



# Draft BAT Guidance Note on Best Available Techniques for the Manufacture of Integrated Circuits

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# 1. INTRODUCTION

## 1.1 GENERAL

This Guidance Note is one of a series issued by the Environmental Protection Agency (EPA), which provides guidance on the determination of Best Available Techniques (BAT) in relation to:

- applicants seeking integrated Pollution Prevention and Control (IPPC) licenses under Part IV of the Environmental Protection Agency Acts, 1992 and 2007,
- existing Integrated Pollution Control (IPC) Licensees, whose licence is to be reviewed under the Environmental Protection Agency Acts, 1992 and 2007,
- applicants seeking Waste licenses under Part V of the Waste Management Acts 1996 to 2008,
- existing Waste Licensees, whose licence is to be reviewed under Waste Management Acts 1996 to 2008.

This Guidance Note shall not be construed as negating the installation/facility statutory obligations or requirements under any other enactments or regulations.

## 1.2 BAT GUIDANCE NOTE STRUCTURE

This Guidance Note has been structured as follows:

Section	Details
1	Introduction
2	Interpretation of BAT
3	Sectors Covered by this Guidance Note
4	Process Description, Risk to the Environment and Control Techniques
5	Best Available Techniques
6	BAT Associated Emission Levels
7	Compliance Monitoring

Where relevant, references are made to other detailed guidance; such as the reference documents (BREF) published by the European Commission, Agency Guidance Notes for Noise in Relation to Scheduled Activities, and the determination of BAT should be made giving regard to these.

The information contained in this Guidance Note is intended for use as a tool to assist in determining BAT for the specified activities.

## 2. INTERPRETATION OF BAT

### 2.1 STATUS OF THIS GUIDANCE NOTE

This Guidance Note will be periodically reviewed and updated as required to reflect any changes in legislation and in order to incorporate advances as they arise.

Techniques identified in these Guidance Notes are considered to be current best practice at the time of writing. The EPA encourages the development and introduction of new and innovative technologies and techniques, which meet BAT criteria and look for continuous improvement in the overall environmental performance of the sectors activities as part of sustainable development.

### 2.2 INTERPRETATION OF BAT

BAT was introduced as a key principle in the IPPC Directive 96/61/EC<sup>1</sup>. This Directive has been incorporated into Irish law via the Protection of the Environment Act 2003. To meet the requirements of this Directive, relevant Sections of the Environmental Protection Agency Act 1992 and the Waste Management Act 1996 have been amended to replace BATNEEC (Best Available Technology Not Entailing Excessive Costs) with BAT.

Best available techniques (BAT) is defined in Section 5 of the Environmental Protection Agency Acts, 1992 and 2007, and Section 5(2) of the Waste Management Acts 1996 to 2008 as the “most effective and advanced stage in the development of an activity and its methods of operation, which indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent or eliminate or, where that is not practicable, generally to reduce an emission and its impacts on the environment as a whole” where:

**B** ‘**best**’ in relation to techniques means the most effective in achieving a high general level of protection of the environment as a whole.

**A** ‘**available techniques**’ means those techniques developed on a scale which allows implementation in the relevant class of activity under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced within the State, as long as they are reasonably accessible to the person carrying on the activity.

**T** ‘**techniques**’ includes both the technology used and the way in which the installation is designed, built, managed, maintained, operated and decommissioned.

The range of BAT associated emission level values specified in Section 6 indicate those that are achievable through the use of a combination of the process techniques and abatement technologies specified as BAT in Section 5. The licensee must demonstrate to the satisfaction of the Agency, during the licensing process, that the installation/facility will be operated in such a way that all the appropriate preventative measures are taken against pollution through the application of BAT and justify the application of other than the most stringent ELV in the range.

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<sup>1</sup> Directive 2008/1/EC codified version.

At the installation/facility level, the most appropriate techniques will depend on local factors. A local assessment of the costs and benefits of the available options may be needed to establish the best option. The choice may be justified on:

- the technical characteristics of the installation/facility;
- its geographical location;
- local environmental considerations;
- the economic and technical viability of upgrading existing installation.

The overall objective of ensuring a high level of protection for the environment as a whole will often involve making a judgment between different types of environmental impact, and these judgments will often be influenced by local considerations. On the other hand, the obligation to ensure a high level of environmental protection including the minimisation of long-distance or transboundary pollution implies that the most appropriate techniques cannot be set on the basis of purely local considerations.

The guidance issued in this Note in respect of the use of any technology, technique or standard does not preclude the use of any other similar technology, technique or standard that may achieve the required emission standards and is demonstrated to the Agency to satisfy the requirement of BAT.

## 2.3 BAT HIERARCHY

In the identification of BAT, emphasis is placed on pollution prevention techniques rather than end-of-pipe treatment.

The IPPC Directive 2008/1/EC and the Environmental Protection Agency Acts 1992 and 2007 (Section 5(3)), require the determination of BAT to consider in particular the following, giving regard to the likely costs and advantages of measures and to the principles of precaution and prevention:

- (i) the use of low-waste technology,
- (ii) the use of less hazardous substances,
- (iii) the furthering of recovery and recycling of substances generated and used in the process and of waste, where appropriate,
- (iv) comparable processes, facilities or methods of operation, which have been tried with success on an industrial scale,
- (v) technological advances and changes in scientific knowledge and understanding,
- (vi) the nature, effects and volume of the emissions concerned,
- (vii) the commissioning dates for new or existing activities,
- (viii) the length of time needed to introduce the best available techniques,
- (ix) the consumption and nature of raw materials (including water) used in the process and their energy efficiency,
- (x) the need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it,
- (xi) the need to prevent accidents and to minimise the consequences for the environment, and
- (xii) the information published by the Commission of the European Communities pursuant to any exchange of information between Member States and the

industries concerned on best available techniques, associated monitoring, and developments in them, or by international organisations, and such other matters as may be prescribed.

### **3. SECTOR COVERED BY THE GUIDANCE NOTE**

This Guidance Note covers the following activities under the First Schedule to the Environmental Protection Agency Acts 1992 to 2007:

13.2: The manufacture of integrated circuits.

It should be noted that the *BAT Guidance Note on Best Available Techniques for the Surface Treatment of Metals and Plastic Materials*, issued by the Agency covers the manufacture of printed circuit boards.

## 4. PROCESS DESCRIPTION, RISK TO THE ENVIRONMENT AND CONTROL TECHNIQUES

Further reference to Best Available Techniques included in this Note may be found in the Integrated Pollution Prevention and Control (IPPC) Reference Document on *Best Available Techniques (BREF) for the Surface Treatment of Metals and Plastics*, August 2006.

### 4.1 DESCRIPTION OF PROCESSES

The following is a general outline of the integrated circuit manufacturing process. Many iterations of the following steps are carried out to complete the manufacture of the integrated circuit chip.

#### **Wafer Preparation**

Raw silicon wafers are prepared by slicing pure silicon ingots and chemically and mechanically polishing/cleaning with a slurry to obtain a very flat surface. Wafers are then rinsed and dried.

This is typically carried out at Silicon Foundries, which are separate from the Integrated Circuit (IC) manufacturing installations.

A thin layer of silicon oxide is formed on the surface of the wafer. This oxide layer is then covered with a photoresist material.

#### **Photolithography**

The required patterns of the circuit are imprinted on the wafers using UV light through pattern masks. The UV light denatures the photoresist material, exposing it and allowing it to be washed away or removed in the following etching step.

#### **Etching**

The patterns created in lithography are transferred onto the wafer surface by etching away exposed areas. The process may be wet etch or dry etch:

Wet Etch: The wafers are immersed in an acid solution. The wafers are then washed with deionised water and allowed to dry.

Plasma Etch or Dry Etch: The wafers are placed in a vacuum chamber called a plasma etcher. The plasma is generated by applying microwave or radio-frequency excitation. The etching gas (such as perfluorocarbon (PFC) gases) is ionised. The plasma physically or chemically interacts with solid surface materials, the photoresist, silicon layers or silicon dioxide layers, forming volatile products that are then removed from the wafer surface.

The remainder of the photoresist is then chemically removed.

## Thin Film Processes

Thin films are deposited onto the surface of the wafer. There are several types of processes:

Ion implantation:

Ion implantation is used to introduce impurities or ‘dope’ the silicon with materials such as phosphorous, boron or arsenic. The implant is done under vacuum where a dopant or source material is ionised, accelerated through a voltage and shot into selectively exposed regions of the wafer. Implantation changes the electrical characteristics on the wafer.

Chemical vapour deposition: Chemical vapour deposition consists of reacting two or more gases in a chamber to form a solid film on the wafer surface. This layer can be either an insulating or conducting layer depending on the process step.

Physical vapour deposition:

In physical vapour deposition or sputtering, metal is physically dislodged from a source electrode and deposited on the wafer surface placed on the other electrode.

Plating:

Copper is applied to create copper layers by immersion in an electrolytic solution of copper sulphate in sulphuric acid.

## Chemical Mechanical Polish

Chemical mechanical polish or planarisation, involves polishing back the surface of the wafer to achieve a uniform flat layer. The wafer is polished both mechanically and chemically by a polish head and an abrasive slurry solution. A post polish scrub step removes abrasives from the wafer surface.

## Assembly and testing

Connections are established on the wafer through electrolytic deposition of lead, tin, copper and other metal solders. Post solder cleaning can be carried out.

The wafer is separated into individual integrated circuits through laser or diamond saws. The individual integrated circuits are then tested and packaged. This operation is often carried out at a separate site.

## 4.2 RISK TO THE ENVIRONMENT

The key environmental issues for installations manufacturing integrated circuits are emissions to air, emissions to waters, fluorinated gas usage, water consumption, energy use, raw material consumption, and waste.

### 4.2.1 Emissions to Air

Air emissions can be significant for the sector depending on the type of process undertaken. The nature of air emissions include greenhouse gases such as PFCs and pollutants potentially hazardous to health. Point of use treatment systems are widely used to treat air emissions at source with treatment technology such as burners and scrubbers and thermal oxidisers to further abate air emissions. The use of such treatment technologies can also lead to air emissions of NOx, etc..

#### **4.2.2 Emissions to Waters**

Aqueous emissions from this sector include dissolved solids, , fluorides, metals, nitrogen and acidic streams. Aqueous emissions are typically discharged to sewer, in accordance with requirements specified by the Water Services Authority. Specific treatments for certain specific streams are usually undertaken (e.g. metal removal by electrolytic recovery or ion exchange) followed by pH adjustment.

#### **4.2.3 Water Consumption**

Water is used in the process in the form of ultra pure water (UPW) for the rinsing of wafers. It is also used for cooling and air scrubbing requirements.

#### **4.2.4 Energy Use**

Energy is consumed in the operation of production equipment/tools and utilities. The operation of heating ventilation air conditioning systems to maintain clean room conditions, as well as production of ultra pure water (UPW) are some of the major sources of energy consumption.

#### **4.2.5 Raw Material Consumption**

The main raw materials consumed in the manufacture of integrated circuits are semiconductor wafers, photoresist chemicals, VOCs, etching gases (PFCs, SF<sub>6</sub>, NF<sub>3</sub>), acid solutions, and metals.

#### **4.2.6 Waste**

Waste streams comprise a combination of hazardous waste (including acid, metal and solvent solutions, the majority of which can be recovered) and general waste including metal, wood, canteen and office waste and calcium fluoride cake.

#### **4.2.7 Site Remediation**

The condition of the site when activities cease and the need for remediation is a potential environmental issue.

#### **4.2.8 Other Emissions**

Other sources of emissions can include noise and odour but in general these are usually not significant for the processes involved.

### **4.3 CONTROL TECHNIQUES**

#### **4.3.1 General Preventive Techniques**

The following general techniques can be applied to activities manufacturing integrated circuits.

##### **4.3.1.1 Environmental Management**

The implementation of an Environmental Management System (EMS). The EMS should incorporate, as appropriate to individual circumstances, the following features:

- Definition of an environmental policy for the installation by senior management.

- Planning and establishing objectives and targets.
- Implementation and operation of procedures:
  - Structure and responsibility
  - Training, awareness and competence
  - Communication
  - Employee involvement
  - Documentation
  - Efficient process control
  - Maintenance programme
  - Emergency preparedness and response
- Checking performance and taking corrective action:
  - Monitoring and measurement
  - Corrective and preventive action
  - Maintenance of records
  - Independent (where applicable) internal auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained.
- Management review.
- Preparation of a regular environmental statement.
- Validation by certification body or external EMS verifier.
- Development and use of cleaner technologies.
- Annual waste minimisation report showing efforts made to reduce specific consumption together with material balance and fate of all materials.
- Consideration of the impact of decommissioning at the design stage for new plants.
- Optimisation and increased efficiency of the manufacturing process, particularly the optimal use of material inputs and increased reuse and recycling.
- Regular benchmarking with continuous optimisation against this benchmarking; and the taking of actions based on this benchmarking data to the extent allowable. Benchmarking for choice of input materials, consumption of input materials, consumption of water, energy use, emissions to air, discharges to water, generation of waste.
- Inventory control.
- Utility billing (water, energy) per process line.

#### **4.3.1.2 Minimisation of Raw Material Consumption**

Carry out ongoing process review to reduce material use per unit of product, and ongoing review of possible alternative materials that are more benign and/or environmentally preferable.

Where possible redesign processes to substitute materials with more benign and environmentally preferable chemicals, including:

- choice of process materials e.g. substitution with lower Global Warming Potential (GWP) PFC gases,
- choice of product constituent materials e.g. choice of fire resistant materials, solder materials, etc.

Choice of starting wafer materials which will minimise the number of process steps required and correspondingly reduce the amount of chemicals and energy used per unit product.

Work with equipment/tool manufacturers to reduce raw material inputs.

Choice of processes that maximise the number of dies produced per wafer.

Choice of membranes in DI/RO units that will minimise ion exchange regeneration frequencies.

#### **4.3.1.3 Minimisation of Water Consumption**

Optimisation and reduction of water consumption through:

- Use of supercritical carbon dioxide at high temperatures and pressures for the washing of chips.
- Water sub-metering.
- Individual process line water billing.
- Use of water-efficient processes and equipment.
- Efficient methods for wafer rinsing (see below).
- Use of sleep mode switches to reduce water use when process is not operational.
- Verification at each start-up that water flows are at design levels.
- Choice of low fouling membranes in DI/RO units that will minimise ion exchange regeneration frequencies.

Efficient methods for wafer rinsing:

- Evaluation of the number of rinse steps and their duration.
- Switching from continuous flow to on-demand rinsing.
- Use of automatic, timer-controlled shut-off or flow-reducing devices for process rinse lines that are not in constant use.
- Use of counter-current rinsing.
- Use of spray rinsing.
- Use of flow-reducing devices.
- Use contaminant measurements with flow control valves to control the flow of UPW and regulate automatic dumps in rinsing operations.
- Use better operating procedures for drag-in and drag-out, minimising the contamination from the drag-out.
- Reduce the rate of "trickle flows" maintained through process rinse baths, during periods when processing is not taking place.

Cooling Systems

- Eliminate all uses of water for once-through or "single-pass" cooling.
- Use air-cooled equipment instead of water-cooled equipment, where appropriate.

#### **4.3.1.4 Minimisation of Energy Consumption**

Overall considerations for reducing energy consumption are outlined in the BREF on energy efficiency. The following specific techniques are in relation to integrated circuit manufacture.

- Minimise clean-room volumes.

- A programme to find optimal ventilation flowrates with the minimum power consumption that has no effect on cleanliness, relative humidity, temperature, etc.
- Clean-room occupancy sensors or timers.
- Consideration of separate chiller loops where different temperatures are required.
- Recovery of heat:
  - in clean-room ventilation systems via air-to-air heat exchange or heat pumps.
  - from chillers.
- Work with equipment/tool manufacturers to reduce energy consumption.
- Use of energy efficient equipment especially vacuum pumps, chillers, heaters, and power transformers.
- Use of variable speed drives.
- Use of natural heating/cooling from outside air.
- Use of idle mode functions for tools when not in use.

#### **4.3.1.5 Minimisation of Air Emissions**

Segregate waste gas streams according to type utilising associated abatement equipment.

Substitution of PFCs for chamber cleaning with lower GWP potential PFCs or alternative chemistries in the case of new processes.

Substitution of PFCs for plasma etching, where possible, with lower GWP potential PFCs.

Use of wipes pre-impregnated with VOCs for cleaning.

Fugitive emission identification and reduction programme.

Minimisation of tank filling losses.

Containment of VOC vapour during use using condensers, etc.

#### **4.3.1.6 Minimisation of Noise**

This Guidance Note does not cover noise emission sources. For guidance on measures in relation to noise, have regard to any relevant guidance issued by the Agency, e.g. *IPC Guidance Note for Noise in relation to Scheduled Activities*.

#### **4.3.1.7 Requirements for organic solvents with specified risk phrases**

Those installations which fall under the Solvents Directive must replace as far as possible the materials used in those activities that contain organic solvents with risk phrases R45, R46, R49, R60, or R61<sup>2</sup> with less harmful materials within the shortest possible time.

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2 R45 (may cause cancer)  
R46 (may cause heritable genetic damage)  
R49 (may cause cancer by inhalation)  
R60 (may impair fertility)

### 4.3.2 Preventive Techniques for Specific Processes or Unit Operations

Use of alternative cleaning processes such as supercritical fluids, sonic cleaning, cryogenics, hot-UPW, dilute cleaning solutions, where feasible.

Optimise the solids content in slurries used in Chemical Mechanical Polishing to the lowest possible without effect on the process.

Choose mechanical and chemical abrasives in Chemical Mechanical Polishing that are benign e.g. alumina, silica, citric acid, etc.

Use of two chamber drying systems for solvent vapour drying, where one chamber is used for solvent vaporisation and second is used for solvent drying of the wafers.

Investigation of alternative etch removal techniques including supercritical carbon dioxide.

Tracking and optimisation of the quantity of PFCs used for chamber cleaning.

Production of ultra-pure water using techniques which minimise chemical usage.

### 4.3.3 Techniques for Containment

#### 4.3.3.1 Storage

Storage of chemicals should be in bunded areas. The considerations outlined in the Storage BREF, Section 5.1.1.3. Preventing incidents and (major) accidents: 'Soil protection around tanks – containment' should be taken into account. For guidance on measures in relation to storage, have regard to the *IPPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities*.

Use of bulk storage and distribution where possible.

All storage vessels and containers should be enclosed or fitted with adequately fitting lids.

All fixed storage and mixing tanks should be fitted with high-level alarms and level indicators and/or automatic shut-off valves in liquid supply to prevent overflow. See Storage BREF, Section 4.1.6.1.6 and Section 5.1.1.3. Preventing incidents and (major) accidents: Operational procedures and instrumentation to prevent overfill.

All tanks and containers should be labeled indicating the contents.

Organic solvent containing waste (e.g. wipes, protective clothing, absorbents from spills, etc.) should be stored in closed containers.

Suitable spill handling and containment equipment should be readily available in all chemical storage and handling areas.

All process pipelines should be over ground.

Materials (excluding bulk liquids) should be stored, handled, and processed within suitable buildings.

#### **4.3.3.2 Segregation**

Separate collection of storm water from areas which could be potentially contaminated, i.e. chemical storage and use areas, with the facility to shut-off discharge as appropriate.

Separate collection of cooling water and process effluents of different origin in order to permit appropriate treatment options.

#### **4.3.4 Techniques for Recovery, Reuse and Recycling**

##### **4.3.4.1 Reuse of water**

Recovery and recycling of waste UPW water and reuse within the semiconductor manufacturing process itself. For example, return of final stage rinse waters to the UPW plant to re-treat the water.

Use of technologies to recycle and recover process waste water for reuse including membrane technologies such as reverse osmosis in combination with other techniques, for example UV sterilisation, carbon filtration, etc..

Reuse reject water streams from UPW plants in:

- Boilers (reduced need for treatment chemicals and boiler blowdown)
- Cooling towers (reduced need for treatment chemicals)
- Humidity-control devices
- Air emission abatement scrubbers
- Landscape sprinkling systems
- Fire-fighting (water)

Recycling of condensate from make-up air handlers.

##### **4.3.4.2 Recovery and reuse of solvents**

Recovery and on-site reuse of solvents, where quality requirements allow. Refer to the BAT Guidance Note on Best Available Techniques for Solvent Use in Coating, Cleaning and Degreasing and Solvents Directive.

##### **4.3.4.3 Recovery and reuse of acids**

Recovery and on-site reuse of acids.

##### **4.3.4.4 Capture and reuse of fluorinated gases**

Capture and reuse of fluorinated gases on process lines where a single gas is in use and throughput volume is high.

##### **4.3.4.5 Recovery of metals from waste streams**

Recovery of metals from waste streams and waste waters through electrolytic recovery.

##### **4.3.4.6 Production of fertiliser out of waste ammonia streams**

Production of fertiliser out of waste ammonia-containing streams, where feasible taking into account the amount of energy used in the treatment processes.

### 4.3.5 Treatment Techniques

#### 4.3.5.1 Treatment of Air Emissions

Separate treatment of air emissions according to type in order to permit use of appropriate abatement options. Treatment techniques for air emissions depend on the type of emission:

- VOCs: thermal oxidation, thermal oxidation with concentration, VOC adsorption/desorption, or carbon filtration.
- Fluorinated gases and other substances from etching and chamber cleaning: fueled burner followed by a wet scrubber; fuelled catalytic oxidiser followed by a wet scrubber; electrically heated chamber followed by a wet scrubber; or plasma reactor to destroy fluorinated gases before dilution with nitrogen purge; dry scrubbers can also be used in place of wet scrubbers (gases and by-products react with chemical resin to form solids).
- Acid gases: scrubbers.
- Ammonia: scrubbers.
- Particulates – cyclones, filters.
- Particulates classified as carcinogenic – HEPA filters.

#### 4.3.5.2 Treatment of Waste Water

Separate collection of process effluents of different nature in order to permit appropriate treatment options.

Neutralisation of acidic and basic streams.

Use of electrolytic recovery or ion exchange or to remove metals from individual streams where feasible, otherwise precipitation of metals and filtration.

Filtration or microfiltration to remove solids, solid metal particles, etc.

Use of precipitation, flocculation and filtration to remove fluoride.

Use of catalysed hydrolysis to remove cyanide.

Use of biological treatment to remove BOD and COD.

Use of biological treatment to remove nitrogen.

Use of biological treatment and/or chemical/mechanical treatment for phosphorus (P) removal.

Appropriate level of effluent monitoring before, during and after treatment to provide the necessary information to operate the treatment plant, check effectiveness of treatment, indicate potential for improvement, and demonstrate compliance.

### 4.3.6 Techniques for Appropriate Disposal

Waste classified as hazardous, once all reduction, reuse, and recovery options have been exhausted, should only undergo physico-chemical treatment, be incinerated in a hazardous waste incinerator, or be disposed of in a landfill for hazardous waste.

Certain non-hazardous wastes can be landfilled or incinerated in a municipal waste incinerator, once all reduction, reuse, and recovery options have been exhausted, and subject to the acceptance criteria of individual facilities. Such wastes include:

- General municipal type waste, with the exception of certain packaging waste streams which must be segregated and recycled – namely aluminium, cardboard, glass, paper, plastic sheeting, steel, and wood packaging.

It should be noted that total biodegradable waste going to landfills is being progressively limited under the landfill directive (Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste).

## 5. BEST AVAILABLE TECHNIQUES FOR THE MANUFACTURE OF INTEGRATED CIRCUITS

### 5.1 INTRODUCTION

As explained in Section 2, this Guidance Note identifies BAT but obviously does so in the absence of site-specific information. Accordingly, it represents the requirements expected of any new activity covered by the Note, and ultimately the requirements expected of existing installations, but does not include additional requirements which may form part of the granting of a licence for a specific site.

The approach to be used in selecting BAT is based on the following hierarchy:

- Process design/redesign changes to eliminate emissions and wastes.
- Waste reduction by means of process control, inventory control, etc.
- Substitution of materials, fuels etc. by environmentally less harmful materials.
- Reuse of materials within the process and in products.
- Recycling of wastes in other applications.
- End-of-pipe techniques to control, abate or treat emissions.
- Safe disposal.

The technical feasibility of the measures listed below has been demonstrated by various sources. Used singly, or in combination, the measures represent BAT solutions when implemented in the appropriate circumstances. These circumstances depend on plant scale, process type, materials in use, etc.

### 5.2 BAT – GENERAL PREVENTATIVE MEASURES

#### 5.2.1 Environmental Management

Effective management is important in achieving good environmental performance. It is an important component of BAT and forms part of the definition of techniques given in Article 2 of the Directive. For BAT a management system includes the following elements (see Section 4.3.1.1 of this document for details):

- A management policy and commitment
- Incorporates design and maintenance elements which include for the assessment of the effects of existing plant and any new or substantially changed processes on the degree of protection of air, water and land as follows;
- A training element.

#### 5.2.2 Preventive Measures

BAT is to implement the following preventive measures, where relevant and feasible for the installation:

- Techniques in Section 4.3.1.2 to minimise raw material consumption,
- Techniques in Section 4.3.1.3 to minimise water consumption,
- Techniques in Section 4.3.1.4 to minimise energy consumption,

- Techniques in Section 4.3.1.5 to minimise air emissions,
- Techniques to minimise noise in the *IPC Guidance Note for Noise to Scheduled Activities* and any other noise guidance issued by the Agency.
- Prevention techniques in Section 4.3.2 for processes as relevant.

### 5.2.3 Material Substitution Measures

If substances or preparations with risk phrases R45, R46, R49, R60, or R61 due to organic solvent content are in use for activities that fall under the Solvents Directive, BAT is to replace them as far as possible with less harmful materials within the shortest possible time. See Section 4.3.1.7 of this document.

### 5.2.4 Techniques for Containment

BAT is to do the following, as relevant to the installation:

- The storage techniques outlined in Section 4.3.3.1.
- The segregation techniques outlined in Section 4.3.3.2.

### 5.2.5 Techniques for Recovery, Reuse and Recycling

BAT is to evaluate the following techniques, to implement those feasible for the installation, and to carry out this review on an annual basis for processes where such techniques have not yet been implemented:

- Techniques for reuse of water outlined in Section 4.3.4.1,
- recovery and on-site reuse of solvents (Section 4.3.4.2),
- recovery and on-site reuse of acids (Section 4.3.4.3),
- capture and reuse of fluorinated gases (Section 4.3.4.4),
- recovery of metals (Section 4.3.4.5),
- Production of fertiliser out of waste ammonia-containing streams (Section 4.3.4.5).

### 5.2.6 Measures for Treatment and Disposal

#### 5.2.6.1 Treatment of Air Emissions

After all measures have been taken to minimise air emissions, BAT is to implement separate treatment of air emission streams to the extent feasible.

For activities other than those that come under the Solvents Directive, BAT is to meet the ELVs specified in Table 6.1, as relevant, through the application of the techniques described in Section 4.3.5.1 as appropriate.

For activities that come under the Solvents Directive, BAT is to meet the emission levels specified in the Tables included in Section 6.1.2, as appropriate.

- where VOCs are in use with the specified risk phrases above the stated mass flow emissions (see Section 6.1.2.1), BAT is to meet the emission levels specified in Table 6.1.1 as relevant; or
- where existing installations are using existing equipment and using VOCs other than those with the specified risk phrases, BAT is to meet the emission levels specified in the Tables included in Section 6.1.2, as appropriate; or

- If the activity does not fall under indent 1 or 2 (above), BAT is to meet the relevant waste gas emission levels and the fugitive emission value specified in Table 6.1.2.3.

#### **5.2.6.2 Collection, Treatment, and Disposal of Waste Water**

After all measures have been taken to minimise emissions to waters, BAT is to implement separate treatment of different types of process effluent streams to the extent feasible.

BAT is to meet the emission levels specified in Table 6.2, as relevant, through the application of the techniques described in Section 4.3.5.2 as appropriate.

BAT is to separately collect surface water from areas that can be potentially contaminated.

BAT is to monitor separately collected surface water, as appropriate, prior to any dilution with uncontaminated surface waters.

#### **5.2.6.3 Treatment and Disposal of Waste**

BAT is to minimise the quantity and load of waste generated using the preventive techniques outlined in Section 4.3.1 of this document and then recover or dispose of the waste using appropriately licensed recovery or disposal facilities as outlined in Section 4.3.6.

## 6. BAT ASSOCIATED EMISSION LEVELS

### 6.1 EMISSION LEVELS FOR DISCHARGES TO AIR

Achievable emission levels for discharges to air based on BAT are given in Tables 6.1 and tables included in Section 6.1.2 below. The requirements for compliance with S.I. No 543 of 2002 - Emissions of Volatile Organic Compounds from Organic Solvents Regulations, 2002, need to be established by the licensee.

The BAT emission limit values for emissions to air are as follows:

**Table 6.1 BAT Associated Emission Levels for Emissions to Air\***

Constituent Group or Parameter <sup>Note 1</sup>	Class	Emission Level (mg/m <sup>3</sup> )	Mass Flow Threshold (g/hr) <sup>Note 2</sup>
Carcinogenic Substances (Note 3)	<b>Class I (limits set for class total)</b> <ul style="list-style-type: none"> <li>- arsenic and its compounds (except for arsine), as As</li> <li>- benzo(a)pyrene</li> <li>- cadmium and its compounds, as Cd</li> <li>- water-soluble compounds of cobalt, as Co</li> <li>- chromium (VI) compounds (except for barium chromate and lead chromate), as Cr</li> </ul>	0.05	0.15
	<b>Class II (limits set for class total)</b> <ul style="list-style-type: none"> <li>- acrylamide</li> <li>- acrylonitrile</li> <li>- dinitrotoluenes</li> <li>- ethylene oxide</li> <li>- nickel and its compounds (except for nickel metal, nickel alloys, nickel carbonate, nickel hydroxide, nickel tetracarbonyl) as Ni</li> <li>- 4-vinyl-1,2-cyclohexane-diepoxy</li> </ul>	0.5	1.5
	<b>Class III (limits set for class total)</b> <ul style="list-style-type: none"> <li>- benzene</li> <li>- bromoethane</li> <li>- 1,3-butadiene</li> <li>- 1,2-dichloroethane</li> <li>- 1,2-propylene oxide (1,2-epoxy propane)</li> <li>- styrene oxide</li> <li>- o-toluidine</li> <li>- trichloroethane</li> <li>- vinyl chloride</li> </ul>	1.0	2.5
Organic Substances	<b>Class I (limits set for class total)</b> <ul style="list-style-type: none"> <li>- Substances listed in Annex 1</li> </ul>	5 - 20	100

(Note 3)	<ul style="list-style-type: none"> <li>- Substances not listed under their name in Annex 1 which comply with one of the following criteria as described in council Directive 67/548/EEC ;           <ul style="list-style-type: none"> <li>• R40, R62, R63</li> <li>• They are toxic or very toxic (e.g. R26 R50, R54, R57,)</li> <li>• They may cause irreversible harm or damage (e.g. R39)</li> <li>• They may cause sensitisation when inhaled (e.g. R42)</li> <li>• They are highly odour intensive,</li> <li>• They are slowly degradable and accumulative (e.g. R33)</li> </ul> </li> </ul>		
	<b>Class II (limits set for class total)</b> <ul style="list-style-type: none"> <li>- 1-bromo-3-chloropropane</li> <li>- 1,1-dichloroethane</li> <li>- 1,2-dichloroethylene,cis and trans</li> <li>- ethanoic acid</li> <li>- methyl formate</li> <li>- nitroethane</li> <li>- nitromethane</li> <li>- octamethylcyclotetrasiloxane</li> <li>- 1,1,1-trichloroethane</li> <li>- 1,3,5-trioxane</li> </ul>	20 - 100	500
Total Organic Carbon (As C)	Not included in Class I or II above <b>(limits set for class total)</b>	50	500
Mercaptans		2	100
Amines (total)		10	100
Trimethylamine		2	100
Phenols, Cresols & xylools		2	100
Toluene di-isocyanate		1	100
Organic Substances with Photochemical Ozone Potential (R59)		20	500

Vaporous or Gaseous Inorganic Substances	<b>Class I (limits set on a per substance basis)</b> - arsine - cyanogen chloride - phosgene - phosphine	0.5	2.5
	<b>Class II (limits set on a per substance basis)</b> - bromine and its gaseous compounds, as hydrogen bromide - chlorine - hydrocyanic acid (HCN) - fluorine and its gaseous compounds, as HF - hydrogen sulphide	0.27 - 3 Note 5	15
	<b>Class III (limits set on a per substance basis)</b> - ammonia - gaseous inorganic compounds of chlorine, as HCl	4 - 30	150
	<b>Class IV (limits set on a per substance basis)</b> - sulphur oxides (sulphur dioxide and sulphur trioxide), as SO <sub>2</sub> - nitrogen oxides (nitrogen monoxide and nitrogen dioxide), as NO <sub>2</sub>	5 - 350	1800
	- nitrogen monoxide and nitrogen dioxide, as NO <sub>2</sub> (thermal or catalytic post combustion facilities)	200	-
	- Carbon monoxide (thermal or catalytic post combustion facilities)	100	-
Inorganic Dust Particles (Note 3)	<b>Class I (limits set on a per substance basis)</b> - mercury and its compounds, as Hg - thallium and its compounds, as Tl	0.05 - 0.2	0.25
	<b>Class II (limits set for class total)</b> - lead and its compounds, as Pb - cobalt and its compounds, as Co - nickel and its compounds, as Ni - selenium and its compounds, as Se - tellurium and its compounds, as Te	0.1 - 0.5	2.5
	<b>Class III (limits set for class total)</b> - antimony and its compounds, as Sb - chromium and its compounds, as Cr - easily soluble cyanides (e.g. NaCN), as CN - easily soluble fluorides (e.g. NaF), as F - copper and its compounds, as Cu - manganese and its compounds, as	0.1 - 1	5

	Mn - vanadium and its compounds, as V - tin and its compounds, as Sn - Other substances with risk phrases R40, R62 or R63		
Carbon Monoxide (CO)		50 - 250	-
Total Particulates		20	200
Other			Note 4

- For existing activities, BAT associated emission levels shall as a minimum, be considered TA Luft (Technical Instructions on Air Quality Control - TA Luft in accordance with art. 48 of the Federal Immission Control Law (BImSchG) dated 15 March 1974 (BGBI. I p.721). Federal Ministry for Environment, Bonn 1986, including the amendment for Classification of Organic Substances according to Section 3.1.7 TA.Luft, published in July 1997).

Note 1: Where a substance falls into more than one category in Table 6.1, the lower emission limit value applies.

Note 2: The Mass Flow Threshold is calculated in g/hr or kg/hr and is determined to be the maximum emission which can occur over any one hour period of plant operation. Where the Mass Flow in the raw gas exceeds the mass flow threshold given in the Table, abatement will be required to reduce the emission to below the appropriate emission level or mass flow threshold.

Note 3: Where substances of several classes are present, in addition to the above limit, the sum of Classes I & II shall not exceed the Class II limit and the sum of Classes I & III, II & III or I, II & III shall not exceed the Class III limit.

Note 4: Any relevant polluting substances as specified in Schedule to S.I. No. 394 of 2004: EPA (Licensing)(Amendment) Regulations, 2004.

Note 5: A mass flow emission limit may be set in conjunction with, or instead of, an emission limit value.

## 6.1.2 ELVs for Emission to Air for activities falling under the Solvents Directive

### 6.1.2.1 Emission Limit Values for activities falling under the Solvents Directive with VOCs with Specified Risk Phrases Above Stated Mass Flow Emissions

The BAT emission limit values for activities falling under the Solvents Directive are as follows for VOCs with the specified risk phrases above the stated mass flow emissions:

**Table 6.1.2.1 Emission Limit Values for activities falling under the Solvents Directive with VOCs with Specified Risk Phrases Above Stated Mass Flow Emissions**

Activities falling under the Solvents Directive: Volatile organic compounds (VOCs) (as C) with Risk Phrase	Mass flow threshold of the sum of such compounds <small>Note 1</small>	Emission Limit Value (mass sum of the individual compounds)
R45 (may cause cancer)	$\geq 10 \text{ g/h}$	$2 \text{ mg/Nm}^3$
R46 (may cause heritable genetic damage)		
R49 (may cause cancer by inhalation)		
R60 (may impair fertility)		
R61 (may cause harm to the unborn child)		
R40 (limited evidence of a carcinogenic effect) and halogenated	$\geq 100 \text{ g/h}$	$20 \text{ mg/Nm}^3$

Note 1: This applies at the point of discharge whether abatement is present or not.

### 6.1.2.2 Emission Limit Values for Installations falling under the Solvents Directive that are Existing Activities Using Existing Equipment

The BAT emission limit values are as follows for activities falling under the Solvents Directive that are existing<sup>3</sup> installations using existing equipment and using VOCs other than those with the specified risk phrases:

3 Under the solvents Directive, an existing installation is an installation that is in operation on or before 30 June 2003. A new installation is an installation that is put into operation on or after 1 July 2003.

In addition to this, an existing installation that undergoes a substantial change, the part of the installation which undergoes the change must either: be treated as a new installation, or be treated as an existing installation, provided that the total emissions of the whole installation does not exceed those that would have resulted had the substantially changed part been treated as a new installation. A substantial change is as defined under the IPPC Directive for an IPPC activity, or an increase of more than 25% in emissions of VOCs (where solvent consumption is less than 10 tonnes/year), or an increase of more than 10% in emissions of VOCs (where solvent consumption is 10 tonnes/year or more).

Also the EPA can decide a change is a substantial change, if it considers it may have significant negative effects on human health or the environment.

**Table 6.1.2.2 Emission Limit Values for Installations falling under the Solvents Directive that are Existing Activities Using Existing Equipment**

Activities falling under the Solvents Directive: Existing Installations using existing equipment	Emission Limit Value (mg C/Nm <sup>3</sup> )	
	Incineration	Any other abatement equipment
Volatile Organic Compounds (VOCs) (as C)	50	150

**6.1.2.3 Emission Limit Values for All Other Installations falling under the Solvents Directive**

Activities falling under the Solvents Directive which do not have specified risk phrase VOC emissions above the stated mass flow emissions and which do not operate existing equipment must meet the waste gas and fugitive ELVs in table 6.1.2.3 for the relevant activity or activities.

Those that could be of possible relevance to integrated circuit manufacture are set out in table 6.1.2.3.

**Table 6.1.2.3 Emission Limit Values for All Other Installations falling under the Solvents Directive - emission limit value and fugitive emission value**

	All other activities falling under the Solvents Directive: Solvent consumption (t/year)	Threshold (solvent consumption (t/year))	VOCs waste gas emission limit value mg C/m <sup>3</sup>	VOCs fugitive emission value % of solvent input
4	Surface cleaning (using substances/preparations with VOCs classified as R40, R45, R46, R49, R60, or R61) (>1)	1 - 5 > 5	20*	15
			20*	10
5	Other surface cleaning (>2)	2 - 10 >10	75**	20**
			75**	15**
8	Other coating, including metal, plastic, textile, fabric, film and paper coating (>5)	5 - 15 > 15	100	25
			50/75***	20
16	Adhesive coating (> 5)	5 - 15 > 15	50 <sup>(1)</sup>	25
			50 <sup>(1)</sup>	20

\* Limit refers to mass of compounds in mg/Nm<sup>3</sup> and not to total carbon.

\*\* Installations which demonstrate to the competent authority that the average organic solvent content of all cleaning material used does not exceed 30% by weight are exempt from application of these values.

\*\*\* The first emission limit value applies to drying processes, the second to coating application processes.

Note 1: If techniques are used which allow reuse of recovered solvent, the emission limit value in waste gases shall be 150.

## 6.2 EMISSION LEVELS FOR DISCHARGES TO WATER VALUES

The following table sets out emission levels that are achievable using BAT for wastewater treatment. However establishing emission limit values within a licence for direct discharges to surface water from wastewater treatment plant and stormwater discharges must ensure that the quality of the receiving water is not impaired or that the current Environmental Quality Standards (EQS) are not exceeded.

All parameters will not be relevant to every installation and will depend on the types of materials in use, the treatment techniques in use, and the nature of the receiving water.

All discharges to sewer are subject to approval from the Water Services Authority.

Compliance with the Water Framework Directive (2000/60/EC) is required where relevant, in particular Article 16.

**Table 6.2: BAT Associated Emission Levels for Discharges to Water \***

Constituent Group or Parameter	Emission Levels (mg/l unless otherwise stated)	Percentage Reduction <sup>3</sup>	Notes
pH	6 - 9 pH units		
Toxicity	5 - 10 TU		1
BOD <sub>5</sub>	25	>90% removal	
Total Nitrogen (as N)	15	>80% removal	2,4
Total Ammonia (as N)	10		
Total Phosphorus (as P)	2	>80% removal	
Fluoride	50		
Oils, Fats and Grease	10		
Arsenic	0.05 - 0.5		
Chromium (VI)	0.1		6
Chromium (Total)	0.1 - 0.5		6
Copper	0.3 - 0.5		6
Lead	0.4 - 0.5		6
Tin	0.4 - 2		6
Metals			5,6
Mineral oil	20		
Priority Substances under the water framework Directive			5
Other			5,7
No Tainting	No Tainting		

\* All values refer to daily averages based on a 24-hour flow proportional composite sample, except where stated to the contrary and for pH, which refers to continuous values. Levels apply to effluent prior to dilution by uncontaminated streams, e.g. storm water, cooling water, etc.

- \* Temperature measured downstream of a point of thermal discharge must not exceed the unaffected temperature by more than 1.5°C in salmonid waters and 3°C in cyprinid waters (Freshwater Fish Directive 79/659/EEC).

Note 1: The number of toxic units (TU) =  $100/x$  hour EC/LC50 in percentage vol/vol so that higher TU values reflect greater levels of toxicity. For test regimes where species death is not easily detected, immobilisation is considered equivalent to death.

Note 2: Total Nitrogen means the sum of Kjeldahl Nitrogen, Nitrate N and Nitrite N.

Note 3: Reduction in relation to influent load.

Note 4: Limits will depend on the sensitivity of the receiving waterbody.

Note 5: BAT associated emissions levels are highly dependent on production process, wastewater matrix and treatment. These parameters shall be considered on a site-specific basis when setting emission limit values.

Note 6: PARCOM recommendation 92/4 applies to a wastewater emission from the electroplating industry discharging to water or public sewer. Where the sum total of metals specified in combined is <200g/day prior to treatment, their emission level values may be increased fourfold. Applies to activities other than printed circuit board manufacture. Applies to wastewater streams specially treated (PARCOM 92/4).

Note 7: Any relevant polluting substances as specified in Schedule to S.I. No. 394 of 2004: EPA (Licensing)(Amendment) Regulations, 2004.

## **7. COMPLIANCE MONITORING**

The methods proposed for monitoring the emissions from this sector are set out below. Licence requirements may vary from those stated below due to site location considerations, sensitivity of receiving media and scale of the operation.

### **7.1 MONITORING OF EMISSIONS TO AIR**

For emissions to air, establish existing back-ground conditions prior to start-up, of key emission constituents

Either continuous or periodic stack monitoring, as required by the licence, taking account of the nature, magnitude and variability of the emission and the reliability of the control techniques.

Monitor solvent / VOC usage by annual mass balance reports and use to determine fugitive emissions.

Monitor fluorinated gas usage by annual mass balances and use to determine emissions.

Monitoring of boiler combustion efficiency in accordance with the manufacturer's instructions at a frequency determined by the Agency.

Periodic monitoring for other parameters as determined by the Agency.

### **7.2 MONITORING OF AQUEOUS EMISSIONS**

For emissions to water, establish existing conditions prior to start-up, of key emission constituents, and salient flora and fauna.

Monitoring of flow and volume.

Exact monitoring requirements in terms of parameters and frequency will be decided on taking into account the nature, size, and location of the site; the scale of the operation; the types of materials in use; the type of waste water treatment in use, the reliability of any control techniques; and the nature of the receiving sewer or water.

Samples for monitoring must be taken prior to dilution by any uncontaminated stormwater and unfiltered prior to analysis. Similarly, emission limit values apply prior to dilution and unfiltered prior to analysis.

### **7.3 MONITORING OF EMISSIONS TO GROUND**

There should be no direct emissions to groundwater, including during extraction and treatment of groundwater.

### **7.4 MONITORING OF WASTE**

- The recording in a register of the types, quantities, date and manner of disposal/recovery of all wastes.
- Leachate testing of sludges and other material as appropriate being sent for disposal.
- Annual waste minimisation report showing efforts made to reduce specific consumption together with material balance and fate of all waste materials.

## **7.5 NOISE EMISSIONS MONITORING**

For guidance on measures in relation to noise, have regard to the Guidance Note for Noise in relation to scheduled activities and any other noise guidance issued by the Agency.

## Appendix 1

### Organic Substances of Class I Pursuant to Table 6.1

Substance	CAS-Number
1,1,2,2-Tetrabromoethane	79–27–6
1,2,3-Propanetriol, trinitrate	55–63–0
1,2,4-Benzenetricarboxylic acid	528–44–9
1,2-Benzenediol (Pyrocatechin)	120–80–9
1,2-Ethanediamine, N-(2-aminoethyl)-	111–40–0
1,2-Ethanediol, dinitrate	628–96–6
1,2-Propanediol, dinitrate	6423–43–4
1,3-Butadiene, 1,1,2,3,4,4-hexachloro-	87–68–3
1,3-Propanediamine	105–83–9
1,4-Dioxane	123–91–1
1,5-Naphthalenediamine	2243–62–1
1,6-Hexamethylene diisocyanate	822–06–0
1,6-Hexanediamine	124–09–4
1-Butanamine,	109–73–9
1-Butanethiol	109–79–5
1-Naphthalenamine	134–32–7
1-Propene, 3-chloro-2-methyl-	563–47–3
2,4,7-Trinitrofluorenone	129–79–3
2,5-Furandione	108–31–6
2-Butenal (Crotonaldehyde)	123–73–9
2-Butyne-1,4-diol	110–65–6
2-Chloro-1,3-butadiene (Chloroprene)	126–99–8
2-Cyclohexen-1-one, 3,5,5-trimethyl-	78–59–1
2-Ethoxyethyl acetate	111–15–9
2-Furancarboxaldehyde (Furfural)	98–01–1
2-Furanmethanamine	617–89–0
2-Hexanone	591–78–6
2-Imidazolidinethione	96–45–7
2-Methyl-m-phenylenediamine	823–40–5
2-Naphthyl phenyl amine	135–88–6

Substance	CAS-Number
2-Nitro-p-phenylenediamine,2	5307-14-2
2-Propanamine, 2-methyl-	75-64-9
2-Propenal (Acrolein, Acrylaldehyde)	107-02-8
2-Propenoic acid, butyl ester	141-32-2
2-Propenoic acid, ethyl ester (Ethyl acrylate)	140-88-5
2-Propenoic acid, methyl ester	96-33-3
2-Propyn-1-ol	107-19-7
3,3'-Diamino-benzidine	91-95-2
4,4'-Methylenebis(2-methylcyclohexylamine)	6864-37-5
4-Amino-2-nitrophenol	119-34-6
4-Methyl-3-oxa-1-pentanol	109-59-1
4-Tert-butyltoluene	98-51-1
Acetaldehyde	75-07-0
Acetamide	60-35-5
Acetamide, N-phenyl-	103-84-4
Acetic acid anhydride	108-24-7
Acetic acid ethenyl ester	108-05-4
Acetic acid, chloro-	79-11-8
Acetic acid, chloro-, methyl ester	96-34-4
Acetic acid, methoxy-	625-45-6
Acetic acid, trichloro-	76-03-9
Acrylic acid	79-10-7
Alkyl-lead compounds	
Aniline	62-53-3
Aniline, N-methyl-	100-61-8
Benzenamine, 2,4-dimethyl-	95-68-1
Benzenamine, 2-methyl-5-nitro-	99-55-8
Benzenamine, 4-methoxy-	104-94-9
Benzenamine, 5-chloro-2-methyl-	95-79-4
Benzenamine, N,N-dimethyl-	121-69-7
Benzene, (dichloromethyl)-	98-87-3
Benzene, 1,1'-methylenebis[4-isocyanato-	101-68-8
Benzene, 1,2,4,5-tetrachloro-	95-94-3
Benzene, 1-chloro-2-nitro	88-73-3

Substance	CAS-Number
Benzene, 1-chloro-4-nitro-	100-00-5
Benzene, 1-methyl-3-nitro-	99-08-1
Benzene, 1-methyl-4-nitro-	99-99-0
Benzene, 2,4-dichloro-1-methyl-	95-73-8
Benzene, nitro-	98-95-3
Benzenesulfonyl chloride	98-09-9
Benzoyl chloride	98-88-4
Benzoyl peroxide	94-36-0
Biphenyl (Diphenyl)	92-52-4
Bis(2-ethylhexyl)phthalate	117-81-7
Butylamine, iso-	78-81-9
Camphor	76-22-2
Caprolactam	105-60-2
Carbamic chloride, diethyl-	88-10-8
Carbon tetrachloride	56-23-5
Carbonyl sulfide	463-58-1
Chloroacetic acid isopropyl ester	105-48-6
Chloroform (Trichloromethane)	67-66-3
Chloromethane	74-87-3
Chloropicrin (Trichloronitromethane)	76-06-2
Diaminoethane (Ethylenediamine)	107-15-3
Dichlorophenols	
Diglycidyl ether	2238-07-5
Diisocyanattoluol,2,6-	91-08-7
Di-n-butyltindichloride	683-18-1
Dinitronaphthalene (all isomers)	27478-34-8
Diphenyl ether	101-84-8
Diphenylamine	122-39-4
Diphenylmethane-2,4'-Diisocyanate	5873-54-1
Ethanamine, N-ethyl-	109-89-7
Ethane, 1,1,2,2-tetrachloro-	79-34-5
Ethane, 1,1,2-trichloro-	79-00-5
Ethane, 1,1-dichloro-1-nitro-	594-72-9
Ethane, hexachloro-	67-72-1

Substance	CAS-Number
Ethane, pentachloro-	76–01–7
Ethanedial (Glyoxal)	107–22–2
Ethanethiol (Ethyl mercaptan)	75–08–1
Ethanol, 2-chloro-	107–07–3
Ethanolamine	141–43–5
Ethene, 1,1-dichloro-	75–35–4
Ethene, 1,1-difluoro- (Genetron 1132a)	75–38–7
Ethyl chloride	75–00–3
Ethyl chloroacetate	105–39–5
Ethylamine	75–04–7
Ethylene	74–85–1
Formaldehyde	50–00–0
Formamide	75–12–7
Formic acid	64–18–6
Glutaral	111–30–8
Hexahydrophthalic Anhydride	85–42–7
Hexanoic acid, 2-ethyl-	149–57–5
Hydrazine, phenyl-	100–63–0
Hydroquinone (1,4-Benzenediol)	123–31–9
Isophorone diisocyanate	4098–71–9
Ketene	463–51–4
Kresole	1319–77–3
Lead acetate (monobasic)	1335–32–6
Mecrylate	137–05–3
Methanamine, N-methyl-	124–40–3
Methane, isocyanato-	624–83–9
Methane, tribromo-	75–25–2
Methanethiol (Methyl mercaptan)	74–93–1
Methyl bromide	74–83–9
Methyl chloride	107–05–1
Methyl iodide	74–88–4
Methylamine	74–89–5
Methylene chloride	75–09–2
m-Nitroaniline	99–09–2

Substance	CAS-Number
Montanic acid waxes, Zn–salts	73138–49–5
Morpholine	110–91–8
N,N,N',N'',N'''- Pentamethyldiethylenetriamine	3030–47–5
Naphthalene, 1,5-diisocyanato-	3173–72–6
Nitrocresols	
Nitrophenols	
Nitropyrenes	5522–43–0
Nitrotoluene (all isomers)	1321–12–6
N-Methyl-N,2,4,6-tetrannitroaniline (tetryl)	479–45–8
N-Vinylpyrrolidone	88–12–0
o-Nitroaniline	88–74–4
Oxalic acid	144–62–7
p-Benzoquinone	106–51–4
Pentachloronaphthalene	1321–64–8
Phenol	108–95–2
Phenol, 2,4,5-trichloro-	95–95–4
Phenol, p-tert-butyl	98–54–4
Phenyl-1-(p-tolyl)-3-dimethylaminopropane,1-	5632–44–0
Phthalic anhydride	85–44–9
Phthalonitrile	91–15–6
Piperazine	110–85–0
p-Nitroaniline	100–01–6
Propane, 1,2-dichloro-	78–87–5
Propane, 1-bromo-	106–94–5
Propanoic acid, 2,2-dichloro-	75–99–0
p-Toluidine	106–49–0
Pyridine	110–86–1
Sodium chloroacetate, Sodium salts	3926–62–3
Sodium Trichloroacetate	650–51–1
Tetrachloroethylene	127–18–4
Thioalcohols	
Thioethers	
Thiourea	62–56–6
Toluene-2,6-diisocyanate-	584–84–9

Substance	CAS-Number
Trichloroaphtalene	1321–65–9
Trichlorobenzenes (all isomers)	12002–48–1
Trichloroethylene	79–01–6
Trichlorophenols	
Tricresyl phosphate (ooo,oom,oop,omm,omp,opp)	78–30–8
Triethylamine	121–44–8
Trimellitic anhydride	552–30–7
Tri-n-butylphosphate	126–73–8
Trinitrotoluene (TNT)	118–96–7
Xylenols (except for 2,4-Xylenol)	1300–71–6

**Table A-2 Class I Organic Substance Criteria**

Substances that meet any one of the following criteria are Class I Organic Substances:

There is good cause to believe the substance is carcinogenic or mutagenic (risk phrase R40 or R68).
There is good cause to believe the substance is toxic for reproduction (risk phrase R62 or R63).
The substance is classified as toxic or very toxic (R23, R24, R25, 26, 27, 28, or combinations thereof).
The substance is classified as may cause irreversible harm or damage (R39 or R48)
The substance may cause sensitisation by inhalation (R42)
The substance is highly odour-intensive
The substance is slowly degradable and accumulative

## Appendix 2

### PRINCIPAL REFERENCES

- 1.1 Integrated Pollution Prevention and Control Final Draft Reference Document on Best Available Techniques on Surface Treatment using Organic Solvents, EU, November 2006.
- 1.2 Integrated Pollution Prevention and Control reference document on Best Available Techniques on Emissions from Storage, published by the European Commission, July 2006.
- 1.3 Integrated Pollution Prevention and Control reference document on Best Available Techniques for the Waste Treatments Industries, published by the European Commission, August 2006.
- 1.4 Integrated Pollution Prevention and Control reference document on Best Available Techniques for Waste Incineration, published by the European Commission, August 2006.
- 1.5 Integrated Pollution Prevention and Control reference document on Best Available Techniques in Common Waste Water and Waste Gas Treatment/Management Systems in the chemical sector, published by the European Commission, February 2003.
- 1.6 Integrated Pollution Control Licensing BATNEEC Guidance Note for the Manufacture of Integrated Circuits & Printed Circuit Boards (EPA No. LC 20(10/96)).

## Appendix 3

### GLOSSARY OF TERMS AND ABBREVIATIONS

BAT	Best Available Technique
Surface Treatment BREF	Integrated Pollution Prevention and Control final draft reference document on Best Available Techniques on surface treatment using organic solvents, second working draft published by the European Commission, November 2006.
Storage BREF	Integrated Pollution Prevention and Control reference document on Best Available Techniques on Emissions from Storage, published by the European Commission, July 2006.
Waste Water & Gas Treatments BREF	Integrated Pollution Prevention and Control reference document on Best Available Techniques in Common Waste Water and Waste Gas Treatment/Management Systems in the chemical sector, published by the European Commission, February 2003.
Waste Incineration BREF	Integrated Pollution Prevention and Control reference document on Best Available Techniques for Waste Incineration, published by the European Commission, August 2006.
Waste Treatments BREF	Integrated Pollution Prevention and Control reference document on Best Available Techniques for the Waste Treatments Industries, published by the European Commission, August 2006.
°C	Degree Celsius
CO	Carbon Monoxide
ELVs	Emission Limit Value
kg	Kilogramme
GWP	Global Warming Potential
m <sup>3</sup>	Cubic Metre
mg	Milligramme
Nm <sup>3</sup>	Normal Cubic Metre (101.3 kPa, 273 K)
NOx	Nitrogen Oxides
O <sub>2</sub>	Oxygen
PFC	Perfluorocarbon
t	Tonne (metric)
UPW	Ultra Pure Water
VOC	Volatile Organic Compounds