BASEL CONVENTION
ON THE CONTROL OF TRANSBOUNDARY MOVEMENTS
OF HAZARDOUS WASTES AND THEIR DISPOSAL

SECRETARIAT

UNEP

TECHNICAL GUIDELINES ON HAZARDOUS WASTES:

PHYSICO-CHEMICAL TREATMENT BIOLOGICAL TREATMENT

Basel Convention Series/SBC No: 99/007
Geneva, September 1999

SBC

BASEL CONVENTION
ON THE CONTROL OF TRANSBOUNDARY MOVEMENTS
OF HAZARDOUS WASTES AND THEIR DISPOSAL

SECRETARIAT

TECHNICAL GUIDELINES ON HAZARDOUS WASTES:

PHYSICO-CHEMICAL TREATMENT (D9) BIOLOGICAL TREATMENT (D8)

Basel Convention Series/SBC No: 99/007
Geneva, September 1999

SBC

Foreword

These technical guidelines are principally meant to provide guidance to countries who are building their capacity to manage waste in an environmentally sound and efficient way and in their development of detailed procedures or waste management plan or strategy. They should not be used in isolation by the competent authorities for consenting to or rejecting a transboundary movement of hazardous waste as they are not sufficiently comprehensive for environmentally sound management of hazardous waste and other waste as defined by the Basel Convention. These technical guidelines concern waste generated nationally and disposed of at the national level as well as waste imported as a result of a transboundary movement, or arising from the treatment of imported wastes.

It is necessary to consider this document in conjunction with the Document on Guidance in developing national and/or regional strategies for the environmentally sound management of hazardous wastes (SBC Publication - Basel Convention Highlights No. 96/001 - December 1995) adopted by the second meeting of the Conference of the Parties. In particular, special attention should be given to the national/domestic legal framework and the responsibilities of the competent authorities.

These guidelines are meant to assist countries in their efforts to ensure, as far as practicable, the environmentally sound management of the wastes subject to the Basel Convention within the national territory and are not intended to promote transboundary movements of such wastes.

CONTENTS

INTRODUCTION

These Technical Guidelines address disposal operations covered by categories D8 and D9 of Annex IV of the Basel Convention, that is to say, Biological treatment processes (D8) and Physico-chemical treatment processes (D9). The Guidelines seek to provide concise information to help competent and other authorities better understand the scope and nature of biological and physico-chemical processes. They are intended to serve two purposes:

- to provide authorities responsible for developing waste plans/strategies and for planning national/regional waste management infrastructure with supportive guidance on the options available and on factors affecting their scope, range and applicability.

- to assist competent authorities review and determine appropriate waste management options, including consideration of applications received to undertake transboundary movements of waste.

Information will be provided on the general technical and technological principles underpinning processes, the applicability of particular processes to waste types, infrastructure considerations for processes at the operational level, broad-brush indicators of cost and matters related to process residues and their final disposal. It should be made clear that the identification of waste types and other factors included for each of the processes described is not intended to be a prescriptive list. Further, the use of most of the options may require approval of relevant competent authorities.

It is important to emphasise at the outset that whilst these Technical Guidelines provide information and guidance about processes and their applications, they are not intended to be a design manual supplying all the information needed to plan, design, construct and operate a facility. Nor do they seek to identify every factor or consideration which might need to be taken into account in deciding the suitability of any particular process. Such a document would inevitably be of considerable length and go far beyond the scope of this series of Guidelines. Specialist and more detailed texts exist and may be found in reference libraries, but are usually of comparatively narrow scope, dealing only selected elements of the material in this Guideline. Limited information can be obtained from equipment manufacturers. Those seriously considering planning/ constructing/installing any waste process facility, whether covered by D8/D9 or not, would be well advised to seek independent expert advice to confirm both general process suitability and detailed design and operational requirements.

Status and Background

It is important to clarify the purpose and scope of the D8 and D9 categories within the context of Annex IV. Article 2.4 of the Convention defines “disposal” as being any operation specified in Annex IV, this consisting of two sections - section A listing operations which are deemed not to lead to the possibility of resource recovery, recycling, reclamation, direct re-use or alternative uses (each assigned a “D” number), and section B listing operations which may lead to resource recovery etc (each assigned an “R” number). It follows from this that under the Basel Convention the term “disposal” is applied to both recovery processes and processes which are sometimes called “final disposal”.

The full descriptors of the D8 and D9 categories listed in Annex IV, and which are the subject of these Technical Guidelines, are as follows:

D8 *Biological treatment not otherwise specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A.*

D9 *Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations in Section A, (eg evaporation, drying, calcination, neutralisation, precipitation etc).*

Taking all this into account, it would appear that the processes falling within the categories of D8 and D9 must have the following characteristics:

(i) They must be biological or physico-chemical treatment process respectively.
(ii) They must be potentially applicable to Basel hazardous waste treatment, even if they are sometimes more associated with other applications.
(iii) They must generate, in the course of their application, final compounds or mixtures which are discarded by means of another Section A (ie "D" number) operation.

On the basis of the above characteristics, it is apparent that a wide range of processes may fall within the scope of these Guidelines. There is some limitation in so far as the definitions of D8 and D9 exclude processes specified elsewhere in Annex IV. It could therefore be argued that as some operations in Section B of Annex IV, (eg R2, Solvent reclamation/regeneration) clearly imply, the use of a specific process (in this case distillation), then that processes should not therefore be included. Whatever the justification for this thinking, the value of the Guidelines lies in providing as broad a picture of available processes as possible, and processes are therefore included even where they are specified by implication in Section B. Undoubtedly, some of the processes included are more usually associated with non-waste applications such as manufacturing and production activities, but they could have application for wastes covered by the Convention.

The range of individual processes covered in these Guidelines is therefore large, and are by no means equivalent in scope, application or purpose. Many have a narrow range of application and can only be employed successfully with wastes of a particular physical form and/or chemical composition. Furthermore, the presence of particular contaminants, even at very low concentrations, can have a seriously adverse effect on process efficiency, so successful application of D8 and D9 processes will often depend on accurate knowledge of waste composition, together with confidence that it will not vary beyond certain limits.

Environmental status

One of the leading principles of waste management is source reduction, by which the generation of waste should be reduced to the minimum in terms of quantity and/or hazard potential. The problems associated with waste disposal will be avoided altogether if there is no need to discard waste in the first place, and will be lessened if the quantity of waste is reduced or its hazardous characteristics altered. Redesigning of processes, adoption of better and more advanced technology and use of different raw materials may eliminate or reduce quantitative waste generation and/or ensure it is of a less hazardous character.

Modern waste management policies attach differing levels of acceptability to waste management and processing options. An arrangement which incorporates this concept is a *Waste Hierarchy*, where the available options are listed in order of priority. It is usually accepted that such listings indicate preferred choices rather than rigid requirements, and that other factors will invariably contribute to final option selection. Whilst the precise order of options can vary slightly in detail between Hierarchies developed by different policy making bodies, the general thrust is consistent. It is unanimously agreed that the preferred option is to avoid generating waste in the first place, coupled with a reduction in the quantity/hazard of unavoidably generated waste. Thereafter, wastes which are nevertheless generated should be reused/recycled/recovered/regenerated etc. Only where none of these are feasible should “final”disposal options be considered.

Within those final disposal options, relevant biological and physico-chemical treatment processes, along with processes such as incineration, are usually collectively considered preferable to landfill. Although most waste hierarchies do not differentiate between the various biological and physico-chemical treatment processes covered by these Guidelines, the processes are probably not of equivalent status if full account is taken of process detail and of the principles underlying the hierarchy. Later sections of these Guidelines will look at the processes in more detail and whilst “ranking” the processes is beyond the scope of these Guidelines, comment will be made where appropriate as to the value or importance of any particular processes.

PART 1
PRINCIPLES OF BIOLOGICAL AND PHYSICO-CHEMICAL TREATMENT PROCESSES AND THE PROVISION OF FACILITIES

All the processes covered by these Technical Guidelines contribute, in some degree, to the environmentally sound disposal of at least some hazardous and other wastes. As we have noted previously, the descriptors D8 and D9 cover a large number of diverse and disparate processes, many of which are effective for only a limited range of wastes. We will address the range of application of processes in later sections of these Guidelines, but the purpose of this section is to examine the general principles of the processes, along with matters relating to the provision and operation of installations offering those processes. In that context we will refer briefly to issues such as infrastructure/ transport, scale of operation, personnel/manpower/training, environmental impact, performance monitoring and licensing/permitting. These issues are covered only briefly because the material is not specific to biological and physico-chemical treatment processes, but applies to all waste management process options. Additionally, a thorough examination of these matters would require substantial text, would make the Guidelines much longer and might distract from the primary objective of providing information on the biological and physico-chemical treatment processes themselves.

All the processes covered by this Technical Guideline seek to alter the chemical or physical form of the waste in some way that is ultimately beneficial to the achievement of environmentally sound management of that waste. There are many individual ways in which this can be done, but they all reduce to the principles of destruction, separation, concentration and containment. The principles of the types of processes will be set out in the next main section but the following descriptions (which overlap) may be more helpful:

- Elimination of the hazardous properties of the waste by converting the hazardous constituents to non-hazardous substances. Chemical, electro-chemical or biological reactions may achieve this.
- Using chemical reactions to alter the chemical nature/structure of the hazardous constituents of a waste. This will alter the properties of the waste and may reduce the degree of hazard and consequently the risk of environmental harm.
- Converting hazardous constituents of a waste into other substances which, although still hazardous, may then be more amenable to other physical, chemical or biological treatment/separation processes.
- Conversion of hazardous wastes into a form designed to prevent or significantly reduce release into the environment.
- Processes which selectively absorb or retain constituents of wastes, leaving the bulk of the waste free (or substantially free) of those constituents.
- Processes which separate constituents of a waste on the basis of some physical property.
- Mechanical separation processes.

Many practical waste management systems will utilise two or more of these principles in combination.

It is important to appreciate that many of these processes do not destroy the hazardous constituents of wastes. What most of them do is to separate them, in their original or modified form, from the bulk of the original waste mass. The point is that the greater part of the waste is thus rendered less or non-hazardous, and can be dealt with more easily, at less cost and with much less threat to the environment. However, in these cases the hazardous constituents have not been destroyed, but are concentrated into a relatively small mass of residue, possibly in an altered chemical form and possibly in conjunction with residual reagents or with some separating medium. That waste must then be dealt with in an environmentally sound manner and is likely itself to require specialised attention.

It is also important to remember that wastes are rarely single pure substances and will almost always be mixtures containing contaminants in varying concentrations. The process principles set out in paragraph 10 clearly depend for their success upon carrying out chemical and biological reactions and utilising techniques for separating parts of waste streams. It will follow that the presence of unexpected components in a waste, even as minor contaminants, could render the process largely ineffective. This could be because the other substances interfere with the process chemistry or biology, because they damage the fabric of the facility, or because they simply pass through the process unaffected (and possibly undetected) to contaminate otherwise supposedly safe residues. We will look in more detail at this aspect in the later section discussing individual processes.

Site location, infrastructure and transport

Installations for the biological and physico-chemical treatment of hazardous and other wastes will usually be found either at individual locations generating appropriate wastes, or as "central" facilities to which wastes are brought from a number of generating sites. In the former case the precise characteristics and parameters of the waste stream should be well known to the site management, and the installation can be designed to deal efficiently with that waste. So-called "central" facilities may take a wider range of wastes and may, accordingly, have to provide more flexible capacity.

Locating a new treatment plant at an existing factory is largely a matter of local logistics within the available space, as infrastructure, services etc are probably already in place. Locating a new treatment facility intended for operation as a central service plant for a variety of waste generators requires many factors to be taken into account. Assuming the wastes are to be moved to the central facility by road transport, then a suitable road network must link all the sites involved. Within that limitation it is to be preferred, subject to environmental impact and public safety considerations, if a site is selected which minimises the total distance over which wastes must be transported. If wastes are to be moved to the facility by other means such as pipelines, then the practical and geographical problems of establishing safe and secure pipeline routes will be important.

It is increasingly considered appropriate to carry out environmental impact assessments of sites proposed for all activities which carry significant potential to cause environmental damage. Such assessments will take detailed account of the site itself and of the activity proposed as well as the features of the surrounding area, including human habitation, flora and fauna and existing natural resources. A decision that an activity may be permitted can be subject to conditions such as installing additional safety features, limiting hours of operation, restricting the precise range of materials handled etc. It is likely that many of the processes covered by descriptors D8 and D9 would be thought appropriate for environmental impact assessment. *(For further information on Environmental Impact Assessments, see Annex 2 on page 61).*

Infrastructure requirements include the availability of utilities and raw materials - availability moreover which must necessarily carry a high level of reliability. Many of the D8 and D9 processes depend on uninterrupted, steady and continuous operations and problems may arise from supply failures of power, water and fuels or of treatment chemicals and reagents. Infrastructure requirements should also be taken to include the availability of environmentally sound facilities for the further treatment and/or disposal of any solid or liquid residues from the process.

It is important to understand that a properly designed process facility, capable of meeting the standards of environmentally sound waste management, needs to include much more than the basic process plant itself. Undoubtedly, a process installation of sorts can be created at very low cost if concepts of total site integrity and design are disregarded. For example, a couple of tanks positioned on rough ground could provide a means of carrying out chemical neutralisations, but very probably fail to provide the many other features necessary to ensure safe, efficient and effective operations. Features essential for the support of the primary operation include laboratories, maintenance workshops, changing rooms for employees, medical facilities, administration and control etc, and the provision of adequate facilities for waste reception/ checking, storage and pre-treatment. All elements of a facility should be subject to proper design standards and criteria and should be constructed to recognised fabrication/manufacturing standards, using appropriate materials of construction.

Transportation of waste is a specialised activity requiring appropriate equipment and suitably trained staff. Tankers and tank containers used for transporting wastes in bulk are usually of specialist design and manufacture, incorporating additional features appropriate for wastes. Many wastes are moved in old drums - a tempting approach given that many waste generators will also accumulate drums from their activities. The use of drums in this way is not necessarily wrong, but great care must be taken to ensure that the drum is in sufficiently good condition and that it is manufactured of material suitable for the waste concerned. All wastes undergoing transportation should be labelled to show what they are, what hazards they may display, precautions to be taken if there is loss of containment and actions required in various emergency situations. Guidance on packaging and labelling is available from a number of sources, including the UN Recommendations on the Transport of Dangerous Goods (known as the Orange Book).

Type and scale of operation

The type of processes selected for use in any particular case must be chosen with great care and on the basis of detailed knowledge of the quantity, composition and variability of the various wastes which are expected to be treated. For any existing, established operation, new wastes must be rigorously examined to ensure that they are compatible with the installed processes and with the wastes already accepted. It has already been pointed out that many of the processes are effective for only specific types of wastes and that effectiveness can be compromised by interactions with unidentified constituents or with constituents introduced from other waste streams. It would be impossible to highlight every instance where these sorts of difficulties could arise, but this extremely complex situation will be addressed in more detail in later paragraphs.

Some of the processes covered by these Technical Guidelines can be operated as continuous or batch processes. Choice will depend upon both the process characteristics, the nature of the waste and the pattern of its generation. Broadly speaking, continuous processes are those capable of a high degree of automation and control and are more likely to suit relatively large volume wastes generated in a steady and consistent stream, with minimum risk of sudden variations in concentrations and constituents. Batch processes can be more appropriate for low volume/high concentration wastes, for wastes of significantly varying composition and for wastes which generally require a high level of individual supervision and control. It follows that manpower requirements for continuous processes are likely to be low compared to batch methods, and that costs accordingly may be lower where continuous process methods can be employed.

Decisions as to scale and capacity of process installations will depend to a large extent on the expected business demand - both immediate and longer term. Continuous processing operations will have some variability in throughput and process flow, but batch processing may offer significant additional capacity by extending to two, three or four shift operating. Installing capacity which far exceeds demand probably makes no commercial sense, but it may well be technically inefficient too. Not all processes are fully effective at low throughput levels, and in such cases it may well be better to design the installation on a modular basis so that extra units can be added as demand requires.

On a cautionary note, great care is needed in assessing likely demand for any proposed new treatment facility, especially where existing practices involve less environmentally acceptable options. There have been many real examples of new facilities encountering serious economic difficulties because the quantities of waste received following opening have been far less than was expected. Potential customers may prove to be unwilling to pay the higher costs invariably associated with new and environmentally more acceptable disposal. Faced with such costs, they may try to continue with existing methods where that is permitted, but where it is not, either resort to illegal methods or take measures to reduce/eliminate the waste at source. Whilst waste elimination or reduction is to be applauded in itself, it is little comfort to the operator of a new facility running under capacity. Initial market assessments must try to take account of both the price sensitivity of the potential business and the extent to which regulatory and enforcement authorities will seek to enforce legislation and influence the destination of wastes.

Personnel and manpower

Many of the processes covered in these Technical Guidelines incorporate sophisticated equipment and technology requiring highly trained staff and back-up expertise. All processes covered need at least some measure of skill, expertise and judgement if they are to be operated safely and effectively. A decision to set up a new waste facility must incorporate recognition of the need to recruit adequate numbers of suitably qualified and trained staff. It cannot be emphasised too strongly that without these, the effectiveness of the treatment processes may be seriously compromised, and if appropriate staff cannot be secured, then operation of the process would not be advised.

Areas of professional technical expertise which may be required, depend on the particular process, but are likely to need several of the following: analytical and general chemistry, biology and biochemistry, chemical and mechanical engineering, instrumentation and control technology and safety management. In addition to prior-acquired professional qualifications, general training programmes, including refresher and up-dating material, will be required for all staff. For positions such as process or general operators, where recruits may not be required to hold a technical qualification, it is important to select individuals who are capable of learning the basic technical background to the processes and of understanding what they are doing.

Permitting and performance

Many legislative systems now require waste management facilities to hold some sort of permit/licence. These can provide a useful means of applying controls on the way the plant is operated by making the permit/licence subject to conditions and providing powers to revoke it where compliance is unsatisfactory. Conditions fall into two groups - those which relate to matters which must be done or agreed before the permit/licence is granted and those which cover the subsequent or ongoing operation of the facility. Elaboration of emergency plans for incidents, taking into account the possible impact of the facility, should be included in permit conditions.

Pre-grant conditions would cover matters such as approval of facility design and construction, definition of the range of wastes to be accepted, agreement on emission/discharge limits, satisfactory completion of commissioning trials, site security arrangements, evidence of staff competence, establishment of insurance or performance bonds where required, operating procedures drafted and available etc. Ongoing operating conditions would typically cover maintenance and tidiness of the site, continuing adequacy of staff competence, continuing provision of insurance/financial guarantees, compliance with operating procedures, keeping of waste receipt, process and disposal records as required, training programmes and monitoring of emissions and of the local environment.

Monitoring of emissions would usually be defined in terms of the frequency and methodology with which each determinant should be tested for each type and source of emission from the facility, whether solid, liquid or gas. For the avoidance of doubt, "emissions" should be taken to include waste streams generated by the process, solid residues and sludges and waste waters. Monitoring of the local environment, if required, would typically be a programme of testing of the area surrounding a facility with the objective of highlighting any alteration in the levels of contamination. The programme would usually be designed to collect samples of soil/foliage/air from a spread of agreed locations in the area, and to analyse them for agreed species. The permit would usually address how all monitoring data was to be processed and distributed, such as by submission to the enforcement authorities, publishing in some publicly accessible register etc.

PART 2
PHYSICO-CHEMICAL AND BIOLOGICAL TREATMENT PROCESSES

In the following section we look in some detail at the individual processes which fall within D8 and D9 and which may be applied to the environmentally sound management of waste. As explained in paragraph 5, processes covered are those which have some potential for application to waste management are covered - even if any actual application is less than common. Other physico-chemical and biological processes undoubtedly exist, but there is little purpose in further extending the length of these Technical Guidelines by describing processes which have practically no relevance to the subject. For convenience and clarity we shall sub-divide the processes into groups based on similar principles, but the distinction is not always precise and clear-cut, and some overlap is possible.

Physical/Mechanical treatment processes
Chemical treatment processes
Physical/Chemical treatment processes
Immobilisation techniques
Biological treatment processes

Most processes are applied to aqueous solutions or aqueous suspensions/sludges of substances. That does not necessarily preclude application to organic systems or to aqueous systems with organic constituents in the form of miscible or separate phases or as solid matter in suspended or settled (ie sludge) form. However, it is worth noting that the presence of organic materials may harm the fabric of some process plant and render it less effective if not ineffective. Where relevant, processes will be conducted under conditions of stirring and agitation so that settled material is taken into suspension and subjected to the process conditions. Most processes apply only to certain Basel hazardous wastes. Annex I of this guidance gives the possible treatment options for each Y category.

Physical /Mechanical Treatment Processes

In this section the treatment processes often involve the separation of a part of a waste stream, perhaps following a prior treatment stage, or as a precursor to some subsequent processing (or both). The principle of separation will be related to a physical property such as particle size or relative density. Many of the physical separation processes which exist are often applied for the primary purpose of isolating components of a waste for recovery. However, even in the context of final disposal, it is often the case that separation is advantageous as this may reduce the quantity or hazardousness of the residue and simplify the process.

Manual Separation	
Brief Description	*Separation of solid waste by visual inspection and removal of selected items.*
Waste Types	*Any discrete, separable items in a mixed stream of solid waste. Of limited application to hazardous wastes, but might find a use where isolated items of a hazardous nature were mixed with general waste, and there was good reason to try to remove them prior to disposal of the general waste.*
Process Principles	*Visual inspection of solid waste, either by batch or on a continuous basis such as via a conveyor belt, and removal of particular items.*
Equipment/ Manpower/ Infra-structure	*Conveyor belts onto which wastes for inspection can be placed or open (preferably covered) areas for spreading batches of waste. High levels of manpower required.*
Adverse Factors	*Labour intensive. In the hazardous waste separation context, inefficient if items of hazardous nature are small (eg batteries) or otherwise difficult to see. Not appropriate where hazardous items may cause risk of injury to persons undertaking separation.*
Cost Indicator	*Although equipment requirements are minimal, manpower is high. Can be expensive if wage rates are high and if no value is gained from recovery of separated items.*
Residues and fate of hazardous constituents	*Hazardous items separated must be dealt with according to their nature. Main waste stream may be less hazardous as result of separations, but must be evaluated to determine suitable final disposal.*

Size Reduction	
Brief Description	*A process in which force is applied to solid waste material to break up the unit size and generate smaller fragments/particles.*

Waste Types	*Any solid waste where subsequent processing may be assisted by having smaller sized, more manageable fragments. The process is more commonly encountered in the chemicals and minerals industry and perhaps in the separation of plastics, but in the hazardous waste context this could include solid cyanide salts from case hardening, electronic equipment and catalysts.*
Process Principles	*Producing smaller fragments or particles increases the specific surface area and is likely to improve leachability of constituents, reaction speeds etc. Processes may be operated in conjunction with other subsequent separation techniques such as sieving.*
Equipment/ Manpower/ Infra-structure	*Crushers and milling plant provide an engineered means to reduce size of friable materials, but on a cruder and much smaller scale, it may be possible to break down materials by manual means, including the use of pneumatic drills and percussion hammers. Non-friable materials may be size-reduced by shredder and/or macerator. Manpower requirements for fully automated crushers will be low, but are unlikely to be encountered in a hazardous waste context. Manual methods will be labour intensive.*
Adverse Factors	*Production of dust, which with a hazardous substance could pose serious control and containment problems.*
Cost Indicator	*Large crushers, mills, shredders and macerators can be expensive to purchase, particularly with associated material handling plant. Regular maintenance is required. The operating costs are moderate but manual methods will require more manpower and incur cost accordingly.*
Residues and fate of hazardous constituents	*The process is not, in itself, separating components or doing anything to alter the chemical identity of the materials. So the size-reduced material retains whatever hazardous properties it previously possessed and must be dealt with accordingly.*

Special Physical Sorting	
Brief Description	*A process involving the sorting of items in a solid waste stream utilising special detection and monitoring methods.*
Waste Types	*No obvious examples involving Basel hazardous wastes, but ore separation and glass in municipal waste could be general examples.*
Process Principles	*The basis of separation can include any type of measurable detection such as reflection, transmission and absorption of radiation, shape and colour.*
Equipment/ Manpower/ Infra-structure	*Applied to a stream of material passing on a conveyor. Identified items for separation must be removed in some way. The process is usually fully automated, but will require some oversight and supervision.*

Adverse Factors	*Restricted to areas where items have suitable differentiating characteristics. Efficiency of detecting required items in passing mixed waste stream may be limited.*
Cost Indicator	*Quite expensive in capital cost terms, but operating costs fairly low where good throughputs provide high utilisation.*
Residues and fate of hazardous constituents	*Depends what is being separated and how efficiently it is being done. Separated items must be dealt with as appropriate and may be of some value. The remaining stream of waste must be assessed as to appropriate subsequent disposal.*

Sieving and Screening	
Brief Description	*Separation of differing particle sizes by passing through one or more sieves.*
Waste Types	*Contaminated soils, particularly those containing specific hazardous items/articles. Some pretreated waste such as shredder waste. Streams of waste solid materials where a component(s) has significantly different sized particles.*
Process Principles	*Wastes consisting of mixed solid particles/items are passed over or through sieving screens which allow material of certain particle sizes to pass through. The size of particles passing through will depend on the size of openings on the screen, and a range of sizes would usually be available for selection as appropriate. Some systems can use more than one screen size in a succession of separations, thus dividing the original waste into several size classifications. Screen systems are often vibrated to assist passage of the material and prevent blinding.*
Equipment/ Manpower/ Infra-structure	*Although the principle is simple, most applications are on fairly large quantities of material. Installations may be quite large and automated, and will need to provide for materials conveyance and movement and for safe storage of any separated hazardous wastes. Manpower requirements are fairly low. For small sieving and screening tasks, manual screens could be employed, but with higher manpower requirements.*
Adverse Factors	*Separation is never 100% efficient. Material needs to be at least fairly dry.*
Cost Indicator	*Plants for large quantities can have high initial cost, but with large volume throughputs the unit cost may be fairly low. Manual operations involve very low equipment cost but need more manpower.*

Residues and fate of hazardous constituents	*Separated hazardous wastes will need subsequent disposal in an appropriate manner. The balance of the material, from which the hazardous components have been separated, may still contain some of the hazardous material (depending on the separation characteristics of the waste stream). Disposal decisions must be made accordingly and after necessary testing.*

Sedimentation and Settling	
Brief Description	*A process in which solid matter suspended in a liquid phase (usually water) settles due to its greater density.*
Waste Types	*Neutralised acids and alkalies containing suspended metal hydroxides. Waste water streams from which metals and other species have been precipitated. Certain oil/water mixtures.*
Process Principles	*Gravitational forces are used to settle more dense materials/solids suspended in a liquid phase. This can be effected on a batch basis simply by leaving the material standing in a vessel or continuously by using settlers in which shape and a gentle water flow encourage effective separation. The process is intended to generate clear, solid-free liquids and a smaller portion in which the solid material is concentrated. The separated liquid may comprise more than one phase. Separation may be assisted by the heating of the material. Settlement and the thickening of the phase containing the solids may be assisted with the use of coagulants and flocculants.*
Equipment/ Manpower/ Infra-structure	*Specially designed settling tanks provide improved efficiency and effectiveness, and may well require associated pumping facilities. Such plant usually operates as an adjunct to another process. Manpower requirements low.*
Adverse Factors	*Some suspended solids do not readily settle, even with flocculation aids. Sedimentation and settling of hot mixtures, such as may be generated from certain processes such as neutralisation of strong acids, may be slow/delayed.*
Cost Indicator	*Sedimentation is not, in itself, an expensive part of the total process requirement, but specially designed settling tanks will cost a moderate sum.*
Residues and fate of hazardous constituents	*The intention is that the settled solids, containing the metal hydroxides, precipitates etc should be a medium to thick sludge, and that a further dewatering stage (such as filtration) be applied. The process plan would be that the supernatant liquor, although possibly containing a high dissolved salt level, should be clear and ready for final disposal. However, further treatment may be required if residual concentrations of contaminants so dictate.*

Centrifuging	
Brief Description	*A process utilising centrifugal forces to accelerate the separation of suspended matter in (usually) a liquid medium.. In the case of colloidal solutions, flocculants may need to be added.*
Waste Types	*Aqueous effluents with finely divided solid particles, for example, those which have already been subject to other settlement and separation processes. Colloidal solutions. Oil/water mixtures/emulsions and other emulsions.*
Process Principles	*Centrifugal forces are generated by spinning the waste at great speed in special plant. The suspended solid or droplets are caused to separate more readily than would otherwise be the case. Different types include the decanter, the disc centrifuge and the ultracentrifuge - a device which spins at even greater speeds and applies greater separation forces for emulsions and colloids. The forces involved are sometimes finely balanced, so consistent waste stream characteristics and properties are advantageous.*
Equipment/ Manpower/ Infra-structure	*Centrifuges are specialised and dedicated items of equipment which must be purchased to suit specific needs. Most will run more or less continuously, but supervision is necessary together with the capacity to deal with regular maintenance. Reliable power supplies are desirable.*
Adverse Factors	*Efficiency of separation is sensitive to the waste stream characteristics so variations in the waste stream can lead to problems. Plant can experience high levels of wear and tear.*
Cost Indicator	*Centrifuge based processing tends to be fairly expensive. Equipment capital costs are high and power consumption and maintenance contribute to high operating costs.*
Residues and fate of hazardous constituents	*Process outputs may include (depending upon the input) a solids phase rich in metal hydroxides/precipitates etc, destabilised emulsions which will separate into phases upon free standing, an oil rich phase or an essentially aqueous phase, likely to be contaminated. It is in the nature of the centrifuge that separations are rarely perfect and that no phase is a clean, discrete substance. All outputs must therefore be checked to establish appropriate subsequent disposal.*

Air Classification	
Brief Description	*A process which depends on differences in density, size and shape to separate mixed materials placed in a strong flow of air.*
Waste Types	*Mixtures of plastics or paper and metal containing materials. Fragmented/shredded materials containing metal fractions. Electronic scrap.*

Process Principles	*When mixed materials are placed in a strong flow of air, the tendency to be carried along by the air flow will be a function of their density, size and shape. Light materials may be carried readily in the air flow, with dense items remaining unaffected. Vertical and horizontal systems can be arranged, in conjunction with tuning the air flow velocity, to achieve good separation of a wide range of constituents, including paper, card, plastics of various kinds, resins, and metal bearing items.*
Equipment/ Manpower/ Infra-structure	*Specialised and purpose designed equipment can comprise cylindrical rotating classifiers or stationary units of other shapes. Manpower requirements are not large on the classifiers themselves, but may be more substantial on pre-classifier processes and on general supervision and maintenance of what can be messy and untidy activities.*
Adverse Factors	*Process sensitive to variations in the differences of density, so can be thrown out by varying moisture levels. Effective separation is more likely with a broader spread of densities etc - unlikely to be very effective with components of similar characteristics.*
Cost Indicator	*Specialist plant is fairly expensive in terms of capital cost. Operating costs are fairly high due to power consumption, maintenance and housekeeping.*
Residues and fate of hazardous constituents	*Separations are rarely 100% effective so different fractions inevitably contain proportions of the other components. Compositions must be checked before decisions as to final disposal can be made.*

Ballistic Separation	
Brief Description	*A process in which separation takes place on the basis of the difference in trajectory of materials with differing elasticities, air resistance and inertia.*
Waste Types	*Mixed waste streams of solid material with components/constituents of differing physical characteristics. Not a particularly significant process for Basel hazardous wastes, but could be applied to the separation of plastics from metals, of shredder waste and of the of fractions of incinerator slags. Best suited to processing specific and consistent feedstocks rather than as a multi-purpose process for occasional or varied application.*
Process Principles	*If horizontal forces are applied to materials, the extent to which they are thrown sideways will depend upon air resistance, elasticity and inertia. This physical law can be put to use to separate components of a mixture. Plant arrangements to do this can include throwing/ ejecting the materials from a rotating device and catching the different fractions, which will fall at various distances from the throwing/ejecting system.*

Equipment/ Manpower/ Infra-structure	*Purpose-built equipment available, but improvisation possible depending upon the materials concerned and their hazard characteristics. Low to moderate manpower for major installations - probably higher manpower requirements for any occasional application.*
Adverse Factors	*Effective separation only where waste mix characteristics are ideal for the purpose, otherwise, significant cross contamination likely.*
Cost Indicator	*Low to moderate, possibly higher for low throughput, occasional applications.*
Residues and fate of hazardous constituents	*Each separately collected fraction must be examined to establish for what uses/other disposal options it might be suitable. Hazardous constituents not necessarily fully concentrated into a single fraction(s).*

	Elutriation
Brief Description	*A process which separates particles of differing size and density, in a liquid medium moving at a fixed velocity.*
Waste Types	*Not a particularly significant process for Basel hazardous wastes, but could separate plastics from metals, components of ores and slags and shredded material where components display differing densities/resistance to flow. Best suited to processing specific and consistent feedstocks rather than as a multi-purpose process for occasional or varied application.*
Process Principles	*A liquid is passed upwards through a vertical cylinder at fixed, but variable velocity, and the mixed waste introduced into the flow, usually at a point approximately half way down the cylinder. Assuming the velocity of the liquid flow has been correctly adjusted to suit the particular waste mixture, some components of the waste will sink to the bottom of the cylinder against the liquid flow, whilst others will be carried with the flow. Components thus entrained in the liquid flow can be passed through a succession of vertical cylinders with differing liquid velocities so as to achieve further separation of fractions.*
Equipment/ Manpower/ Infra-structure	*The basic equipment is simple, but the ability to adjust liquid velocity and to hold it reasonably steady for long periods of processing is crucial. Pumps with accurately controllable throughputs are necessary, but invariably will be more expensive. Manpower requirements fairly low.*
Adverse Factors	*Suitable only where waste components are not soluble in the liquid medium employed. Separated fractions will be wet and may need drying - a potentially expensive step.*
Cost Indicator	*Low to moderate, excluding drying of fractions.*

Residues and fate of hazardous constituents	*Each fraction will need to be examined to determine what use or disposal process is suitable. The carrying liquid may need checking for finely divided, suspended or dissolved hazardous components.*

Flotation/Float and Sink	
Brief Description	*A process which takes place in a liquid medium and which separates constituents on the basis of their differing densities or differing flotation properties.*
Waste Types	*Not a particularly important process for Basel hazardous wastes. Concentration of ore type residues, separation of constituents of shredded wastes and plastics and treatment of certain effluent streams containing suspended material.*
Process Principles	*Where constituents of a solid mixed waste have differing densities, or where they possess differing surface properties and can be wetted to differing degrees, it may be possible to bring about separation by causing one or more of the constituents to float to the surface of a liquid medium, whilst the remaining materials stay or settle on the bottom. It is often beneficial, if not essential, to use supplementary techniques which encourage differential flotation, such as surfactants/frothing agents and fine gas bubbles to entrain selectively one or more of the constituents. It is possible to use two or more flotation separators in series, operating under different conditions if necessary, to bring about separation of more complex mixtures.*
Equipment/ Manpower/ Infra-structure	*Flotation bath usually purpose built but need not especially complex, can be batch or continuous in operation. May require means to collect and dry the separated phases. Manpower requirements low.*
Adverse Factors	*Separations may not be very efficient. Not normally suitable where hazardous constituents may dissolve in the flotation medium.*
Cost Indicator	*Low to moderate cost for well utilised plant, especially operating automatically.*
Residues and fate of hazardous constituents	*Hazardous materials in the original waste may end up predominantly in either the floated fraction or the settled one, and either fraction may contain traces of any hazardous substance present.*

Cyclone and Centrifugal Separators	
Brief Description	*A process based on the application of centrifugal forces to separate components of different densities and sizes in a mixture of solid materials/particulates. Also applied to the removal of entrained solid particles from waste gas streams.*
Waste Types	*Not a particularly important process for Basel hazardous wastes. Separation of ore type residues, shredded wastes, plastics and metals etc and any air-conveyed waste stream. Often applied to gaseous discharges from industrial and other processes for the separation and removal of entrained particulate matter.*
Process Principles	*Substances subjected to movement in a curved or circular path will experience centrifugal forces, which will cause large mass or high density particles/objects to be thrown outwards. These will strike the wall of the containing vessel and fall to the bottom. Velocity and curvature will determine the extent of the centrifugal force, and hence, the separating power of the process. In practice, mixtures to be processed in this way will be introduced via a flow of air which will carry the constituents through the process. In some facilities velocity may be variable, but curvature will usually be a fixed design feature of each unit. Waste gas streams containing particulates, such as from incinerators or metal foundries, may be similarly processed. In all cases, a number of cyclones may be used in series to increase efficiency or to separate different fractions. An important advantage is that equipment is usually made of metal and can be operated at high temperatures.*
Equipment/ Manpower/ Infra-structure	*Cyclones are specialist equipment items which are, to a certain degree, designed for particular applications and requirements. Generally they will operate continuously with minimal supervision and maintenance.*
Adverse Factors	*Separation powers are limited, especially for very small particle sizes, such as below 10 microns. Not usually suitable for general/multi-purpose applications.*
Cost Indicator	*Moderate cost to purchase initial equipment but operating costs only low-moderate.*
Residues and fate of hazardous constituents	*Hazardous constituents in the original waste input may end up in any of the separated fractions or, if too fine for separation, will remain in the gas train. As separation is unlikely to be perfect, traces of hazardous constituents may be present in all/other fractions. Testing is necessary to assist disposal decisions.*

Hydrocycloning	
Brief Description	*A separation process taking place in a liquid medium where centrifugal forces are applied to solid particles suspended in the liquid medium.*
Waste Types	*Not a particularly important process for Basel hazardous wastes. Separation of ore particles, separation of mixed plastics, removal of suspended material from some effluent/waste water streams.*
Process Principles	*Centrifugal forces applied to solids suspended in a liquid medium will cause those particles with densities up to that of the liquid medium itself to move to the outer wall of the cyclone and move down the wall. These particles thus become separated from the others, which remain in the liquid medium. Whilst the normal liquid medium is water, it is possible to conduct the process with solutions of salts or organic solvents so as to increase the range of liquid medium densities. Separation efficiencies may not be adequate with a single cyclone and several can be used in series.*
Equipment/ Manpower/ Infra-structure	*Hydrocyclones are specialised plant items but are not especially complex. They operate continuously and pumping systems are needed to introduce liquids into the cyclone with sufficient velocity to generate the centrifugal forces required. May require facilities for the collection and drying of the separated constituents. Manpower requirements fairly low.*
Adverse Factors	*Limited rage of separation potential - small differences in density may lead to inefficient and ineffective separation. Not normally suitable for wastes where hazardous constituents may be soluble in the liquid medium.*
Cost Indicator	*Capital cost of an installation would be moderate, with moderate operating costs.*
Residues and fate of hazardous constituents	*Hazardous materials present in the original waste may end up in the separated fraction or remain in the liquid medium. Either may contain traces of any hazardous substance originally present.*

Magnetic/Electromagnetic Separation	
Brief Description	*A process which utilises the magnetic properties of substances to separate them from other non-magnetic material.*
Waste Types	*Not a particularly important process for Basel hazardous wastes. Mixed waste streams containing magnetic material, that is to say ferrous materials and ferromagnetic alloys/ores eg shredded/pulverised automobile waste. Screening of ash from incinerator hearths, especially from municipal waste where metal cans may be present.*

Process Principles	*Magnetic properties are possessed by a small range of substances, and this can be utilised to separate these substances from other materials with which they are mixed. Magnetic attraction can lift magnetic components from a stream of waste passing, for example, on a conveyor. Non-magnetic materials will not be attracted to the magnetic source, but depending on the nature of the waste mixture/stream, other material may captured incidentally. Often an ancillary process to some other activity.*
Equipment/ Manpower/ Infra-structure	*Magnetic sources are usually electro magnets, which can be turned on and off as required. Waste streams must be presented to the magnetic source in such a way as to ensure magnetic material is able to be lifted away from the bulk of the waste. Conveyor belts are often used for this purpose.*
Adverse Factors	*Applicable only to the relatively few magnetic materials.*
Cost Indicator	*Basic magnetic sources are not particularly expensive, and the separation process, in isolation, will be low cost. However, the main processes to which magnetic separation is ancillary may well be much more expensive.*
Residues and fate of hazardous constituents	*Clearly depends on the wastes and hazardous constituents involved. Magnetic materials, ie ferro substances, are unlikely themselves to be particularly hazardous, but they may be contaminated with material that is. Magnetically separated material should be tested if hazardous substances are present in the original waste. The residual stream should also be tested to decide further disposal options.*

Electrostatic Precipitation	
Brief Description	*The application of an electric charge to particulates in a gas stream can cause those particulates to be removed downstream via attraction to an electrode of opposite charge. This is an abatement process and therefore not a process applicable to all Basel wastes.*
Waste Types	*Not a process particularly applicable to Basel hazardous wastes. Mainly used for flue gas cleaning in the form of the removal of particulates and droplets.*
Process Principles	*As gases pass a source of electrical charge, particles and droplets entrained in the gas may receive a static charge. Further along the gas path an electrode of opposite charge will attract those charged particles and droplets, removing them from the gas stream. Gas velocity and strength of charge influence the process effectiveness, although not all particles are equally amenable to accepting a charge. This process is invariably an adjunct to a principal process generating the waste gas and will often be operated in conjunction with other gas cleaning processes. Effective and efficient removal of particulates down to sub-micron size.*

Equipment/ Manpower/ Infra-structure	*This is specialist plant, sized to suit specific applications. So as to ensure that all gases pass close to a particle attracting/gathering electrode, the gas flow is usually channelled into numerous small cross-section tubes, each of which has an electrode in its centre. Provision must be made to remove periodically the accumulated particles from the electrodes and to collect the material. All this is usually done automatically. Manpower needs low, but occasional major maintenance work required.*
Adverse Factors	*Equipment may clog up and fail if particulate nature/form changes. Efficiency sensitive to performance of the principal process generating the waste gas stream.*
Cost Indicator	*Equipment cost very high, but routine operating not especially expensive.*
Residues and fate of hazardous constituents	*The collected solid material will comprise the dusts and particulates which would have otherwise been emitted to the atmosphere. These may contain toxic and heavy metals as well as organic products of (in)complete combustion - depending on the nature and quality of the principal process.*

Absorption	
Brief Description	*A process in which one or more of the constituents of a liquid or gas are retained on a solid medium (the absorbent) with which the liquid/gas is brought into contact.*
Waste Types	*Usually applied to the removal of trace organic constituents from waste waters, but less commonly for metals.*
Process Principles	*The process is not usually seen as a primary treatment option, but as a back-up or for residual "polishing" after other processes. The absorbent is usually a very porous substance which attracts and retains certain species present in the waste stream which passes over or through it. Absorbents include active carbon and a range of polymers and resins. They are not generally very specific as to the species they attract. The waste stream is usually contacted with the absorbent by passing through a column or reactor bed of the material, although it is possible to mix absorbent with the waste stream on a batch basis, and separate by filtration etc. Recovery of the absorbed species is not usually required, but may be possible in some cases. Processes are usually scaled such that the absorbent medium need not be replaced very frequently.*
Equipment/ Manpower/ Infra-structure	*Plant requirements involve a vessel or columns containing the absorbent and through which the liquid or gas is passed by use of pumps, blowers etc. Manpower is minimal.*
Adverse Factors	*Absorbents tend not to be very specific in terms of what they will absorb. Accidental and sudden peak loading of contaminants may rapidly utilise the absorbing capacity of the medium, giving ineffective subsequent treatment until the medium is replaced.*

Cost Indicator	*Absorbents are of moderate cost, but rate of use usually designed to be low.*
Residues and fate of hazardous constituents	*Exhausted absorbents may contain significant quantities of the substances they have absorbed, which may be highly toxic. Some absorbents can be regenerated by thermal treatment, which should destroy the organic materials absorbed. However, where regeneration is not undertaken, care will be needed in determining suitable disposal of such absorbents.*

Evaporation	
Brief Description	*A process, usually applied to liquid systems for the purpose of concentration, in which the liquid is vaporised from the system. It is often the case that the vaporisation is assisted by the application of thermal energy.*
Waste Types	*Of limited application in the disposal of Basel hazardous wastes. Practically any aqueous or solvent based system is capable of being evaporated. Applications tend to be recovery orientated and include concentration of salt solutions and of ore slurries and partial drying of sludges. High salinity waste waters may sometimes be evaporated to dryness where no acceptable opportunity exists for discharge to a water course eg at remote inland sites. It would not usually be considered environmentally sound management to evaporate organic solvents to atmosphere, either for final disposal or incidental to a recovery activity, although systems to capture the vapours are acceptable.*
Process Principles	*Any liquid has a partial vapour pressure and will exhibit some tendency to undergo a change of state to a gas/vapour. This will be enhanced as the temperature approaches the boiling point of that liquid. If the system is uncontained, then as the liquid vaporises and escapes, the liquid remaining in the residue diminishes, so that if there are suspended or dissolved constituents present then the residue becomes more concentrated. Aqueous systems may be permitted to evaporate to atmosphere, but where solvents are involved then it is desirable to take steps to capture the solvent. Evaporation is also a function of the area of contact between the liquid and the vapour phase, and thin film evaporators exploit this characteristic.*
Equipment/ Manpower/ Infra-structure	*Certain types of evaporation can be done in open lagoons, where climate and geography permit. Otherwise, various specialised items of equipment can be utilised, from simple heated open top vessels to sophisticated automatic thin film evaporators with vapour capture and condensation. Manpower requirements are low.*
Adverse Factors	*Need to ensure that evaporation does not lead to atmospheric pollution and the emission of constituents which would be otherwise prohibited.*

Cost Indicator	*Very low for lagoon based evaporation to fairly high for specialist equipment using all necessary refinements.*
Residues and fate of hazardous constituents	*Case specific. Both the concentrated material and the evaporated substance(s) may be hazardous or contain hazardous materials/contaminants, and testing is required to determine any final disposal.*

Distillation	
Brief Description	*A process which separates components of a mixture of liquids, or of liquids and dissolved /suspended solids, by applying thermal energy and vaporising components, then recondensing that vapour in a separate stage.*
Waste Types	*This process is primarily one of material recovery, usually involving the separation by distillation of solvents in a mixture. It provides a valuable pre-treatment for solvent waste streams, allowing useful material to be separated and hence reducing the quantity of waste requiring disposal. In that context, it is applied principally to mixed solvent waste streams, particularly those containing a solvent of some value.*
Process Principles	*In some respects, a specialised form of evaporation. As thermal energy is applied to a mixture of liquids, and its temperature rises, so the components are vaporised. These vapours are conducted to a separate unit/stage of the process where they are cooled and thus condense, giving a pure (or at least purer) substance. As the temperature of the mixture rises, the component with the lowest boiling point usually vaporises first, followed by the next, and so on. This process, known as fractional distillation, provides the basis for separation of the components. However, separation is not always possible as some solvents will not distil as single pure substances, but come off as mixtures with other components. Even then, the process will leave behind dissolved/suspended contaminants.*
Equipment/ Manpower/ Infra-structure	*Distillation plant, particularly for fractional distillation, is specialised and complex. Plants can be more or less automated and continuous. Moderate levels of manpower are required, including quality control.*
Adverse Factors	*Complexity of many waste streams, especially where little thought is given to segregation of components, can make distillation ineffective. Azeotropes can affect recovery efficiency, and render process ineffective, thus resulting in larger volumes for final disposal.*
Cost Indicator	*Distillation itself is a fairly expensive process to operate, but is usually self-financing by virtue of the value of the recovered solvent and the reduction in volume for final disposal.*

Residues and fate of hazardous constituents	*The distilled material should be of value as a product. Distillation residues will be concentrates of the contaminants that were present in the waste all along, and appropriate final disposal methods must be chosen accordingly.*

Crystallisation	
Brief Description	*A process in which a solution containing dissolved salts is made to yield those salts in crystalline form.*
Waste Types	*Of very limited application in the disposal of Basel hazardous wastes, but any dissolved crystalline substance will be amenable to crystallisation from its solute, which will often be water, but need not necessarily be so.*
Process Principles	*The process is primarily one of purification and separation, and relies on the fact that crystalline substances will come out of a solution in which the amount present exceeds the solubility. Moreover, when crystallising from solution, salts will usually do so as pure material, leaving impurities behind in the solute. The process of bringing about crystallisation depends on causing the amount of salt dissolved to exceed its solubility in the volume of solute present, and this can be done in two ways. Firstly, the solution can be evaporated, driving off solute until there is insufficient left to provide for all the salt to remain in solution. Salts will then crystallise out. Secondly, if the solubility of the solute is reduced by cooling to a point where there is insufficient solute to provide for the salts present, again, salts will crystallise out.*
Equipment/ Manpower/ Infra-structure	*With evaporative crystallisation, equipment will be much the same as for evaporation itself, that is to say, vessels with jacketing or internal coils to provide heating capability, and the facility to collect solute vapours if these are not acceptable for atmospheric discharge. Where cooling techniques are to be used, again vessels fitted with jackets or coils are required, but with a capability to generate cooling fluids to pass through them. The process is very often batch based, although continuous equipment may well be applicable in very large, mass production applications. Manpower requirements are moderate, owing to the need to remove and package the crystallised material.*
Adverse Factors	*Some salts will remain in solution in remaining volume of solute. (Evaporation to dryness will result in all impurities being present in the solid residue).*
Cost Indicator	*Can be fairly costly due to energy inputs for evaporation and/or the cost of cooling the solute mass. Clearly only an option worth considering where the value of the recovered salts is sufficient to cover cost.*

Residues and fate of hazardous constituents	*Crystallised materials should be at least fairly pure and of use. Residual solute will contain remainder of the salts and any other contaminants present in the original material. Testing will be required to determine final disposal.*

Filtration	
Brief Description	*A process in which a sludge or a waste water or other liquid containing suspended solids is forced through a medium such as fabric, paper, sinter glass, finely perforated plate etc, such that the liquid passes through the medium leaving the solid material behind. In the case of colloidal solutions flocculants may need to be added.*
Waste Types	*Settled/thickened sludges from neutralisation/precipitation etc processes. Raw waste waters containing suspended solids. Aqueous solvents from chemical production.*
Process Principles	*Many variations! May operate on gravity, with the filtrate left to pass through the filter medium otherwise unaided, an approach not suited to thick sludges but possibly effective for large volume flows with very low solid levels. Most industrial applications use pressure feed to force the liquid through the filter medium or vacuum to pull it through. Filter types include batch operations with possibilities of automation or a continuous operation. The efficiency of dewatering depends upon the characteristics of the waste to be filtered (ie the size and nature of the solid particles) and upon the filter process used. Usually used in conjunction with sedimentation/settlement systems as a further stage in dewatering of process sludges.*
Equipment/ Manpower/ Infra-structure	*Gravity systems can include large area filter beds and will invariably be appropriate only where very low suspended solid levels occur in reasonably high liquid flows. Popular mechanical plant systems include plate filter-presses (pressure feed, batch operation but able to be automated), tubular filters (usually pressure feed and batch operation) and rotary vacuum filters (vacuum and continuous operation). Filter media can include cloth, paper, powder filter beds, sinter glass, perforated plates. Fineness of separation can be controlled by fabric weave, sinter porosity etc, and for some types of equipment this can be changed to suit need fairly easily. Facilities will usually require feedstock retention tanks to smooth flow and possibly filtrate collection and treatment capacity. Manpower requirements are moderate for manually operated filters working on a batch basis, but low for automated and continuous activities.*
Adverse Factors	*Unsuitable or incorrect porous size in filters may render process ineffective. Too coarse and solid material is passed, too fine and the filter may “blind” and cease to function.*

Cost Indicator	*Filtration plant tends to involve quite high capital cost, especially mechanical plant. Quite significant operating costs may be incurred, particularly where vacuum systems are preferred or where frequent renewal of the filter media is necessary.*
Residues and fate of hazardous constituents	*Filtered solids, especially from pressure filter systems, can appear quite dry and solid, although it is usually the case that around at least 50% moisture is still present. These solids will contain the metal hydroxides other precipitates or suspended matter from the original waste and final disposal selection must reflect this. Final filtrate should be clear and free from suspended solid, but testing for residual dissolved contaminants is usually necessary.*

Soil Flushing/Washing	
Brief Description	*A process in which soil is flushed or washed so as to extract contaminants for separate/external treatment.*
Waste Types	*Contaminated soils, both excavated and in situ. Most contaminants can be extracted, depending upon choice of washing medium, but removal of persistent organic species such as PCB is one of the more common applications.*
Process Principles	*Contaminated soils are contacted with a washing medium selected to dissolve the species causing the contamination. Selection of wash liquor is critical - the most effective materials for dissolving the required species may themselves pose operational and environmental problems. The wash liquors are then be processed in some way, often involving separation of the contaminants and recycling of the liquor, and the soils returned for higher grade use, subject to satisfactory levels of decontamination. It is often the case that contaminated soils are excavated and processed in a suitable adjoining plant, but it may sometimes be possible to carry out the work in situ by injecting the washing medium and collecting it via pre-installed systems.*
Equipment/ Manpower/ Infra-structure	*For external washing of excavated material, various plant arrangements would offer a washing capability, including mixing soils and washing liquors in rotating or shaking vessels, and static systems where soils are placed in engineered containment and washing liquors passed through them for collection at the base. If volatile solvents are being used for washing of soils, provision will have to be made to ensure that vapour loss to atmosphere is controlled to a minimum. Work of this type invariably involves a significant amount of materials movement and even where this is allied with excavators and conveyors, manpower requirements will be fairly intensive.*

Adverse Factors	*Some soil contaminants may not readily transfer to a suitable wash liquor. With static wash systems liquor may "channel" through soil bed and fail to contact much of the material. Whilst surplus washing liquors will drain from the soils, significant liquid retention may occur. Additional processing may be necessary to remove such retained materials, depending on nature of the wash liquor and the requirements for the washed soil.*
Cost Indicator	*Processing of this type is invariably fairly expensive.*
Residues and fate of hazardous constituents	*The washed soil will require testing to establish the degree of decontamination and the uses for which it is then suitable. Wash liquors will contain the contaminants removed from the soil and will need to be disposed of in a manner appropriate to the substances involved.*

Drying	
Brief Description	*The removal of liquids or moisture from solids, sludges and slurries to yield a dry material.*
Waste Types	*It would be unusual to consider drying waste prior to disposal, but the process could be applied to any sludges or slurries, or to any solid material which is moist or wet.*
Process Principles	*Liquids associated with solids will vaporise if in an uncontained state. The rate of evaporation will increase with temperature, and where materials need to be really dry, temperatures in excess of the boiling point of the liquids involved may be necessary. Vapours from organic solvents should not be released to atmosphere and arrangements will be necessary to collect and deal with them in an appropriate way. Accelerated drying will occur if a vacuum system is employed to remove vapour from the solid material.*
Equipment/ Manpower/ Infra-structure	*Drying plant comprises an enclosed chamber in which the materials to be dried can be placed, together with the facility to raise the internal temperature of the chamber and, where a vacuum system is operated, extraction of vapours via a vacuum pump. All systems should provide for the capture and condensation of vapours released unless they are water vapour.*
Adverse Factors	*Verify that the temperature required for effective removal of vapours does not cause any decomposition of the material being dried.*
Cost Indicator	*Drying can be a fairly expensive process.*
Residues and fate of hazardous constituents	*Dried materials will probably be intended as products, but should be tested for residual moisture. The collected and condensed vapours will require appropriate processing/ disposal.*

Autoclaving	
Brief Description	*A sterilisation process involving the application of heat and pressure.*
Waste Types	*Clinical waste and any other infectious materials.*
Process Principles	*Microbial species are destroyed at elevated temperatures, so if contaminated material is subjected to suitably high temperatures then the microbial activity is eliminated. Autoclaves usually operate with steam under pressure, thus ensuring temperatures well above 100 degrees centigrade.*
Equipment/ Manpower/ Infra-structure	*Autoclaves are specialised pieces of equipment providing space into which the contaminated material can be placed as well as means to inject steam under pressure. Plant may also have a vacuum capability so as to assist in the removal of contaminated liquid and vapour, and to enable more than one cycle of temperature and pressure to be applied without having to open the vessel. Processes are batch based and require manpower for charging and emptying the vessel.*
Adverse Factors	*The process only sterilises the items which were contaminated. The items remain intact as items, and may still possess intrinsic hazards, such as with hypodermic needles.*
Cost Indicator	*Moderate to high cost is involved in provision and use of autoclave plant.*
Residues and fate of hazardous constituents	*The treated material should be essentially free of microbial activity, as should the condensate/liquid collected in the treatment vessel. However, the treated material is effectively unchanged by the process and may still pose risk and/or aesthetic concern.*

Microwave Irradiation	
Brief Description	*A process involving the use of (usually) microwave energy to irradiate and sterilise bioactive material. The microwave treatment process may reduce the volume of waste.*
Waste Types	*Clinical waste and other infectious or bioactive material.*
Process Principles	*Microbial species are destroyed at elevated temperatures, so if contaminated material is subjected to suitably high temperatures then the microbial activity is eliminated. Microwave irradiation generates high temperatures - in effect "cooking" the material, and in the process destroying the microbial activity. Special provision may be necessary for the gases and vapours vented at the end of the process - which may present odour problems.*

Equipment/ Manpower/ Infra-structure	*Microwave ovens provide the usual basic equipment. Plant is usually operated on a batch basis, since although a continuous operation is theoretically possible, it is considered good practice in most cases to keep the infectious wastes enclosed until no longer active.*
Adverse Factors	*The process only sterilises the items which were contaminated. They remain intact as items, and may still possess intrinsic hazards, such as with hypodermic needles, or pose aesthetic problems such as with tissue and body parts. Smell problems can occur with the venting of the gases in the "oven" after processing.*
Cost Indicator	*Moderate cost.*
Residues and fate of hazardous constituents	*Treated material should be free of microbial activity, but will be essentially physically unaltered. Vented gases and vapours should also be free of activity, but this may need to be verified from time to time.*

Chemical Treatment Processes

Chemical treatment processes are those where the waste is subjected to a chemical reaction, involving the addition of other chemicals as reagents, so that beneficial chemical transformations take place. The "beneficial" transformation may involve the complete breakdown of the hazardous species to less or non-hazardous by products, the conversion of the hazardous species to a different and more readily separable/removable form, or its conversion to a form in which further treatment becomes possible. Many of the processes in this section are those used frequently for treating aqueous hazardous wastes, effluents and waste waters containing metals and other inorganic species.

Chemical Reduction - Oxidation	
Brief Description	*Processes in which oxidising and reducing agents are used to bring about beneficial chemical transformation of constituents of the waste. See "Adverse Factors" for chlorinated byproducts.*
Waste Types	*Especially used for part-treatment of chromic acid (reduction from hexavalent to trivalent state), for the breaking down of cyanide, and for preliminary treatment of waste water. Can also remove/reduce many organic species in solution, break down metal complexes (making them easier to treat with other processes), remove certain metals from solution (eg Hg, Pb, Ag, Sb) and convert species such as sulphite, ammonia, nitrite etc.*

Process Principles	*Oxidising and reducing agents are brought into contact with the waste species under appropriate temperature and concentration conditions. Oxidation or reduction reactions may break down or otherwise beneficially alter the chemical form of the hazardous constituents. Common oxidising agents include chlorine, sodium and calcium hypochlorite, ozone, hydrogen peroxide, potassium permanganate and occasionally "per"acid compounds. Common reducing agents include ferrous sulphate and sulphur dioxide.*
Equipment/ Manpower/ Infra-structure	*Reaction and storage tanks, probably with mixing. Ancilliary processes may be required for separation, filtration etc. Manpower must cover familiarity with the complex chemistry involved. Supplies of power and water, availability of reagents and disposal of residues and waste water.*
Adverse Factors	*Contaminants and/or poor process control can lead to very high reagent consumption. Large scale storage of chlorine requires special precautions. All oxidising and reducing agents must be stored and used with care. Most listed reagents will increase salt loading in process liquors. Some countries do not permit the use of chlorine for the treatment of cyanide and other species because the process may lead to the formation of chlorinated organic compounds.*
Cost Indicator	*Many of the reagents are in the moderate to fairly high cost range - even at locations close to manufacturing sources. Process plant need not be especially sophisticated and costly, but well designed and constructed plant will inevitably cost significant sums of money. Where continuous/automatic processing is appropriate, capital cost may be higher, but savings should be made on operating costs. Skilled supervision and control staff are required, although probably to a lesser extent for automated processing.*
Residues and fate of hazardous constituents	*For cyanide and many organic species, the constituents may be effectively destroyed. Note that with cyanide wastes the anionic or metal part of the compound is probably not affected and may require some additional treatment. Otherwise, toxic and heavy metals and their compounds will ultimately form part of a settled solid phase which may well be separated by filtration or similar process. It will then be necessary to dispose of the separated material containing the concentrated hazardous constituents. Waste waters from the processes will require appropriate discharge.*

Chemical Neutralisation	
Brief Description	*Adjustment of pH (acidity/alkalinity) to neutral conditions, possibly including the consequent precipitation of insoluble species such as hydroxides.*

Waste Types	*Acidic or alkaline solutions, including those containing dissolved salts of metals which can form insoluble species, notably hydroxides.*
Process Principles	*Acidic and alkaline solutions possess intrinsic corrosive properties which will be mitigated by adjusting the pH to around neutral. In so doing, it will also be the case that certain dissolved metals are precipitated as insoluble hydroxides, separable from the aqueous phase by a settlement or filtration process. Common reagents for neutralising acids are lime and sodium hydroxide. Alkaline wastes may be neutralised with any commonly available acids such as sulphuric or hydrochloric acid. Neutralisation of strong acids and alkalies can liberate large quantities of heat. Different metal hydroxides form at slightly different pH values, but whilst this may appear to offer opportunities for separation of different metals, with potential for recovery, in practice it is rarely possible to achieve sufficiently clean separation.*
Equipment/ Manpower/ Infra-structure	*At the simplest level, reaction and storage tanks, with mixing, and compatible with the corrosive nature of the wastes. Ancilliary processes for settlement and separation of solids may be required (see later). Manpower requirements are moderate but must embrace the chemistry of metals and their compounds. Analytical testing capability is vital. Supplies of neutralisation reagents are required.*
Adverse Factors	*Many metals do not form hydroxides under the conditions of this process. Some that do (eg Zn and Sn) may redissolve if excessive alkali is used. Metals which ordinarily precipitate hydroxides very efficiently, such as Cu and Ni will not form hydroxides in the presence of complexing reagents such as ammonia and additives used in some electroplating solutions. Hydroxides will easily redissolve if disposed of in situations where subsequent contact with acids occurs.*
Cost Indicator	*Unit reagent costs range from low to fairly expensive, but neutralisation of very strong acidic or alkaline wastes may require large quantities. Simple neutralisation plant, with ancilliary separation/filtration, need not be especially sophisticated and costly, although basic site infrastructure will inevitably add to the cost. Continuous/automatic processing may be suitable in some cases at initially higher capital cost, but lower manpower, supervision and control costs should follow.*
Residues and fate of hazardous constituents	*The hazard of the corrosiveness of acids and alkalies is eliminated upon neutralisation. Species precipitated and separated/filtered will be concentrated into the relatively small volume of residue. Dissolved species not precipitated by pH adjustment are likely to remain in the bulk of the aqueous phase, which may require additional processing.*

Chemical Precipitation	
Brief Description	*Chemical reactions which cause hazardous/unwanted constituents to be precipitated from solution and separated.*
Waste Types	*Mainly metal salt bearing wastes, including neutral, acidic and alkaline materials.*
Process Principles	*Embraces chemical neutralisation and metal hydroxide formation, but goes further. Addition of reagents may cause reactions which precipitate undesired species from solution and enable separation and removal. Depends upon there being a suitable insoluble form for the substance in question - which is not always the case. Sulphides of metals are often insoluble and sulphide liberating reagents are readily available. Fluoride and sulphate levels in waste waters can be reduced by adding lime and forming calcium salts. Otherwise it is a case of examining the chemistry of the waste components and identifying a species which is insoluble then determining whether it can be converted by processes available. This category would often be used in conjunction with neutralisation, and may require filtration/separation plant.*
Equipment/ Manpower/ Infra-structure	*At its simplest, a reaction tank with mixing and storage tanks - all compatible with the wastes involved. Probably needs ancillary facilities for separating and filtering precipitated solids. Manpower needs are moderate, but must include general inorganic chemical expertise. Analytical capability essential together with access to reagents.*
Adverse Factors	*Limited number of hazardous substances for which suitable insoluble species exists. Sophisticated chemistry and process requirements for some species are possible, but often impractical other than when very high value materials are involved.*
Cost Indicator	*Reagents very variable in cost - lime usually inexpensive but sulphide generation can be more costly. Basic processing need not be particularly sophisticated and costly, although potential exists for much more expensive processes to be selected. Site infrastructure requirements inevitably add cost. Continuous automated processing may be appropriate in some cases at higher capital cost but with savings in subsequent operations.*
Residues and fate of hazardous constituents	*Species precipitated and separated/filtered will be concentrated into the residue and subsequent disposal must reflect that. Dissolved species unable to be removed as an insoluble precipitate will remain in the bulk of the waste which may then require additional treatment or selection of appropriate final disposal.*

Chemical Dechlorination	
Brief Description	*The chemical removal or stripping of chlorine from organic species.*
Waste Types	*PCBs, dioxins/dibenzofurans, possibly certain pesticides. The principle use is the removal/reduction of PCB concentrations in electrical transformer oils.*
Process Principles	*Powerful reducing agents combine with the chlorine atoms on the organic molecule and remove them. The reagents usually involved dispersions of sodium metal in an anhydrous medium such as a glycol. The dechlorinated organic molecule usually remains intact, but may polymerise, whilst the chlorine reacts with the sodium to form sodium chloride. Usually operated as a (semi) continuous process connected to item being treated.*
Equipment/ Manpower/ Infra-structure	*In the most frequent application, the plant is portable and taken to the treatment location. The plant requires a closed reaction vessel, some means of filtering solid residue from the return, processed waste and the means to circulate the fluids from the transformer, through the reactor and back to the transformer. Apart from the wastes, the reagents are dangerous if not handled correctly, so the facility must incorporate many safety features. Manpower requirements are low, but must be highly trained. Testing of PCB levels is a very specialised analytical task.*
Adverse Factors	*Reagents will be very expensive and very dangerous to use and to store. Without careful quality control reagent could be wasted on other constituents. Total elimination of contaminant can prove difficult - a compromise between reagent use/cost and acceptable residual concentrations may be necessary.*
Cost Indicator	*In the transformer oil regeneration application, the process is expensive, but may still be attractive in relation to the alternative of incineration and purchase of new transformer fluids. As a pure disposal process for concentrated PCB wastes which are being discarded anyway, it is not usually an attractive option due to very high reagent cost.*
Residues and fate of hazardous constituents	*The chlorine combines with the sodium to form sodium chloride. The organic molecule, stripped of chorine, forms a semi-polymerised residue. These are filtered from the process for routine disposal.*

Hydrolysis	
Brief Description	*A chemical reaction in which water causes another substance to breakdown.*

Waste Types	*Substances which are unstable in water and break down. These can include some pesticides and organo-phosphorus compounds and substances such as phosphorus halides, thionyl chloride, silicon tetrachloride etc which will react violently with water.*
Process Principles	*Substances which are unstable in contact with water (or aqueous acids and alkalies) may react with the water, breaking down to form simpler residues. These residues are likely to retain some hazardous properties, and may require further treatment. The reactions can be violent, such as between phosphorus halides and water, and special care will be needed if these processes are to be carried out under controlled conditions. Some reactions may result in the liberation of much heat.*
Equipment/ Manpower/ Infra-structure	*The usual approach is to add the waste to be hydrolysed to the water in small increments, or by slow continuous addition. Efficient mixing in a suitably sized reaction vessel is essential, and in cases where the reaction is particularly vigorous, fume extraction and treatment may be necessary - a significant additional cost. It is unlikely that the more violently reacting wastes will be encountered frequently or in large quantities, so specially designed, automated plants are unlikely to be worth considering. Simpler hydrolysis reactions can partially be automated. Likely to be used in conjunction with other processes. Manpower requirements are moderate to low, although awareness of the chemical properties and hazards of these wastes is essential.*
Adverse Factors	*Violent reaction in some cases. Possible incomplete destruction of hazardous species.*
Cost Indicator	*Low to moderate in most cases, although subsequent treatment of residues may be significant. The more vigorously reacting substances will require more equipment, time and resource.*
Residues and fate of hazardous constituents	*Hydrolysis of water-reactive halides will generate acidic wastes which need subsequent neutralisation, and possibly separation/filtration. Hydrolysis of pesticides will generate a waste water containing fragments which might retain some activity and/or hazardous characteristics.*

Electrolysis and Electrochemical Destruction	
Brief Description	*The use of electrical power to break down or alter chemical compounds and, in some cases, remove them from solution.*
Waste Types	*Some metal salts and metal complexes in aqueous solution, species such as cyanide and some other dissolved compounds.*

Process Principles	*When a direct electrical current is passed through an aqueous solution chemical changes may take place at the anode and cathode involving oxidation and reduction reactions respectively. This derives from the transfer of electrons associated with the direct current. Metals such as Cu, Ni, Zn, Au, Ag and Sn will, if present, be removed from solution and deposited on the cathode. Different metals are deposited at different electrical potentials, but efficient metal separation by control of electrical potential is seldom achievable with mixed waste solutions. Species such as cyanide may be broken down at the anode. The nature and design of the electrode can be of significance. Reactions tend to be governed by equilibrium factors, so it becomes increasingly difficult to achieve further contaminant removal/destruction as concentrations diminish. The process may often be more suitable for applications connected with materials recovery.*
Equipment/ Manpower/ Infra-structure	*Electrolytic systems require lined reaction tanks in which to carry out the process, but these are not usually very large. In a waste context, storage tanks may be required to hold stocks for treatment. Special electrical equipment is necessary, including DC transformer and controllers and these can be fairly expensive. Electrolytic systems involve specialist knowledge and skill, but otherwise manpower needs are not high. As the electrolytic process is unlikely to remove/destroy completely the hazardous species, facilities for further treatment of the residues will usually be required. Reliable sources of electrical power.*
Adverse Factors	*Electrolytic process adversely affected by contaminating substances, which may also cause severe electrode wear and very poor electrical efficiency. Inability to reduce contaminant concentrations to levels low enough for final disposal.*
Cost Indicator	*A specialised process which has reasonably high costs in comparison with other processes which tackle the same sorts of wastes.*
Residues and fate of hazardous constituents	*Electrodes may contain deposited metals of value. Residual liquors will probably still contain significant concentrations of hazardous substances and will often require further treatment stages.*

Flocculation and Coagulation	
Brief Description	*A process involving the aggregation of fine suspended solids so that they exhibit better settlement, separation and filtration characteristics.*
Waste Types	*All suspended solid containing waste waters, especially those with very fine, almost colloidal material. May typically arise from neutralisation and precipitation processes.*

Process Principles	*Addition of flocculating or coagulating agents, usually polyelectrolytes, causes the particles to agglomerate by surface binding processes. Larger particles may be formed, and may settle more quickly into denser layers. This may also beneficially affect subsequent dewatering stages such as filtration.*
Equipment/ Manpower/ Infra-structure	*Practically nil. The polyelectrolyte needs to be mixed prior to adding to the existing suspended solution, but no other facility is required.*
Adverse Factors	*Polyelectrolytes are not universally effective. The characteristics of polyelectrolytes vary considerably with exact molecular size and shape, and the most appropriate one for an area of application must be established - largely by trial and error.*
Cost Indicator	*Polyelectrolytes are fairly expensive to purchase, but as only small quantities are used at each application, overall cost is low.*
Residues and fate of hazardous constituents	*Should improve separation of solid phase and increase probability that supernatant liquor is free of suspended hazardous constituents.*

Physical/Chemical Treatment Processes

Processes in this section are something of a hybrid, in so far as the process relies on the exhibition and use of both physical and chemical properties for the process to operate successfully.

Solvent Extraction	
Brief Description	*A process in which an aqueous system containing dissolved or suspended organic material is mixed with an immiscible solvent which then dissolves the organic material. The two immiscible phases then may be separated.*
Waste Types	*Not usually applied to the disposal of Basel wastes, but could be used to remove selected organic contaminants from waste waters and metal ions in complexed form.*
Process Principles	*Organic matter suspended or dissolved in an aqueous system may preferentially pass (or partition) into an organic solvent phase brought into contact with it. Where the solvent is immiscible with the aqueous system, the two phases may then be simply separated. Partition is rarely 100% efficient, so residues of the organic materials may remain in the aqueous phase. The process is usually used to clean aqueous streams or to extract organic materials from a manufacturing process stream. Can be operated as a batch or continuous process.*

Equipment/ Manpower/ Infra-structure	*A closed vessel in which the aqueous material and the immiscible solvent can be brought into contact, involving usually either mixing or shaking, and which permits separation of the phases.*
Adverse Factors	*So called immiscible solvents will have some slight solubility in water, so themselves may cause trace contamination. Vigorous mixing and shaking may cause emulsification and consequent problems of separation.*
Cost Indicator	*Batch operating equipment is relatively simple and inexpensive, although continuous systems will cost more in capital terms.*
Residues and fate of hazardous constituents	*The immiscible solvent phase will attract most of the organic material originally in the aqueous phase. Traces of organics, together with traces of the solvent, are likely to be in the aqueous material after processing.*

Pertraction	
Brief Description	*A solvent extraction type process where a membrane is placed between the phases so that the organic solvent and aqueous phases do not come into direct contact.*
Waste Types	*Not usually a process applied to the disposal of Basel hazardous wastes, but could be used for removal of complexed metal ions and organic constituents such as phenols and chlorinated hydrocarbons.*
Process Principles	*The organic constituents of the aqueous phase are attracted to the pores of the membrane through which the material is passed. They pass through the membrane into the solvent. The absence of direct contact avoids the risk of emulsification, and reduces the risk of contaminating the aqueous phase with solvent. It may also increase the range of solvents which can be used. Process amenable to continuous operation. Suitable for specific situations rather than general, multi-purpose operation.*
Equipment/ Manpower/ Infra-structure	*Along with all membrane systems, this involves very specialised equipment and will be designed for individual applications - not likely to be useful for occasional or multi-purpose applications. Low to moderate manpower requirements.*
Adverse Factors	*Solids in aqueous phase may cause fouling of the membrane, so some pretreatment might be required.*
Cost Indicator	*Moderate cost due to membrane process.*
Residues and fate of hazardous constituents	*The immiscible solvent phase will attract most of the organic material originally in the aqueous phase. Traces of organics are likely to remain in the aqueous material after processing.*

Stripping/Desorption	
Brief Description	*A process in which volatile components of a liquid mixture can be removed by passing a stream of gas through the liquid.*
Waste Types	*Ammonia rich aqueous wastes, phenolic wastes, any aqueous waste with volatile organic components/contaminants.*
Process Principles	*Vigorous passing of a gas through a liquid can cause volatile components to be carried out in the gas flow. Such gases must then be processed in some way - condensation may yield the organic materials directly, or the organic rich gas may have sufficient calorific value to be used as a fuel. Gases should not react with the liquid. Air and steam (which will also assist volatilisation) are amongst those most frequently used, but more exotic gases can be used in special cases. The process may combine the use of vacuum to improve removal efficiency.*
Equipment/ Manpower/ Infra-structure	*Gas can be injected easily into practically any vessel, but good efficiency dictates that the gas flow through the liquid should be well distributed. Collection of the stripping gas is necessary, followed by some separation of organics or, alternatively, use as a fuel in a suitable local application. Gases other than air and steam may be difficult to obtain. Manpower requirements are low.*
Adverse Factors	*May generate large gas volumes for relatively little stripping. Only effective for volatile organics.*
Cost Indicator	*Basic stripping with air/steam would be low cost, but costs can increase significantly with use of other gases, the need to process the gas stream, or application of vacuum.*
Residues and fate of hazardous constituents	*The stripped liquid should contain much reduced concentrations of organics, but may still contain traces of those removed together with others not sufficiently volatile to come off in the conditions. Testing necessary to determine further disposal requirements. Stripped material will contain much of the organic material and must be disposed of appropriately.*

Chromatography	
Brief Description	*A process in which substances may be separated on the basis of their differing retention times when washed through a column of absorbent material.*
Waste Types	*Not a process normally encountered in the direct treatment of Basel hazardous wastes, but may be able to separate useful components from mixed organics prior to disposal.*

Process Principles	*Substances absorb onto a stationary medium with differing strengths, and will be washed off the medium with differing levels of ease. Chromatography involves a column of absorbent material onto which is absorbed the mixture to be separated. The column is then washed through (eluted) with a solvent which moves the different components down the column at different speeds. These components can be separately collected in their relevant solvent fractions. The absorbent in the column and the eluting solvent need to be selected to suit the individual case. This a batch operating process, suited to regular processing of similar mixtures. Recycling of eluate solvents would be a frequent feature.*
Equipment/ Manpower/ Infra-structure	*A packed column, solvent storage and the means to collect separate fractions of eluate are essential. Some sort of monitoring capability so that the different fractions can be tracked down the column will be important if the activity is not routine. Eluate recycling will be important economically and would incorporate isolation of separated species from solvent. Distillation/evaporation systems may be appropriate. Manpower requirements quite high in relation to unit process.*
Adverse Factors	*Quantitative loadings not high, process slow and fairly labour intensive. Some of the solvents providing the best separation characteristics can be quite hazardous in themselves.*
Cost Indicator	*A fairly expensive process to use.*
Residues and fate of hazardous constituents	*The separated fractions are likely to be fairly pure, but may nevertheless be of limited use and require disposal. Solvents used for elution should be readily recyclable with minimal losses. Absorbent will be usable many times before discarding, but may then contain accumulated hazardous residues.*

Membrane based processes

Membrane technologies separate solutes/contaminants from the liquids in which they are present by the use of semi-permeable membranes. Semi-permeable membranes function by selectively rejecting certain species, based on factors such as size, ionic valency and polarity. There are a number of processes based on the use of semi-permeable membranes, connected in the main with purification and concentration of well characterised, consistent streams. These processes are not particularly associated with the disposal of Basel hazardous wastes, but may offer separation and recovery opportunities for waste streams which would otherwise be subject to disposal, and thus reduce the quantity of waste requiring final disposal. Processes are described briefly and collectively in the following table. The processes are dealt with together because their differences, in the context of hazardous waste management, are too slight to merit separate entries.

Membrane Based Processes (Reverse Osmosis/Ultrafiltration/Pervaporation/Electrodialysis)	
Brief Description	*Semi-permeable membrane based processes in which constituents can be separated by what is, in effect, filtration at the molecular level.*
Waste Types	*Oil/water emulsions, including particulate stabilised systems (subject to pretreatment). Aqueous systems with dissolved salts such as from electroplating or with low levels of dissolved persistent organic species such as halogenated hydrocarbons and PCBs.*
Process Principles	*Membrane systems, often in the form of tubes, plates or capillaries allow some constituents of a mixture to pass through whilst retaining others. The input side of the membrane may be at pressure to encourage the separation process through the membrane. Other enhancing motive forces can include electrical potential. Depending on the circumstances and on the particular process, the contaminants may either be the substances retained by the membrane or allowed to pass through it. Feedstocks for semi-permeable membrane processes may require some pretreatment to remove substances with the potential to damage the membrane.*
Equipment/ Manpower/ Infra-structure	*Semi permeable process plant is highly specialised and usually designed for specific applications by specialist manufacturers. Plant will usually require support facilities in the way of reception and storage tanks, perhaps a blending and balancing capability and possibly pretreatment, such as for removal of coarse suspended solids and the initial breaking of emulsions by heat or pH adjustment. Disposal facilities for the separated aqueous and solids phases will be required. Although essentially continuous processes, process control requirements are significant and manpower needs low to moderate.*
Adverse Factors	*All membrane processes are sensitive to feedstock composition, including the presence of contaminants. The membranes may be damaged by the actions of unexpected contaminants.*
Cost Indicator	*Moderately expensive. Initial capital cost of membrane-based processes is high with moderate operating costs. Unit costs will fall with high volume, low contamination streams, which can be processed for long periods without interruption for repairs and maintenance.*
Residues and fate of hazardous constituents	*Separations are never 100% efficient. Where the non-hazardous substance is the one passing through the membrane, then it is likely to yield a very pure stream, with the contaminants concentrated in the retained material. Where the hazardous substances pass through the membrane, the material so passed will be rich in those hazardous substances, but the material retained by the membrane is likely to contain some hazardous material. Testing of such materials will be necessary to establish suitable disposal options.*

Leaching	
Brief Description	*A process in which soluble components are washed out of a solid substance.*
Waste Types	*Contaminated soils, gravels, aggregates and rocks. Catalysts and sludges containing toxic and heavy metals. Theoretically, any solid waste which contains a soluble component which may need to be extracted.*
Process Principles	*Relies on the fact that components of a solid may have widely differing solubilities in various solvents. A solvent is chosen which readily dissolves the components requiring to be removed, but does not dissolve (at least to a significant extent) the other materials. The liquid with dissolved material passes through and is collected, leaving the solid matter. Efficiency of process depends on suitability of the solvent, surface area over which contact and leaching can take place and the time allowed for equilibrium to be reached. Whilst many leaching activities are based on water, it is feasible to use acids, alkalies and organic solvents - in which case various special precautions relating to environmental releases of gases vapours and liquids must be observed.*
Equipment/ Manpower/ Infra-structure	*Can be done in the open air, on hard standing etc where the leaching liquid is water and the substances being leached are not especially hazardous. Otherwise the process can be conducted in large man-made vessels such as artificial beds, bunkers, or for smaller scale needs, tanks. Mixing/agitation may be beneficial. May involve high levels of material movement, in which case manpower requirements are likely to be large.*
Adverse Factors	*Hard to ensure really effective surface contact with all the solid, channelling through large masses of solid is a recognised problem.*
Cost Indicator	*At the extreme of simplicity, the process can be fairly low cost, but in more complex cases the cost rises significantly.*
Residues and fate of hazardous constituents	*The leachate is likely to contain most of the potentially extractable substances and must be dealt with accordingly. The remaining solid may well retain some of the extractables, and is likely to be moistened with the liquid - which may itself have some hazardous properties.*

Scrubbing	
Brief Description	*A process in which waste gas streams or liquid wastes are subjected to a cleaning process by contacting them with a washing liquid or slurry, or in some cases, a solid powder.*

Waste Types	*Processing of waste gas streams from operations such as incineration, neutralisation etc. Washing/cleansing of wastes stream such as waste oils with acids.*
Process Principles	*Components of waste gas streams, both gaseous and entrained solid matter and droplets, can be removed to varying degrees by scrubbing processes which contact the gas stream with (usually) aqueous washing medium. The washing liquid may be alkaline, acidic or neutral, and may include slurries of lime. Soluble gases from the gas stream will dissolve and some capture of particulate and droplet will occur, together with neutralisation either in situ or in an ancillary treatment plant to which the wash liquors are taken. The scrubbing process may take the form of spraying the wash liquid into the gas stream, or of passing the gases through the liquid in packed towers or bubble trays. Scrubbing of acidic waste gas streams can be done by injecting an alkaline powder such as lime. Separately, waste liquids may benefit from scrubbing to help remove impurities prior to carrying out some other process. An example would be the scrubbing of waste oils with concentrated sulphuric acid to oxidise and char organic contaminants, which are then removed by settlement and filtration prior to distillation of the cleansed waste oil.*
Equipment/ Manpower/ Infra-structure	*Scrubbing usually takes place in an enclosed vessel specially designed for the purpose. The action of scrubbing can be carried out in several distinct ways involving different types of plant. Plants must be designed for the particular application required. Wash or scrubbing liquors will require treatment such as neutralisation, settlement, filtration etc, and provision for this must be made. Scrubbers usually operate continuously with minimal manpower requirements, but may have large electrical power and water demands. Different types of scrubber designed to remove different components, may be used in series where necessary.*
Adverse Factors	*Conventional scrubbers have only limited value in removing entrained particulate, being effective only for the coarser sizes.*
Cost Indicator	*Modern, efficient gas scrubbers are usually medium to high cost units to purchase and will be fairly expensive to operate.*
Residues and fate of hazardous constituents	*Depends on composition of waste being treated. Treated gases and liquids may still contain detectable levels of contaminants, so must be tested. Scrubber liquids (and sometimes solids) will contain the dissolved and suspended matter and will require appropriate further treatment. Acid tars are difficult to deal with and will require specialised disposal.*

UV Irradiation/Ozonolysis	
Brief Description	*A process in which molecules are broken down by a combination of ozone and energy inputed to the system via UV irradiation.*

Waste Types	*Applicable to assisting the breakdown of halogenated and stable organic molecules, including when dispersed in a medium such as soil.*
Process Principles	*Some molecules will break down if exposed to ozone. If they are also subjected to appropriate energy inputs from UV irradiation, the effectiveness and scope of the process is much increased. Sources of suitable radiation are available.*
Equipment/ Manpower/ Infra-structure	*Sources of radiation directed onto the materials to be treated.*
Adverse Factors	*May be slow, incomplete and unpredictable in some instances, and ineffective for contaminants beneath the surface of the solid mass.*
Cost Indicator	*Low to moderate where specifically set up as a process.*
Residues and fate of hazardous constituents	*Breakdown of contaminants may be incomplete, and breakdown products may not necessarily be non-hazardous.*

Ion Exchange	
Brief Description	*A reversible process in which dissolved ionic constituents of a solution may, when in contact with a suitable resin, exchange with other ionic species on the resin.*
Waste Types	*The process is especially suitable for material recovery but has applications in waste disposal, particularly for consistent and predicable waste water streams containing low concentrations of certain metals.*
Process Principles	*Ionic constituents of a (waste) stream may exchange with ionic species on the resin, thereby causing the exchanged species to concentrate on the resin until the capacity for exchange is exhausted. The resin is regenerated by a process which releases the exchanged material and concentrates it into a much reduced volume. For example, dilute waste water may have copper replaced by a relatively innocuous metal such as sodium. The effect is both to render the waste water more suitable for discharge and to locate the copper on the resin. Regeneration of the resin would release the copper into a small volume of concentrated liquor. Resins may be made to exchange anionic or cationic species. It may be possible for resins to remove specific substances such as a single metal from mixed streams, but this will depend on the circumstances of each case.*

Equipment/ Manpower/ Infra-structure	*Resins are packed into columns through which waste streams are passed at flow rates suitable for effective exchange. Facilities are required for flushing with regenerating solutions and for collecting/treating concentrated flush liquors. Reputable suppliers provide all this as a package. Systems may be automated, but manpower requirements are not usually large.*
Adverse Factors	*Resins may be poisoned by unexpected constituents or rapidly exhausted by unexpectedly high loadings. Efficiency of removal declines as concentrations get lower.*
Cost Indicator	*Initial installations can be fairly costly but subsequent routine use should not be particularly expensive.*
Residues and fate of hazardous constituents	*Waste waters after processing would be expected to contain much lower concentrations of the hazardous constituents removable by the resin, but tests should be carried out to verify suitability for final discharge/disposal. Concentrated liquors may have value for recovery, but otherwise will require appropriate disposal.*

Immobilisation Techniques

Immobilisation techniques have to be considered when other processes cannot be used. The term is used to cover several processes which share the principle of "conditioning" a waste so as minimise the possibility of release into the environment at large. Conditioning is mainly of a physical nature, although some chemical retention is sometimes claimed. The processes are based on the philosophy that if a substance is contained so that hazardous constituents are not able to be released, then the process has merit in avoiding/reducing the possibility of pollution. The principles of the processes are to place a waste in some sort of containment, such as by encapsulating it in another substance or in converting it into a concrete-like mass from which leaching of constituents is unlikely, or at worst - minimal. A lack of globally standard terminology in this area results in several descriptive terms being used in a rather loose and flexible way, such as immobilisation, inertisation, stabilisation, solidification, cementation (which can also mean something else altogether), and encapsulation. We will look at two main approaches.

Solidification	
Brief Description	*Cement-based process which seeks to convert waste to solid, inert mass, preventing its release or dispersion into the environment.*
Waste Types	*Metal treatment sludges (hydroxides etc), waste waters with low residual concentrations of metals, miscellaneous inorganic sludges. Most organic compounds and some inorganic compounds, especially substances like sodium chloride, are unsuitable in anything above trace concentrations.*

Process Principles	*Usually based on the chemistry of cement, both Portland and the much older pozzolanics, inorganic wastes are transformed into solid, stable materials with much reduced environmental dispersion risk. Blending of the waste, whether already in neutral sludge form or requiring pre-treatment, with fillers, bulkers and cement type reagents, forms the product which sets hard over a period of time. Organic type binders and solidifying agents, such as asphalt and resins can also be encountered, but much less frequently. The concept is based on generating a product of low permeability and hence low leachability, with concrete-like strength to prevent physical fragmentation and keep surface area to a minimum. It is claimed for some commercial processes that the entrapment of the hazardous waste in the solid matrix involves not only a physical constraint, but that chemical bonding of toxic metals can also be demonstrated.*
Equipment/ Manpower/ Infra-structure	*Usually carried out in large mixing vessels, in which both initial treatment and cement type reactions can be conducted. Provision must be made to transfer the reaction product, whilst still mobile, to the location in which it is intended that it solidify. Storage and holding tanks for waste inputs and to permit optimum blending flexibility. Manpower requirements moderate to low, but expertise in cement chemistry is essential together with good laboratory capability for waste testing and quality control. Electrical power and water required, together with nearby location for solidified residue.*
Adverse Factors	*Cement chemistry is complex and getting a genuinely hard, solid process product requires great care and integrity. Organic contaminants can easily affect the solidification reactions.*
Cost Indicator	*The basic process can be inexpensive, with wastes serving for some of the reagents and processing often carried out on a large scale. With purchased and quality raw materials, some of which can be expensive (and especially so if at locations remote from manufacture), costs can be much higher.*
Residues and fate of hazardous constituents	*The whole basis of these processes is that the product generated is capable of being placed directly into landfill/storage without further treatment.*

Encapsulation	
Brief Description	*A process in which waste is enclosed within a casing or layer of some inert and resistant substance so as to prevent the escape of that substance into the wider environment.*
Waste Types	*Any discrete article or item which can be covered by a layer of some other material or set into an inert mass. Typical articles include small containers of (unknown) wastes such as from laboratories and items of contaminated equipment.*

Process Principles	*By surrounding the waste requiring disposal with an inert/strong/impermeable layer or mass, it will become relatively safe to dispose of it to landfill. This is the principle of containment, ie if contaminants are contained and not available for release into the environment, then this should be seen as representing an acceptable approach to disposal. Common methods include placing items into 200 litre drums filled with concrete. More sophisticated processes have involved coating articles and small containers with multi-layered man-made plastics and resins.*
Equipment/ Manpower/ Infra-structure	*Placing items in concrete within 200 litre drums is a simple manual process. More sophisticated coating processes would require specialised equipment, probably tailor- made for the particular application.*
Adverse Factors	*Process relies on continued integrity and stability of encapsulated unit.*
Cost Indicator	*Setting in concrete is a relatively inexpensive process, although pre-sorting and checking for suitability requires time and skill. More sophisticated coating type processes are likely to be expensive.*
Residues and fate of hazardous constituents	*The whole basis of these processes is that the encapsulated product can be placed directly into a landfill/storage site without further treatment.*

Biological Treatment Processes

Biological processes represent a large sector of treatment opportunity, but have several special features and requirements. The basic principle, common to all, is that natural, micro-organism based activity breaks down certain compounds either through metabolism to provide nutrient energy or through co-metabolism. Effective processing depends on selecting a micro-organism suitable for the species requiring treatment, and on carrying out the treatment under conditions which are suitable, including careful control of the nature and composition of the waste. Generally speaking, biological processes have little effect on inorganic wastes including metals, although some absorption into a sludge phase may occur with some processes.

Biological treatment systems, in common with most processes covered in these Technical Guidelines, become less efficient as concentrations of treatable constituents diminish. Optimum process time is a compromise between completeness of reaction and ever extending time to achieve it. The various biological processes fall into two main categories; aerobic processes in which the presence of oxygen is necessary, and those operating in oxygen free conditions, known as anaerobic processes. Many of the processes utilising biological activity operate as continuous processes, although some may be used on a batch basis.

Specialist advice would be required on availability or development of suitable micro-organisms for specific requirements. Table I below lists some examples, however not all those listed are commercially available. With any biological process, only organic species to which the micro-organism is adapted will be degraded. Individual microbial species are not universally applicable to all organic substances, although they may modify their form to accommodate changes in composition of feedstock. Some classes of organic substances are not particularly amenable to effective treatment by biological means. Halogenated substances are a notable example, although some micro-organisms exist which can effect a partial treatment. Some chlorinated species can be extremely toxic to biological systems and can destroy treatment capability by killing the micro-organisms even at very low concentrations.

Generally speaking, to provide effective treatment, biological processes need known, consistent and predictable feedstocks. Sharp variations in concentration or flow rate may result in ineffective treatment, and new/unexpected constituents in a waste may be toxic to the microbes or simply pass through the process unaffected. Furthermore, since the waste acts as the nutrient for the microbes, temporary cessation of waste flow could cause the microbes to die, with total loss of process capability until the bioactivity is regenerated. In order to control the efficiency of the process, constant monitoring of effluents is required.

As a general observation on process costs, most biological treatment methods are based on relatively high throughputs of consistent composition wastes, processed at least semi-automatically and requiring minimum process variation and supervision. Whilst initial construction and installation costs for purpose-built plant may be fairly high, unit throughput costs will usually be quite low - at least compared to many of the physico-chemical treatment processes dealt with previously in these Guidelines.

Aerobic Processes:

Activated Sludge Treatment	
Brief Description	*An aqueous based process in which organic species are biodegraded in contact with a bio-active sludge.*
Waste Types	*Waste waters or organic solid waste dispersed in an aqueous system. Not suitable for high organic loadings. Suitable only for organic species to which the micro-organisms are conditioning in the active sludge.*
Process Principles	*A process in which effluent is passed through a tank containing an established biomass-rich active sludge, which is agitated and aerated. During its residence in the tank the conditioned biomass metabolises biodegradable substrates in the effluent. After treatment the active sludge is settled in a clarifier producing a clear treated effluent and a sludge which is recycled to the tank. Excess biomass is removed regularly to maintain the equilibrium of the process.*
Equipment/ Manpower/ Infra-structure	*Various configurations of activated sludge tank are available depending on the quality of effluent required. An aeration and mixing system are required which need a reliable electricity supply. The process requires skilled manpower to operate and maintain it and a sophisticated control and instrumentation system.*

Adverse Factors	*May not treat unexpected constituents. May accumulate toxic metals in sludge.*
Cost Indicator	*Low.*
Residues and fate of hazardous constituents	*In most cases the process aims to generate waste waters capable of being discharged to a watercourse, but this must always be verified by testing. In specific cases, the process may be used as a pretreatment for hazardous wastes before discharge to a sewer for further treatment.*

Trickle Filter	
Brief Description	*A process in which aqueous phase organic species are broken down by contact with a bacterial rich slime established on a filter.*
Waste Types	*Waste waters and aqueous wastes with organic constituents where the organics are conditioned to the micro-organisms in the slime.*
Process Principles	*A filter bed is established, comprising crushed rock, clinker, or plastic contact units on which a bacterially rich slime is grown. The waste water is sprayed onto and trickled through the filter allowing the organic matter to contact the bacterial slime. A counter flow of air passes up through the bed , creating the conditions necessary for breakdown of the organic species.*
Equipment/ Manpower/ Infra-structure	*Filter beds are often circular with rotating spay/distribution arms for applying the aqueous waste. Construction is fairly simple, but may require forced upward airflow through the filter. Clarification of the processed waste water is required together with discharge facility. Continuous process, low manpower needs, low power and utilities.*
Adverse Factors	*In common with many biological processes, bacterial bed vulnerable to damage from unexpected, toxic constituents. Constituents of a waste stream incapable of treatment by the micro-organisms in the slime will pass through unaffected.*
Cost Indicator	*Low.*
Residues and fate of hazardous constituents	*In most cases the process aims to generate waste waters capable of being discharged to a watercourse, but this must always be verified by testing. In specific cases the process may be used as a pretreatment for hazardous wastes before discharge to a sewer for further treatment.*

Rotating Biological Contactor	
Brief Description	*A process in which aqueous phase organic species are broken down by contact with a bacterial rich slime established on a filter.*
Waste Types	*Waste waters and aqueous wastes with organic constituents suitable for the bioactive slime. Can deal with higher loadings and with wastes of lower biodegradability.*
Process Principles	*Active bacterial slime is grown on vertical rotating discs of suitably porous material. The discs are partially submerged in the waste liquid and rotated in the waste to be treated such that they are alternately in the waste and in the air/oxygen. Surplus slime settles to the bottom of the vessel and must be periodically removed.*
Equipment/ Manpower/ Infra-structure	*Purpose-built plant consisting of vessel and rotating discs, with separation capability for surplus slime. Low manpower requirements and relatively low power demands. Processed waste water discharge facility.*
Adverse Factors	*In common with many biological processes, bacteria vulnerable to damage from unexpected, toxic constituents. Constituents of a waste stream incapable of treatment by the micro-organisms in the slime will pass through unaffected.*
Cost Indicator	*Low.*
Residues and fate of hazardous constituents	*In most cases the process aims to generate waste waters capable of being discharged to a watercourse, but this must always be verified by testing. In specific cases the process may be used as a pretreatment for hazardous wastes before discharge to sewer for further treatment.*

Aerated Lagoons and Stabilisation Ponds	
Brief Description	*Wastes contained in shallow lagoons/ponds are subject to biological degradation with mixing and/or enhanced oxygenation.*
Waste Types	*Waste waters and aqueous waste with low organic loadings.*
Process Principles	*The process is carried out in a lagoon or pond - this requiring some sort of mixing as well as aeration. The process is slow compared to more structured processes, but can be operated on the basis of continuous or batch treatment.*
Equipment/ Manpower/ Infra-structure	*Lagoons and ponds should be essentially impermeable. This may require an artificial lining. Mixing and aeration is required. Process takes many days to complete and needs little attention during this interval. Low manpower and low power and utilities.*
Adverse Factors	*Slow, as well as the general concerns about unsuitable constituents in the waste affecting the microbes or not being treated by them.*

Cost Indicator	*Low.*
Residues and fate of hazardous constituents	*In most cases the process aims to generate waste waters capable of being discharged to watercourse, but this must always be verified by testing. In specific cases the process may be used as a pretreatment for hazardous wastes before discharge to sewer for further treatment.*

Composting	
Brief Description	*A process in which solid and semi solid waste is subject to biological decomposition.*
Waste Types	*Much used for vegetative and cellulosic waste, but with no application for hazardous wastes.*
Process Principles	*Material is placed in controlled stacks on the ground with sources of bioactivity mixed in (eg wood chips, sewage sludge). Aeration must be controlled along with pH, temperature and moisture levels. Full decomposition can take very long periods, sometimes more than a year.*
Equipment/ Manpower/ Infra-structure	*Whilst the process can be carried out in the open air, need for control of the conditions mentioned above indicates that covered areas, if not buildings or special units, would be much preferable. Some machine assisted manpower is required to move and turn the stacks of developing compost.*
Adverse Factors	*Time to achieve complete reaction. Non-degraded constituents will remain in compost and may adversely affect subsequent use.*
Cost Indicator	*Low.*
Residues and fate of hazardous constituents	*The only output is the composted material, which will contain any non-biodegradable constituents from the original waste.*

Anaerobic Processes:

Anaerobic Digestion	
Brief Description	*A process in which the waste is contacted with the micro-organism in the absence of oxygen, such that it degrades to form substances such as methane.*
Waste Types	*Simple organic materials, but can be of high strength. Metal-bearing waste are best avoided.*

Process Principles	*The process will usually employ closed reactors in which the waste and the micro-organisms are mixed and to which air/oxygen is denied. The reactor can control conditions and allow the reaction to proceed at optimum speed. Reaction can be especially sensitive to waste composition variations.*
Equipment/ Manpower/ Infra-structure	*The reactors and the equipment for safe handling of the flammable gases generated will usually come as a package, but will cost significant sums of capital. However, operations are usually straightforward with low manpower requirements. Possible methane revenue.*
Adverse Factors	*Process sensitivity to waste composition and possible need for acclimatisation.*
Cost Indicator	*Low to medium.*
Residues and fate of hazardous constituents	*Methane gas should be useable as a fuel. Treated waste waters are intended to be fit for discharge to sewer or watercourse, but this must be checked. Surplus sludge must be tested, but may be suitable for routine disposal.*

Related Anaerobic Processes	
Brief Description	*Several similar processes rely on the anaerobic process, but differ in detail over the physical arrangements. These are: anaerobic contact process, the upflow anaerobic sludge blanket, the upflow anaerobic filter and the stationary down flow reactor*.
Waste Types	*Aqueous waste streams with moderate to high organic loadings.*
Process Principles	*All involve contact between the biomass and the feedstock in anaerobic conditions. Differences arise over arrangements for optimising contact area and for supporting the biomass, operating temperature and liquid flow. All will generate methane gas, settled sludge and a processed waste water.*
Equipment/ Manpower/ Infra-structure	*All units are specialised items designed for particular applications and scales of operation. Units operate continuously with minimal manpower requirements.*
Adverse Factors	*As with all biological processes, there is some sensitivity to waste composition.*
Cost Indicator	*Low to medium cost, especially if the unit can achieve good volumetric throughput.*
Residues and fate of hazardous constituents	*Methane gas should be useable as a fuel. Treated waste waters are intended to be fit for discharge to sewer or watercourse, but this must be checked. Surplus sludge must be tested, but may be suitable for routine disposal.*

Other Biological Processes:

Land Application/Treatment/Farming	
Brief Description	*A process which utilises the natural capacity of soils to bring about the biodegradation of organic matter.*
Waste Types	*High organic content sludges, avoiding persistent organics, heavy /toxic metals and low volatility solvents.*
Process Principles	*Soils contain naturally occurring bacteria and organic material spread onto or mixed into such soils will undergo biodegradation. The application of suitable wastes to the land must take account of loading as well as waste composition.*
Equipment/ Manpower/ Infra-structure	*Machinery for spreading or for sub-surface injection. After initial application, manpower and utility requirements minimal.*
Adverse Factors	*Non-degradable waste constituents remain in the soil. Land area practically sterile for agricultural purposes. Risks to wildlife whilst waste is still present.*
Cost Indicator	*Low if non-availability of land for other purposes is unimportant.*
Residues and fate of hazardous constituents	*Not applicable - residues remain in the ground.*

Bioremediation	
Brief Description	*A process approach much in favour for dealing with contaminated land in which suitable micro-organisms are deliberately introduced to the land with the intention that they breakdown the harmful species present.*
Waste Types	*Land contaminated with organic substances for which suitable micro-organisms exist. Inorganic/metal contamination will not normally be assisted by this approach. Persistent and halogenated contamination may be more difficult to tackle fully, but it may well be possible to make some useful progress.*
Process Principles	*Depending on the area, depth and extent of the contamination, coupled with the degree of remediation sought, it may be possible to carry out a treatment just by applying bioactive material to the surface of the land, by subsurface injection or by ploughing. Otherwise, excavation of the soil and external treatment may be necessary. It may be necessary to develop optimum micro-organisms at laboratory level, using samples of the actual contaminated soil.*

Equipment/ Manpower/ Infra-structure	*A range of mechanical handling equipment is likely to be necessary, depending on the particular situation. Manpower could be high if material movements play a major part.*
Adverse Factors	*Difficulty of establishing extent of contamination. Time required for biological process to take effect means project will be drawn out and equipment tied up.*
Cost Indicator	*Low to high depending on the widely differing characteristics of the situation.*
Residues and fate of hazardous constituents	*The object must be to allow the treated soil to remain in its original location. Any non-biodegradable constituents will remain in the soil unless other decontamination measures are adopted.*

Annex 1
Waste Categories and Treatment Methods

This section of the Technical Guidelines looks briefly at the Annex I "Y" categories, and at some of the waste types covered by them. It then attempts to indicate the classes of physico-chemical and biological treatment which might find successful application for those categories. The purpose of this exercise is to further assist competent and other relevant authorities correlate waste categories with processes available and judge the appropriateness of waste management process options for particular wastes about which they are concerned.

It is acknowledged that this objective is difficult to meet via a brief and concise text. For example, a few individual Annex I categories are already the subject of their own dedicated Technical Guidelines ranging from around 20 to 50 pages in length. These documents discuss thoroughly the types of waste generated and the waste management options which may offer environmentally sound disposal. To cover all Annex I categories to a similar degree of depth and detail would require a document of at least a further 400-500 pages, and that is neither practicable nor consistent with the purpose, format and objective of these Guidelines. Nevertheless, it is hoped and believed that further supporting information will be beneficial, even if it provides only general guidance and does not cover every possibility or situation which may arise.

Accordingly, a paragraph is devoted to each Annex I category offering brief comments about waste generation and disposal options which may be applicable. Distinction is usually drawn between processes which serve to separate, extract or concentrate a species from a waste stream and processes which offer "final" disposal for that species. Information is summarised in table form at the end.

Note: Waste management process options identified as potentially applicable are confined to the physico-chemical and biological treatment processes dealt with in these Guidelines. Other Annex IV disposal operations (such as incineration and landfill) may also be appropriate, and indeed may sometimes provide the obvious or preferred option!

Y1. As the principal concern with clinical waste is the risk of exposure to infectious organisms, it is usually good practice to avoid any process which exposes wastes to the open air. Important relevant processes for treating such wastes include autoclaving and microwave/irradiation which destroy the bio-activity.

Y2. The production and preparation of pharmaceuticals will yield many types of waste. Important relevant processes will include distillation, absorption, filtration, solvent extraction, ion-exchange and evaporation of primary wastes and neutralisation, flocculation, membrane processes and biological treatment of aqueous effluents and waste waters.

Y3. Pharmaceuticals, drugs and medicines will involve a potentially wide range of organic and inorganic substances. Relevant processes could include oxidation/reduction with neutralisation for inorganic and part organic materials, dissolution and biological treatment for certain organic materials and encapsulation for small items of great difficulty.

Y4. The production, formulation and use of biocides and phytopharmaceuticals involves both inorganic and organic substances and wastes. Relevant processes may include distillation, evaporation, solvent extraction, drying, absorption and ion-exchange for primary wastes and oxidation/reduction, neutralisation, flocculation, settlement, membrane processes and biological methods for aqueous effluents and waste waters.

Y5. The manufacture, formulation and use of wood preserving chemicals involves organic and inorganic substances. The concentrated chemicals themselves may typically be dealt via distillation, neutralisation, precipitation, oxidation/reduction, solidification and encapsulation. Washings and waste waters may be dealt with using neutralisation, precipitation, settlement, ion exchange, absorption, membrane concentration techniques, and biological methods.

Y6. The production of solvents involves principally organic feedstocks, but with catalysts for some of the synthetic processes. Such catalysts often contain comparatively exotic metals. Formulation and use of solvents broadens the possible range of wastes. Relevant processes applicable to the primary wastes can include distillation, evaporation, adsorption, leaching, neutralisation, precipitation, settlement, filtration, solidification and encapsulation. Waste waters and aqueous washings can include absorption, ion exchange, neutralisation, precipitation, settlement, membrane processes and biological treatment.

Y7. Cyanide based heat treatment residues will usually be solid and will need to be dissolved in water before processing. Oxidation reactions, possibly coupled with precipitation, settlement and filtration, are the most common for this material. Electrolytic and biological methods may have some application. Sometimes the waste has quenching oil associated with it, in which case some form of separation such as flotation may be required.

Y8. Waste mineral oils may be subjected to various clean-up processes leading to recovery in some form. These may range from simple settlement, through evaporation, dewatering, drying, filtration and centrifuging, to acidic scrubbing and distillation. (See Y10 for oils contaminated with PCBs etc).

Y9. Waste oil/water, hydrocarbons/water mixtures and emulsions can utilise many different processes to effect a separation and clean up. Much will depend on the ratio of oil and water and of the presence of suspended solid matter. Separation processes can include settlement with heat, chemical emulsion breaking (acidification followed by neutralisation), centrifuging, filtration, flotation and membrane processes. Clean up of the oil phase may then follow the options identified under Y8. In some cases, oil/water systems predominantly consisting of oil may be amenable to treatment by biological methods.

Y10. Waste substances and articles comprising or containing PCBs, PCTs and PBBs may be amenable to direct treatment or may be better dealt with by separating the contaminant and treating it in isolation. Contaminated waste oils and inert liquids may be treated by chemical dechlorination. Aqueous systems may be contacted with an absorbing medium to remove the PCB. Solid waste may be washed/rinsed and lose materials leached with a suitable solvent. Biological methods may be appropriate for low concentration waste waters and soils.

Y11. Physico-chemical treatments offer few practical and effective opportunities for dealing with tarry residues from refining, distillation and pyrolytic treatments. Immobilisation techniques may be helpful in some cases and there may sometimes be value in separation of components via washing/leaching methods. Biological methods may offer some scope, depending on the particular constituents present.

Y12. Wastes from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnishes are likely to be predominantly organic, although some pigments and dyestuffs may be inorganic. Processes most applicable to the organic materials include distillation, settlement, absorption evaporation, drying and filtration, together with biological and possibly membrane processes for some materials,

including aqueous effluent type streams. Inorganic materials may involve filtration, flocculation/ coagulation and immobilisation techniques.

Y13. Wastes from the production, formulation and use of resins, latex, plasticisers and glues/adhesives are likely to be predominantly organic, although some inorganic substances may be encountered, especially with plasticisers. Dealing with the wastes may involve a wide range of processes, including physical separation options such as sieving and screening, air classification, size reduction etc, and distillation, filtration, centrifuging, float and sink and biological methods. Inorganic materials may involve precipitation and immobilisation techniques.
Y14. New, unidentified and unknown chemicals from research and development and teaching always pose special problems for waste management. Clearly, they can possess practically any hazard characteristic, even though it may not be known or even suspected. Quantities will often be small, making evaluation work not only expensive, difficult and risky, but impractical. Of the processes available within the scope of these Guidelines, few are really suitable unless there is some significant level of awareness of the nature and properties of the materials. Given such knowledge, practically any process may be suitable in certain circumstances, but completely unknown material in small quantities may be best dealt with by encapsulation.
Y15. Wastes of an explosive nature, not subject to specialist explosives legislation, may include both organic and inorganic materials. Hydrolysis may be appropriate, or dissolution and dispersion at non-critical levels (not a process previously listed). Biological methods may also offer prospects for organic based materials and chemical processing for inorganic ones.
Y16. Waste from the production, formulation and use of photographic chemicals etc will be mainly inorganic in nature. Separation of silver-rich paper from other material may be important, using techniques such as air classification, float and sink, and manual sorting. Liquid wastes may be treated by precipitation, neutralisation, settlement and filtration or electrolysis. Organic wastes may be suitable for distillation or biological treatment.
Y17. Wastes resulting from the surface treatment of metals and plastics can embrace a very wide range of solid powders and residues and organic and inorganic liquids and sludges. Many of the processes covered in these Guidelines can find application in some circumstances. Separation of metals and plastics from each other and from other materials can involve separation processes such as air classification, ballistic separation, sieving and screening, manual and special sorting, float and sink, flotation, magnetic separation etc. Organic materials may involve distillation, evaporation, adsorption, washing, membrane techniques and biological methods. Inorganic materials may require neutralisation, precipitation, oxidation/reduction, settlement and filtration.
Y18. Residues arising from industrial waste activities cover many types of materials, but many would be dealt with by methods other than those covered by these Guidelines. Processes which may find application include washing and leaching, magnetic separation, sieving and screening, air classification, immobilisation techniques and composting.
Y11. Metal carbonyls are invariably highly toxic and volatile and are often powerful oxidising agents. Most react with water (hydrolysis) to yield toxic and flammable vapours. As constituents of wastes, hydrolysis offers a route to degradation, but requires great caution in the control and disposal of the gases and vapours released. Precipitation, settlement and filtration may deal with the metal originally associated with the carbonyl.
Y20. Beryllium and its compounds are invariably highly toxic, particularly via inhalation of dusts and fumes. Final disposal options focus on the need to isolate and contain the material and to prevent its dispersion into the wider environment. Options relevant to these Guidelines include washing, settlement, filtration and possibly neutralisation and precipitation for separation and isolation, leading to a thickened slurry or filtercake type material. Immobilisation processes may be applicable to generate a more stable material for eventual deposit.
Y21. Hexavalent chromium compounds are generally soluble and hence impossible to precipitate

from solution and remove by filtration etc. Concentration of low levels of hexavalent chromium in aqueous effluent may be achieved by ion exchange, the use of absorbents and possibly membrane techniques. Electrolytic techniques may permit chromium metal to be plated out of hexavalent solutions. Chemical processing of hexavalent solutions involves reduction of the chromium to its trivalent state, followed by neutralisation, precipitation as the trivalent hydroxide, settlement and filtration. Immobilisation techniques may afford more stability to the final residues.

Y22. Copper compounds may utilise a very wide range of relevant processes. These include separation processes such as sieving, air classification, ballistic separation, float and sink, size reduction, magnetic separation etc for slags, mixed scraps, shredded wastes and dry material generally. For liquid wastes containing dissolved or suspended copper compounds there is neutralisation, precipitation, flocculation, settlement, filtration, washing, drying, crystallisation, electrolytic, membrane processes, ion exchange and absorbents for removing and isolating compounds. Immobilisation techniques may afford improved stability for the final residues. Choice depends on the exact nature of the waste and the circumstances. Note that attempting to precipitate copper hydroxide in the presence of ammonia will result in the formation of soluble cuprammonium species.

Y23. Zinc compounds may utilise a very wide range of relevant processes. These include separation processes such as sieving, air classification, ballistic separation, float and sink, size reduction, magnetic separation etc for slags, mixed scraps, shredded wastes and dry material generally. For liquid wastes containing dissolved or suspended zinc compounds, neutralisation, precipitation, flocculation, settlement, filtration, washing, drying, crystallisation, electrolytic, membrane processes, ion exchange and absorbents may all be used to remove and isolate compounds. Immobilisation techniques may afford improved stability for the final residues. Choice depends on the exact nature of the waste and the circumstances. Note that attempting to neutralise acidic zinc solutions with sodium hydroxide will, if excess alkali is used, cause precipitated zinc hydroxide to redissolve, thus preventing separation.

Y24. Arsenic and arsenic compounds are invariably toxic, so whatever species is eventually generated for final disposal, avoidance of environmental dispersion must be a critical consideration. Processes associated with the physical separation of arsenical materials may include size reduction, sieving, washing, filtration etc. Chemical processing may involve neutralisation, precipitation, settling, flocculation and filtration, with immobilisation techniques applied to residues for enhanced stability.

Y25. Selenium and selenium compounds are generally toxic, although trace levels can be important dietary components for some species. Avoidance of environmental dispersion is important in final disposal of residues. Processes associated with the physical separation of selenium materials may include size reduction, sieving, washing, filtration etc. Chemical methods may involve neutralisation, precipitation, settling flocculation and filtration, with immobilisation techniques applied to residues for enhanced stability.

Y26. Cadmium and cadmium compounds have enjoyed widespread use over the years and are widely dispersed in the environment. They are very toxic, the focus of much environmental concern, and their use in many applications is being phased out or drastically reduced. Many processes relevant to these Guidelines may have use in dealing with cadmium wastes. Processes include manual sorting, sieving, air classification, flotation and float and sink, chemical processing/precipitation, electrolytic deposition, ion exchange, settlement, filtration and membrane processes. Immobilisation techniques may afford improved stability for the final residues.

Y27. Antimony and antimony compounds are perhaps less commonly encountered, but do display toxic properties. Relevant processes can include precipitation, settlement and filtration, and possibly ion exchange and membrane processes. Residues may be subjected to immobilisation techniques for added stability.

Y28. Tellurium and tellurium compounds are not commonly encountered and are mostly considered to be of relatively low toxicity. Their chemistry has similarities to selenium (Y25) and some waste processing opportunities are accordingly similar.

Y29. Mercury and mercury compounds are invariably toxic and all are considered to be serious environmental polluters. The emphasis in disposal is therefore to contain and prevent dispersal into the wider environment. Many former applications for mercury and its compounds are now being phased out in an attempt to avoid the need for dealing with their wastes. Relevant processes include float and sink, settling, absorption, distillation, precipitation, filtration, ion exchange, membrane processes and immobilisation techniques.

Y30. Thallium and thallium compounds are toxic, but the metal and its compounds are not frequently encountered in waste management activities. Relevant processes include precipitation, settlement, flocculation and filtration as well as electrolysis, although immobilisation techniques may render residues more stable.

Y31. Lead and lead compounds are widely dispersed in the environment. Most are inorganic, but there are a few organometallics which pose rather different problems. Relevant processes for the inorganic and metal itself include manual sorting, sieving and screening, air classification, ballistic separation, flotation, magnetic separation, precipitation, settlement, flocculation and filtration. The organometallic compounds may be initially oxidised to produce an inorganic lead compound and an organic material.

Y32. Inorganic fluorine compounds (excluding calcium fluoride) are generally toxic on account of the fluorine, and may also be associated with a potentially toxic cation. Many inorganic fluorides are reasonably soluble in water. Membrane processes may be helpful in some cases for separating and concentrating the fluorine species, but final disposal options relevant to these Guidelines are likely to involve precipitation as calcium fluoride and/or use of immobilisation techniques.

Y33. Inorganic cyanides arise principally as solids from heat treatment or as solutions/liquids from electroplating and surface treatment. Solid material will need to be dissolved for subsequent treatment, this involving processes such as size reduction and dissolution. The cyanide itself can be readily oxidised, followed by neutralisation, settlement/flocculation and filtration. Electrolytic systems can also break down cyanide. Attention must also be given to the metals associated with the cyanide, as in plating activities these may include environmentally sensitive materials such as cadmium, nickel, copper and zinc - all of which must be dealt with by the process.

Y34. Acidic solutions or acids in solid form will require neutralisation. Solid material will usually first need to be dissolved and may benefit from size reduction to aid dissolution speed. Neutralisation may in itself bring metals from solution, but precipitation may be required as well. Settlement, flocculation/ sedimentation and filtration are also likely to be required.

Y35. Basic solutions or bases in solid form will require neutralisation. Solid material will usually first need to be dissolved and may benefit from size reduction to aid dissolution speed. Neutralisation may in itself bring metals from solution, but precipitation may be required as well. Settlement, flocculation/ sedimentation and filtration are also likely to be required.

Y36. Asbestos (dust and fibres) are dealt with by relatively few relevant processes. Environmentally sound waste management principles dictate that asbestos wastes should be collected and bagged separately, and not allowed to become mixed with other wastes. If they are nevertheless mixed, separation is not easy and process choice must avoid proliferation and release of dust/fibres - wet methods may be preferred. Final disposal requires containment and prevention of wider environmental dispersal. Immobilisation techniques may have application from amongst processes covered by these Guidelines.

Y37. Organic phosphorus compounds usually hydrolyse on contact with water, the further breakdown of hydrolysis products sometimes assisted by oxidation. Organophosphorus compounds may absorb onto suitable substances and be separated and concentrated by membrane processes, by distillation and by solvent extraction. Extraction from substrates such as soil may be carried out by leaching or washing. Biological processes may be effective in some cases.

Y38. Organic cyanides often hydrolyse in contact with water, the further breakdown of hydrolysis products sometimes assisted by oxidation. Organic cyanides may absorb onto suitable absorbents, and may be separated and concentrated from waste streams by membrane processes, by distillation and by solvent extraction. Extraction from substrates such as soil may be carried out by leaching or washing. Biological processes may be effective in some cases.

Y39. Phenols and phenol compounds including chlorophenols may be separated and concentrated from waste streams by membrane processes, by absorption and possibly by distillation. Extraction from substrates such as soil may be carried out by leaching, solvent extraction or washing. Phenols may break down if subjected to strong oxidising agents and chlorine atoms can be stripped from chlorophenol molecules by chemical dechlorination. Some phenols are destroyed by biological processes, but chlorinated species are not usually efficiently broken down.

Y40. A number of processes are applicable to the disposal of ethers, mainly in connection with separating and/or concentrating them from other substances. These include distillation, evaporation and absorption, along with membrane processes. Some biological processes will breakdown ethers.

Y41. Halogenated organic solvents can utilise several of the processes in these Guidelines, particularly for separation, extraction and concentration of the solvent from other waste material. Relevant processes include distillation, evaporation, solvent extraction, absorption, stripping, washing/leaching, flotation and membrane processes. Destruction of halogenated solvents by processes relevant to these Guidelines is confined to chemical dechlorination and (to a very limited extent), biological methods.

Y42. Organic solvents, excluding halogenated solvents, employ much the same processes for separation, extraction and concentration as halogenated species (see Y41). Final disposal of non-halogenated organic solvents by processes relevant to these Guidelines is principally confined to biological methods.

Y43. Congeners of polychlorinated dibenzo-p-furan may require extraction, separation and concentration from the larger volume of waste. This may be achieved by solvent extraction, washing, leaching, absorption and possibly membrane processes. Destruction of the dibenzofurans by processes relevant to these Guidelines is confined to chemical dechlorination and possibly biological methods. Small caches of concentrated dibenzofuran waste may sometimes be considered for encapsulation.

Y44. Congeners of polychlorinated dibenzo-p-dioxin: see Y43 above.

Y45. Organohalogen compounds other then those specifically referred to in Y39, Y41, Y42, Y43 and Y44 would include halogenated plastics, rubbers and resins, halogenated oils and greases, possibly refrigerants as covered by one of the Annexes to the Montreal Protocol and possibly also PCBs etc - although these have already been addressed in Y10. Relevant processes may include separation processes using sieving, air classification, flotation and float and sink, solvent extraction, washing, leaching, absorption, distillation and evaporation. Destruction of the chlorinated species within the scope of the processes covered by these Guidelines is limited to chemical dechlorination and possibly biological methods.

Annex 2
Additional Information concerning Environmental Impact Assessments (EIA)

The term "Environmental Impact Assessment", whilst used widely, does not enjoy a globally standardised meaning. This Annex provides some guidance as to what the expression is intended to mean in the context of Technical Guidelines issued under the provisions of the Basel Convention.

Number 9 in the UNEP series of publications, Environmental Law Guidelines and Principles, addresses Environmental Impact Assessments, and for a comprehensive consideration of the subject, the interested reader is recommended to refer to that document. A brief summary of the goals and principles of EIAs, drawn from that document, is set out below.

Definition:

EIA means an examination, analysis and assessment of planned activities with a view to ensuring environmentally sound and sustainable development.

Goals:

1. To establish that before decisions are taken by the competent authority or authorities to undertake activities that are likely to significantly affect the environment, the environmental effects of those activities should be taken fully into account.
2. To promote the implementation of appropriate procedures in all countries consistent with national laws and decision making processes, through which the foregoing goal may be realised.
3. To encourage the development of reciprocal procedures for information exchange, notification and consultation between States when proposed activities are likely to have significant transboundary effects on the environment of those States.

Principles: (abbreviated)

1. States should ensure that activities are not undertaken without prior, structured consideration of environmental effects. Where significant effects may be anticipated, an assessment should be undertaken in accordance with the following principles.
2. Criteria for determining the requirement for an EIA should be clearly defined in legal/policy sources.
3. The EIA process should identify, at an early stage, the key issues for study.
4. Minimum elements of an EIA should be:
-description of the activity
-description of the potentially affected environment, and specific information about environmental effects
-description of practical alternatives
-assessment of direct/indirect, cumulative, long/short term effects of the potential impacts
-description and assessment of measures available to mitigate adverse environmental impacts
-indication of areas of uncertainty, gaps in knowledge etc
-indication of likelihood of significant transboundary effects
-a brief non-technical summary

5. Assessments of environmental effects should reflect environmental significance
6. Impartial examination is necessary
7. Opportunities should be given for interested parties, independent experts and the general public to comment on the EIA data and preliminary conclusions, prior to final decision.
8. Reasonable time should be allowed for external comment
9. The decision should be in writing, available to any interested party, state reasons for the decision and include provisions/conditions if appropriate
10. Following the decision, it may be appropriate in some cases to arrange for supervision of the activity and its effects on the environment
11. States should seek to establish bilateral, regional and multilateral agreements concerning reciprocity and cooperation over activities which may have significant transboundary effects
12. When an EIA indicates possible significant transboundary effects the State in which the proposed activity is located should advise the affected State(s), provide them with relevant available information and undertake discussions with them in due course.
13. The requirements for EIAs should be embodied in appropriate, binding measures

Table I
Some Examples of Microbial Species for the Detoxification of Hazardous Wastes

Hazardous Pollutant	Microbial Species
Phenols	Achromobacter, Alcaligenes, Acinetobacter, Arthrobacter, Azotobacter, Bacillus cereus, Flabovacterium, Pseudomonas putida, P. aeruginosa, Nocardia, Candida tropicalis, Trichosporon cutaneum, Aspergillus, Penicillium and Neurospora.
Dyes and dye intermediates	Bacillus sp., Flarabaderium sp., Pseudomonas sp.
Hydrocarbons	Escherichia coli, P. putida, P. aeruginosa and Candida
Pesticides:	
DDT	P. aeruginosa
Linuron	B. sphaericus
2, 4 - D	Arthrobacter and P. cepacia
2, 4, 5 - D	P. cepacia
Parathion	Pseudomonas sp., E coli, P. stutzeri and P. aeruginosa
Cyanide	Bacillus megatherium, B. subtillis, Pseudomonas sp., Arthrobacter sp., Nocardia, Fusarium solani, Aspergillus niger, Rhizopus nigricans and Rhizoctonia solani
Dioxins	Mutants strain of Pseudomonas (sp. NCIB 9816 Strain II)
Polyaromatic hydrocarbons (PAH), Hexachlorobenzene (HCB), Polychlorinated Biphenyls (PCB), 2,3,7,8-trichloro-di-benzo-p-dioxin (TCCD)	Saccharomyces cerevisiae

Table II
Summary of Processes and Y Categories

Annex I category	Phys/Mech Process	Chemical Process	Phys/chem Process	Immobilisation	Biological Process
Y1	X				
Y2	X	X	X		X
Y3		X		X	X
Y4	X	X	X		X
Y5	X	X	X		X
Y6	X	X	X	X	X
Y7	X	X			X
Y8	X	X			
Y9	X	X	X		X
Y10	X	X	X		X
Y11			X	X	X
Y12	X	X	X	X	X
Y13	X	X	X	X	X
Y14	X	X	X	X	X
Y15		X			X
Y16	X	X			X
Y17	X	X	X		X
Y18	X		X	X	X
Y19	X	X			
Y20	X	X		X	
Y21	X	X		X	
Y22	X	X	X	X	
Y23	X	X	X	X	
Y24	X	X		X	
Y25	X	X		X	
Y26	X	X	X	X	
Y27	X	X	X	X	
Y28	X	X		X	
Y29	X	X	X	X	
Y30	X	X	X	X	
Y31	X	X			
Y32		X	X	X	
Y33	X	X			
Y34	X	X			
Y35	X	X			
Y36				X	

Y37	**X**	**X**	**X**		**X**
Y38	**X**	**X**	**X**		**X**
Y39	**X**	**X**	**X**		**X**
Y40	**X**		**X**		**X**
Y41	**X**	**X**	**X**		**X**
Y42	**X**		**X**		**X**
Y43	**X**	**X**	**X**	**X**	**X**
Y44	**X**	**X**	**X**	**X**	**X**
Y45	**X**	**X**	**X**		**X**

Secretariat of the Basel Convention (SBC)
Geneva Executive Center
15 chemin des Anémones
CH-1219 Châtelaine - Geneva
Switzerland

Tel:	**(41.22) 917 82 18**
Fax:	**(41.22) 797 34 54**
E-mail:	**sbc@unep.ch**
Website:	**http://www.unep.ch/basel**