energy-intensive industries these issues may be of minor impact and should not distract effort from the major energy issues, but they should nonetheless find a place in the programme, particularly where they constitute more than 5 percent of the total energy consumption.
- 4 **Energy management techniques** should be in place, according to the requirements of **Section 2.3** noting, in particular, the need for monitoring of energy flows and targeting of areas for reductions.
- 5 **An energy efficiency plan** should be provided that:
 - identifies all techniques relevant to the installation, including those listed above and in **Section 2.7.3**, that are applicable to the installation
 - estimates the CO₂ savings that would be achieved by each measure over its lifetime
 - and, in the case where the activities are NOT covered by a CCA or DPA; provides information on the equivalent annual costs of implementation of the technique, the costs per tonne of CO₂ saved and the priority for implementation. A procedure is given in the Energy Efficiency Guidance Note.
- 6 An example format of the energy efficiency plan is shown in **Table 2.9**.

Table 2.9: Example format for energy efficiency plan

ALL APPLICANTS			ONLY APPLICANTS WITHOUT CCA		
Energy efficiency measure	CO ₂ savings (tonnes)		Equivalent Annual Cost (EAC) £k	EAC/CO ₂ saved £/tonne	Date for implementation
	Annual	lifetime			

The Energy Efficiency Guidance Note provides an appraisal methodology. If Operators use other appraisal methodologies they should state the method in the Application, and provide evidence that appropriate discount rates, asset life and expenditure (£/t) criteria have been employed.

The energy efficiency plan is required to ensure that the Operator has considered all relevant techniques. However, where a CCA or DPA is in place the Regulator will only enforce implementation of those measures in categories 1-3 above.

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2.7.3 Further energy-efficiency requirements

Indicative BAT requirements for further energy-efficiency requirements

- 1 The following techniques should be implemented where they are judged to be BAT based on a cost/benefit appraisal according to the methodology provided in Appendix 4 of the Guidance Note [H2 Energy efficiency for IPPC](#).

Energy-efficiency techniques

Energy supply techniques
- 2 The following techniques should be considered:
 - use of Combined Heat and Power (CHP)
 - generation of energy from waste
 - use of less polluting fuels
- 3 The Operator should provide justification that the proposed or current situation represents BAT, irrespective of whether or not a CCA or DPA is in place, where there are other BAT considerations involved, eg.:
 - the choice of fuel impacts upon emissions other than carbon dioxide, eg. sulphur dioxide;
 - the potential for practical energy recovery from waste conflicts with energy efficiency requirements.
- 4 Where there is an on-site combustion plant other guidance is also relevant. For plants greater than 50MW, Operators should consult the IPC guidance on power generation (reference IPC S2 1.01 Combustion Processes: Large boilers and furnaces 50MW(th) and over and supplement IPC S3 1.01 Combustion Processes). Operators of plant of 20-50MW should consult the Local Authority Air Pollution Control guidance. On IPPC installations this guidance will be generally applicable to plant under 20MW also. For incineration plant S2.5.01 Waste Incineration should be consulted (all available from the [EA website](#)).

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2.8 Accidents

This section covers accidents and their consequences. It is not limited to major accidents but includes spills and abnormal operation.

Some installations will also be subject to the Control of Major Accident Hazards Regulations 1999 (COMAH) (see [Appendix 2](#) for equivalent legislation in Scotland and Northern Ireland). IPPC and COMAH can sometimes overlap, and some systems and information may be usable for either regime.

The COMAH regime applies to major hazards, and for accident scenarios covered by COMAH, Operators may refer in the Application to any COMAH reports already held by the Regulator. However, the accident provisions under IPPC also cover those which are below the classification threshold for major accidents under COMAH, so Operators need to consider smaller accidents and abnormal operation scenarios as well. Guidance prepared in support of the COMAH Regulations (see the [COMAH guides](#)), may also help IPPC Operators in considering ways to reduce the risks and consequences of accidents - whether or not they are covered by the COMAH regime.

General management requirements are covered in [Section 2.3](#). For accident management, there are three particular components:

- identification of the hazards posed by the installation/activity
- assessment of the risks (hazard x probability) of accidents and their possible consequences
- implementation of measures to reduce the risks of accidents, and contingency plans for any accidents that do occur

Indicative BAT requirements for accidents and abnormal operations (Sheet 1 of 3)

- 1 A formal structured accident management plan should be in place which covers the following aspects:

A - Identification of the hazards to the environment posed by the installation using a methodology akin to a Hazop study. Areas to consider should include, but should not be limited to, the following:

 - transfer of substances (eg. filling or emptying of vessels);
 - overfilling of vessels;
 - emissions from plant or equipment (eg. leakage from joints, over-pressurisation of vessels, blocked drains);
 - failure of containment (eg. physical failure or overfilling of bunds or drainage sumps);
 - failure to contain firewaters;
 - wrong connections made in drains or other systems;
 - incompatible substances allowed to come into contact;
 - unexpected reactions or runaway reactions;
 - release of an effluent before adequate checking of its composition;
 - failure of main services (eg. power, steam, cooling water);
 - operator error;
 - vandalism.
- 2 **B - assessment of the risks.** The hazards having been identified, the process of assessing the risks should address six basic questions:
 - how likely is the particular event to occur (source frequency)?
 - what substances are released and how much of each (risk evaluation of the event)?
 - where do the released substances end up (emission prediction - what are the pathways and receptors)?

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Indicative BAT requirements for accidents and abnormal operations (Sheet 2 of 3)

- what are the consequences (consequence assessment – what are the effects on the receptors)?
- what are the overall risks (determination of overall risk and its significance to the environment)?
- what can prevent or reduce the risk (risk management – measures to prevent accidents and/or reduce their environmental consequences)?

The depth and type of assessment will depend on the characteristics of the installation and its location. The main factors to take into account are:

- the scale and nature of the accident hazard presented by the installation and the activities
- the risks to areas of population and the environment (receptors)
- the nature of the installation and complexity of the activities and the relative difficulty in deciding and justifying the adequacy of the risk-control techniques

C - identification of the techniques necessary to reduce the risks. The following techniques are relevant to most installations:

- there should be an up-to-date inventory of substances, present or likely to be present, which could have environmental consequences if they escape. This should include apparently innocuous substances that can be environmentally damaging if they escape (for example, a tanker of milk spilled into a watercourse can destroy its ecosystem). The Permit will require the Regulator to be notified of any significant changes to the inventory.
- procedures should be in place for checking and handling raw materials and wastes to ensure compatibility with other substances with which they may accidentally come into contact.
- storage arrangements for raw materials, products and wastes should be designed and operated to minimise risks to the environment.
- there should be automatic process controls backed-up by manual supervision, both to minimise the frequency of emergency situations and to maintain control during emergency situations. Instrumentation will include, where appropriate, microprocessor control, trips and process interlocks, coupled with independent level, temperature, flow and pressure metering and high or low alarms.
- physical protection should be in place where appropriate (eg. barriers to prevent damage to equipment from the movement of vehicles).
- there should be appropriate secondary containment (eg. bunds, catchpots, building containment).
- techniques and procedures should be in place to prevent overfilling of tanks - liquid or powder - (eg. level measurement displayed both locally and at the central control point, independent high-level alarms, high-level cut-off, and batch metering).
- where the installation is situated in a floodplain, consideration should be given to techniques which will minimise the risk of the flooding causing a pollution incident or making one worse.
- security systems to prevent unauthorised access should be provided where appropriate.
- there should be formal systems for the logging and recording of all incidents, near-misses, abnormal events, changes to procedures and significant findings of maintenance inspections.
- there should be procedures for responding to and learning from incidents, near-misses, etc.
- the roles and responsibilities of personnel involved in incident management should be formally specified.
- clear guidance should be available on how each accident scenario might best be managed (eg. containment or dispersion, to extinguish fires or to let them burn).
- procedures should be in place to avoid incidents occurring as a result of poor communications between staff at shift change or during maintenance or other engineering work.
- safe shutdown procedures should be in place.

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Indicative BAT requirements for accidents and abnormal operations (Sheet 3 of 3)

- communication channels with emergency services and other relevant authorities should be established, and available for use in the event of an incident. Procedures should include the assessment of harm following an incident and the steps needed to redress this
- appropriate control techniques should be in place to limit the consequences of an accident, such as isolation of drains, provision of oil spillage equipment, alerting of relevant authorities and evacuation procedures.
- personnel training requirements should be identified and training provided.
- the systems for the prevention of fugitive emissions are generally relevant ([Section 2.2.4](#) and [Section 2.2.5](#)) and in addition, for drainage systems:
 - procedures should be in place to ensure that the composition of the contents of a bund sump, or sump connected to a drainage system, are checked before treatment or disposal;
 - drainage sumps should be equipped with a high-level alarm or with a sensor and automatic pump to storage (not to discharge);
 - there should be a system in place to ensure that sump levels are kept to a minimum at all times;
 - high-level alarms and similar back-up instruments should not be used as the primary method of level control.
- duplicate or standby plant should be provided where necessary, with maintenance and testing to the same standards as the main plant;
- spill contingency procedures should be in place to minimise accidental release of raw materials, products and waste materials and then to prevent their entry into water.
- process waters, potentially contaminated site drainage waters, emergency firewater, chemically-contaminated waters and spillages of chemicals should be contained and, where necessary, routed to the effluent system and treated before emission to controlled waters or sewer. Sufficient storage should be provided to ensure that this can be achieved. Any emergency firewater collection system should take account of the additional firewater flows and fire-fighting foams, and emergency storage lagoons may be needed to prevent contaminated firewater reaching controlled waters (see the [Releases to water references](#)).
- consideration should be given to the possibility of containment or abatement of accidental emissions from vents and safety relief valves/bursting discs. Where this may be inadvisable on safety grounds, attention should be focused on reducing the probability of the emission.

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2.9 Noise

Within this section “noise” should be taken to refer to “noise and/or vibration” as appropriate, detectable beyond the site boundary.

Where noise issues are likely to be relevant, the Operator will be required, in the Application, to provide information on the following: (for more details see [H3 Part 1 Noise](#))

- the main sources of noise and vibration that will fall within the IPPC installation and also on Infrequent sources of noise and vibration
- the nearest noise-sensitive sites
- conditions/limits imposed under other regimes
- the local noise environment
- any environmental noise measurement surveys, modelling or any other noise measurements
- any specific local issues and proposals for improvements.

The level of detail supplied should be in keeping with the risk of causing noise-related annoyance at sensitive receptors.

Where an installation poses no risk of noise-related environmental impact because the activities undertaken are inherently quiet, this should be justified and no further information relating to noise need normally be supplied. It should, however, be remembered that there can still be an underlying level of annoyance without complaints being made.

The PPC Regulations require installations to be operated in such a way that “all the appropriate preventative measures are taken against pollution, in particular through the application of BAT”. The definition of pollution includes “emissions that may be harmful to human health or the quality of the environment, cause offence to human senses or impair or interfere with amenities and other legitimate uses of the environment”. BAT is therefore likely to be similar, in practice, to the requirements of the statutory nuisance legislation, which requires the use of “best practicable means” to prevent or minimise noise nuisance. It is understood that raw material handling can generate noise where glass is being recycled or broken up. It is suggested that consideration be given to the use of sonic booths or sound proofing to control the generation of noise where such activities are being carried out.

In the case of noise, “offence to any human senses” can normally be judged by the likelihood of complaints, but in some cases it may be possible to reduce noise emissions still further at reasonable costs, and this may exceptionally therefore be BAT for noise emissions.

For advice on how noise and/or vibration related limits and conditions will be determined see [H3 Part 1 Noise](#)

Indicative BAT requirements for noise and vibration (Sheet 1 of 2)

Describe the main sources of noise and vibration (including infrequent sources); the nearest noise-sensitive locations and relevant environmental surveys which have been undertaken; and the proposed techniques and measures for the control of noise.

- 1 The Operator should employ basic good practice measures for the control of noise, including adequate maintenance of any parts of plant or equipment whose deterioration may give rise to increases in noise (for example, maintenance of bearings, air handling plant, the building fabric as well as specific noise attenuation measures associated with plant, equipment or machinery).

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Indicative BAT requirements for noise and vibration (Sheet 2 of 2)

Describe the main sources of noise and vibration (including infrequent sources); the nearest noise-sensitive locations and relevant environmental surveys which have been undertaken; and the proposed techniques and measures for the control of noise.

- 2 The Operator should also employ such other noise control techniques to ensure that the noise from the installation does not give rise to reasonable cause for annoyance, in the view of the Regulator and, in particular, should justify where either Rating Levels (LAeq,T) from the installation exceed the numerical value of the Background Sound Level (LA90,T).
- 3 Further justification will be required should the resulting field rating level (LAR,TR) exceed 50 DB by day and a facade rating level exceed 45 DB by night, with day being defined as 07:00 to 23:00 and night 23:00 to 07:00.
- 4 In some circumstances "creeping background" may be an issue. Where this has been identified in pre application discussions or in previous discussions with the local authority, the Operator should employ such noise control techniques as are considered appropriate to minimise problems to an acceptable level within the BAT criteria.
- 5 Noise surveys, measurement, investigation (which can involve detailed assessment of sound power levels for individual items of plant) or modelling may be necessary for either new or existing installations depending upon the potential for noise problems. Operators may have a noise management plan as part of their management system.

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2.10 Monitoring

This section describes monitoring and reporting requirements for emissions to all environmental media. Guidance is provided for selecting the appropriate monitoring methodologies, frequency of monitoring, compliance-assessment criteria and environmental monitoring.

2.10.1 Emissions monitoring

Indicative BAT requirements for emissions monitoring (Sheet 1 of 2)

Describe the proposed measures for monitoring emissions, and the frequency, measurement methodology and evaluation procedure proposed.

- The following monitoring parameters and frequency are normally appropriate in this sector. Generally, monitoring should be undertaken during commissioning, start-up, normal operation and shut-down unless the Regulator agrees that it would be inappropriate to do so.
- Continuous monitoring (or at least sampling in the case of water) and recording are likely to be required under the following circumstances:
 - Where the potential environmental impact is significant or the concentration of substance varies widely.
 - Where a substance is abated continuous monitoring of the substance is required to show the performance of the abatement plant. For example continuous monitoring of dust is needed after a fabric filter to show the effectiveness of the filter and indicate when maintenance is needed, or sampling BOD from an effluent treatment plant.
 - Where other control measures are required to achieve satisfactory levels of emission (e.g. material selection).
- Where effective surrogates are available, they may be used to minimise monitoring costs.
- Where monitoring shows that substances are not emitted in significant quantities, it may be possible to reduce monitoring frequency.
- For analysis techniques and compliance criteria see [Appendix 1](#).

Monitoring and reporting of emissions to air

- Where appropriate, periodic visual and olfactory assessment of releases should be undertaken to ensure that all final releases to air should be essentially colourless, free from persistent trailing mist or fume and free from droplets.
- The Operator should also have a fuller analysis carried out covering a broad spectrum of substances to establish that all relevant substances have been taken into account when setting the release limits. This should cover the substances listed in Schedule 5 of the Regulations unless it is agreed with the Regulator that they are not applicable. The need to repeat such a test will depend upon the potential variability in the process and, for example, the potential for contamination of raw materials. Where there is such potential, tests may be appropriate.

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Indicative BAT requirements for emissions monitoring (Sheet 2 of 2)

Describe the proposed measures for monitoring emissions, and the frequency, measurement methodology and evaluation procedure proposed.

- 8 Any substances found to be of concern, or any other individual substances to which the local environment may be susceptible and upon which the operations may impact, should also be monitored more regularly. This would particularly apply to the common pesticides and heavy metals. Using composite samples is the technique most likely to be appropriate where the concentration does not vary excessively.
- 9 In some sectors there may be releases of substances that are more difficult to measure and whose capacity for harm is uncertain, particularly when combined with other substances. "Whole effluent toxicity" monitoring techniques can therefore be appropriate to provide direct measurements of harm, for example, direct toxicity assessment. See [Section 2.2.2](#).

Monitoring and reporting of waste emissions

- 10 For waste emissions, the following should be monitored and recorded:
- the physical and chemical composition of the waste
 - its hazard characteristics
 - handling precautions and substances with which it cannot be mixed

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2.10.2 Environmental monitoring (beyond installation)

Indicative BAT requirements for environmental monitoring (beyond installation)

Describe the proposed measures for any environmental monitoring, and the frequency, measurement methodology and evaluation procedure proposed.

- 1 The Operator should consider the need for environmental monitoring to assess the effects of emissions to controlled water, groundwater, air or land, or emissions of noise or odour.
- 2 Environmental monitoring may be required, for example, when:
 - there are vulnerable receptors
 - the emissions are a significant contributor to an Environmental Quality Standard (EQS) that may be at risk
 - the Operator is looking for departures from standards based on lack of effect on the environment;
 - to validate modelling work.
- 3 The need should be considered for:
 - groundwater, where it should be designed to characterise both quality and flow and take into account short- and long-term variations in both. Monitoring will need to take place both up-gradient and down-gradient of the site
 - surface water, where consideration will be needed for sampling, analysis and reporting for upstream and downstream quality of the controlled water
 - air, including odour
 - land contamination, including vegetation, and agricultural products
 - assessment of health impacts
 - noise
- 4 Where environmental monitoring is needed, the following should be considered in drawing up proposals:
 - determinands to be monitored, standard reference methods, sampling protocols
 - monitoring strategy, selection of monitoring points, optimisation of monitoring approach
 - determination of background levels contributed by other sources
 - uncertainty for the employed methodologies and the resultant overall uncertainty of measurement
 - quality assurance (QA) and quality control (QC) protocols, equipment calibration and maintenance, sample storage and chain of custody/audit trail
 - reporting procedures, data storage, interpretation and review of results, reporting format for the provision of information for the Regulation
- 5 Guidance on air quality monitoring strategies and methodologies can be found in [Monitoring Guidance](#).

Introduction			Techniques for pollution control			Emissions			Impact		
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.10.3 Monitoring of process variables

Indicative BAT requirements for monitoring of process variables

Describe the proposed measures for monitoring those process variables that may have a significant effect on emissions.

- 1 Some process variables may affect the environment and these should be identified and monitored as appropriate. Examples might be:

2.10.4 Monitoring standards (Standard Reference Methods)

The Environment Agency has introduced its Monitoring Certification Scheme (MCERTS) to improve the quality of monitoring data and to ensure that the instrumentation and methodologies employed for monitoring are fit for purpose. Performance standards have been published for continuous emissions monitoring systems (CEMs), ambient air quality monitoring systems (CAMs), chemical testing of soils and manual stack emissions monitoring. Other MCERTS standards are under development to cover portable emissions monitoring equipment, water monitoring instrumentation, data acquisition and Operators' own arrangements, such as installation, calibration and maintenance of monitoring equipment, position of sampling ports and provision of safe access for manual stack monitoring.

The following should be described in the application, indicating which monitoring provisions comply with MCERTS requirements or where other arrangements have been made:

- monitoring methods and procedures (selection of Standard Reference Methods)
- justification for continuous monitoring or spot sampling
- reference conditions and averaging periods
- measurement uncertainty of the proposed methods and the resultant overall uncertainty
- criteria for the assessment of non-compliance with Permit limits and details of monitoring strategy aimed at demonstration of compliance
- reporting procedures and data storage of monitoring results, record keeping and reporting intervals for the provision of information to the Regulator
- procedures for monitoring during start-up and shut-down and abnormal process conditions
- drift correction calibration intervals and methods
- the accreditation held by samplers and laboratories or details of the people used and the training/competencies

Indicative BAT requirements for monitoring standards (Standard Reference Methods) (Sheet 1 of 2)

Describe the methods proposed for analysing emissions and for environmental monitoring.

- 1 As far as possible, Operators should ensure their monitoring arrangements comply with the requirements of MCERTS where available, for example using certified instruments and equipment, and using a stack testing organisation accredited to MCERTS standards. Where the monitoring arrangements are not in accordance with MCERTS requirements, the Operator should provide justification and describe the monitoring provisions in detail. See [MCERTS approved equipment](#) for future information on MCERTS and a listing of MCERTS equipment.

Introduction			Techniques for pollution control			Emissions			Impact		
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

Indicative BAT requirements for monitoring standards (Standard Reference Methods) (Sheet 2 of 2)

Describe the methods proposed for analysing emissions and for environmental monitoring.

Sampling and analysis standards

- 2 The analytical methods given in [Appendix 1](#) should be used. In the event of other substances needing to be monitored, standards should be used in the following order of priority:
 - Comité Européen de Normalisation (CEN)
 - British Standards Institution (BSI)
 - International Standardisation Organisation (ISO)
 - United States Environmental Protection Agency (US EPA)
 - American Society for Testing and Materials (ASTM)
 - Deutsches Institut für Normung (DIN)
 - Verein Deutscher Ingenieure (VDI)
 - Association Française de Normalisation (AFNOR)
- 3 Further guidance on standards for monitoring gaseous releases relevant to IPC/IPPC is given in the [Monitoring Guidance](#). A series of updated Guidance Notes covering this subject is being prepared. This guidance specifies manual methods of sampling and analysis that will also be suitable for calibration of continuous emission monitoring instruments. Further guidance relevant to water and waste is available from the publications of the Standing Committee of Analysts.
- 4 If in doubt the Operator should consult the Regulator.

Introduction			Techniques for pollution control			Emissions			Impact		
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

2.11 Closure

The PPC Regulations require an Applicant to submit a site report, describing the condition of the site, as part of the application. Guidance on this is in Annex C of the Guide for Applicants (see [PPC Part A\(1\) Installations: Guide for Applicants \(England and Wales\)](#)) or Guidance for SEPA Staff On Land and Groundwater Considerations for PPC Part A Installations (Scotland) (see [PPC Part A Installations: Guide for Applicants \(Scotland\)](#)).

Indicative BAT requirements for closure (Sheet 1 of 2)

Describe the proposed measures, upon definitive cessation of activities, to avoid any pollution risk and to return the site of operation to a satisfactory state (including measures relating to the design and construction of the installation, where appropriate.)

- 1 **Operations during the IPPC Permit**
Operations during the life of the IPPC Permit should not lead to any deterioration of the site if the requirements of the other sections of this and the specific-sector notes are adhered to. Should any instances arise which have, or might have, impacted on the state of the site, the Operator should record them along with any further investigation or ameliorating work carried out. This will ensure that there is a coherent record of the state of the site throughout the period of the IPPC Permit. This is as important for the protection of the Operator as it is for the protection of the environment. Any changes to this record should be submitted to the Regulator.
- 2 **Steps to be taken at the design-and-build stage of the activities**
Care should be taken at the design stage to minimise risks during decommissioning. For existing installations, where potential problems are identified, a programme of improvements should be put in place to a timescale agreed with the Regulator. Designs should ensure that:
 - underground tanks and pipework are avoided where possible (unless protected by secondary containment or a suitable monitoring programme)
 - there is provision for the draining and clean-out of vessels and pipework prior to dismantling
 - lagoons and landfills are designed with a view to their eventual clean-up or surrender
 - insulation is provided that is readily dismantled without dust or hazard
 - materials used are recyclable (having regard for operational or other environmental objectives)
- 3 **The site-closure plan**
A site closure plan should be maintained to demonstrate that, in its current state, the installation can be decommissioned to avoid any pollution risk and return the site of operation to a satisfactory state. The plan should be kept updated as material changes occur. Common sense should be used in the level of detail, since the circumstances at closure will affect the final plans. However, even at an early stage, the closure plan should include:
 - either the removal or the flushing out of pipelines and vessels where appropriate and their complete emptying of any potentially harmful contents
 - plans of all underground pipes and vessels
 - the method and resource necessary for the clearing of lagoons
 - the method of ensuring that any on-site landfills can meet the equivalent of surrender conditions
 - the removal of asbestos or other potentially harmful materials unless agreed that it is reasonable to leave such liabilities to future owners
 - methods of dismantling buildings and other structures, see [Ref 1](#) which gives guidance on the protection of surface and groundwater at construction and demolition-sites

Introduction			Techniques for pollution control			Emissions			Impact		
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	Installation issues

Indicative BAT requirements for closure (Sheet 2 of 2)

Describe the proposed measures, upon definitive cessation of activities, to avoid any pollution risk and to return the site of operation to a satisfactory state (including measures relating to the design and construction of the installation, where appropriate.)

- testing of the soil to ascertain the degree of any pollution caused by the activities and the need for any remediation to return the site to a satisfactory state as defined by the initial site report
- 4 For existing activities, the Operator should complete any detailed studies, and submit the site-closure plan as an improvement condition to a timescale to be agreed with the Regulator but in any case within the timescale given in [Section 1.1](#) (Note that radioactive sources are not covered by this legislation, but decommissioning plans should be co-ordinated with responsibilities under the Radioactive Substances Act 1993.)

Introduction			Techniques for pollution control			Emissions			Impact		Issues for multi-operator Installations
In-process controls	Emissions controls	Management	Raw materials	Waste handling	Waste recovery or disposal	Energy	Accidents	Noise	Monitoring	Closure	

2.12 Issues for multi-operator Installations

In some cases it is possible that actions that benefit the environmental performance of the overall installation will increase the emissions from one Permit-holder's activities. For example, taking treated effluent as a raw water supply will probably slightly increase emissions from that activity, but could dramatically cut the total emissions from the whole installation.

Where you are not the only Operator of the installation, describe the proposed techniques and measures (including those to be taken jointly by yourself and other Operators) for ensuring the satisfactory operation of the whole installation

Indicative BAT requirements for installation-wide issues

If you are not the only Operator of the installation, describe the proposed techniques and measures taken by you and the other Operators to ensure satisfactory environmental performance of the installation as a whole.

- 1 The Operator should consider possibilities for minimising environmental impact to the environment as a whole, by operating together with other Permit holders. Possibilities include:
 - Communication procedures between the various Permit-holders; in particular those needed to ensure that the risk of environmental incidents is minimised.
 - Benefiting from the economies of scale to justify the installation of a CHP plant.
 - The combining of combustible wastes to justify a combined waste-to-energy/CHP plant.
 - The waste from one activity being a possible feedstock for another.
 - The treated effluent from one activity being of adequate quality to be the raw water feed for another activity.
 - The combining of effluent to justify a combined or upgraded effluent-treatment plant.
 - The avoidance of accidents from one activity that may have a detrimental knock-on effect on the neighbouring activity.
 - Land contamination from one activity affecting another – or the possibility that one Operator owns the land on which the other is situated.

3 Emission benchmarks

3.1 Emissions inventory

The Regulations require the Applicant to describe the nature, quantities and sources of foreseeable emissions into each medium. This will be done by completing the inventory of emission and consumption in the H1 software tool. The information required is as follows.

Provide a table of significant emissions of substances (except noise, vibration, odour and heat which are covered in their respective sections) that will result from the proposals and should include, preferably in order of significance:

- substance (where the substance is a mixture, for example, VOCs or COD, separate identification of the main constituents or inclusion of an improvement proposal to identify them)
- source, including height, location and efflux velocity
- media to which it is released
- any relevant EQS or other obligations
- benchmark
- proposed emissions normal/max expressed, as appropriate for:
 - mass/unit time
 - concentration
 - annual mass emissions
- statistical basis (average, percentile etc.)
- notes covering the Operators confidence in his ability to meet the benchmark values
- if intermittent, the appropriate frequencies
- plant loads at which the data is applicable
- whether measured or calculated (the method of calculation should be provided)

The response should clearly state whether the emissions are current emission rates or those planned following improvements, and should cover emissions under both normal and abnormal conditions for:

- point-source emissions to surface water, groundwater and sewer
- waste emissions
- point-source emissions to air
- significant fugitive emissions to all media, identifying the proportion of each substance released that is due to fugitives rather than point-source releases
- abnormal emissions from emergency relief vents, flares and the like
- indirect and direct emission of carbon dioxide associated with energy consumed or generated

Emissions of carbon dioxide associated with energy use should be broken down by energy type and, in the case of electricity, by source, for example, public supply, direct supply or on-site generation. Where energy is generated on-site, or from a direct (non-public) supplier, the Operator should specify and use the appropriate factor. Standard factors for carbon dioxide emissions are provided in the guidance note [H2 Energy efficiency for IPPC](#).

Where VOCs are released, the main chemical constituents of the emissions should be identified.

For waste, emissions relate to any wastes removed from the installation, or disposed of at the installation under the conditions of the Permit, for example, landfill. Each waste should have its composition determined and the amounts expressed in terms of cubic metres or tonnes per month. A suitable table on which to record this information is provided in the electronic version of this Guidance Note.

Indicative BAT requirements for emission benchmarks

Describe the nature, quantities and sources of foreseeable emissions into each medium (which will result from the techniques proposed in Section 2).

- 1 The Operator should compare the emissions with the benchmark values given in the remainder of this Section.
- 2 Where the benchmarks are not met, the Operator should revisit the responses made in Section 2 as appropriate and make proposals for improvements or justify not doing so as part of the BAT assessment.

3.2 Emission benchmarks

Introduction to emission benchmarks

Guidance is given below on release concentrations or mass release rates achievable for key substances using the best combination of techniques. These BAT-based benchmarks are not mandatory release limits and reference should be made to Section 1 and the Guide for Applicants regarding their use.

3.2.1 Emissions to air associated with the use of BAT

The emissions quoted below are daily averages based upon continuous monitoring during the period of operation. See [Section 3.2.6](#) for the standard conditions that should be applied. Care should always be taken to convert benchmark and proposed releases to the same reference conditions for comparison. To convert measured values to reference conditions, see the [Monitoring Guidance](#) for more information. The benchmarks given do not take sampling, analytical errors, or uncertainties into account. These will be considered when setting an ELV for a Permit.

Limits in Permits may be set for mean or median values over long or short periods. The periods and limits selected should reflect:

- the manner in which the emission may impact upon the environment
- likely variations which will arise during operation within BAT
- possible failure modes and their consequences
- the capabilities of the monitoring and testing system employed

Where emissions are expressed in terms of concentrations and where continuous monitors are employed, it is recommended that limits are defined such that:

- not more than one calendar monthly average during any rolling twelve month period shall exceed the benchmark value by more than 10%
- not more than one half hour period during any rolling 24 hour period shall exceed the benchmark value by more than 50% (for the purpose of this limit half hourly periods commence on the hour and the half hour)

Where spot tests are employed:

- the half hour limit above shall be applied over the period of the test
- the mean of three consecutive tests taken during a calendar year shall not exceed the benchmark value by more than 10%

This Guidance covers a wide range of chemical processes and abatement techniques. Although continuous monitoring should be undertaken wherever practicable, the small scale and batch nature of many processes in the sector will make period testing at critical stages in the batch more appropriate.

Table 3.1: Emissions to air

Released substance	Benchmark value (mg/Nm ³) (a)	Comments (Based on IPC S2 4.02 unless indicated from information in LVOC or Waste Water/ Waste Gas Treatment BREFs)
Active ingredients (pharmaceuticals, agrochemicals, etc)	0.15	
Amines (total, as DMA)	10	
Ammonia	10	BREFs (acid scrubbing)
Benzene	5	
Bromine	10	
Cadmium and cpds (as Cd)	0.1	
Carbon disulphide	5	
Carbon monoxide	100	
Chlorine	10	
1,2-dichloroethane	1 - 5	BREFs (1mg/Nm ³ by incineration treatment)
Formaldehyde	2	BREFs
Fluorine and cpds (as HF)	5	
Hydrogen bromide	5	
Hydrogen chloride	10	
Hydrogen cyanide	2	
Hydrogen fluoride	5	
Hydrogen iodide	5	
Hydrogen sulphide	5	
Iodine	10	
Lead and cpds (Total particulate as Pb)	4	
Lead compounds (Total non-particulate as Pb)	20	
Mercury and cpds (as Hg)	0.1	
Nitrobenzene	5	
Nitropropane	5	
Organic sulphides and mercaptans (as H ₂ S)	2	

Table 3.1: Emissions to air

Released substance	Benchmark value (mg/Nm ³) (a)	Comments (Based on IPC S2 4.02 unless indicated from information in LVOC or Waste Water/ Waste Gas Treatment BREFs)
Oxides of sulphur (as SO ₂)	50 - 100	BREFs (50mg/m ³ by wet scrubbing)
Oxides of nitrogen (acid-forming oxides, as NO ₂)	50 - 200	BREFs (50mg/m ³ by SCR, 200 mg/m ³ by wet scrubbing)
Particulate matter	5 - 20	BREFs (5 mg/m ³ by fabric filter, 20mg/m ³ by ESP)
Phenols, cresols and xylols (as phenol)	10	
Phosgene	1	
Tetrachloroethane	1 - 5	BREFs (1mg/m ³ by incineration treatment)
Trimethylamine	2	
Vinyl chloride	1 - 5	BREFs (1mg/m ³ by incineration treatment)
VOC total Class A (b)	20	
VOC Total Class B (b) (expressed as carbon)	75	

Note (a):

- The reference conditions applicable to these levels are: temperature 273 K (0°C), pressure 101.3 kPa (1 atmosphere), no correction for water vapour or oxygen.
- Where the term "expressed as" is used, a correction should be carried out using the ratio of the atomic or molecular weights of the substances as appropriate.
- All releases should be essentially colourless, free from persistent trailing mist or fume and free from droplets.
- Releases from the installation should not give rise to an offensive odour noticeable outside the site where the process is carried on.

Note (b):

- Releases of VOCs should be individually identified, where possible. The VOC concentration levels generally apply where the following total mass release rates are exceeded:
 - Total Class A 100g/h (expressed as individual VOCs)
 - Total Class B 5 tonne/yr or 2 kg/h, whichever is the lower (expressed as carbon)
 - Note, however, that releases below these mass emission rates may not be trivial, and so may still require controls and the setting of appropriate emission limits values.
- The use of a concentration limit is not normally appropriate in the case of an emission from an air-deficient saturated vapour space such as a storage tank or process vessel. An approach based on limiting total mass released or mass per unit of production is likely to be more effective.
- The term "Volatile Organic Compounds" includes all organic compounds released to air in the gas phase. See also [Appendix 4](#).

3.2.2 Emissions to water associated with the use of BAT

Wastewater treatment systems can maximise the removal of metals using precipitation, sedimentation and possibly filtration. The reagents used for precipitation may be hydroxide, sulphide or a combination of both, depending on the mix of metals present. It is also practicable in many cases to re-use treated water.

Where automatic sampling systems are employed, limits may be defined such that:

- not more than 5% of samples shall exceed the benchmark value

Where spot samples are taken:

- no spot sample shall exceed the benchmark value by more than 50%

Table 3.2: Emissions to water

Discharged substance	Benchmark values (mg/l) (a)	Comments
Total hydrocarbon oil content (IR method)	1-3	
Biological oxygen demand (BOD) (5 day ATU @ 20°C)	20-30	
Chemical oxygen demand (COD) (2 hour)	30 - 125	(from BREFs)
Ammoniacal nitrogen (as N)	10-20	
Suspended solids (dried at 105°C)	20-30	(from BREFs)
Pesticides and chlorinated organic compounds(b, c)	See TGN A4	

Note (a):

The levels given are ranges achievable after effluent treatment and are not emission limit values. They are given on the basis of flow-weighted monthly averages.

For pollutants resistant to biodegradation, achievement of the levels will require isolation at source and separate specialised treatment.

On-site effluent treatment is preferred for these processes. Where discharge to sewer is proposed, the applicant should demonstrate that this option represents BAT, taking into account:

- the substances released and their separability and degradability
- the type of sewage treatment available
- the security of the sewage treatment system, eg with regard to storm overflow
- the relative performance of the available sewage treatment compared with that of the site dedicated option

Compliance with limits imposed by the sewerage undertaker does not guarantee compliance with BAT.

Note (b):

EC Directive 90/415/EEC(14) gives limits for releases to water from the production and use of 1,2-dichloroethane, trichloroethylene, perchloroethylene and trichlorobenzene.

Note (c):

SI 1989 No 2286(15) gives annual mean concentration standards for certain dangerous substances in receiving waters.

3.2.3 Standards and obligations

In addition to meeting the requirements of BAT, there are other national and international standards and obligations that must either be safeguarded through the IPPC Permit or, at least, taken into account in setting Permit conditions. This is particularly the case for any EC-based EQSs.

EC-based EQ standards

IPPC: A Practical Guide explains how these should be taken into account and contains an annex listing the relevant standards. (See **Appendix 2** for equivalent legislation in Scotland and Northern Ireland). They can be summarised as follows:

Air quality

- Statutory Instrument 1989 No 317, Clean Air, The Air Quality Standards Regulations 1989 gives limit values in air for nitrogen dioxide (any emission from the process should not result in a breach of this standard beyond the site boundary), sulphur dioxide and suspended particulates.
- Environmental Protection, The Air Quality Regulations 1997.
- Statutory Instrument 2000 No.928, Air Quality (England) Regulations 2000 gives air quality objectives to be achieved by:
 - 2005 for nitrogen dioxide
 - 2004 for SO₂ and PM₁₀
 - 2003 for CO, 1,3-butadiene and benzene
 - in two stages for lead by 2004 and 2008 respectively

Water quality

- Directive 76/464/EEC on Pollution Caused by Dangerous Substances Discharged to Water contains two lists of substances. List I relates to the most dangerous, and standards are set out in various daughter Directives. List II substances must also be controlled. Annual mean concentration limits for receiving waters for List I substances can be found in SI 1989/2286 and SI 1992/337 the Surface Water (Dangerous Substances Classification) Regulations. Values for List II substances are contained in SI 1997/2560 and SI 1998/389. Daughter Directives cover EQS values for mercury, cadmium, hexachlorocyclohexane, DDT, carbon tetrachloride, pentachlorophenol, aldrin, dieldrin, endrin, isodrin, hexachlorobenzene, hexachlorobutadiene, chloroform, 1,2-dichloroethane, trichloroethane, perchloroethane and trichlorobenzene.
- Other waters with specific uses have water quality concentration limits for certain substances. These are covered by the following Regulations:
 - SI 1991/1597 Bathing Waters (Classification) Regulations
 - SI 1992/1331 and Direction 1997 Surface Waters (Fishlife) (Classification) Regulations
 - SI 1997/1332 Surface Waters (Shellfish) (Classification) Regulations
 - SI 1996/3001 The Surface Waters (Abstraction and Drinking Water) (Classification) Regulations

Future likely changes include:

- Some air quality and water quality standards may be replaced by new ones in the near future.
- The SED on the limitation of emissions of VOCs due to the use of organic solvents in certain activities and installations.

Other standards and obligations

Those most frequently applicable to most sectors are:

- Hazardous Waste Incineration Directive
- Waste Incineration Directive.
- Large Combustion Plant Directive.

- Reducing Emissions of VOCs and Levels of Ground Level Ozone: a UK Strategy (published by the Department of the Environment in October 1993. It sets out how the Government expects to meet its obligations under the UNECE VOCs Protocol to reduce its emissions by 30% (based on 1988 levels) by 1999, including the reductions projected for the major industrial sectors).
- Water Quality Objectives – assigned water quality objectives to inland rivers and water courses (ref. Surface (Rivers Ecosystem) Classification).
- The UNECE convention on long-range transboundary air pollution (negotiations are now underway which could lead to a requirement further to reduce emissions of NO_x and VOCs. A requirement to further reduce SO₂ emissions from all sources has been agreed. The second Sulphur protocol (Oslo, 1994) obliges the UK to reduce SO₂ emissions by 80% (based on 1980 levels) by 2010).
- The Montreal Protocol.
- The Habitats Directive (see [Section 4.3](#)).
- Sulphur Content of Certain Liquid Fuels Directive 1999/32/EC (from 1 January 2003, the sulphur content of heavy fuel oil must not exceed 1% except when it is burnt in plants fitted with SO₂ abatement equipment. Sulphur levels in gas oil must not exceed 0.2% from 1 July 2000, and 0.1% from the start of 2008.)

3.2.4 Units for benchmarks and setting limits in permits

Releases can be expressed in terms of:

- “**concentration**” (for example mg/l or mg/m³), which is a useful day-to-day measure of the effectiveness of any abatement plant and is usually measurable and enforceable. The total flow must be measured/controlled as well
- “**specific mass release**” (for example, kg/ product or input or other appropriate parameter), which is a measure of the overall environmental performance of the plant (including the abatement plant) compared with similar plants elsewhere
- “**absolute mass release**” (for example, kg/hr, t/yr), which relates directly to environmental impact

When endeavouring to reduce the environmental impact of an installation, its performance against each of these levels should be considered, as appropriate to the circumstances, in assessing where improvements can best be made.

When setting limits in Permits, the most appropriate measure will depend on the purpose of the limit. It may also be appropriate to use surrogate parameters, which reflect optimum environmental performance of plant as the routine measurement, supported by less frequent check-analyses on the final concentration. Examples of surrogate measures would be the continuous measurement of conductivity (after ion-exchange treatment) or total carbon (before a guard-column in activated carbon treatment) to indicate when regeneration or replacement is required.

The emission level figures given in this chapter are based on average figures, not on maximum, short-term peak values, which could be expected to be higher. The emission levels given are based on a typical averaging period of not less than 30 minutes and not greater than 24 hours.

3.2.5 Statistical basis for benchmarks and limits in permits

Conditions in Permits can be set with percentile, mean or median values over annual, monthly or daily periods, which reflect probable variation in performance. In addition, absolute maxima can be set.

Where there are known failure modes, which will occur even when applying BAT, limits in Permits may be specifically disapplied, but with commensurate requirements to notify the Regulator and to take specific remedial action.

For water: UK benchmarks or limits are most frequently 95 percentile concentrations or absolute concentrations, (with flow limited on a daily average or maximum basis).

For air: benchmarks or limits are most frequently expressed as daily averages or, typically 95 percent of hourly averages.

3.2.6 Reference conditions for releases to air

The reference conditions of substances in releases to air from point-sources are:

To convert measured values to reference conditions, see the [Monitoring Guidance](#) for more information.

4 Impact

4.1 Impact assessment

The Operator should assess that the emissions resulting from the proposals for the activities/installation will provide a high level of protection for the environment as a whole, in particular having regard to EQS etc, revisiting the techniques in Section 2 as necessary. The use of [IPPC Environmental Assessments for BAT](#), and the [IPPC Environmental Assessments for BAT software tool](#), and the other tools on the Application CD, will lead the Applicant through the process.

The depth to which the impact assessment should go should be discussed with the Regulator. For some low risk sites the requirements may be reduced.

Indicative BAT requirements for impact assessment (Sheet 1 of 2)

Provide an assessment of the potential significant environmental effects (including trans-boundary effects) of the foreseeable emissions.

- 1 Provide a description, including maps as appropriate, of the receiving environment to identify the receptors of pollution. The extent of the area may cover the local, national and international (for example, transboundary effects) environment as appropriate.
- 2 Identify important receptors, which may include: areas of human population including noise or odour-sensitive areas, flora and fauna (that is, Habitat Directive sites, special areas of conservation, Sites of Special Scientific Interest (SSSI or in Northern Ireland ASSI) or other sensitive areas), soil, water, that is groundwater (water below the surface of the ground in the saturation zone and in direct contact with the ground and subsoil) and watercourses (for example, ditches, streams, brooks, rivers), air, including the upper atmosphere, landscape, material assets and the cultural heritage.
- 3 Identify the pathways by which the receptors will be exposed (where not self-evident).
- 4 Carry out an assessment of the potential impact of the total emissions from the activities on these receptors. [IPPC Environmental Assessments for BAT](#) provides a systematic method for doing this and will also identify where modelling needs to be carried out, to air or water, to improve the understanding of the dispersion of the emissions. The assessment will include comparison (see [IPPC: A Practical Guide](#)) with:
 - community EQS levels
 - other statutory obligations
 - non-statutory obligations
 - environmental action levels (EALs) and the other environmental and regulatory parameters defined in [IPPC Environmental Assessments for BAT](#)
- 5 In particular it will be necessary to demonstrate that an appropriate assessment of vent and chimney heights has been made to ensure that there is adequate dispersion of the minimised emission(s) to avoid exceeding local ground-level pollution thresholds and limit national and transboundary pollution impacts, based on the most sensitive receptor, be it human health, soil or terrestrial ecosystems.

Indicative BAT requirements for impact assessment (Sheet 2 of 2)

Provide an assessment of the potential significant environmental effects (including trans-boundary effects) of the foreseeable emissions.

- 6 Where appropriate, the Operator should also recognise the chimney or vent as an emergency emission point and understand the likely behaviour. Process upsets or equipment failure giving rise to abnormally high emission levels over short periods should be assessed. Even if the Applicant can demonstrate a very low probability of occurrence, the height of the chimney or vent should nevertheless be set to avoid any significant risk to health. The impact of fugitive emissions can also be assessed in many cases.
- 7 Consider whether the responses to Sections 2 and 3 and this assessment adequately demonstrate that the necessary measures have been taken against pollution, in particular by the application of BAT, and that no significant pollution will be caused. Where there is uncertainty about this, the measures in Section 2 should be revisited as appropriate to make further improvements.
- 8 Where the same pollutants are being emitted by more than one permitted activity on the installation, the Operator should assess the impact both with and without the neighbouring emissions.

4.2 Waste Management Licensing Regulations

Indicative BAT requirements for waste management licensing regulations

Explain how the information provided in other parts of the application also demonstrates that the requirements of the relevant objectives of the Waste Management Licensing Regulations 1994 have been addressed, or provide additional information in this respect.

- 1 In relation to activities involving the disposal or recovery of waste, the Regulators are required to exercise their functions for the purpose of achieving the relevant objectives as set out in Schedule 4 of the Waste Management Licensing Regulations 1994. (For the equivalent Regulations in Scotland and Northern Ireland, see [Appendix 2](#).)
- 2 The relevant objectives, contained in paragraph 4, Schedule 4 of the Waste Management Licensing Regulations 1994 (SI 1994/1056 as amended) are extensive, but will only require attention for activities that involve the recovery or disposal of waste. Paragraph 4 (1) is as follows:
 - ensuring the waste is recovered or disposed of without endangering human health and without using process or methods which could harm the environment and in particular without:
 - risk to water, air, soil, plants or animals or
 - causing nuisance through noise or odours or
 - adversely affecting the countryside or places of special interest
 - implementing, as far as material, any plan made under the plan-making provisions
- 3 The application of BAT is likely to already address risks to water, air, soil, plants or animals, odour nuisance and some aspects of effects on the countryside. It will, however, be necessary for the Operator briefly to consider each of these objectives individually and provide a comment on how they are being addressed by your proposals. It is also necessary to ensure that any places of special concern that could be affected, such as SSSIs, are identified and commented upon although, again, these may have been addressed in your assessment for BAT, in which case a cross-reference may suffice.
- 4 Operators should identify any development plans made by the local planning authority, including any waste local plan, and comment on the extent to which the proposals accord with the contents of any such plan (see [Section 2.6](#)).

4.3 The Habitats Regulations

Indicative BAT requirements for the habitats regulations

Provide an assessment of whether the installation is likely to have a significant effect on a European site in the UK and, if it is, provide an assessment of the implications of the installation for that site, for the purpose of the Conservation (Natural Habitats etc.) Regulations 1994 (SI 1994/2716)

- 1 An application for an IPPC Permit will be regarded as a new plan or project for the purposes of the Habitats Regulations (for the equivalent Regulations in Scotland and Northern Ireland see [Appendix 2](#)). Therefore, Operators should provide an initial assessment of whether the installation is likely to have a significant effect on any European site in the UK (either alone or in combination with other relevant plans or projects) and, if so, an initial assessment of the implications of the installation for any such site. The application of BAT is likely to have gone some way towards addressing the potential impact of the installation on European sites and putting into place techniques to avoid any significant effects. The Operator should provide a description of how the BAT assessment has specifically taken these matters into account, bearing in mind the conservation objectives of any such site.
- 2 European sites are defined in Regulation 10 of the Habitats Regulations to include Special Areas of Conservation (SACs); sites of community importance (sites that have been selected as candidate SACs by member states and adopted by the European Commission, but which are not yet formally classified); and Special Protection Areas (SPAs). It is also Government policy (set out in PPG 9 on nature conservation) that potential SPAs and candidate SACs should be considered to be European sites for the purposes of Regulation 10.
- 3 Information on the location of European sites and their conservation objectives is available from:
 - English Nature (01733 455000), www.english-nature.org.uk
 - Countryside Council for Wales (01248 385620), www.ccw.gov.uk
 - Scottish Natural Heritage (0131 447 4784), www.snh.org.uk
 - Joint Nature Conservation Committee (01733 866852), www.jncc.gov.uk
 - Environment and Heritage Service, Northern Ireland, www.ehsni.gov.uk
 - Environment and Heritage Service, Northern Ireland (02890254754), www.ehsni.gov.uk
- 4 The Regulator will need to consider the Operator's initial assessment. If it concludes that the installation is likely to have a significant effect on a European site, then the Regulator will need to carry out an "appropriate assessment" of the implications of the installation in view of that site's conservation objectives. The Regulations impose a duty on the Regulator to carry out these assessments, so it cannot rely on the Operator's initial assessments. Therefore the Regulator must be provided with any relevant information upon which the Operator's assessment is based.
- 5 Note that in many cases the impact of the Habitats Regulations will have been considered at the planning application stage, in which case the Regulator should be advised of the details.

References

For a full list of available Technical Guidance see Appendix A of the Guide for Applicants or visit the Environment Agency Website <http://www.environment-agency.gov.uk>. Many of the references below are being made available free of charge for viewing or download on the Website. The same information can also be accessed via the SEPA web site <http://www.sepa.org.uk>, or the NIEHS web site www.ehsni.gov.uk. Most titles will also be available in hard copy from The Stationery Office (TSO). Some existing titles are not yet available on the Website but can be obtained from TSO.

- Ref 1 IPPC Reference Document on Best Available Techniques (BREFs) - European Commission <http://eippcb.jrc.es>. BREFs with relevance to the Speciality Organic Chemicals sector include:
- *Common Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector*, (February 2003)
 - *Economics and Cross-media Effects*, (draft November 2002)
 - *Emissions from Storage*, (draft September 2001)
 - *General Principles of Monitoring*, (November 2002)
 - *Industrial Cooling Systems*, (December 2001)
 - *Large Volume Organic Chemical Industry*, (February 2003)
 - *Mineral Oil and Gas Refineries*, (February 2003)
 - *Waste Treatments Industries*, (draft February 2003)
- Ref 2 *The Pollution Prevention and Control Act (1999)* (www.hmsso.gov.uk).
- Ref 3 *The Pollution Prevention and Control Regulations (SI 2000 No. 1973)* (www.hmsso.gov.uk).
- Ref 4 *IPPC: A Practical Guide* (for England and Wales) (or equivalents in Scotland and Northern Ireland) www.defra.gov.uk/environment/ppc/ippcguide/index.htm
- Ref 5 Guidance for applicants
- *PPC Part A(1) Installations: Guide for Applicants (England and Wales)* (includes Preparation of a Site Report in a Permit Application) www.environment-agency.gov.uk
 - *PPC Part A Installations: Guide for Applicants (Scotland)* (includes guidance for SEPA staff on land and groundwater considerations) www.sepa.org.uk
- Ref 6 Assessment methodologies:
- *Environmental Assessment and Appraisal of BAT (Horizontal Guidance Note IPPC H1 - Issue 2, November 2002)* www.environment-agency.gov.uk
- Ref 7 Waste minimisation and raw materials efficiency references
- *Environment Agency's web page*. Waste minimisation information accessible via: www.environment-agency.gov.uk/subjects/waste/131528
 - *Waste Minimisation – an environmental good practice guide for industry* (helps industry to minimise waste and achieve national environmental goals). Available free to companies who intend to undertake a waste reduction programme (tel: 0345 33 77 00)
 - *Profiting from Pollution Prevention – 3Es methodology* (emissions, efficiency, economics). Video and A4 guide aimed at process industries. Available from Environment Agency, North East region, Regional PIR (tel: 0113 244 0191)
 - *Envirowise*. A joint DTI/DEFRA programme, with over 200 separate case studies, good practice guides, leaflets, flyers, software tools, environmental benchmarking, etc covering 12 industry sectors, packaging, solvent use and the generic areas of waste minimisation, reduced water usage and effluent flow, and cleaner technology. Envirowise is accessible via a free and confidential helpline (tel: 0800 585 794) or via the web site www.envirowise.gov.uk
 - *Waste Minimisation Interactive Tools (WIMIT)*. Produced by Envirowise in association with the Environment Agency and the BOC Foundation (a software tool designed for small- and medium-businesses). Available free from the Envirowise Helpline (tel: 0800 585 794)
 - *Waste Management Information Bureau*. The UK's national referral centre for help on the full range of waste management issues. It produces a database called Waste Info, which is available for on-line searching and on CD-ROM. Short enquiries are free. (tel: 01235 463 162)
 - *Waste Minimisation - A Practical Guide*, Institution of Chemical Engineers, 1995, plus Training Package E07. Basic course which contains guide, video, slides, OHPs etc. (tel: 01788 578 214)
- Ref 8 Water efficiency references:
- *Envirowise* (see Ref 7) More than 50 case studies, good practice guides, software tools, environmental benchmarking, etc on the subject of reduced water usage and effluent discharges.

- *Optimum use of water for industry and agriculture dependent on direct abstraction: Best practice manual.* R&D technical report W157, Environment Agency (1998), WRc Dissemination Centre, Swindon (tel: 01793 865 012)
- Ref 9 Releases to air references:
- *Waste Water and Waste Gas Treatment BREF*, (see Ref 1)
 - *Guidance on effective flaring in the gas, petroleum and associated industries*, HMIP Technical Guidance Note (Abatement) A1, 1993, ISBN 0-11-752916-8 www.tso.co.uk/bookshop
 - *Pollution abatement technology for the reduction of solvent vapour emissions*, HMIP Technical Guidance Note (Abatement) A2, 1994, ISBN 0-11-752925-7 www.tso.co.uk/bookshop
 - *Pollution abatement technology for particulate and trace gas removal*, HMIP Technical Guidance Note (Abatement) A3, 1994, ISBN 0-11-752983-4 www.tso.co.uk/bookshop
 - *BIO-WISE - profiting through industrial biotechnology*, A DTI programme of Case Studies, demonstrator programmes and guides to the use of biotechnology to improve the environmental performance of sectors such as Chemicals and Engineering - including reduction in emissions to water and to air. Free advice and information is available from the BIO-WISE web site www.dti.gov.uk/biowise and Helpline 0800 432 100
 - *Envirowise*, (see Ref 7) A variety of case studies, good practice guides, software tools, environmental benchmarking, etc, on the subject of reducing emissions to air
 - *Guidelines on Discharge Stack Heights for Polluting Emissions*, HMIP Technical Guidance Note (Dispersion) D1 (see Ref 17)
- Ref 10 Releases to water references
- *Waste Water and Waste Gas Treatment BREF* (see Ref 1)
 - *Effluent Treatment Techniques*, Environment Agency Technical Guidance Note (Abatement) A4, 1997, ISBN 0-11-310127-9 www.tso.co.uk/bookshop
 - *Policy and Practice for the Protection of Groundwater (PPPG)* www.environment-agency.gov.uk
 - *Envirowise* (see Ref 7) More than 50 cases studies, good practice guides, software tools, environmental benchmarking, etc, on the subject of reducing water pollution and usage.
 - *PPG 02 - Above-ground oil storage tanks*, Environment Agency Pollution Prevention Guidance Note. Provides information on tanks and bunding which has general relevance beyond just oil www.environment-agency.gov.uk
 - *PPG 03 - The use and design of oil separators in surface water drainage systems*, Environment Agency Pollution Prevention Guidance Note www.environment-agency.gov.uk
 - *PPG 18 - Managing Fire-water and major spillages*, Environment Agency Pollution Prevention Guidance Note www.environment-agency.gov.uk
 - *PPG 26 - Storage and handling of intermediate bulk containers*, Environment Agency Pollution Prevention Guidance Note www.environment-agency.gov.uk
 - *Construction of bunds for oil storage tanks*, Mason, P. A, Amiss, H. J, Sangarapillai, G. Rose, Construction Industry Research and Information Association (CIRIA), Report 163, 1997, CIRIA, 6 Storey's Gate, Westminster, London SW1P 3AU. Abbreviated versions are also available for masonry and concrete bunds. www.ciria.org.uk or www.environment-agency.gov.uk
- Ref 11 Waste management references
- *Investigation of the criteria for, and guidance on, the land spreading of industrial wastes* – Final report to DETR, the Environment Agency and MAFF, May 1998
- Ref 12 Energy references:
- *(Interim) Energy Efficiency Guidance*, (draft Horizontal Guidance Note IPPC H2 - v2, June 2001) www.environment-agency.gov.uk
- Ref 13 COMAH guides
- *A Guide to the Control of Major Accident Hazards Regulations 1999*, Health and Safety Executive (HSE) Books L111, 1999, ISBN 0 07176 1604 5
 - *Preparing Safety Reports: Control of Major Accident Hazards Regulations 1999*, HSE Books HS(G)190, 1999
 - *Emergency Planning for Major Accidents: Control of Major Accident Hazards Regulations 1999*, HSE Books HS(G)191, 1999
 - *Guidance on the Environmental Risk Assessment Aspects of COMAH Safety Reports*, Environment Agency, 1999 www.environment-agency.gov.uk
 - *Guidance on the Interpretation of Major Accidents to the Environment for the Purposes of the COMAH Regulations*, DEFRA, 1999, ISBN 753501 X, available from The Stationery Office www.tso.co.uk/bookshop
- Ref 14 Monitoring Guidance

- *MCERTS approved equipment* - link via <http://www.environment-agency.gov.uk/business/mcerts>
 - *Sampling facility requirements for the monitoring of particulates in gaseous releases to atmosphere*, HMIP Technical Guidance Note (Monitoring) M1, 1993, ISBN 0-11-752777-7 www.tso.co.uk/bookshop
 - *Standards for IPC Monitoring Part 1: Standards, organisations and the measurement infrastructure*, HMIP Technical Guidance Note (Monitoring) M3, 1995, ISBN 0-11-753133-2 www.tso.co.uk/bookshop
 - *Standards for IPC Monitoring Part 2: Standards in support of IPC Monitoring*, HMIP Technical Guidance Note (Monitoring) M4, revised 1998
 - *UK Direct Toxicity Assessment Demonstration Programme, Technical Guidance*, Research Report No. 00/TX/02/07 UKWIR 2000
- Ref 15 Noise references:
- *Noise Guidance Part 1 - Regulation and Permitting*, (Horizontal Guidance Note IPPC H3, Part 1 - September 2002)
 - *Noise Guidance Part 2 - Assessment and Control*, (Horizontal Guidance Note IPPC H3, Part 2 - September 2002)
- Ref 16 Closure references
- *PPG 06 - Working at Construction and Demolition-sites*, Environment Agency Pollution Prevention Guidance Note www.environment-agency.gov.uk
 - *Guidance for Operators on the Requirements of Closure Site Reports in PPC Permit Surrender Applications* www.environment-agency.gov.uk
- Ref 17 Air Dispersion
- *Guidelines on Discharge Stack Heights for Polluting Emissions*, HMIP Technical Guidance Note (Dispersion) D1, 1993, ISBN 0-11-752794-7 www.tso.co.uk/bookshop; (or www.environment-agency.gov.uk for summary only)
- Ref 18 Fire Fighting
- *BS 5908: Code of Practice for Fire Precautions in the Chemical and Allied Industries*
 - *PPG 18 - Managing Fire-water and major spillages*, Environment Agency Pollution Prevention Guidance Note (see Ref 10)
- Ref 19 Volatile Organic Compounds
- *The Categorisation of Volatile Organic Compounds*, 1995 HMIP Research Report No DOE/HMIP/RR/95/009 (www.environment-agency.gov.uk)
- Ref 20 Environment Agency Technical Guidance for the previous (IPC) regulatory regime
- *Speciality Organic Chemicals*, IPC S2 4.02, Environment Agency, 1999, ISBN 0-11-310154-6 www.tso.co.uk/bookshop or www.environment-agency.gov.uk
 - *Waste Incineration*, IPC S2 5.01, Environment Agency, 1996, ISBN 0-11-310117-1 www.tso.co.uk/bookshop or www.environment-agency.gov.uk
- Ref 21 Novel reactor and Process Intensification papers
- *Chemical reaction engineering: A multi-scale approach to a multi-objective task*. Jan Lerou & Ka Ng, DuPont Central Research and Development - Chemical Engineering Science, Vol 51, No 10, pp 1595-1614, 1996 (Copyright Elsevier Science Ltd)
 - *Alternative multiphase reactors for fine chemicals. A world beyond stirred tanks?* E H Stitt, Syntex, Chemical Engineering Journal 90 (2002) pp 47-60 www.elsevier.com/locate/cej
 - *3rd International Conference on Process Intensification for the Chemical Industry - Smaller, Cheaper and Safer Production*, Antwerp, Belgium, 25-27 October 1999, Proceedings published by BHR Group Limited ISBN 1-86058-215X www.bhrgroup.co.uk
 - *4th International Conference on Process Intensification for the Chemical Industry - Better Processes for Better Products*, Brugge, Belgium, 10-12 September 2001, Proceedings published by BHR Group Limited ISBN 1-85598-0363 www.bhrgroup.co.uk
 - *Process intensification: transforming chemical engineering*, A Stankiewicz & J A Moulijn, Chemical Engineering Progress, January 2000, pp 22-34, Published by AIChE. www.cepmagazine.org
 - *ATLAS Project*, 1996-7 EU research programme into innovative technologies, oriented towards (but not exclusively) energy efficiency techniques [http:// europa.eu.int/comm/energy_transport/atlas](http://europa.eu.int/comm/energy_transport/atlas)

Abbreviations

BAT	Best Available Techniques – see IPPC A Practical Guide or the Regulations for further definition
BAT Criteria	The criteria to be taken into account when assessing BAT, given in Schedule 2 of the PPC Regulations
BOD	Biochemical Oxygen Demand
BREF	BAT Reference Document
CEM	Continuous Emissions Monitoring
CHP	Combined heat and power plant
COD	Chemical Oxygen Demand
ELV	Emission Limit Value
EMS	Environmental Management System
EQS	Environmental Quality Standard
ETP	Effluent treatment plant
FOG	Fat Oil Grease
ITEQ	International Toxicity Equivalents
MCERTS	Monitoring Certification Scheme
NIEHS	Northern Ireland Environment and Heritage Service
SAC	Special Areas of Conservation
SECp	Specific Energy consumption
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
TSS	Suspended solids
TOC	Total Organic Carbon
VOC	Volatile organic compounds

Appendix 1: Some common monitoring and sampling methods

Table 4.1: Measurement methods for common substances to water

Determinand	Method	Detection limit Uncertainty	Valid for range mg/l	Standard
Suspended solids	Filtration through glass fibre filters	1 mg/l 20%	10-40	ISO 11929:1997, EN872 - Determination of suspended solids
COD	Oxidation with di-chromate	12 mg/l 20%	50-400	ISO 6060: 1989, Water Quality - Determination of chemical oxygen demand
BOD5	Seeding with micro-organisms and measurement of oxygen content	2 mg/l 20%	5-30	ISO 5815: 1989, Water Quality Determination of BOD after 5 days, dilution and seeding method EN 1899 (BOD 2 Parts)
AOX	Adsorption on activated carbon and combustion	-- 20%	0.4 - 1.0	ISO 9562: 1998, EN1485 - Determination of adsorbable organically bound halogens.
Tot P				BS 6068: Section 2.28 1997, Determination of phosphorus – ammonium molybdate spectrometric method
Tot N				BS 6068: Section 2.62 1998, Determination of nitrogen Part 1 Method using oxidative digestion with peroxydisulphate, BS EN ISO 11905
pH				SCA The measurement of electric conductivity and the determination of pH, ISBN 0117514284
Turbidity				SCA Colour and turbidity of waters 1981, ISBN 0117519553 EN 27027:1999
Flow rate	Mechanical ultrasonic or electromagnetic gauges			SCA Estimation of Flow and Load, ISBN 011752364X
Temperature				
TOC				SCA The Instrumental Determination of Total Organic Carbon and Related Determinants 1995, ISBN 0117529796 EN 1484:1997
Fatty acids				Determination of Volatile Fatty Acids in Sewage Sludge 1979, ISBN 0117514624
Metals				BS 6068: Section 2.60 1998, Determination of 33 elements by inductively coupled plasma atomic emission spectroscopy
Chlorine				BS6068: Section 2.27 1990, Method for the determination of total chlorine: iodometric titration method
Chloroform Bromoform				BS 6068: Section 2.58, Determination of highly volatile halogenated hydrocarbons – Gas chromatographic methods
Dispersants Surfactants Anionic Cationic Non-ionic				SCA Analysis of Surfactants in Waters, Wastewaters and Sludges, ISBN 01176058 EN 903:1993 (Used for anionic surfactants)
Pentachloro- Phenol				BS5666 Part 6 1983, Wood preservative and treated timber quantitative analysis of wood preservatives containing pentachlorophenol EN 12673:1997 (used for chlorophenol and polychlorinated phenols)

Table 4.1: Measurement methods for common substances to water

Determinand	Method	Detection limit Uncertainty	Valid for range mg/l	Standard
Formaldehyde				SCA The determination of formaldehyde, other volatile aldehydes and alcohols in water
Phosphates and nitrates				BS 6068: Section 2.53 1997, Determination of dissolved ions by liquid chromatography
Sulphites and sulphates				BS 6068: Section 2.53 1997, Determination of dissolved ions by liquid chromatography
Ammonia				BS 6068: Section 2.11 1987, Method for the determination of ammonium: automated spectrometric method
Grease and oils	IR absorption	0.06 mg/kg		SCA The determination of hydrocarbon oils in waters by solvent extraction IR absorption and gravimetry, ISBN 011751 7283

Table 4.2: Measurement methods for air emissions

Determinand	Method	Avg'ing time Detection limit Uncertainty	Compliance criterion	Standard
Formaldehyde	Impingement In 2,4 dinitro-phenyl- Hydrazine HPLC	1 hour 1 mg/m ³ 30%	Average of 3 consecutive samples below specified limit	US EPA Method 316 Method specific to formaldehyde.
Ammonia	FTIR or Ion Chromatography	1 hour 0.5mg/m ³ 25%		US EPA Method 320 for extractive instruments. US EPA Method 26 for wet chemistry.
VOCs	Speciated - Adsorption Thermal Desorption GCMS	1 hour 0.1 mg/m ³ 30%		BS EN 1076:1997 Workplace atmospheres. Pumped sorbent tubes for the determination of gases and vapours. Requirements and test methods.
	Total Organic Carbon	1 hour 0.4 mg/m ³ calculated	Continuous or spot check	BS EN 12619:1999. Determination of the mass concentration of total gaseous organic carbon at low concentrations in flue gases – continuous flame ionisation method.3
Chloroform	Absorption on activated carbon solvent extraction. GC analysis	1 hour 1 mg/m ³ 20%	Average of 3 consecutive samples below specified limit	MDHS 28 Chlorinated hydrocarbon solvent vapours in air (modified)
Oxides of Sulphur	UV fluorescence Automatic analyser	1 hour 1 ppm 10%	95% of hourly averages over a year below specified limit	BS6069 Section 4.4 :1993 (ISO 7935) Stationary source emissions-determination of mass concentrations of sulphur dioxide4.
	Wet sampling train Ion chromatography	1 hour 1 mg/m ³ 25%	Average of 3 consecutive samples below specified limit	BS6069 Section 4.1:1998 (ISO 7934) Method for the determination of the mass concentration of sulphur dioxide-hydrogen peroxide/barium perchlorate method
Hydrogen Chloride	Wet sampling 3 analytical methods	30 minute minimum 0.2 mg/m ³ calculated	One test	BS EN 1911:Parts 1-3:1998 Manual method of determination of HCl
Particulate matter	Extractive – sample train	3 minutes per point 5 mg/m ³ 10%	One test	BS EN 13284-1:2002 Determination of low range mass concentration of dust — Part 1: Manual gravimetric method.

Table 4.2: Measurement methods for air emissions

Determinand	Method	Avg'ing time Detection limit Uncertainty	Compliance criterion	Standard
	Continuous – Automatic analyser	Continuous N/A 10%	Continuous	BS ISO 10155:1995 Automated Monitoring of mass concentrations of particles – performance characteristics, test methods and specifications.
PCDD/F	Extractive – Sample train GC/MS	4 hour minimum 8 hour maximum 0.1 ng I-TEQ/m ³ calculated		BS EN 1948:1997 determination of the mass concentration of PCDD/F

Measurement uncertainty is defined as total expanded uncertainty at 95% confidence limit calculated in accordance with the Guide to the Expression of Uncertainty in Measurement, ISBN 92-67-10188-9, 1st Ed., Geneva, Switzerland, ISO 1993.

See also [Monitoring Guidance](#)

Appendix 2: Equivalent legislation in Wales, Scotland & Northern Ireland

The legislation referred to in the text is that for England. The following are the equivalents for Scotland, Wales and Northern Ireland.

Table 4.3: Equivalent legislation

England	Wales	Scotland	Northern Ireland
PPC Regulations (England and Wales) 2000, SI 2000 No.273 (as amended)	As England	PPC (Scotland) Regulations 2000, SSI 2000 No.323 (as amended)	PPC (NI) Regulations 2003, SR 2003 No.323
SI:1994 1056: Waste Management Licensing Regulations	As England	As England	To be prepared
The Water Resources Act 1991	As England	COPA 1974 (S30A-30E equiv to Part III WRA91); Natural Heritage (Scotland) Act 1991 (Part II equiv to Part I WRA91)	The Water (NI) Order 1999
SI 1989 No.317: Clean Air, The Air Quality Standards Regulations 1989 SI 1995 No. 3146: The Air Quality Standards (Amendments) Regulations 1995	As England	As England	SR 1990 No.145: The Air Quality Standards Regulations (Northern Ireland) 1990 SR1996 No.23: The Air Quality Standards (Amendments) Regulations (Northern Ireland) 1996
SI 2000 No.928: The Air Quality (England) Regulations 2000	SI 2000 No.1940 (W.138): The Air Quality (Wales) Regulations 2000	SSI 2000/97: The Air Quality (Scotland) Regulations	No NI equivalent
SI 2001 No.2315: The Air Quality Limit Values Regulations 2001	SI 2001 No.2683 (W.224): The Air Quality Limit Values (Wales) Regulations 2001	SSI 2001 No.224: The Air Quality Limit Values (Scotland) Regulations 2001	SI 2002 No.94: The Air Quality Limit Values (Northern Ireland) Regulations 2002
SI 1989 No 2286 and 1998 No 389: The Surface Water (Dangerous Substances Classification) Regulations. (Values for List II substances are contained in SI 1997/2560 and SI 1998/389)	As England	SI 1990/126: Surface Water (Dangerous Substances) (Classification) (Scotland) Regulations	Surface Waters (Dangerous Substances) (Classification) Regulations 1998. Statutory Rules of Northern Ireland 1998 No 397
SI 1991 No.1597: Bathing Waters (Classification) Regulations 1991	As England	SI 1991 No.1609: Bathing Waters (Classification) (Scotland) Regulations 1991	The Quality of Bathing Water Regulations (NI) 1993
SI 1997 No.1331: The Surface Waters (Fishlife) (Classification) Regulations 1997	As England	SI 1997 No.2471 (S.163): The Surface Waters (Fishlife) (Classification) (Scotland) Regulations 1997	The Surface Water (Fishlife) (Classification) Regulations (NI) 1997
SI 1997 No.1332: The Surface Waters (Shellfish) (Classification) Regulations 1997	As England	SI 1997 No.2470 (S.162): The Surface Waters (Shellfish) (Classification) (Scotland) Regulations 1997	The Surface Water (Shellfish) (Classification) Regulations (NI) 1997

Table 4.3: Equivalent legislation

England	Wales	Scotland	Northern Ireland
SI 1994 No.2716: The Conservation (Natural Habitats, etc) Regulations	As England	As England	Conservation (Natural Habitats etc) Regulations (Northern Ireland) 1995
SI 1999 No.743: Control of Major Accident Hazards Regulations (COMAH) 1999	As England	As England	SR 2000 No.93: Control of Major Accident Hazards Regulations (Northern Ireland) 2000
SI 1998 No.2746: The Groundwater Regulations 1998	As England	As England	SR 1998 No.401: The Groundwater Regulations (Northern Ireland) 1998

Appendix 3: Volatile Organic Compounds

Introduction

Volatile organic compounds (VOCs) are of serious environmental concern because of the harmful or offensive properties that they exhibit in varying degrees. These include:

- direct toxicity to human health and other eco-systems
- contribution to photochemical ozone creation at ground level with consequent harmful effects
- destruction of stratospheric ozone
- contribution to global climate change; and
- sensory effects such as malodour

The harmfulness of VOCs varies greatly, not only because the individual and combined significance of these properties exhibits wide variation between substances, but also because it is dependent on the presence of the substance in the environment. This is related to mass release rate and subsequent dispersion and to the environmental persistence and fate of the substance under prevailing conditions.

Categorisation

In order to assess BAT for processes that release VOCs, it is necessary to categorise VOCs according to their harmfulness.

Substances such as benzene, vinyl chloride and 1,2-dichloroethane pose serious health risks to humans and are regarded as highly harmful. These are given individual, very low achievable levels of emission in guidance.

Some other VOCs carry a lesser but still significant health risk or may contribute substantially to photochemical ozone creation or stratospheric ozone destruction or global warming. These are regarded as of medium harmfulness and are allocated to Class A. They will include the substances listed in the Montreal Protocol, the phase-out of which is covered by EC Regulations 594/91, 3952/92, 2047/93 and 3093/94.

The remaining majority of VOCs are of low harmfulness but are also substances whose release should be prevented or minimised. These are allocated to Class B.

Odorous VOCs may be offensive at extremely low concentrations and this property may indicate the need for very tight control of a substance that would otherwise be categorised as of low harmfulness.

The research report "The Categorisation of Volatile Organic Compounds" (DOE/HMIP/RR/95/009) provides a method of categorisation, information on the properties of some 500 VOCs and a summary table of resulting categorisations.

In seeking to categorise a VOC, first search the summary table of categorisations. If the VOC is not included, the method and decision tree given in the research report should be used to arrive at a conclusion supported as well as possible by information from established sources. These include the Registry of Toxic Effects of Chemicals, the "CHIP" list, the Montreal Protocol and Sax' Dangerous Properties of Industrial Materials.

Knowledge of the harmful effects of VOCs is developing and there may be occasional differences of experts' opinions on the precise interpretation of information. In these few instances, it will be prudent to adopt the more cautious view.

Achievable Benchmark Levels

The levels of emission that can be achieved are dependent on factors that include the process itself, the VOC concerned and the abatement method used.

Where possible, process- and substance-specific achievable levels of release are given in Table 3.1 of this Note. However, in the absence of sufficient information or where it is agreed that an assessment is not possible, the following guidelines may be used to provide a practical approach to setting limits.

- The benchmark release concentrations given below should be aimed for where the following mass release limits are exceeded:

Total Class A - 100 g/h

Total Class B (expressed as carbon) - 2 kg/h

- but emissions below these mass emission levels may not be trivial, and so may still require controls and the setting of appropriate release limits.

- Highly harmful VOCs pose major human health risks and have individual guidance levels given in Table 3.1 of this Note.
- For Class A compounds, BAT abatement techniques should achieve a benchmark release level of 20 mg/m³ for continuous emissions.
- Some VOCs cause significant malodour problems even at very low concentrations after dispersion, and limits lower than Class A compounds may be required.
- Class B compounds are those of low environmental harmfulness such as acetone and toluene and the Class B benchmark level has been set at 75 mg/m³ (expressed as carbon) based on abatement techniques involving adsorption with activated carbon.
- For mixed streams the release level may be calculated by summing the class levels multiplied by their respective mass fractions.
- The use of a release concentration limit is not normally appropriate in the case of a release from an air-deficient saturated vapour space such as storage tanks for solvents or process vessels. An approach based on limiting total mass released or mass per unit of production is likely to be more effective.
- In some processes, the VOCs released to air may well consist of partial oxidation products rather than defined compounds that can be classified as above. In such cases an approach based on a TOC release concentration is likely to be more appropriate.

Appendix 4: Groundwater Regulations 1998

Schedule of listed substances and recommendations for List I (DEFRA)

List I

- 1.-(1) Subject to the sub paragraph below, a substance is in List I if it belongs to one of the following families or groups of substances:
- (a) organohalogen compounds and substances that may form such compounds in the aquatic environment
 - (b) organotin compounds
 - (c) substances that possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment (including substances that have those properties that would otherwise be in List II)
 - (d) mercury and its compounds
 - (e) cadmium and its compounds
 - (f) mineral oils and hydrocarbons
 - (g) cyanides.
- 1.-(2) A substance is not in List I if it has been determined by the Regulator to be inappropriate to List I on the basis of a low risk of toxicity, persistence and bioaccumulation.

List II

- 2.-(1) A substance is in List II if it could have a harmful effect on groundwater and it belongs to one of these families or groups of substances:
- (a) the following metalloids and metals and their compounds:

zinc	tin	copper
barium	nickel	beryllium
chromium	boron	lead
uranium	selenium	vanadium
arsenic	cobalt	antimony
thallium	molybdenum	tellurium
titanium	silver	
 - (b) biocides and their derivatives not appearing in List I
 - (c) substances that have a harmful effect on the taste or odour of groundwater, and compounds liable to cause the formation of such substances in such water and to render it unfit for human consumption
 - (d) toxic or persistent organic compounds of silicon, and substances that may cause the formation of such compounds in water, excluding those which are biologically harmless or are rapidly converted in water into harmless substances
 - (e) inorganic compounds of phosphorus and elemental phosphorus
 - (f) fluorides
 - (g) ammonia and nitrates.
- 2.-(2) A substance is also in List 2 if:
- (a) it belongs to one of the families or groups of substances set out in paragraph 1(1) above

- (b) it has been determined by the Regulator to be inappropriate to List I under paragraph 1(2); and
- (c) it has been determined by the Regulator to be inappropriate to List II having regard to toxicity, persistence and bioaccumulation.
- 3.-(1) The Secretary of State or Scottish Ministers may review any decision of the Regulator in relation to the exercise of its powers under the paragraphs above.
- 3.-(2) The Secretary of State or Scottish Minister shall notify the Regulator of his decision following a review under List 1 sub paragraph 1 above and it shall be the duty of the Regulator to give effect to that decision.
- 4.- The Regulator shall from time to time publish a summary of the effect of its determinations under this Schedule in such manner as it considers appropriate and shall make copies of any such summary available to the public free of charge.

List of substances recommended to be confirmed as List I

- as recommended by the Joint Agency Groundwater Directive Advisory Group.

Aldrin	Diuron
Atrazine	Endosulfan
Azinphos-ethyl	Fenitrothion
Bromoxynil (as Bromoxynil-phenol)	Fenthion
Bromoxynil octanoate	Heptachlor
Cadmium	Hexachlorobenzene
2-Chloroaniline	Hexachlorobutadiene (HCBD)
Chlorobenzene	Hexachlorocyclohexane
Chlordane	Hexachloroethane
Chloro-2,4-dinitrobenzene	Hexachloronorborene
Chlorfenvinphos	Hexaconazole
4-Chloro-3-methylphenol	3-Iodo-2-propionyl n-butyl carbamate (IPBC)
Chloro-2-nitrobenzene	Linuron
Chloro-3-nitrobenzene	Malathion
Chloro-4-nitrobenzene	Mercury
2-Chlorophenol	Mevinphos
Chlorothalonil	Oxydemeton-methyl
2-Chlorotoluene	Parathion
a-Chlorotoluene	Parathion-methyl
Chlorpyrifos	Pentachlorobenzene
Coumaphos	Pentachloroethane
Cypermethrin	Pentachlorophenol (PCP)
DDT	Permethrin
Demeton	Propanil
Diazinon	Simazine

Dibutyl bis(oxyauroyl)tin	Tetrabutyltin
Dichlofluamid	1,2,4,5-Tetrachlorobenzene
Dichloroaniline	Tetrachloroethylene
1,2-Dichlorobenzene	Triazophos
1,3-Dichlorobenzene	Tributyl tin oxide (TBTO)
1,4-Dichlorobenzene	Tributyl-phosphate
Dichloronitrobenzene (all isomers)	Trichlorfon
2,4-Dichlorophenol	1,2,4-Trichlorobenzene
1,3-Dichloropropene	Trichloroethylene
Dichlorprop	Trichlorophenol (all isomers)
Dichlorvos	Trifluralin
Dicofol	Triphenyl tin oxide (TPTO)
Dieldrin	Triphenyl-phosphate
Dimethoate	