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Recommendations to preserve and extend sludge utilization and disposal routes

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National foreword

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— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

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Recommendations to preserve and extend sludge utilisation and disposal routes

This CEN Report was approved by CEN on 19 January 2000. It has been drawn up by the Technical Committee CEN/TC 308.

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Contents

Foreword

This document has been prepared by CEN /TC 308, "Characterisation of sludge".

This document is currently submitted to CEN/BT for publication as a CEN Report.

This document has been endorsed by EUREAU[1)].

1) EUREAU is European Union of National Associations of Water Suppliers and Waste Water Services.

Summary

This report has been prepared within the framework of CEN/TC 308 on Characterization of Sludges. The Scope includes sludges from treating municipal, industrial and food processing wastewaters, sludge from treating raw water to make it potable, and other residues having similar potential environmental impacts. The objectives of the report are to analyse the current situation with regard to sludge management in Europe, and to recommend the approaches to preserve and extend sludge use and disposal outlets for the future.

Sludge is the inevitable residue of treating raw potable water and municipal and industrial wastewaters. However, knowledge of the quantities of sludges produced is incomplete. Treatment of these waters is designed to remove unwanted constituents from the water and concentrate them into a small side-stream - “sludge”. The sludge may also contain surplus biomass cultured during biological treatment processes. The objective of treatment is to avoid adverse impacts on the environment and human health when the effluent is discharged into the environment or water is supplied for human consumption. The concentration of beneficial constituents and of pollutants in (and health risks associated with) a sludge depends on the initial quality of the wastewater or raw water, and the extent of treatment required to meet quality standards for effluent discharge, and potable water.

Where effluent quality standards are raised, in order to reduce pollutant loads on the environment, the quantity of sludge produced inevitably increases. To be consistent, the use or disposal of the sludge must also be environmentally acceptable, sustainable and cost-effective. Sludge management typically represents about half of the overall costs of wastewater treatment. Its management will become increasingly complex as environmental standards become more stringent, and if outlets for sludge become more constrained by legislation and public attitudes.

EU policy on waste is to discriminate against disposal and promote waste avoidance, minimisation and recycling. Disposal of sludge to sea was legislated to cease by the end of 1998. Disposal of sludges to landfill, which is currently the major outlet for some sludges in Europe, is widely regarded as unsustainable. Sludge production cannot be avoided (although the quantity can be reduced by treatment) in fact demands for higher effluent quality will generally increase the amount of sludge produced. The only remaining options are recycling or destruction by combustion. Recycling options include use on land as an organic fertiliser or soil conditioner for farming, land restoration, etc. Destruction options include combustion with or without energy recovery, gassification, and using the sludge as a process fuel, with the ash being used or landfilled.

It should always be remembered that many sludges and residues contain beneficial constituents and properties that have very positive environmental advantages. For example recycling phosphate and thus reducing the need to extract primary raw material and extending the life of the planet’s reserves.

Some countries have applied a greater level of precaution into the regulatory controls for some sludges in an attempt to build stakeholder confidence, and this has made sludge management increasingly difficult and costly. Nevertheless, sludge must go somewhere, and the challenge for sludge managers is to secure cost-effective outlets for sludge that are sustainable and protect the environment and human health, and to encourage political and public acceptance of this. This will require improvements in sludge quality and the methods of disposal and recycling, which may be achieved through improved up-stream control of the quality of wastewater treated, the adoption of advanced sludge treatment processes, and perhaps changing the formulation of products and other measures to reduce diffuse inputs or sources.

The opportunities for improving the quality of water and municipal wastewater entering treatment plants are limited. For potable water, the source and quality of raw water is usually fixed to the surface and groundwater resources available locally. For sewage, industrial effluent controls have dramatically reduced point source pollution over the last 30 years (in those countries with effective legislation) to the extent that sludge quality is now increasingly dictated by diffuse pollution of water entering the sewerage system from domestic premises and road run-off, and these sources are inherently difficult to control. Industrial recession can also have a beneficial effect on sludge quality when polluting factories are forced to close. For industrial wastewater treatment, the quality of sludge has been improved through the adoption of production processes that generate less waste, and further improvements are likely through developments in industrial process technologies and integrated pollution prevention and control measures.

A range of sludge treatment options is available to improve sludge quality and processes have been developed and adopted as necessary, according to local circumstances and legal requirements. These generally focus on reducing the content of water, odour and pathogens in sludge. Technologies are emerging for the removal of contaminants, such as heavy metals, but they are expensive and are therefore not a practicable option at present. In order to secure outlets for sludge in the near future, advanced treatment of sludge may increasingly be required, for instance to have assured pathogen removal, or to produce sludge of high dry solids content to improve the flexibility of use options as a fuel or as a high quality soil additive. These choices will be largely driven by legislation and customer and public pressures, and depend in part on an entrepreneurial management approach. High quality sludge products have a market value, offering the possibility of increased revenues in the future, and this will be an additional incentive to achieve quality assured sludge products, provided that legislation and controls permit such developments.

Currently, only the use of sewage sludge in agriculture is controlled by specific legislation. There are no comparable regulations on the recycling of other sludges, animal manures or organic wastes despite the fact that they are likely to incur the same environmental problems, although they may be subject to more general environmental legislation. Some countries have some integration of environmental standards for sludge and waste use, but none is comprehensive. A uniform and comprehensive approach is urgently needed at the EU level to ensure that all sludges, animal manures and organic wastes are subject to the same consistent control measures. The benefit of this is would be that the environmental loads from some major sources of potential environmental contamination would be controlled and accounted for. One very unfortunate consequence of the present inconsistencies is so called sludge tourism (i.e. the transboundary movement of sludges to regions with less stringent environmental controls).

In a similar way a consistent approach to emissions to atmosphere from all combustion processes (power stations, incinerators, brickworks, cement plants, etc.) and of dust is recommended. These processes can have wide-reaching impacts. Globally atmospheric deposition is the dominant of some elements or pollutants.

In addition to global environmental impacts it is important that the loadings on specific sites are considered to ensure the sustainable use of those sites.

The quantity of sewage sludge produced is very small in relation to other residuals that may be used on land and that have similar potential environmental impacts, but it is the only strictly regulated residue throughout Europe, with specific requirements for quality, monitoring, record keeping and reporting. Such controls are entirely consistent with the avoidance of environmental pollution and risk to public health, but it is now inconsistent that other sludges are not similarly controlled. This is particularly true for livestock wastes, which are by far the single largest source of organic waste (more than 60%). Despite particular examples such as the Nitrate Directive, there is no comprehensive EU control strategy for livestock wastes, but it is the cause of significant pollution, and it is time that this inconsistency was corrected.

Europe has been rocked by food scares. Even though there is no evidence of disease transmission when sewage sludge has been used according to current legislation, absence of evidence is not the same as absence of effect, and it is time that process standards for stabilisation and sanitisation for all sludges used on soils where food is grown are more closely defined so as to avoid another food scare. This is partly a matter of science, but public perception is another very real concern in this area. It should be remembered that no link has ever been proved between disease transmission and the proper use of sewage sludge in accordance with current controls. However a particular concern is “new” pathogens that are starting to appear in some countries, some examples are brown rot in potatoes, which was thought to be restricted to warm climates but is now in Northern Europe, *E. coli* O157, which is tolerated by sheep and cattle but highly infective of humans, and *Salmonella typhimurium* DT104, which can display multi-antibiotic resistance. In order to control these “emerging” organisms and the “traditional” ones, consistent rules for the management of all sludges are needed. Appropriate hygiene standards for sludges can be achieved through adopting quality assured processes which can reliably reduce pathogen numbers to the desired low levels. This is now the approach being developed in the US for livestock wastes, and it is an appropriate approach for all wastewater treatment sludges in Europe, including livestock wastes.

Recommendations

The principal recommendation of this report is that, not withstanding subsidiarity, consistent application of the principles of control are necessary at the European level, to regulate the quality and use of all water cycle sludges (including some other residuals) that have similar potential environmental effects. The development of such measures should consider, and would subsequently support, the following key issues, not in any order of priority :

— give confidence to sludge producers to invest in appropriate technologies to achieve safe, secure and sustainable sludge management ;

— reinforce the precautionary principle in a practical and enabling manner consistent with sustainable development ;

— encourage quality assurance with independent audit and accreditation of sludge use and disposal in order to avoid mistakes and to build confidence in the processes ;

— avoid transboundary problems and market distortions in sludge use and disposal ;

— develop and promote integrated co-treatment of sludges and other organic wastes ;

— promote material cycle integration, with the priority on sludge use on land to conserve organic matter and complete nutrient cycles, combustion as an energy source, or material use such as animal feed, etc. while discriminating against disposal options (material cycle exclusion) ;

— promote acceptance of sludge management and use by all stakeholders ;

— encourage/require improved reporting and publication of data about the use and disposal of sludges to encourage improvement by peer comparison and to promote stakeholder confidence by transparency.

The priority in securing sustainable management of all sludges is establishing consistent standards based on sound scientific principles that protect human, animal and plant health and the environment (including soil and its fauna and flora). This would include formulating appropriate sludge quality standards and an appropriate strategy for maintaining sludge use and disposal during the period whilst they are phased in. Such standards would lead to industry developing the technologies by which these can be achieved reliably and cost-effectively.

There has been a huge amount of scientific research into the effects of sludges, especially sewage sludge. Development of an integrated approach should be based on risk assessment. Quality standards should be set according to the precautionary principle, to ensure environmental protection and sustainable development. The exercise should also be conducted in the context of expansion of the EU and the situation of the new members. There should be a commitment to the necessary research and operational surveillance to establish the rigorous scientific basis for standards and technologies that are appropriate for securing sludge use for the long term future. A new regulatory regime should be designed to encourage and enable beneficial use of sludges in line with the EU waste strategy, to ensure the integration of sludge within material cycles, and should discriminate against disposal. This should be backed by quality assurance with independent audit to avoid mistakes and validate compliance. Independent accreditation is also desirable to give confidence to the processes.

1 Introduction

Increased material flows in the environment are a natural consequence of development, however, for sustainable growth the flows particularly of wastes have to be managed in order to conserve resources and protect the environment.

The promotion of sustainable growth respecting the environment is one of the primary objectives of the Treaty on European Union. Article 130 r (1) of the Treaty lays down that action by the Community relating to the environment shall be based on :

— the precautionary principle ;

— the principles of preventive action ;

— rectification of environment damage at source ;

— the polluter should pay.

The principles of preventative action require that the European Community must first address itself to waste avoidance and minimisation before considering waste recovery, recycling and how waste should ultimately be disposed of if none of the previous options are feasible. The basic principle of action must be to support and ameliorate the valuable components in wastes and reduce the presence of harmful substances.

CEN/TC 308 “Characterization of Sludges” considers that water cycle sludges are part of the material flows. These sludges include :

1) Wastewater sludge/sewage sludge of household and municipal origin ;

2) Industrial organic wastewater sludge from :

   — potato processing ;
   — slaughterhouses ;
   — sugar beet processing ;
   — animal food production ;
   — dairy farming ;
   — livestock farming ;
   — fish processing and canning ;
   — tanneries ;
   — pulp and paper industries ;
   — olive oil production ;
   — pharmaceutical production ;
   — fruit and vegetable processing and canning ;
   — soft drinks production breweries ;
   — vinification ;
   — alcohol and alcoholic liquors production ;

— gelatine and glue production ;

— malt factories ;

— margarine and fat production ;

— starch production ;

— biological production of drugs ;

— other ;

3) Water works sludges ;

4) Sludges from the sewerage network ;

5) Cesspool and septic tank sludges (night soil).

The implementation of the Urban Waste Water Treatment Directive (91/271/EEC) will dramatically increase the amount and quality of municipal and industrial wastewater treatment throughout the European Union. Inevitably, the production of sludge will increase and this will require appropriate treatment and disposal. However, this is occurring over a period when there is a number of important changes to European and national waste management policies that will impact all of current sludge use and disposal options. The challenge of the next 10-20 years is to identify the sustainable balance between sludge production, recycling and disposal, and the protection of human and environmental health in an affordable, sustainable and acceptable manner.

Identifying secure and cost-effective disposal and use outlets for sludges (and wastes in general) in the European Union, which are also publicly and politically acceptable, has become an increasingly difficult and complex issue. Some outlets will be prohibited (such as sea disposal from the end of 1998) and all other outlets are facing increasing restrictions (agriculture, landfill and incineration), yet the amount of sludge produced in the EU is increasing rapidly, by at least 50% by 2005. Public expectations of environmental protection are high and the principle of recycling is widely acknowledged as sensible, yet the use of sludge, particularly sewage sludge, barely achieves public acceptability.

Council Directive 75/442 EEC on waste, as amended by Council Directive 91/156/EEC, sets out the following objectives for waste management to be adopted by Member states :

— increased prevention and reduction of waste through the development of clean technologies as well as of products that can be used or recycled ;

— recycling and recovery of waste as secondary raw material ;

— use of waste as a source of energy ;

— recovery and disposal of waste without endangering human health or the environment.

Where the production of waste cannot be avoided, the second priority of EC Directive 75/442 EEC is the use of waste as secondary raw material or for energy production. The use of ”sludges for utilisation” constitutes an instrument of importance to both waste management and national economies. The measures taken to this end intend that :

— amounts of waste are reduced, thus reducing the reliance on landfill disposal ;

— primary raw materials and energy are conserved and, hence, the pressures on the environment and the landscape are eased.

The general waste management policy of the EC is summarised by the hierarchy which gives priority to waste avoidance and minimisation, recycling and recovery of materials and energy, and considers landfill disposal as the least favoured option. The basis of a Community strategy for sludge could be the positive adoption, through policy and action, of the principles of this hierarchy, since this is conceived to be the basis of sustainable development. Since sludge production cannot be avoided if effluent and water quality standards are to be met, then minimising the quantity of sludge for recycling is the highest feasible objective within this hierarchy.

Usefulness is a essential principle of Directive 75/442/EEC, and both harmlessness and usefulness are prerequisites for the use of wastes.

In different European countries, there are various initiatives to maximise the use of sludges but there are no uniform guidelines or measures. TC 308 was founded due to the lack of, and differences in, technical guidelines on the investigation and evaluation of waste for recycling. Working Group 3 of TC 308 was established to establish uniform principles for the future utilisation of sludges and specifically to undertake the following :

- identify appropriate contacts within each country covered by CEN ;
- develop a questionnaire to derive information on type, quality and outlets of sludges ;
- identify current and prospective sustainable methods of reducing, handling, utilisation and disposal of sludges ;
- produce a report to CEN on recommendations to preserve and extend sludge utilisation and improve other disposal routes.

This report addresses the last and considers issues of sludge quality criteria, classification for disposal/utilisation options, quality assurance, comparison with other wastes and the development of a European strategy on sludge. More detailed recommendations are provided by specific codes of practice developed by Working Group 2 (listed in Annex A).

TC 308 defines sludge qualities and the factors which control them. The TC does not set out limit values when defining qualities, although the principles may be established by which appropriate standards may be set. There is scope to extend the range of standard methods available for measuring sludge quality. Sludge quality criteria can be used to classify sludge as to its suitability for particular use or disposal option and this has been undertaken by allocating priorities to particular properties according to outlet. Assignment of numerical standards must be done locally, but within the EU framework, because of the complex social, political, geographical, climatic and scientific factors which determine where they are set.

It is imperative that the suitability of all types of sludge for use and disposal, and their associated potential environmental impacts, are evaluated according to uniform criteria. Impacts in this context do not necessarily imply readily quantifiable “damage”, they also refer to increases in the background concentrations of contaminants throughout the environment, which may lead to an overall degradation of the environmental quality, possible unforeseen and long-term impacts, and positive environmentally enhancing aspects. Hence the need for a precautionary approach to setting standards to protect air, water and soil to ensure sustainable development.

Providing residue/waste producers and recyclers, and the competent authorities with relevant and uniform guidelines will help ensure that pollutants are not purposefully, or as a side effect of use, channelled into the ecosystem by way of dilution or non-specific binding. A uniform framework would also ensure that the most appropriate sludge management option can be selected for local conditions that not only provides consistent environmental protection but also avoids unnecessarily stringent restrictions that could prejudice sludge recycling and force sludge to be disposed of in a less sustainable manner.

Thus the priority must be to :

- improve the sustainability of existing outlets ;
- ensure optimum sludge utilisation in the future ;
- find new useful outlets.

2 Principles of use and Disposal

2.1 Options for sludge use and disposal

The Waste Framework Directive (91/156/EEC amending 75/442/EEC on waste) requires Member States to take the necessary measures to ensure that waste is recovered or disposed of without endangering human health and without using processes that could harm the environment, and in particular :

— without risk to water, air, soil and plants and animals ;

— without causing a nuisance through noise or odours ;

— without adversely affecting the countryside or places of special interest.

Member States shall also take the necessary measures to prohibit the abandonment, dumping or uncontrolled disposal of waste. The Directive incorporates the polluter pays principle and introduces the concept of the waste management hierarchy, which places the priority on waste avoidance, minimisation and recycling and discriminates against disposal. In decreasing order of preference, the hierarchy is :

— avoidance ;

— minimisation ;

— re-use - recycling, energy recovery ;

— landfill.

This general strategy addresses waste management in the context of sustainable development, the principle of which is to replace technologies which are polluting and based on non-renewable resources, by ones which do not consume finite resources and are based on avoiding, minimising and reusing wastes. The aim is to achieve development that is in ecological balance, avoids pollution and preserves biological diversity.

Waste use and recovery incorporates materials recycling, beneficial use on land, and recovery of energy. No one single type of use should automatically be preferred to any other as this will depend on the best practicable environmental option for a particular waste stream in a particular locality.

Priority is given to the use of wastes over other disposal routes, if :

— it is technically feasible ;

— it is environmentally acceptable ;

— it is secure ;

— the cost is acceptable ;

— there are economic advantages from the use or sale of sludge, such as from energy production, sludge-based products, etc.

A range of outlets has been developed for the management of sludges, which includes various recycling and disposal options, and the relative importance of these varies between countries according to local operational and economic circumstances, and national policy and legislation on waste management and environmental protection.

If environmental water quality is to be protected, it is impossible to avoid producing sludge. If tighter effluent quality standards are applied, sludge production will be increased. It is difficult to minimise sludge production without additional sludge treatment to reduce the bulk (e.g. by dewatering, drying, etc.) and solids content (e.g. by incineration, gassification, wet air oxidation, thermal hydrolysis followed by digestion, etc.) of sludge.

Use is the preferred option for wastes, provided that this is compatible with protection of the environment and human health. Landfill disposal is the option of last resort and discriminatory measures are being introduced in many countries to ensure that this principle is followed.

Thus, in broad terms, there are only two possible outlets for sludge (see Figure 1) :

1) reintegration into material cycles ;

   — direct utilisation (agriculture, land reclamation, etc.) ;

   — indirect - modified utilisation ;

      — composting - soil improvers, fertiliser, etc. ;

      — thermal treatment or processing - energy recovery (e.g. fuel production by pyrolysis, incineration, co-combustion as a fuel in power plants and industrial processes such as brick and cement production) and mineral recovery (e.g. vitrified products) ;

2) removal from material cycles ;

   — direct landfill (mono or mixed) ;

   — indirect - modified after thermal processing (disposal of ash, vitrified material).

To select the most appropriate outlet for sludge depends on detailed assessment of sludge quality and the local opportunities for sludge use or disposal. The key sludge quality criteria are :

— chemical ;

— biological ;

— physical ;

— vector attraction (odour, aesthetic consideration, etc.).

The presence of contaminants and/or pathogens in sludges is unavoidable due to the nature of wastewater and potable water production and treatment, since the objective of wastewater treatment is to remove potentially environmentally harmful components into a small amount of sludge so that the larger portion of water can be returned safely to the environment or used for human consumption. This is also the reason why sludges have beneficial uses in agriculture and energy recovery due to the presence of nutrients and organic matter, the latter containing significant calorific value which is released by combustion.

Mitigation measures are adopted which are effective in reducing the significance of undesirable components in sludge, as well as the imposition of specific controls on sludge quality and its use on land (e.g. Directive 86/278/EEC) to avoid uncontrolled and excessive accumulation of contaminants in the soil which may prejudice soil fertility in the long-term.

Wastewater treatment (with source control) = Sludge production

Sludge treatment		
Aims of treatment	**Options**	**Examples**
Conditioning	Chemical	Iron salt addition Lime addition
	Thermal	Hydrolysis
Separation of phases	Thickening	Thickener
	Mechanical dewatering	Belt press Filter press Centrifuge
	Drying	Drum dryer Disc dryer
Conversion	Biological	Anaerobic digestion Aerobic digestion Composting
	Chemical	Lime stabilisation
	Thermal	Pyrolysis/gasification Incineration Vitrification

Sludge outlets		
Integration in material cycle	**Energy recovery**	**Removal from material cycle**
Agriculture Landscaping Land reclamation Horticulture Construction industry		Landfill Atmosphere (CO_2)

Figure 1 — Examples of options for sludge treatment and disposal

The prevention of the contamination of sewage sludge by controlling the quality of industrial effluent discharge to sewer is well recognised as an essential measure in maintaining good sludge quality (see CEN/TC 308 WG2 Code 2). The principle of up-stream control to avoid contaminating wastewater before treatment and sludge production should be applied to all industries and sludge producers since it encourages wider beneficial use of sludge. Point source pollution control is well understood and widely adopted in the context of sewage, but it is low level contamination possibly from diffuse sources that is difficult to avoid. An approach here is material substitution in products that may contribute to diffuse pollution, for (instance zinc in shampoo). Such sources are of increasing significance to sludge quality, particularly as environmental quality standards for sludge continue to be tightened. This requires further study to understand the type and significance of diffuse sources, and how these may be controlled.

The presence of pathogens in sludges, particularly sewage sludge, depends on the source of wastewater. Infection of man, animals and crops can be avoided by sludge treatment and control of the use of sludge and receiving land. However, the hygienic quality of sludge continues to be a focus of concern, particularly for the large food retailers, and in order to maintain the security of agricultural use, this may require increasing reliance on thermal and chemical treatment processes to achieve higher acceptable sludge quality standards.

2.2 Principles of option selection and control

The principles of precaution and of proportionality are at the centre of European environmental policy. The establishment of environmental quality objectives and standards within this context is essential to protect the environment and human health for sustained development, particularly where sludge is to be integrated into the material cycle.

For the use and disposal of sludge, this requires knowledge of the constituents of sludge, including their potential hazard to all compartments of the environment, the concentrations at which harm may occur, and what constitute safe levels, in the short and long-term. The precautionary approach is applied where knowledge of effects is uncertain, and even where the effects are well characterised, to select how close or how far maximum acceptable values should be set in relation to levels which may cause unacceptable effects. The latter may be set according to lowest or no observable effect level by toxicology.

Where knowledge is uncertain (for instance where a new contaminant is encountered or sludge is to be used in a novel way), risk analysis is used for defining hazard levels and identifying appropriate safety levels. The level of precaution is subsequently set according to the level of safety required, which in part is dependent upon local or national conditions and political and economic considerations. This helps explain the disparities in sludge quality standards for agricultural use in different countries derived from a common scientific basis, for instance between the United States and Europe (described in Annex D)

When sludge is used on agricultural land, the primary objective is to exploit the beneficial properties of the sludge whilst at the same time protecting the soil, consumers of agricultural products and the environment at large. The precautionary principle reflects continuing and sustainable agriculture and implies that the spreading of sludges can under no circumstances lead to an irreversible or unacceptable pollution of soil, even if it is slow and diffuse.

Where the level of safety required is in excess of what can be achieved (i.e. where a contaminant exists at excessive concentrations and may give rise to unacceptable impacts), then alternative approaches are necessary, either to reduce the concentration at source or to find an acceptable alternative means of disposal.

Use of the Best Available Technology (BAT), (also Best Available Technique) may be regarded as an application of the precautionary principle. The principle of BAT states that environmental disturbances are to be prevented wherever technology allows. As it has been formulated in various international conventions and in the draft directive of the European Community on Integrated Pollution Prevention and Control (IPPC), it includes not only the choice of production technology but also the design, maintenance and operation, as well as the eventual dismantling/destruction of the facilities being assessed. The application of the principle in different countries depends on the formulation of the national legislation, including which criteria are to be taken into consideration concomitantly with the best available technology. Normally, there is some kind of financial consideration - the technology must not be unreasonably expensive. The technology must be developed or proven at a scale which allows its implementation in the relevant industrial context. The USEPA uses what it refers to as MACTs (Maximum Achievable Control Technology) for toxic substances, meaning the technology in use at the best ten per cent of the facilities in question.

The principle of BAT may be used to prevent emissions of pollutants even when knowledge of their environmental impact is uncertain. However, application of BAT is no guarantee for acceptable environmental quality. Alternatively, BAT may necessitate unnecessarily extensive measures. Less expensive solutions may be found if there are effect-related targets, for example stating that certain target values for air or water quality are to be met. However, there is an objection to strategies based on the implementation of measures in order to achieve certain environmental quality targets: they allow pollution up to a certain level with no consequences. The demand for BAT may serve as a means of maintaining low levels of pollution in areas that are relatively unpolluted today. For this and other reasons, most countries now combine effect-related and technology-related requirements.

In recent years the principle of the Best Environmental Practice (BEP) has been established. BEP is a broader concept than BAT, and involves the best combination of measures to restrict environmental disturbances for all kinds of sources. It comprises a number of means beyond the implementation of technological measures, such as information to the general public and consumers, economic instruments, and the establishment of systems for recovery or recycling.

The selection sludge use or disposal option(s) for an existing or planned wastewater treatment plant should not be separated from sludge treatment, but should be considered holistically. Ideally the selection of the optimum outlet for the sludge should dictate the choice of sludge treatment, so that the Best Practicable Environmental Option (BPEO) is identified, taking into consideration:

— environmental impacts ;

— practicability ;

— operational security ;

— economics.

This requires a balanced approach where economic considerations should not be the overriding factor. However, historical investments often require that there is a compromise, at least in the short term, but the objective should be to apply the appropriate level of sludge processing, which in the future may increasingly require advanced treatment methods, to secure the most acceptable, safe, affordable and secure method of use or disposal. This should be achievable through comprehensive strategic evaluation of sludge management operations and the uniform compliance within the requirements or the precautionary principle, IPPC and BAT.

Methodologies for assisting in identification of sludge management strategies to meet these requirements are described in Annex F2 and F3.

3 Legislation and environmental quality standards

3.1 European legislation

Environmental legislation in Europe is complex as national legislation is overlain by international agreements and European Council legislation.

There is a number of international agreements (such as the Paris, Helsinki, Basel, North Sea Conventions) and strategic action plans for the Black Sea, Danube and Mediterranean Sea, etc.) whose primary objectives are to address and reduce transboundary pollution, particularly of rivers, lakes and seas which cross or are bounded by several countries. The key issues are nutrient emissions which cause eutrophication and the disposal of wastes. Under the North Sea Convention, it was agreed to cease the disposal of sludge at sea (which was subsequently enforced through EC Directive 91/271/EEC). A major consideration of all of these agreements is the contribution of polluting nutrients from agriculture and wastewater.

The European Commission has established a legal framework for a wide range of environmental issues which have to adopted by Member States through national legislation. The most relevant to sludge management are :

— waste Framework Directive (91/156/EEC amending 75/442/EEC on waste) established the waste management hierarchy ;

— the “Sludge Use in Agriculture” Directive (86/278/EEC) set sludge and soil quality standards and monitoring requirements when sludge is spread on agricultural land. This Directive, (in conjunction with the Standardised Reporting Directive 91/692/EEC) requires (Article 17) :

  — “Five years after notification of this Directive, and every four years thereafter, Member States shall prepare a consolidated report on the use of sludge in agriculture setting out the quantities used, the criteria followed and any difficulties encountered; they shall forward this report to the Commission, which shall publish the information contained therein. In the light of that report, the commission shall if necessary submit appropriate proposal for increased protection of the soil and the environment” ;

  — as noted elsewhere few members have complied fully with Article 17. The Commission will propose revision of this Directive in 1999 which may reduce the existing sludge and soil limits for potentially toxic elements (PTEs) and extend its provisions to pathogens and organic contaminants; however the majority of members have still not satisfied the reporting requirements of 86/278/EEC ;

- urban Waste Water Treatment Directive (91/271/EEC) set minimum sewage treatment standards to be achieved in stages by end of 2005, and prohibits sea disposal of sludge by end of 1998. This Directive also requires Member States to submit reports every two years on its sludge disposal activities ;
- nitrates Directive (91/676/EEC) required Member States to define Nitrate Vulnerable Zones (NVZs) where water quality has or will exceed the EC drinking water standard of 50 mg NO_3 l^{-1}, and to impose maximum annual limits on the addition of nitrogen in fertiliser and organic wastes. Some Member States have designated their whole countries as NVZs ;
- european Waste Catalogue (developed as a requirement of 75/442/EEC) and the Hazardous Waste Directive (91/689/EEC) lists sources and types of wastes and properties which may render them hazardous ;
- ecolabel for Soil Improvers (94/923/EEC) set standards for composted wastes in order to achieve an Ecolabel. The latest revision to this Ecolabel arbitrarily excludes sewage sludge irrespective of quality or performance. The EC intends to publish a draft Directive on compost in 1999 ;
- landfill Directive which will make the disposal of sludge to landfill more difficult ;
- directives and proposals on the incineration of hazardous and non-hazardous wastes ;
- various legislation has improved sludge quality by limiting pollution at source (e.g. Directive 76/464/EEC).

3.2 International, European and national standardisation

Many existing standards produced by ISO and CEN committees have relevance for the use or disposal of water cycle sludges. All of these international standards committees are supported by national standards organisations which contribute to their review and implementation.

The ISO and CEN committees which are working on topics of relevance to sludge management are lists in Annex B.

4 Sludge production, quality and disposal in europe

4.1 Sludge production

Table 1 shows the estimated quantities of various municipal, agricultural and industrial sludges produced in the European Union (Davis and Dalimier 1994). These estimates cover only the EU12 Member States and include organic wastes other than sludge, such as livestock manures (which are already recycled to agriculture) and municipal solid wastes (MSW) (of which the composted organic fraction is increasingly available for use).

Table 1 — Estimated quantities of municipal, agricultural and industrial wastes produced within the European Community (EU12) (`000tDS y^{-1}) (Davis and Dalimier 1994)[2)]

Waste source	Approximate quantities	Use/disposal options
Sewage sludge	6,500	Agriculture, landfill, incineration.
Livestock manure	154,000	Agriculture, compost.
Vegetable/fruit		
Solid residues	?	Animal feed, agriculture landfill.
WWTP sludge	2,000	Agriculture, landfill.
Sugar		
Pulp	?	Animal feed, agriculture.
Lime sludge	?	Agriculture, landfill.
WWTP sludge	6,000	Agriculture, landfill.
Meat		
Blood	?	Agriculture, rendering.
Offal	?	Rendering, landfill, incineration.
WWTP sludge	450	Agriculture, landfill.
Dairy		
Milk/whey	?	Animal feed, agriculture.
WWTP sludge	220	Agriculture, landfill.
Beverage		
Solid residues	?	Animal feed, agriculture, landfill.
WWTP sludge	320	Agriculture, landfill.
Paper		
Pulp	?	Agriculture, landfill.
De-inking	?	Landfill.
WWTP sludge	1,850	Agriculture, landfill.
Textiles	680	Landfill, agriculture.
Leather	40	Landfill, agriculture.
Drinking water	500	Landfill, land.
Chemical industry	?	
e.g. Pharmaceuticals, dyes, Chloroalkali, petroleum, metal finishing		Landfill - often hazardous waste landfills. Some agricultural use.
Domestic Waste		
Whole MSW	65,000	Landfill, incineration.
(biowaste is approx. 33% of total)	?	Composting, recycling, landfill, incineration.
Source separation		

2) WWTP = waste water treatment plant

The estimated relative quantities of the main sludge types produced in Europe are illustrated in Figure 2. The figures for the food and industrial sludges are very approximate as these are based on theoretical calculations since no quantitative data are available. There will also be large regional variations; for instance paper sludge will predominate in Scandinavia, and livestock wastes in the Benelux countries. Clearly there are commercial sensitivities in relation to industrial waste production, but a mechanism by which reliable quantitative (and qualitative) data can be collected throughout the EU is urgently required. From such information, the true resource value as a whole can be assessed, as well as the potential environmental loads. This should lead to a more focused regime that ensures maximum beneficial use commensurate with environmental protection.

From these estimates, there is in excess of 170 million tonnes of sludge produced annually in Europe (EU12), including livestock wastes, but excluding MSW and other solid organic wastes streams from industry. With an estimated 154 million tonnes per year, livestock wastes contribute by far the largest proportion (about 90%) of the wastes in Europe and yet have the least environmental control over its quality and use on land. Eutrophication from excessive application of organic manure is well known, but questions are now being raised about hygienic aspects, especially because of the “emerging” human pathogens. In contrast, sewage sludge contributes less than 4% of the total and its quality, use and monitoring requirements are prescribed in detail.

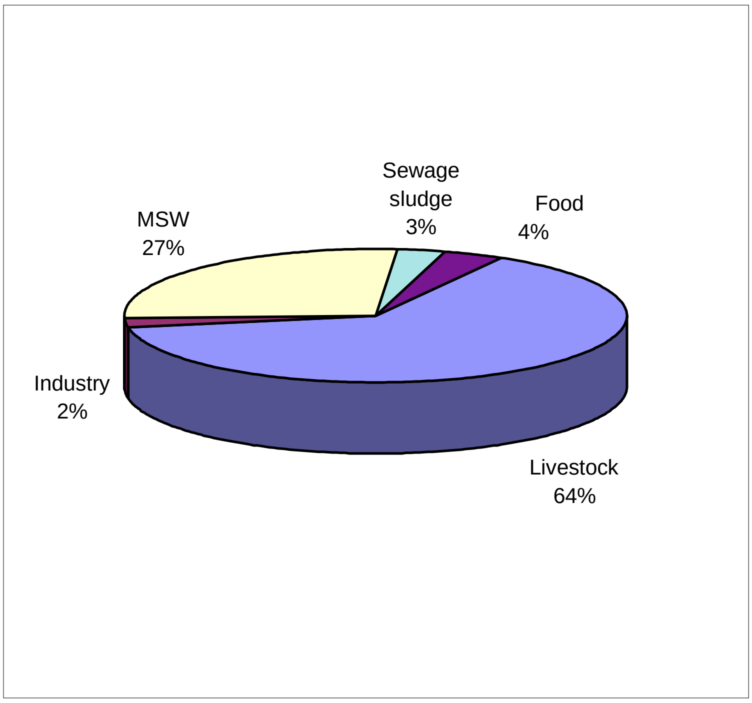

Figure 2 — Estimated relative quantities of principle types of sludges and organic wastes (DS basis)

4.2 Sludge quality

Sludge quality is based on its biological, chemical and physical properties with the emphasis altering according to the outlet of the sludge. Sludge quality depends on the composition of the wastewater from which it is derived and the extent of processing it receives during treatment. Biological properties include the microbiological stability of the organic matter in the sludge, odour and hygienic aspects. Chemical properties include content of potentially toxic elements (PTEs - mostly heavy metals) and organic contaminants, and includes their concentrations and forms which affects their availability to different environmental pathways (e.g. crop uptake, groundwater, etc.). Physical properties include whether solid, plastic or liquid (extent of thickening and dewatering and drying) and aesthetic factors associated for instance with removal of unsightly debris by effective screening. Calorific value will be a quality criterion if the sludge is to be gassified or burnt. The biological and physical qualities of sludge can be altered substantially by treatment processes; such treatment is usually necessary to meet the requirements for use and disposal. Sludges can exhibit wide differences in their physical, chemical and biological characteristics and there can also be seasonal variations in the sludge characteristics. Characterisation of sludge quality criteria is necessary for the design and operation of sludge treatment processes and for assessment and control of environmental impact of the sludge on disposal.

Maximum limit concentrations for six PTEs in sewage sludge and the receiving soil were set by Directive 86/278/EEC, which has required all Member States to introduce these measures into national legislation. The Directive permits countries to introduce lower limit values as local circumstances dictate, and most have done so, and some countries have included additional parameters. As a result the range of national limit values are very wide and often substantially below the maximum limits permitted by the Directive (see Annex C). Significantly lower limit values are now attainable in Europe due to the large reductions in PTE concentrations in sewage sludge achieved over the last 20 years through improvements in industrial processes and the control of industrial discharges to sewer.

Significantly, these limit values only apply to the use of sewage sludge in agriculture, and only a few countries have so far introduced measures to monitor and limit PTE additions to land by other sludges and organic wastes. This is important since sewage sludge contributes only a small proportion of total PTE burden on the environment (Hall and Dalimier 1994) and significant amounts are applied in total to land by other means, particularly livestock manures, atmospheric deposition and fertilisers. This is illustrated by estimates for England and Wales in Table 2.

Table 2 — PTE additions to agricultural holdings in England and Wales (t y^{-1}) (Carrington *et al* 1998)

Source	Zn	Cu	Ni	Pb	Cd	Cr	As	Hg
Sewage sludge	388	237	29	113	2.1	94	1.8	1.5
Atmospheric deposition[a]	2543	647	104	485	20.8	104	33.5	23.1
Fertilisers inc. trace elements	246	96[b]	24	11	11.9	115	9.0	0.1
Lime	44	10	20	8	1.2	24	0	0
Agrochemicals	26	8	0	0	0	0	0	0
Industrial by-products and wastes	210	154	1	<1	<1	210	<1	<0.1
Animal manures [c]	1992	710	56	52	4.1	39	16.2	0.2
Total	5449	1862	234	669	40.2	586	60.5	25.0

[a] Deposition on 1.156 million ha. All agricultural land including rough grazings and commons

[b] Includes 58 t Cu as trace element fertiliser applications

[c] Gross additions including metals recycling in farm system

Directive 86/278/EEC (Article 17) and the Standardised Reporting Directive 91/692/EEC require Member States to submit consolidated reports on sewage sludge use in agriculture - the last national reports were in 1998. The previous report had been far from satisfactory with only Flanders, Germany, Spain and UK making comprehensive reports according to the requirements of 86/278/EEC. Directive 91/271/EEC also requires Member States to report on all sludge disposal activities. Consequently, sludge treatment, quality, use and disposal should be reasonably well characterised when all members comply fully with the reporting requirements. The most recent comprehensive report on this for the EU(12) relied on data for 1992 or earlier (Hall and Dalimier 1994). The situation in the countries seeking to join the EU is even more unknown.

Detailed information on sewage sludge quality is only provided on sludge used in agriculture, and since the Directive sets maximum limit concentrations for agricultural use, these data may well under-estimate the full range of sludge qualities since the more contaminated sludges have to be disposed by other means. However, detailed quality information on all sewage sludges is increasingly available in many, but not all, EU countries. An example is given for the UK in Table 3.

Table 3 — Sludge quality in the UK according to different outlets (median and weighted average concentrations : dry solid and nutrients as %; PTEs as mg kg^{-1}DS, 1996/97 data) (FWR, 1999)

Parameter	Agriculture		Dedicated site	Inciner-ation	Sea disposal	Landfill	Land reclamation	Forestry	Compost	On-site storage
	Median	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
DS %	-	15	6	47	3	22	57	28	32	14
N %	3.53	4.34	5.58	-	4.27	4.27	1.87	2.75	3.47	3.40
P %	1.90	2.24	2.72	-	2.32	1.72	1.91	1.69	0.57	-
Zn	559	792	938	643	993	1242	749	-	423	653
Cu	373	568	472	537	472	457	443	625	277	394
Ni	20	57	68	74	47	98	96	84	-	36
Cd	1.6	3.3	6.5	4.0	3.0	4.2	-	6.9	2.0	2.9
Pb	99	221	361	301	436	244	269	550	173	193
Hg	1.5	2.4	2.6	0.6	1.8	2.4	2.5	3.3	1.0	2.1
Cr	24	157	226	153	245	625	237	158	107	814
Mo	4.7	7.6	9.3	42.3	10.3	12.2	5.9	8.7	4.9	10.3
Se	1.6	2.0	1.7	2.5	1.4	2.2	1.7	1.1	1.5	1.2
As	2.5	5.7	6.4	16.8	6.8	9.7	8.5	8.4	2.1	6.7
F	157	221	295	506	263	339	167	377	144	225

Member States collect the information for the EC reports by periodically carrying out national surveys of sludge management activities, but there is a potential lack of comparability of data between Member States. For instance, mean values of PTEs and nutrients are normally presented (which may or may not be weighted according to sludge production) and this approach is inadequate in describing the significance of these components in sludge. The Commission recently commissioned a study on the problem of comparability (Jacobsen *et al*. 1997), and one of the recommendations was that data should be presented as median values (percentile distributions would be better), which are far more informative on sludge quality than the arithmetic mean.

An example of this is given in Table 3 where median and mean data on the quality of sludge used in agriculture in the UK are compared. The arithmetic mean values are consistently higher than the medians, indicating that the data are not normally distributed, i.e. a few high values skew the data, whereas the majority of sludges have relatively low concentrations. This means that environmental loads of contaminants are likely to be over-estimated where mean values are used.

With the exception of sewage sludge, there are no systematic and comprehensive data available on the quality of other sludges in Europe, although some countries do collate data on certain types of recycled wastes. Where limited data exist on such sludges being used in agriculture, these show that most food and industrial sludges tend to have significant nutrient concentrations but relatively low concentrations of PTEs (Table 4).

By extending the reporting requirements imposed on sewage sludge to other sludges and organic wastes generally, this would provide a quantitative basis upon which informed judgements can be made about the significance of the potential benefits from, and the environmental loads of, all types of sludges (and organic wastes) recycled and disposed.

Livestock manure and MSW are produced in significantly larger quantities than all of the other sludges (as indicated by Figure 2), and both these types of wastes contain significant amounts of organic matter, nutrients, contaminants and pathogens. Consequently, the potential environmental loadings from these wastes is much greater than those from sludges, and it is logical that livestock manure, MSW and sludges should all be subject to the same management and control regime. In a small minority of countries this desirable situation is approached, but the principle should be applied throughout Europe to ensure a consistent approach to beneficial use and disposal and uniform compliance with environmental and health standards.

The lack of a common pan-European approach to the control of all wastes makes the collation of reliable data on waste production, quality, disposal and environmental loads difficult. Since sewage sludge is the most controlled of all sludges and organic wastes, the reporting procedures required under Directives 86/278/EEC, 91/692/EEC and 91/271/EEC could be used as a model for the development of an integrated control mechanism for all wastes recycled to agriculture.

In the absence of sufficient comparable quantitative data, the qualities of different types of food and industrial sludge are described qualitatively in Table 5 (Davis and Dalimier 1994). The ranges in quality indicted are wide due to the large variations that occur in the sources of wastewater and the production and treatment processes involved.

Table 4 — Best available data[1] on chemical quality of a range of food and industrial sludges applied to agricultural land in the UK (mean concentrations, DS and nutrients as %; PTEs as $mg\ kg^{-1}$ DS)

Parameter	Water	Food and drink				Abattoirs			Industry				
	treatment	Gen. food & drink	Dairy	Brewing	Soft drinks	Blood	Stomach	Wash-water	Paper	Textile	Biological treatment	Tannery	Pharmac-eutical
DS	20.8	8.2	5.3	9.2	4.9	11.0	8.6	7.8	21.4	6.4	8.4	6.1	9.0
pH	5.4	5.8	5.6	5.8	4.7	6.6	6.3	6.1	6.9	6.9	6.5	6.7	-
N	2.3	3.5	2.1	3.9	1.3	13.4	8.2	3.2	0.9	7.3	2.6	-	4.6
NH_4N	0.01	0.5	0.3	0.2	0.2	1.7	0.3	0.6	0.02	5.3	0.4	0.2	1.5
P_2O_5	1.5	1.2	0.9	1.7	0.8	1.3	1.5	1.3	0.4	1.2	2.2	-	0.7
K_2O	0.9	1.1	0.5	0.6	0.4	1.0	0.6	0.4	0.2	0.3	0.4	-	0.3
Mg	0.6	0.1	0.05	0.2	0.1	0.03	0.03	0.04	0.1	0.7	0.2	0.0	0.1
Cu	13.3	3.8	2.4	3.1	1.1	3.2	2.4	2.1	32.8	27.5	15.9	<1.0	3.5
Zn	29.3	1.4	1.7	9.9	3.0	12.8	9.0	18.4	29.4	17.2	33.0	-	6.3
Ni	6.1	0.9	0.3	2.4	0.17	0.4	0.8	<1.0	1.3	0.8	1.8	<1.0	0.5
Cd	0.2	0.1	<0.25	0.03	<1.0	<0.25	<0.25	<0.25	0.02	<0.25	<0.25	<0.25	<0.25
Pb	17.4	0.7	5.8	1.3	<1.0	0.3	0.4	<1.0	1.7	2.5	3.5	<1.0	<1.0
Cr	9.9	1.4	0.4	3.2	<1.0	0.3	0.2	1.1	2.4	10.7	5.6	-	<1.0
Hg	0.03	0.06	<0.0106	<0.02	<0.01	<0.01	0.03	<0.01	<0.01	0.08	0.07	<0.01	<0.01
n	8	365	54	80	11	84	6	14	25	3	126	3	24

NOTE 1 Data derived from best available operational information but data sets are small (n= 3 to 365).

Table 5 — Estimated qualities of municipal, agricultural and industrial wastes produced within the European Community (EU12)

Waste source	Dry solids	Nutrients	Contaminants		Pathogens[a]	Acceptability[b]
			Inorganic	Organic		
Sewage sludge	-/+	+	o/+	-/+	-/+	-/+
Livestock manure	-/+	+	-/o	-/o	-/+	-/+
Vegetable/fruit						
Solid residues	o	o	-	-	-	-/+
WWTP sludge	-/o	o	-	-	-	-/+
Sugar						
Pulp	+	o	-	-	-	+
Lime sludge	o/+	o	-	-	-	o/+
WWTP sludge	-/o	o	-	-	-	-/+
Meat						
Blood	-	+	-	-	+	-/o
Offal	o	+	-	-	+	-
WWTP sludge	-/o	o/+	-	-	-/+	-/o
Dairy						
Milk/whey	-	o	-	-	-	-/o
WWTP sludge	-/o	o	-	-	-	-/o
Beverage						
Solid residues	o/+	o/+	-	-	-	o/+
WWTP sludge	-/o	o	-/o	-	-	-/+
Paper						
Pulp	+	-	-	-	-	+
De-inking	-/o	-/o	-/o	-/o	-	-/o
WWTP sludge	-/o	o	-	-	-	-/+
Textiles	-/+	o	-/+	-/+	-	-/+
Leather	-/+	o/+	o/+	o/+	-/+	-/o
Drinking water	-/+	-	-	-	-/o	-/o
Chemical industry	-/+	-	-/+	-/+	-/+	-/o
Domestic Waste						
Whole MSW	+	-/o	o/+	o/+	o/+	o
Source separated	o	o	-/o	-/o	o/+	o/+

[a] Occurrence of pathogens depends on type of wastewater and extent of sludge treatment. Sludges derived from processing crops may contain plant pathogens.

[b] Odour, aesthetics, etc.

NOTE - = low ; o = medium; + = high ; WWTP = wastewater treatment plant.

4.3 Sludge use and disposal

Table 1 shows the principal outlets for the different types of sludges and organic wastes, but for most of these there is a lack of information on the quantities being used or disposed. Most countries have mechanisms by which the use of sludges in agriculture is authorised, but relatively few countries compile this information at the national level, and no information is available at the EU level.

The exception to this will be sewage sludge when all members comply fully with the reporting requirements of Directives 86/278/EEC and 91/271/EEC on sludge use and disposal activities. However there has been information from European sludge surveys that have been carried out periodically (e.g. Newman et al. 1989 referring to 1984; Hall and Dalimier 1994 referring to 1992). In the latter survey, estimates of future sludge production and disposal were made, based on national programmes for implementing Directive 91/271/EEC. This is summarised in Table 6. There is no comparable information for other sludges from industries which will be impacted by the Urban Waste Water Directive.

Table 6 indicates that sewage sludge production will increase by 64% by the end of 2005, compared with production in 1992, assuming all Member States are able to complete the implementation of the Directive by this time. Dramatic changes were also forecast in sludge disposal practices. The most dramatic change is likely to occur in the quantity of sludge disposed of to landfill and to sea, which is forecast to reduce by 50% compared to 1992. This is as a result of the ending of sea disposal by the end of 1998 and the increased pressure on the disposal of organic wastes to landfill through various national measures. The amount of sludge incinerated with energy recovery will increase substantially by more than 5 fold, and would account for 38% of sludge disposal by 2005. Recycling, predominantly to agriculture would increase by 83% and would account for about 45% of future sludge production. The trends are very positive in that, overall, 83% of sludge is likely to used beneficially by 2005, compared with only 50% in 1992, suggesting that the principles of the waste management hierarchy are being implemented.

However, there is concern that neither agricultural use nor incineration may enjoy high public acceptance and the concern now is to ensure the future security of these outlets, and avoid regressing to less sustainable disposal options.

Table 6 — Past and future quantities of sewage sludge used and disposed of in the European Union (EU12) - 10^3tDS y^{-1} (%) (Hall and Dalimier 1994)

Outlet	1984		1992		2000		2005	
Recycling	2057	(37)	2504	(39)	3617	(40)	4576	(45)
Incineration	518	(9)	715	(11)	2088	(24)	3872	(38)
Disposal	2988	(54)	3257	(50)	3200	(36)	1615	(17)
Total	5563	(100)	6476	(100)	8906	(100)	10063	(100)

NOTE Estimate made in 1994.

5 Assessment of sludge management options

5.1 Sludge quality requirements

The relative importance of sludge quality criteria varies according to the use and disposal option for the sludge. Their relative importance according to outlet is given qualitatively in Table 7. Criteria associated with the production and recycling outlets are focused on the acceptability of the sludge to the user together with environmental protection. For incineration and to some extent landfill, the criteria include quality factors that will influence satisfactory running of the process.

Table 7 — Relative importance of sludge quality criteria for use and disposal

Criteria	Product[a] (not managed by sludge producer)	Recycling (managed by sludge producer)	Landfill	Incineration
Physical				
Dry solids	++	++	++	++
Organic matter	+	+	+++[b]	++
Mechanical stability	+++	+	++	+
Litter	++	++	o	o
Calorific value	o	o	o[b]	++
Biological				
Odour	++	++ or +	+	+
Stability	+++	++ or +	+[b]	o
Pathogens	++	++ or +	o	o
Chemical				
Nutrients	++	+++	o	o
Metals	++	++	+	+[c]
Organics	++	++	+[d]	o

a This category means that sludge that has been treated (most often composted) and considered as a product, and no longer a waste. This procedure is not allowed in certain countries. National regulations should be followed in the absence of EC regulations.

b There may be a limit on the content of degradable organic matter.

c Particular attention should be given to: volatile metals, such as Hg, Pb and Zn, for their tendency to be present in emissions; Cr due to potential conversion to soluble form (Cr^{6+}); and Cu for its catalysing effect in the formation of dioxins and furans when chlorine is present.

d Review locally on a risk assessment basis.

Priorities for environmental quality criteria :

+++ very important for this use/disposal
++ important for this use/disposal
+ less important for this use/disposal
o not important for this use/disposal

Table 7 shows that quality requirements for sludge are highest for sludge products, followed by the recycling options with landfill and incineration being less sensitive. It is emphasised that sludge quality must be managed to satisfy the disposal route available, not the reverse if practicable, and the higher the sludge quality the easier it will be to dispose of the sludge because more options will be available. There is therefore a strong incentive to produce a high quality sludge. Sludge quality is quantified by standards that should have a sound scientific basis to ensure environmental protection, be readily measurable preferably by routine methods of analysis and be economically and technically achievable. Quality criteria for the four principal disposal options are discussed in more detail below.

As regards standards, Directive 86/278/EEC deals specifically with the use of sewage sludge in agriculture; there are no other European regulations addressing other sludges and organic wastes in such a specific manner. There is a strong case for providing a single regulatory framework for all sludges covering all treatment and disposal options. The reason for this is to ensure that the management of use and disposal takes into account potential impact on all environmental compartments and finds the best overall environmental solution for sludge disposal in the region in question. Excessively restrictive standards in one particular sector, such as agricultural land or landfill, can preclude sludge use or disposal in that sector, in which case the sludge will have to be disposed of by some other means. As options are lost, the tendency will be to drive sludge disposal by default to expensive minimisation processes with negligible or negative environmental benefit and uncertain sustainability. It is important that restrictive standards can be justified on a scientific basis and that their consequences for sludge disposal have been considered from the perspective of impact on the remaining outlets.

By the same token, sludge producers must make every effort to ensure that their products are as “clean” and as free from contaminants as possible. This can be achieved by strict controls on industrial discharges to the sewer, clean industrial technologies, material subsitution in products to reduce diffuse sources of pollutants, suitable treatment of wastewater and sludge, and public education to minimise undesirable inputs from domestic sources such as litter and other nonbiodegradable materials. A case study that demonstrates the benefits of source control is presented in Annex I.

The quality criteria for specific sludges and outlets should be defined as a means of focusing on wastewater quality to reduce contaminants and identifying appropriate sludge treatment methods to achieve the quality objectives. For the quality critical outlets, such as sludge products and use on land, this is likely to increasingly require advance treatment technologies to provide products of suitable physical and microbiological quality. This will probably necessitate developing a similar approach to that adopted by the USEPA for high quality Class A sludges, which can be used relatively freely because of the efficacy of the treatment processes specified for reducing pathogen content, and Class B sludges that are much more restricted in their use opportunities (see Annex D).

Confidence and a positive attitude by stakeholders to the use and disposal of sludges and related environmental issues is very desirable. The alternative may be an increasingly restrictive regime for sludge use, under which only very low levels of contaminants are permissible, hygienic quality has to be assured by high temperature processes, and application rates are restricted to less than the agronomic optimum. Such high quality standards are technically achievable, but the cost that may cause sludge to be disposed of by other means, which have less obvious environmental impacts and may be less sustainable. Some of the factors that could boost stakeholder acceptance are transparency, direct discussion with, and involvement of, stakeholders, quality assurance, independent accreditation and open support by regulators.

Figure 3 illustrates how the waste management hierarchy can be incorporated into strategic management decisions, with reference to the CEN/TC 308 WG2 documents.

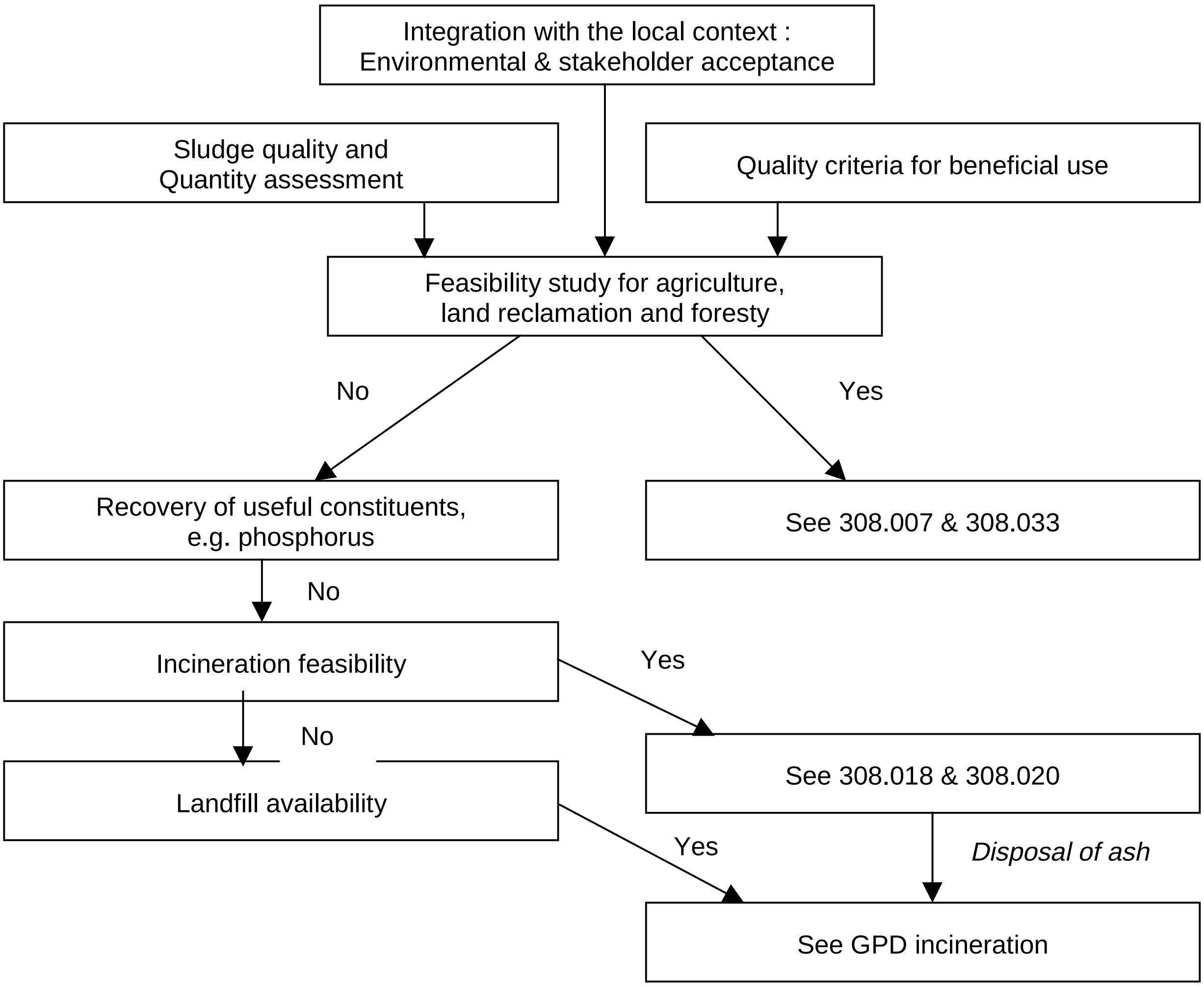

Figure 3 — Basic scheme for deciding on sludge use and disposal options and the relevant CEN/TC 308 WG2 good practice documents (Annex A)

5.2 Technical means of achieving sludge quality objectives

The assessment of technical options for achieving sludge quality objectives in relation to sludge use and disposal should be made with due regard for :

— BAT (Best Available Techniques) - to prevent or minimise pollution to the environment as a whole by direct and indirect releases, having regard for the BPEO (Best Practicable Environmental Option). This would include source control (point and diffuse) of pollutants, supported by enabling legislation ;

— Waste management hierarchy - to prioritise prevention, minimisation, recovery and use, and consider disposal as the last option ;

— BPEO - to evaluate the practicality, environmental impact, security and cost, to ensure that the selected option is the best for the environment as a whole, is sustainable, and does not incur excessive cost.

The management of sludges should always positively discriminate for use options (i.e. integration in material cycles), which may include :

— landspreading of organic fertiliser - traditional, likely to be the largest, single outlet for non-hazardous sludges ;

— products - value-enhanced materials, perhaps bagged for the domestic market, but quality control, pricing and public perception are critical ;

— resource recovery - such as in building materials, for animal feed, retrieval of valuable components (heavy metals, grease, etc.) are potential use options, but are not widely used internationally due to processing costs and commodity prices ;

— energy recovery - the options are incineration with heat and power recovery (sludge only incineration or co-incineration with municipal solid waste), gassification, or co-combustion in power stations and in industrial processes, such as cement and asphalt production. This will become an increasingly important option in the waste management hierarchy, provided there is energy recovery. However, incineration of sludge still leaves a residue (30% of sludge dry solids may remain as ash), the disposal of which can be costly. In industrial co-combustion, the sludge ash usually becomes a component of the product.

The need for disposal facilities should not be ignored since it is difficult to envisage when disposal without recovery (i.e. removal from material cycles) can be avoided completely for all types of sludge. However, it is widely accepted that the landfill disposal of organic wastes is not a sustainable option. Various measures (policy, taxation, legislation) will ensure that landfill disposal can rarely, if ever, be the BPEO for non-hazardous sludges.

Use of sludges is the generally preferred option, but for any particular instance it should be considered within the overall local context; if it represents the BPEO for a particular waste type, once all of the environmental and economic costs and benefits of the different options have been taken into account. Landspreading can represent an economical and environmentally safe means to recover value from a wide range of wastes. However, the pre-treatment and landspreading of sludges of any origin needs to be carried out in all cases without :

— risk to water, air, soil, plants and animals ;

— causing nuisance through noise and odour ;

— adversely affecting the countryside or places of special interest.

In order to secure a sustainable long-term future for landspreading of sludges, waste producers need to demonstrate commitment to the quality of products and the recycling operations.

Organic-rich sludges, such as sewage sludge, should be subjected to treatment by the producer to achieve one or more of the following objectives :

— avoid or reduce potential environmental and health impacts ;

— improve the consistency of product quality ;

— reduce the volume of sludge requiring transport and disposal or recovery ;

— improve the agronomic value ;

— improve ‘marketability’ through better handling, odour and visual aesthetics, and enhanced public perception of the wastes ;

— improve the energy value.

The most common treatment processes include :

— fine screening to remove litter ;

— anaerobic and aerobic digestion (reduces volatile solids, odour and pathogens) ;

- dewatering (volume reduction, improved stackability) ;
- composting (product quality enhancement, co-treatment possibilities) ;
- chemical treatment (e.g. lime - sanitisation and product quality enhancement) ;
- thermal treatment, for :
  - increasing biodegradability before biological stabilisation ;
  - pathogen reduction, preferably before stabilisation ;
  - drying to reduce water content for product quality enhancement and reduced transport costs ;
  - combustion/gassification, to destroy organic matter, for bulk disposal and recovery of energy.

Figure 4 illustrates some of the process options available for treating sludge in relation to the sludge use and disposal options. See also the work of CEN/TC 165 “Wastewater engineering” EN 12255-8:1998 “Wastewater treatment plants - Part 8: Sludge treatment and storage”.

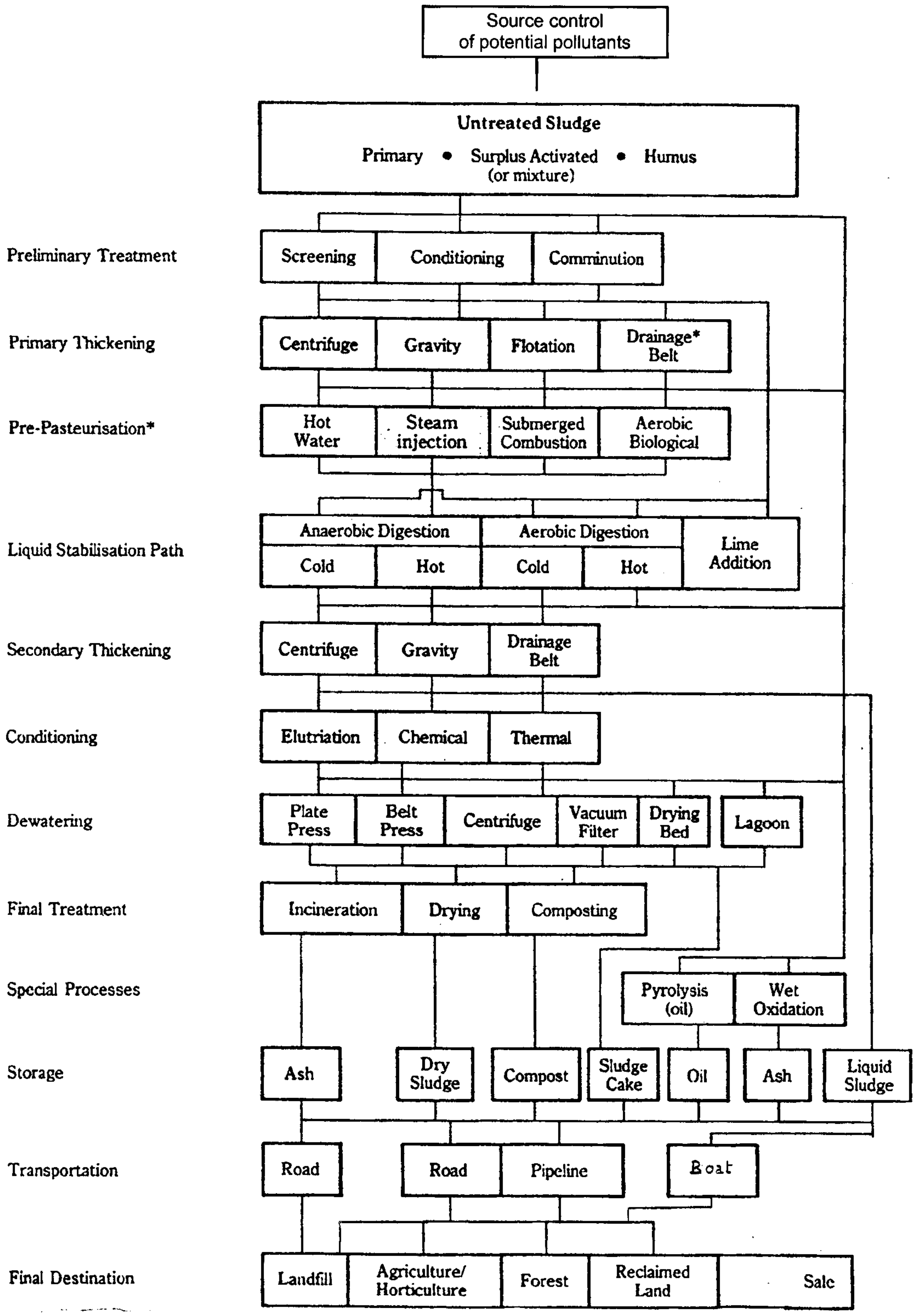

Figure 4 — Technical means of achieving sludge quality objectives in relation to sludge use and disposal

The suitability of these methods is dependent on the chemical, physical and microbiological nature of the sludge, the potential impacts on the potential outlets, and the economics of processing and disposal, including transport. All methods of processing incur additional costs but they can :

— reduce overall costs by minimising the quantity of sludges requiring transport ;
— access lower cost disposal options by improving ;
— make the product attractive to the user, both aesthetically and agronomically ;
— secure long-term access to the landspreading outlet and other recovery options.

Integrated waste management and treatment centres

The concept of completely integrated centralised organic waste treatment centres has been around for some years. A few examples have been constructed in Europe, but it is doubtful that these have been economically viable without state support. In the future, this option may become more attractive and likely to be undertaken by specialised waste management companies. Under certain circumstances, there are benefits from centralised treatment of wastes, where :

— sludges from the same type of industry within a region may be treated at a single treatment centre (this is a common method of operating for sewage treatment works and there are many examples for animal slurry in Europe) ;
— sludges from different industries arising in a locality can be treated in admixture ;
— sludges can be treated in combination with other non-hazardous solid wastes, to produce a single product for use, such as by composting.

The potential benefits of this type of approach are :

— improved treatability ;
— improved economies of scale ;
— avoiding the problems of treating and disposing of difficult or bulky individual non-hazardous sludges or solid wastes ;
— improved product quality, uniformity and marketability.

However, the viability of integrated treatment depends on :

— transport economics - the relative locations of the waste arisings, treatment centres and product outlets ;
— availability of suitable treatment facilities - these may require licensing, planning permission, financing and construction (high cost), and raises issues of ownership, responsibility and liability ;
— suitable outlets for the product - there must be a demand for the product within economic transport distance ;
— product quality - to meet quality standards and public expectations, particularly if revenue is to be raised from the sale of the product.

The treatment processes most suited to integrated treatment and product “manufacture” are :

— anaerobic digestion - of a mixture of different sludges can give enhanced methane production and a product with improved NPK balance. The product can be dewatered (or even thermally dried using biogas) to produce a high quality organic fertiliser ;

— composting - crop residues, separated MSW, green waste, wood processing wastes etc., can provide structural support for composting a wide range of sludges. Well composted materials are aesthetically very acceptable and can be used in situations where sludges would not be acceptable, such as in public parks, etc ;

— chemical treatment - there are some chemical wastes which can be mixed with sludge to produce value-added products. The most notable is the flue dust from the cement industry and from solid fuel power generation plants. The dust is very alkaline and can be used to reduce the odour and pathogen contents of sludge by high pH and heating due to the hydration of CaO. However, the dust may contain appreciable concentrations of some heavy metals. The product is a liming agent and has enhanced potassium content due to the kiln dust, which is normally deficient in sewage sludge used in agriculture ;

In most situations, a new plant would need to be constructed, which in addition to providing sludge treatment, would probably have to include either wastewater treatment facilities or discharge to sewer for treatment at the local municipal wastewater treatment plant (WWTP). An option for consideration by the waste producers and municipalities is to form partnerships to facilitate integrated waste management at the existing WWTPs, to provide full wastewater treatment to appropriate standards as well as the co-treatment of sludges.

For any waste management system that intends to produce a product for use as an organic fertiliser or soil amendment, it is crucial that the target market exists and that the demand for the product will be sufficient to ensure operational security and financial viability. This is the same irrespective of whether the product is sold or given away free of charge. A clear understanding of the market, through market surveys, an understanding of the features and benefits of the product and informative sales support literature are all essential.

The capital and/or operating costs of these individual or integrated treatments is likely to be high, and centralised treatment is generally not economically viable if based solely on the revenue from the sale of product or energy (there are numerous examples of failure due to this). Financial security should be based on gate fees for the wastes accepted for treatment, and any revenue from the sale of products and energy should be regarded as an added bonus. A profit sharing scheme, in which the revenue from the sale of the product is divided between the treatment plant and the waste producers, is a useful incentive device to encourage the waste producers to take an active interest in the quality of their wastes, the product and its marketing.

Sections 5.3 and 5.4 consider in more detail the options for the integration or removal of sludge from material cycles.

5.3 Integration in material cycles

5.3.1 Agriculture

The nutrients in sludge should be accounted for by farmers in their fertilising programmes, thus saving inorganic fertiliser; in some countries this is mandatory. This is a direct economic benefit to the farmer as well as a global environmental benefit since the production of nitrogen fertiliser relies on fossil fuel for its production, and phosphorus is mined, often from ecologically fragile sites. The global reserves of phosphate are finite, supplies are estimated to last no longer than 150-200 years, and their conservation is desirable.

There are two basic requirements for using sludge in agriculture: that it provides an agricultural benefit and that it does not cause harm. The agronomic benefit is derived from nutrients, organic matter, trace elements and in some cases lime, and provides an economic benefit to the farmer through replacement of inorganic fertiliser (which is a global environmental benefit). Sludges may contain potentially hazardous components, but harm can be avoided by ensuring that these occur at sufficiently low concentrations in sludge and through restrictions on application rates, thus avoiding risk to the environment and human, plant and animal health. In the case of sewage sludges, this basic principle is enforced through regulatory measures and quality control.

Agricultural benefit will be achieved when the application of a sludge to land improves soil conditions for crop growth whilst ensuring the protection of environmental quality in the broadest sense.

The benefits can be measured in terms of :

— **crop yield and quality.** The most important indicator of agricultural benefit to which the other benefits each make some contribution ;

— **soil chemical properties.** Benefits that the sludge will bring to the soil in terms of addition of plant nutrients in particular, including trace elements, and improvements in soil pH value ;

— **soil physical properties.** Addition of organic matter; improvements in water holding capacity, porosity, stability, tilth, and workability. Addition of waste chemicals such as gypsum can also improve the workability of some soils ;

— **soil biological properties.** Addition of organic matter improves water retention and aeration, conditions for root growth, populations of worms and micro-organisms, in addition there is growing evidence that some materials (especially composted ones) have properties that directly promote healthier crops ;

— **irrigation.** Application of watery wastes may bring benefit when there is a soil moisture deficit limiting crop growth.

Sludges and other organic wastes can play an important role in maintaining soil organic matter levels. There is growing concern in Europe over the decline in soil organic matter content and thus the sustainability of soil fertility.

Potential disbenefits are :

— **water content.** When sludge has a water content that is inappropriate to the intended method of use there can be great problems. For example if a sludge is dewatered and is to be used as a solid soil amendment, or to be exploited for its calorific value, the use is impaired if dewatering is inadequate ;

— **nutrients.** Potential for run-off and leaching of nutrients to surface and groundwater. This can be limited by applying sludges according to the nutrient demand of the crop, or rotation of crops, being grown. Requirements for controlling nutrient additions to soils in Europe are likely to become more restrictive to control eutrophication problems ;

— **potentially toxic elements.** PTEs represent a long-term hazard from accumulation in soil following repeated applications of sludge. Problems can be limited by restricting additions of PTEs and through soil monitoring. Industrial sludges generally contain lower concentrations of PTEs than sewage sludge, but they may contain uncommon PTEs, consequently such sludges should be analysed for a wide range of PTEs before use to ensure there is no unforeseen contamination. As a first step, and in the absence of any other guidance, all sludges should observe the PTE limit values applied to sewage sludge in Directive 86/278/EEC. However it should be remembered that the availability of these PTEs is related to the matrix that they are in and their chemical forms. The availability of a PTE in a particular sludge may not be the same as it is in sewage sludge. Sludge quality standards are likely to be more restrictive in the future ;

— **organic contaminants.** Sludges may contain organic contaminants from a wide range of compounds but usually at low concentrations that do not present a risk to the environment or human health Sludges should be screened for specific organic contaminants if they are thought likely to occur in sludge because of the source of wastewater or the nature of the industry. Occurrence of contaminants listed in the Dangerous Substances Directive at significant concentrations should be subjected to environmental and toxicological risk assessment before being applied to land. This class of contaminants is often not susceptible to the same sort of source control as PTEs and in order to control them it may be necessary to address the concentrations that are permitted in consumer and other products ;

— **microbial quality.** Sludges derived from sewage, abattoirs, leather and some food industries may contain pathogens and parasites. This is well recognised in sewage sludge but is less so in other sludges. Disease transmission to animals, crops and humans can be avoided by a dual-barrier approach of appropriate treatment followed by restrictions on land use. There is no evidence that this dual-barrier approach has been in-effective for sewage sludge, but hygiene quality standards may be made more rigorous in the near future, which may require more intensive treatment processes for all sludges. There is no evidence to indicate that any incidence of disease transmission has occurred when sewage sludge has been used according to the current control measures, but an absence of evidence does not necessarily prove an absence of effect, and the food industry in particular is concerned about the “emerging” pathogens and desires to avoid further food scares ;

— **excessive acidity or alkalinity.** Some sludges may have extremes of pH due to the nature of the industry from which they are derived. Sludges with <pH 5 should not be used, and highly alkaline wastes should only be used on acidic soil according to good agronomic practices to avoid inducing trace element deficiencies ;

— **sodium content and conductivity.** Sodium can enhance the growth of some crops but excessive amounts can adversely affect soil structure and crop germination and growth, as can excessive salinity. Some sludges can be quite saline ;

— **smell.** Sludges with strong or offensive odours can be treated by stabilisation (digestion, composting, etc.) or chemical (lime) processes to avoid complaints from the public. Where this is not practicable, odorous sludges applied to the land should be rapidly incorporated or injected into the soil ;

— **visual appearance (colour and litter).** This is likely to be a problem in sludges from small sewage works, septic tanks, paper industry, some food industries and industries using strong dyes. Surface applications of such sludges to farmland may be unsightly, give public offence and may also present a hazard to grazing animals. Screening, treatment and appropriate application methods can overcome these potential problems ;

— **texture and handleability.** Sludges that are dusty, gelatinous, oily or greasy can give rise to operational problems. Dust from thermally dried or composted sludges may be hazardous to operators and may cause nuisance to neighbours during spreading which can be exacerbated if particles are brittle, shatter and disintegrate during spreading (in the fertiliser industry the durability of particles is characterised by the Hollman test). Gelatinous sludges are difficult to spread evenly and treated land will be unsightly after spreading and may give rise to localised anaerobicity problems in the soil when incorporated ;

— **high carbon:nitrogen ratio.** This likely to be a problem in sludges from the paper and some food industries. Soil micro-organisms need an adequate supply of nitrogen to break down the added carbon and if the ratio of metabolisable carbon to metabolisable nitrogen is too wide, they will take nitrogen from the soil, which may cause temporary nitrogen immobilisation. This should be avoided by adjustment during treatment rather than applying compensatory nitrogen fertiliser to the land ;

— **biological and chemical oxygen demand.** Most sludges have high BODs and some have high CODs. Thus they can be highly polluting if they contaminate water bodies. The risks of surface run-off and water pollution can be reduced by not landspreading sludge in sensitive areas and by adhering to good spreading practices.

In establishing an operation to use sludge in agriculture or other soil based use options, a site-specific risk assessment should be undertaken observing the following :

1) is the sludge of a generic type capable of providing agricultural benefit ?

2) bearing in the mind the type of sludge, what further information is required concerning its chemical, physical and microbiological properties ? In the light of this information, is the spreading of the sludge still permissible ?

3) from inspection of the proposed spreading site, what special precautions are required to ensure compliance with Article 4 of the Waste Framework Directive 91/156/EEC concerning protection of the environment and human health ?

The factors to be considered in the risk assessment include :

— sludge quality and consistency ;

— land use and management ;

— topography of the site ;

— soil type and analysis ;

— climate ;

— time, method and rate of application ;

— potential risks of pollution to soil and water, and public nuisance ;

— requirements for notification, consultation, monitoring and record keeping.

If there is concern over a particular component of sludge for the use intended, then a detailed risk assessment should be conducted. A possible methodology is outlined in Annex F1, and another is described in Annex D.

5.3.2 Reclamation and forestry

Reclamation and forestry represent significant opportunities for sludge recycling in certain areas where such land is in economic transport distance from sludge production sites. Derelict and disturbed land can benefit significantly from the addition of sludge since the restored soil surface is almost always very deficient in organic matter and usually deficient in nitrogen and phosphorus. In some sites, no soil may be available and converting soil-forming materials into a functioning topsoil needs significant organic and nutrient enrichment. In some countries, forestry is usually established on poorer soils that are less suited to conventional agricultural production Such soil may not lack organic matter but nutrients usually limit timber production, and sludge can significantly improve tree growth.

In most cases, the principles of agricultural benefit apply, as described above, and with particular attention paid to reducing the risks of surface- or ground- water pollution. However, these principles may be overlain by the concept of ecological improvement.

Ecological improvement is associated with the maintenance of habitats and their biodiversity where these would otherwise deteriorate, the provision of new habitats for wildlife and the development or restoration of existing habitats to give greater biodiversity and sustainability. Some derelict land (through neglect) and natural forestry sites provide unique habitats for flora and fauna and have developed their own specialised, and sometimes rare, ecology. Whilst agricultural benefit from sludge application can readily be demonstrated on such sites, it will not be justified (or even permitted) on the basis of ecological improvement since soil enrichment would adversely affect the balance and diversity of species.

In carrying out the risk assessment before sludge application, these aspects should be considered. In addition there is the question of economics, i.e. what is going to fund, or give incentive to, maintenance of the site in the longer term. Restoring land to support commercial agriculture or forestry or some sort of income generating amenity use would satisfy this requirement.

5.3.3 Sludge as raw material

Compost

Sludge as a component of compost may be considered as a raw material for a product which may be marketed for use in horticulture, amenity areas and gardens, etc., as well as for general use in agriculture. The product should conform with the requirements for unrestricted use of sludge, as described in Table 7. This is the most quality critical use of sludge for which excellent physical, chemical and microbiological properties are required. It must also be visually acceptable (i.e. no plastic etc.) and with no unpleasant odour. This necessitates intensive quality assurance and quality control on production and the product since there is likely to be no opportunity for follow-up monitoring when the product is used, unlike the use of sludge in agriculture. Consequently, product standards have to be rigorous to ensure that the content of nutrients and organic matter are within appropriate ranges, PTEs concentrations are low and the content of pathogens are minimal.

Various national quality standards are applied to compost in Europe, but at the EC level currently there is only the Ecolabel standard, this is a voluntary scheme and it is not based on sound science. However, the Commission intends to publish a draft Directive during 1999. The quality criteria as developed by CEN/TC 223 for soil improvers and growing media, which also considered products derived from recycled organic wastes, should be followed. Declaration of the constituents and direction on use are desirable, and legally required in some countries, where the product is sold in bags. Since there are many competing products in this market sector, achieving and maintaining high quality is essential if products based on or containing sludge are to be successful. Currently, very little sludge is used in this way.

Alternative Products

Research has shown that a number of products can be derived from sludge, and whilst some of these have been demonstrated at the pilot-scale, few are commercial viable or cost-competitive with established sludge management methods. Some of these include :

— fuel oil - low-temperature pyrolysis demonstrated successfully at the pilot-scale and may become economically viable in the future when the price of energy increases ;

- building materials - has been successfully tested as a small component of clay fired bricks, with some commercial development. Sludge has also been used in fibreboard production. Ash from sludge incineration is used in blocks and aggregate in some countries, notably Japan ;
- grease extraction - technically feasible but production is currently not cost-effective ;
- metals extraction - technically feasible, but as the metal content of most sludges are now at low concentrations, not worthwhile, likely to produce waste streams that are problematic to dispose of, and expensive ;
- animal feedstuff - this may have application for fish culture (human waste is used extensively in fish farming in the Far East) but likely problems of acceptability in Europe ;
- earthworms and detritivore production - cultured in sludge as a source of protein for feed, and for producing treated material. Tested at the pilot-scale and adopted operationally by a few treatment plants but not considered viable for wide-scale use ;
- protein extraction - may be feasible but problems of contamination ;
- vitamin B_{12} extraction - potentially high value product but technically difficult ;
- recovery of coagulants.

None of these outlets is likely to be more than of local importance at least in the short-term, and all require an 'entrepreneurial spirit' on the part of the sludge producer to promote an unusual outlet for his product. Processing costs are likely to be much higher than the established sludge use and disposal options, but may become economically attractive as pressures on other routes increase costs and world commodity prices, particularly for oil, increase in the future.

5.3.4 Thermal exploitation

For the energy of sludge to be exploited it must contain significant calorific value, normally in the form of organic matter, and the moisture content of the sludge must be low enough for the sludge the burn autothermically, i.e. without the use of support fuel. The calorific value of sludge can be exploited by the following :

- combustion in a dedicated incinerator ;
- co-incinerated with other wastes, such as municipal solid wastes ;
- Gassification ;
- as a supplementary fuel in power plants ;
- as a supplementary fuel in industrial processes, such as cement and asphalt production where the ash is incorporated into the product.

The sludge must be in a suitable physical condition so that it can be easily handled and is suited to the combustion technology employed, particularly if mixed with other fuels or wastes. Thermally dried sludges are the most suitable form of sludge for use as a fuel. The chemical properties are not usually important with regard to the incineration process, particularly as incineration has long been regarded as an appropriate option for contaminated and hazardous sludges. However, this should not remove the need for effective control of contaminants in sludge which may arise, for instance from poor industrial processes or discharge of industrial effluents to sewer.

The key criteria for energy recovery from sludge incineration are dry solids content and calorific value to ensure autothermic operation. Sludge stabilisation prior to incineration is not necessary and it reduces the calorific value of the sludge. Odour and pathogen content may be significant concerns, depending on the location of the plant and health and safety of operators. Organic contaminants in the feed sludge are of negligible concern provided that the incinerator is operated so as to destroy them and the flue gas emissions are within maximum permissible concentrations. Metal content of the sludge is a medium priority and is relevant to stack emission quality compliance and more importantly to the quality of the ash for disposal. Chemical quality standards for sludge for incineration can be back-calculated from the stack emission legislation and standards for ash disposal with which the process will have to comply, assuming a specified abatement efficiency.

The principle concern for incineration is the quality of flue gasses. Gas emission standards are well established and usually require multi-stage gas cleaning technology, which adds considerably to the overall cost of incineration. The strictest emission standards in Europe apply in the Netherlands and Germany (BImSch) - the latter embodies the four principles: protection, precaution, minimal waste formation and beneficial waste heat recovery. The principle of precaution is implemented by setting limit values for some of the key operating conditions of the combustion process and for the concentrations of named pollutants in the stack gas emitted to the atmosphere. The requirement to maintain a minimum flue gas temperature of 800 - 900 ^{o}C (with appropriate retention time) and oxygen content of 6 % (v/v) - equivalent to 40 % excess air in practice - is set in order to ensure that emission of products of incomplete combustion is kept to low levels. These process performance requirements are more readily achievable by fluidised bed type incinerators as opposed to multiple hearth incineration technology. Categories of pollutants to be monitored for compliance in gaseous emissions are :

— total particulates ;

— PTE ;

— micro-pollutants (e.g. PCDD/Fs, PAHs, PCBs and organochlorine pesticides) ;

— gases (NO_x, SO_2, CO, and hydrocarbons) ;

— odours.

Whilst the control of odours, gases such as CO and NO_x, and organics such as hydrocarbons, dioxins and furans, is likely to be achieved through the selection of an appropriate furnace design and operation under suitable conditions, the control of acid gases such as SO_2 and HCl, heavy metals, and particulates is dependent on the type and performance of downstream abatement equipment. Modern electrostatic precipitators and wet scrubbing devices, alone or in series, are capable of achieving the degree of particulate control specified by the German BImSch, while wet alkaline scrubbing is the most common method of acid gas control. Control of emissions of heavy metals is dependent on their speciation and volatility. The wastewaters and solid residues from gas clean-up need to be disposed of appropriately as these are potentially highly polluting wastes.

Incineration of sludge does not provide complete disposal and will leave a mineral ash. For sewage sludge, this is usually about 30% of the original dry solids and is rich in heavy metals, phosphate and other minerals. Incinerator ash is expensive to dispose of in landfill sites. However, the ash can also be used beneficially in the production of building materials, such as lightweight blocks, and where landfill disposal costs are very high (such as in Japan), incineration at vitrification temperatures is economic and converts the ash to a dense glass-like materials which can be moulded paving slabs or used as aggregate. Such processes permanently fix the contaminants so that they are no longer environmentally active.

When considering the energy economics of combusting nitrogenous sludges, the opportunity energy value of that nitrogen if it could have been used as an alternative to nitrogenous fertiliser should not be neglected.

Quality assurance for sludge incineration involves appropriate design and process control supported by effective monitoring of noise, odour and gaseous stack emissions to ensure compliance with standards. Siting of the incinerator and its visual appearance are important factors in achieving environmental acceptability. Despite modern clean technology and the recovery of energy, incineration of sludge and waste generally does not enjoy high public acceptability.

Co-combustion of sludge in power plants

Large full-scale tests have been done in Germany, The Netherlands and Belgium. Normally the sludge is thermally dried before delivery to the power plant, however it would be worthwhile investigating co-combustion of mechanically dewatered sludges without thermal drying. The main interests are the energy recovery and the positive effect on the CO_2 balance by burning recently-fixed carbon instead of fossil carbon.

The ratio of sludge to coal is typically 3-5%. The tests showed that co-combustion had little effect on the emission of most gases. There was a small increase in heavy metals in both the fly ash and the powder ash. As far as the slagging elements were concerned, only the calcium content of the ashes increased. Co-combustion had little effect on the results of leaching tests on the ashes, and it did not jeopardise the potential for using the ashes.

Life Cycle Analyses (LCA) should be conducted to compare co-combustion with mono-thermal destruction.

Co-combustion of sludge in cement plants

Waste incineration in cement plants is described as a potential means of waste treatment in EC Directive 94/67/EEC. Large full-scale trials have been carried out in several European countries (France, Italy, Switzerland, Netherlands) and some of these trials are now being developed on an industrial scale (Switzerland).

A ratio of 3% between sludge and clinker is used and the sludge must be dried before delivery to the cement plant (example WWTP of Zurich to cement works at Siggenthal). The main interests of sludge to the cement industry are the energy recovery (calorific value of sludge is 10 000 to 14 000 kJ $kgDS^{-1}$) and mineral addition (CaO, SiO_2, Fe_2O_3). Water Treatment Works' sludges can also be used as raw materials.

Strict control of cement quality has to be observed: mineral elements and compounds such as phosphates, chlorides, chlorine and mercury must be kept as low as possible, because they interact in the cement matrix and can change the properties of the cement. During the process, the ash is completely integrated into the clinker, including heavy metals which are subsequently not readily released. These chemicals can also modify the plant process and alter environmental conditions (exhaust gas). Additional investment costs are required at the cement plant itself (off-gas treatment) and at the wastewater treatment plant (sludge drying).

LCA should be conducted to identify the best available and long-term option (i.e. co-combustion in cement plant compared with incineration). This option is potentially a sustainable sludge management route recovering energy and minerals from sludge.

Use of sludge and ash in brick production

Dewatered and dried sewage sludges, have been used in hollow and heavy brick production for many decades. Water Treatment Works' sludges and incineration ash can also be incorporated in brick clay.

Sludge is added at 10 - 30% by volume (5 - 10% on dry volume) depending on the composition of the clay. Process operations have to deal with mixing sludge and clay, and the possible emissions of odour and organic substances. Appropriated technologies are required to comply emission standards, and leaching tests should be carried out on the bricks using standard methods.

The use of dried sludge as a raw material for the brick industry seems to be financially attractive when the brick plant is close to the WWTP. Similar to sludge use in cement production, this option is potentially a sustainable sludge management option.

5.4 Removal from material cycles

5.4.1 Sea

By international convention and Directive 91/271/EEC, this option is not permitted from the end of 1998. It has been arguable whether sludge disposal to sea caused any measurable harm, but beneficial use cannot be demonstrated and so this outlet can only be regarded as a disposal.

5.4.2 Thermal destruction

Incineration or other methods of thermal destruction of sludge, such as by wet oxidation, are regarded as disposal options if there is no energy recovery. Most dedicated sludge incinerators are of the fluidised bed type from which it is easier to recover energy, but there are still a number of multiple hearth furnace in use, dedicated to sludge incineration or co-incineration with municipal solid waste, which require fossil fuel to operate. It is likely that these will be progressively closed down and the sludge disposed of or used by other means.

Thermal destruction processes, such as wet oxidation, have poor energy recovery potential. An example of this is the VerTech deep shaft wet oxidation plant at Apeldoorn, which was developed as the ultimate (and very expensive) method of sewage sludge disposal because of the curtailment of other methods of sludge use and disposal in the Netherlands.

Thermal destruction of sludge still leaves about 30% of the dry solids as ash which requires disposal. Since the ash is usually regarded as a hazardous wastes, it requires disposal in special landfill sites, further increasing the cost of this sludge disposal method.

5.4.3 Landfill

The disposal of sludge in sanitary landfill is the most common method of disposal in a number of countries. This is usually as co-disposal with municipal solid waste, although monofill of sludge is also practised. Modern landfill design requires that the base is sealed to avoid leachate contaminating groundwater, and the leachate is usually collected and treated on site or discharged to sewer. Management practices vary: in some countries the ingress of water is avoided to minimise biological activity and leachate volume (the dry tomb approach), whilst in other countries, in-situ stabilisation is encouraged, which results in short-term leachate and methane production (the latter may be collected as a fuel in large sites), but this bioreactor approach has lower environmental hazard in the long-term.

Increasing concerns about environmental emissions (pollution of surface and groundwater and potent greenhouse gases such as methane), and the limited amount of landfill volume in Europe, has resulted in the wide adoption of measures to reduce the amounts of waste being disposed of to landfill, through waste minimisation and recycling, and to reduce the reactivity of materials disposed.

The latter has been addressed by promoting the recycling of organic wastes, such as through source separation and composting of municipal solid waste, and by limiting the amount of reactive materials in wastes disposed of in landfill. This is being achieved by a variety of measures, such as taxation and waste quality standards, either based on leachate quality tests or, as now implemented in a number of countries, specified maximum limits for carbon or organic matter in wastes. Limit values adopted are as low as 5% carbon and thus will exclude sludges from landfills, unless pre-treated to reduce the carbon content. This effectively means that incineration or other thermal treatment of sludge may be an essential prerequisite to provide a material of sufficiently low carbon content.

Currently, a limited number of national regulations and guidelines emphasise the physical stability and acceptable handling qualities of sludge that is going to be landfilled and translate this into a requirement for sludges to have a sufficiently high dry solids content (>30-40 % as specified) to ensure some. The EC Landfill Directive will introduce new requirements which include chemical quality based on eluate tests but currently does not extend to the more onerous limit on carbon content that has been adopted in some countries, however this is a possibility in future revisions.

5.5 Competitive materials

Sludge as a product for use on the land or as a source of energy has to compete in the market place. This can only be achieved on the basis of quality, price and performance.

In agriculture, the competition is from fertilisers and livestock wastes. Mineral fertilisers are supported by an extensive history of field trials and they are perceived to be a more reliable source of nutrients than sludge, which is not necessarily the case when the properties of the sludge are understood. The concentrations of nutrients are stated on the bag. EU regulations ensure some aspects of quality, and farmers understand reasonably well how it performs. However, fertilisers are expensive and likely to become more so, particularly as energy prices increase and as global resources of mined nutrients are depleted. Sludges, on the other hand, can be equally consistent in quality and performance if they are prepared appropriately. They may also bring other benefits such as organic matter, trace elements and biological factors that promote yield and crop health. Some sludge recyclers are so deeply entrenched in a disposal culture that they pay farmers to take sludge: this is inappropriate since it reinforces the perception that sludge is just a waste, and not a useful source of nutrients and organic matter that has agronomic value.

Livestock manure has always been valued for its fertilising and soil conditioning properties, although the advent of industrial livestock production resulted in many intensive producers managing slurry and manure as a waste. This has given rise to soil and water pollution problems in some northern European countries, as well as in North America. The resulting environmental measures to control this problem has adversely affected the opportunities for recycling sludges on land. These measures are evolving throughout Europe into farm management plans which require farmers to make detailed budgets of nutrient inputs to their land from all sources, and this will make sludge use in livestock production areas increasingly difficult. This is likely to result increasingly in sludge producers having to invest in more intensive sludge treatment processes, either to improve sludge quality and reduce the bulk of sludge to improve transport economics for areas where sludge can be used, or to dispose of sludge by other means, by incineration or landfill disposal. The food industry has the same, or greater, concerns about the risk of transmitting the emerging pathogens associated with animal manure that is has with sludges.

Peat, and peat alternatives such as coir, may be regarded as competitors to sludge in the specialised growing media and soil amendment market. However, the opposite could be the case for certain types of sludge, if carefully exploited, since the mixing of sludge and peat substitute materials can produce a value-enhanced material that can compete effectively with traditional peat-based materials. This trades on the perception of a “green” advantage of a wholly recycled product, whereas peat is increasingly associated with habitat destruction. Sludges of high quality are required to exploit this opportunity. The bottom line for this opportunity, as with every other, is that products must perform competitively, people may like the feeling of contributing to the environment as a bonus but they will not accept this as an alternative to performance.

There is an increasing market for alternative and renewable fuels for power and heat production and a number of wastes are already used commercially. For sludges to compete with these, they need to offer high calorific value, low moisture content and suitable handling characteristics, particularly where they are used in admixture with other fuels. Thermally dried sludges should be able to be marketed increasingly as an alternative fuel, and technical developments in combustion technology will see an increasing number of power plants able to accept a range of types of fuel. A concern of the power producers will be the quality of flue gas emissions and whether the use of sludge will exceed their permitted emissions. However, emission controls are likely to get tighter for all power plants which may make sludge use easier as emission abatement technology improves.

6 Options to preserve and extend sludge management ROUTES

6.1 Evaluation of sludge management options

As a basis for evaluating future strategic options for the management of water cycle sludges, it is necessary to analyse of the strengths, weaknesses, opportunities and threats (SWOT) associated with current sludge use and disposal practices. Detailed SWOT analyses of industrial, sewage and water treatment sludges are summarised in Annex E (Tables E1, E2 and E3, respectively) which take into account the specific issues for these generic types of sludge. However, there is a number of common issues from which recommendations can be made to preserve and extend sludge management routes.

Common strengths may be summarised (not in any order of priority) as :

— agronomically valuable constituents - nutrients, organic matter, etc. ;

— predictable beneficial effects ;

— potentially (and intentionally) predictable and uniform quality, according to sludge type and origin, due to the industrial scale of sludge production ;

— most sludges can be used in a range of beneficial outlets (e.g. soil conditioning, energy recovery, etc.) so offer flexibility ;

— most sludges are continuously produced and so are continuously available ;

— long-term use experience of some sludge types, particularly sewage sludge, supported by extensive research ;

— no evidence of negative environmental impacts where appropriately controlled ;

— greater understanding and uniform adoption of the controls and management necessary for sewage sludge to gain benefits and avoid adverse environmental impacts, compared to other sludges and livestock wastes ;

— process technologies available to transform the chemical, physical and biological properties to make the products more acceptable and safer ;

— discrimination against landfill disposal of organic wastes will encourage wider use of sludge ;

— recycling of sludge can conserve resources (e.g. phosphate, energy, etc.) ;

— secure sludge management solutions require acceptance from all stakeholders ;

— environmental standards, publication of performance data and point source control have substantially improved sewage sludge quality in recent years.

Common weaknesses (not in any order of priority) are :

— presence of contaminants and pathogens according to source of wastewater, not all of which can be subject to point-source control (diffuse sources) ;

— bulky - high volume in relation to beneficial constituents ;

— perceived low value ;

— uninteruptible production ;

— high costs to treat and transform sludge to make its use or disposal more amenable or acceptable ;

— uncertain stakeholder acceptance of sludge ;

— pressures from food retailers to increase the extent of treatment for sludge use in agriculture, and in some cases outright hostility ;

— many sludge producers have a disposal culture, and in order to run an effective use activity this needs to be changed to a manufacturing and sales culture ;

— perceptions can dictate political direction more than technical issues ;

— competition from other wastes (e.g. livestock wastes) ;

— lack of common or integrated controlling or enabling legislation at EU level, although this is in part available in some countries.

Common opportunities (not in any order of priority) are :

— potential income generation from sale of quality sludge products (e.g. as soil conditioners or fuel) ;

— technical improvements to reduce operating costs, reduce emissions and improve product quality ;

— continuous improvement through Environmental Management Systems will result in better sludge quality and improved public confidence ;

— emerging technologies (mostly thermal) may facilitate use or disposal opportunities, albeit at higher costs (e.g. energy and material recovery) ;

— integrate waste management to reduce costs, improve products and facilitate use or disposal ;

— enhance stakeholder perception through high quality operations and products, supported by public information campaigns and partnerships ;

— continuing research and development of sludge treatment technologies and on the benefits and impacts of sludge use and disposal ;

— innovative solutions and broader scientific understanding of environmental processes and fates of sludge constituents ;

— common or integrated controlling and enabling legislation at EU level for all types of sludge (and other organic residues).

Common threats (not in any order of priority) are :

— introduction of disabling legislation (e.g. unnecessarily restrictive controls) ;

— vulnerability of all use and disposal routes ;

— lack of certainty may inhibit investment to improve technology and operational practices ;

— political, public, media or food processor / retailer antipathy to sludge. In particular, stakeholder confidence the agricultural and incineration outlets is questionable ;

— susceptibility of sludge to unexpected contamination (e.g. illegal discharge to sewer, industrial accident, etc.) ;

— sludges will inevitably contain certain PTEs etc. due to the chemistry of the planet, and due to diffuse sources (e.g. atmospheric deposition, domestic discharges, surface drainage, etc.) which are not directly controllable ;

— risks (perceived and real) of environmental and health impacts undermining the sustainability of sludge management ;

— loss of potential outlets for sludge (e.g. landfill) ;

— competition from other wastes (e.g. livestock wastes) which is not subject to the same controls as sludge ;

— higher sludge management costs passed to the consumer.

6.2 Recommendations

The principal recommendation of this report is that, not withstanding subsidiarity, consistent application of the principles of control are necessary at the European level, to regulate the quality and use of all water cycle sludges (including some other residuals) that have similar potential environmental effects. The development of such measures should consider, and would subsequently support, the following key issues, not in any order of priority :

— give confidence to sludge producers to invest in appropriate technologies to achieve safe, secure and sustainable sludge management ;

— reinforce the precautionary principle in a practical and enabling manner consistent with sustainable development ;

— encourage quality assurance with independent audit and accreditation of sludge use and disposal in order to avoid mistakes and to build confidence in the processe ;

— avoid transboundary problems and market distortions in sludge use and disposal ;

— develop and promote integrated co-treatment of sludges and other organic wastes ;

— promote material cycle integration, with the priority on sludge use on land to conserve organic matter and complete nutrient cycles, combustion as an energy source, or material use such as animal feed, etc. while discriminating against disposal options (material cycle exclusion) ;

— promote acceptance of sludge management and use by all stakeholders ;

— encourage/require improved reporting and publication of data about the use and disposal of sludges to encourage improvement by peer comparison and to promote stakeholder confidence by transparency.

The priorities in securing sustainable sludge management are establishing consistent standards based on sound science that protect human, animal and plant health and the environment (including water, soil and its fauna and flora). This would include formulating appropriate sludge quality standards and an appropriate strategy for maintaining sludge use and disposal during the period whilst they are phased in. Such standards would lead to industry developing the technologies by which these can be achieved reliably and cost-effectively.

The development of an integrated approach should be based on risk assessment, and quality standards should be set according to the precautionary principle, to ensure environmental protection and sustainable development. The development should recognise the context of expansion of the EU and the condition of the new members. There should be a commitment to the necessary research and operational surveillance to establish the rigorous scientific basis for standards and technologies which are appropriate for securing sludge use well into the next century. However it should also be remembered that there has been a huge amount of research world-wide into the environmental impacts of sludge use and disposal, and that the USEPA has already undertaken a rigorous, peer-reviewed risk assessment for sewage sludge. A new regulatory regime should be designed to encourage and enable beneficial use of sludges in line with the EU waste strategy, to ensure the integration of sludge within material cycles, and should discriminate against disposal.

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List of abbreviations

AOX	total absorbed organohalogens
BAT	best available technology (or best available technique)
BATNEEC	best available technology not entailing excessive cost
BEP	best environmental practice
BOD	biological oxygen demand
BPEO	best practicable environmental option
Cfu	colony forming unit
DEHP	diethylhexylphthalate
DS	dry solids
HEI	highly exposed individual
IPPC	integrated pollution prevention and control
LAS	linear alkylbenzene sulphonate
LOEC	lowest observable effect concentration
MPN	most probable number
MRT	mean residence time
MSW	municipal solid waste
NOEC	no observable effect concentration
NPE	nonylphenol ethoxylate
NVZ	nitrate vulnerable zone
PAH	poly-aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCCD	dioxin
PCDF	furan
PEC	predicted environmental concentration
PNEC	predicted no effect concentration
PTE	potentially toxic element
TEQ	toxicity equivalent quotient
USEPA	United States [of America] Environmental Protection Agency
WWTP	wastewater treatment plant

Annex A
(informative)

Documents developed by CEN/TC 308

Work item	title	prEN
308.005	Characterisation of sludges - Utilisation and disposal of sludges - Vocabulary	EN 12832
308.007	Characterisation of sludges - Good practice for sludge utilisation in agriculture	PrEN 13097
308.018	Characterisation of sludges - Good practice for sludge combustion with or without grease	
308.020	Characterisation of sludges - Good practice for co-combustion of sludges with municipal solid waste	
308.032	Characterisation of sludges - Good practice for sludge production in relation to the use or disposal	PrEN 13714
308.033	Characterisation of sludges - Good practice for sludge utilisation in land reclamation	
308.xxx	Characterisation of sludges - Good practice for landfill of sludge and by-products of sludge after incineration	
	Water quality - Sampling - Part 13: Guidance on sampling of sludges from sewage and water treatment works	EN ISO 5667-13:1997
	Characterisation of sludges - Determination of pH-value	EN 12176:1998
308.009	Characterisation of sludges - Determination of dry residue and water content	prEN 12880
308.011	Characterisation of sludges - Determination of total Kjeldahl nitrogen in sludge	prEN 13346
308.012	Characterisation of sludges - Determination of ammoniacal nitrogen	
308.013	Characterisation of sludges - Determination of nitrate nitrogen	
308.017	Characterisation of sludges - Determination of organic carbon by instrumental method	
308.004	Characterisation of sludges - Determination of the loss on ignition of dry mass	prEN 12879
308.003	Characterisation of sludges - Determination of trace elements - Aqua regia extraction methods	prEN 13346

Annex B
(informative)

International and European Technical Committees

B.1 International Standards Organisation (ISO)

ISO-Technical Committees and Standards influencing use or disposal of sludges

Area	Technical Committee
Water quality	ISO/TC 147
Fertilizers and soil improvers	ISO/TC 134
Air quality	ISO/TC 146
Soil Quality	ISO/TC 190

B.2 European Committee for Standardisation (CEN)

CEN-Standards and Committees influencing use or disposal of sludges

Area	Technical Committee
Water supply	CEN/TC 164
Wastewater engineering	CEN/TC 165
Soil Improvers & Growing Media	CEN/TC 223
Water analysis	CEN/TC 230
Fertiliser & Liming materials	CEN/TC 260
Air quality	CEN/TC 264
Characterisation of waste	CEN/TC 292

Annex C
(informative)

EC and national quality limit values controlling sewage sludge use in agriculture

Table C1	Limit values for potentially toxic elements (PTEs) and other pollutants in sewage sludges.
Table C2	Soil quality limit values for PTEs in soils where sludge is used in agriculture.
Table C3	Maximum application rates of constituents when sewage sludge used in agriculture loads, according to the respective limit values and any national restrictions of maximum dry matter and phosphorus additions (kg/ha/y).
Table C4	Sludge hygiene regulations.

Table C.1 — Limit values for potentially toxic elements and other pollutants in sewage sludges (mg/kgDS)

Country		Pb	Cd	Cr	Cu	Ni	Hg	Zn	As	F	Se	PCDD/F	PCB	AOX	LAS	Σ PAH[b]	NPE[c]	DEHP[d]
86/278/EEC		750-1200	20-40	1000-1750	1000-1750	300-400	16-25	2500-4000				**(ngTEQ/kgDS)**						
Belgium	Flanders	300	6	250	750	100	5	2500	150									
	Walloon	500	10	500	600	100	10	2000										
Denmark	mg/kgDS.	120	0.8	100	1000	30	0.8	4000							2600[a]	6[b]	50	100
Denmark	mg/kg P	10,000	200			2500	200											
Germany	pH 5-6	900	5	900	800	200	8	2000				100	0.2	500				
	pH > 6	900	10	900	800	200	8	2500										
Finland	from 1.1.98	100	1.5	300	600	100	1	1500										
	1.5.94-31.12.97	150	3	300	500	100	2	1500										
France		800	20 [e]	1000	1000	200	10	3000					0.8[f]			9.5[b]		
UK	Grassland	1000								1200								
Ireland		750	20	-	1000	300	16	2500										
Italy		750	20	-	1000	300	10	2500										
Luxembourg	Reference	750	20	1000	1000	300	16	2500										
	Limit	1200	40	1750	1750	400	25	4000										
Netherlands		100	1.25	75	75	30	4.75	300	15									

"to be continued"

Table C.1 — Limit values for potentially toxic elements and other pollutants in sewage sludges (mg/kgDS) *(concluded)*

Country		Pb	Cd	Cr	Cu	Ni	Hg	Zn	Co	Mo	As	F	Se	Toluene	PCDF/D ng/kgDS	PCB	NPE	PAH	AOX
Norway		100	4	125	1000	80	5	1500											
Sweden		100	2	100	600	50	2.5	800											
Sweden LRF SEPA VAV Agreement Nov'96[n]														5		0.4[m]	50	3	
Switzerland		500	5	500	600	80	5	2000		20									500[g]
Spain	pH < 7	750	20	1000	1000	300	16	2500											
	pH > 7	1200	40	1500	1750	400	25	4000											
Austria[l]	Burgenland	500	10	500	500	100	10	2000											
	Lower Austria[h]	400	8	500	500	100	8	2000							100	0.2			500
	Lower Austria[i]	100	2	50	300	25	2	1500							100	0.2			500
	Upper Austria	400	5	400	400	80	7	1600							100	0.2			500
	Vorarlberg[j]	150	4	300	500	100	4	1800							100	0.2			
	Styria	500	10	500	500	100	10	2000	100	20									
	Salzburg[k]	500	10	500	500	100	10	2000	100	20	20		20						
	Tirol[k]	500	10	500	500	100	10	2000	100	20	10								

[a] Linear alkylbenzene sulphonates.

[b] For Denmark Σ acenaphthene, phenanthrene, fluorene ; fluoranthene ; pyrene ; benzofluoranthene (b+j+k) ; benzo (a) pyrene, benzo(ghi)perylene; indeno(1,2,3-cd)pyrene. For FranceΣ fluoranthene ; benzofluoranthene (b) ; benzo (a) pyrene.

[c] nonylphenol + mono and diethoxylates.

[d] di(2-ethylhexyl)phthalate.

[e] Cd in France reducing to 15 by 1/1/00 and 10 by 1/1/04.

[f] France ∑ PCB (7 congeners), for pasture the limit is 0.5 mg/kgDS.

[g] Swiss AOX value is precautionary.

[h] values until 2004.

[i] values post 2004.

[j] sewage sludge must composted or thermally dried.

[k] only guidelines.

[l] some states (e.g. Burgenland and Lower Austria) also have more stringent sewage sludge quality limits that are linked with a reduced stringency on soil sampling; PCB values are max. for each PCB; 7 PCB as annual mean, sum o0f.

[m] with tolerances of exceedance for individual samples.

[n] LRF Federation of Swedish Farmers, SEPA Swedish Environmental Protection Agency, VAV Swedish Water & Wastewater Association.

Table C.2 — Soil quality limit values for PTEs in soils where sewage sludge is used in agriculture (mg/kgDS)

Country		Pb	Cd	Cr	Cu	Ni	Hg	Zn	As	F	Mo	Se	Co	Tl
86/278/EEC		50 - 300	1 - 3	100-150	50-140	30-75	1-1.5	150-300						
Belgium	Flanders	120	1.2	78	109	55	5.3	330	27					
	Walloon	100	1	100	50	50	1	200						
Denmark		40	0.5	30	40	15	0.5	100						
Germany	pH 5-6	100	1	100	60	50	1	150						
	pH > 6	100	1.5	100	60	50	1	200						
Finland		60	0.5	200	100	60	0.2	150						
France	pH > 6	100	2	150	100	50	1	300						
UK	pH 5,0 - 5,5	300	3	400	80	50	1	200	50	500	4	3		
	pH 5,5 - 6,0	300	3	400	100	60	1	250	50	500	4	3		
	pH 6,0 - 7,0	300	3	400	135	750	1	300	50	500	4	3		
	pH > 7	300	3	400	200	110	1	450	50	500	4	3		
Ireland		50	1	-	50	30	1	150						
Italy		100	1.5	-	100	75	1	300						
Luxembourg	Reference Value	50	1	140	50	30	1	150						
	Limit value	300	3	200	140	75	1.5	300						

"to be continued"

Table C.2 — Soil quality limit values for PTEs in soils where sewage sludge is used in agriculture (mg/kgDS) *(concluded)*

Country		Pb	Cd	Cr	Cu	Ni	Hg	Zn	As	F	Mo	Se	Co	Tl	Dioxins[b]	PAH	Benzo-pyrene	PCB
Netherlands		85	0.6	100	36	35	0.3	140	29									
Norway		50	1	100	50	30	1	150										
Sweden		40	0.4	60	40	30	0.3	150 or 100										
Switzerland[a]	"Total"	50	0.8	50	40	50	0.5	150		700	5				5[b]	1[c]	0.2	0.2[d]
	Water soluble		0.02		0.7	0.2		0.5		20								
Spain	pH < 7	50	1	100	50	30	1	150										
	pH > 7	300	3	150	210	112	1	450										
Austria	Burgenland	100	2	100	100	60	1.5	300										
	Lower Austria	100	1.5 (1 pH<6)	100	60	50	1	200										
	Upper Austria	100	1	100	100	60	1	300 (150 pH<6)										
	Salzburg[e]	100	2	100	100	60	2	300	20		10		50					
	Styria	100	2	100	100	60	2	300			10		50					
	Tirol[e]	100	2	100	100	50	2	300	20		10		50					
	Vorarlberg	100	2	100	100	60	1	300										
	ÖNorm	100	3	100	100	50	2	300	20		10		50					

[a] Swiss limits measured as mg/kgDM for soils<15%Organic Matter and mg/dm3 for soils>15%OM.

[b] Dioxins measured in ngΣTEQ/kgDS.

[c] Swiss PAH the 16 components of the USEPA Priority Pollutants list.

[d] Swiss PCB IUPAC No. 28,52,101,118,138,153,180.

[e] only guideline.

Table C.3 - Maximum application rates of constituents when sewage sludge used in agriculture loads, according to the respective limit values and any national restrictions of maximum dry matter and phosphorus additions (kg/ha/y)

Parameters	Denmark	Germany	NL	Norway	Sweden	Switzerland	UK	Finland	France	Ireland	Spain	EC	USA
Lead	1.2	1.49	0.2	0.1	0.1	0.833	15	0.1	1.5	1.5	2.3	15	15
Cadmium	0.008	0.017	0.003	0.004	0.002	0.0083	0.15	0.002	0.03[e]	0.04	0.06	0.15	1.9
Chromium	1	1.49	0.15	0.13	0.1	0.833	15	0.3	1.5	-	3	-	150
Copper	10	1.3	0.2	1	0.6	1	7.5	0.6	1.5	2	3	12	75
Mercury	0.008	0.013	0.002	0.005	0.003	0.0083	0.1	0.001	0.015	0.032	0.048	0.1	0.85
Nickel	0.3	0.33	0.06	0.08	0.05	0.133	3	0.1	0.3	0.6	0.9	3	21
Zinc	40	4.1	0.6	0.7	0.8	3.333	15	1.5	4.5	5	7.5	30	140
Arsenic	0.25	-	-	-	-		0.7	-	-	-	-	-	2.0
Molybdenum	-	-	-	-	-	0.0333	0.2	-	-	-	-	-	0.9
Selenium	-	-	-	-	-		0.15	-	-	-	-	-	5.0
Fluoride	-	-	-	-	-		20	-	-	-	-	-	-
LAS[a]	26												
Σ PAH[b]	0.06												
NPE[c]	0.5												
DEHP[d]	1												
PCB									0.0012[f]				
AOX						0.833							

"to be continued"

Table C.3 - Maximum application rates of constituents when sewage sludge used in agriculture loads, according to the respective limit values and any national restrictions of maximum dry matter and phosphorus additions (kg/ha/y) *(concluded)*

Parameters	Burgenland arable	Burgenland pasture	Lower Austria arable	Lower Austria pasture	Upper Austria >35%DM	Upper Austria >35%DM	Vorarlberg	Styria arable	Styria pasture	Salzburg arable guideline	Salzburg pasture guideline	Tirol arable guideline	Tirol pasture guideline
Lead	1.25	0.625	2.5	1.25	10	5	<160kg	1.25	0.65	1.25	0.65	5	2.5
Cadmium	0.025	0.013	tDS/ha	tDS/ha	tDS/ha	tDS/ha	P_2O_5/ha	0.025	0.013	0.025	0.013	tDS/ha	tDS/ha
Chromium	1.25	0.625	per year	per year	per 3	per 3	per 2 y	1.25	0.625	1.25	0.625	per year	per year
Copper	1.25	0.625			years	years		1.25	0.625	1.25	0.625		
Mercury	0.025	0.013				not more		0.025	0.013		0.013		
Nickel	0.25	0.125				than		0.25	0.125	0.25	0.125		
Zinc	5	2.5				2.5t/y		5	2.5	5	2.5		
Arsenic													
Molybdenum								0.05	0.025	0.05	0.025		
Selenium													
Fluoride													
Cobalt								0.05	0.025	0.05	0.025		
LAS[g]													
Σ PAH[h]													
NPE[i]													
DEHP[j]													

[a] Linear alkylbenzene sulphonates.

[b] Σ acenaphthene, phenanthrene, fluorene ; fluoranthene ; pyrene ; benzfluoranthene (b+j+k) ; benz (a) pyrene, benz(ghi)perylene ; indeno (1,2,3-cd) pyrene.

[c] nonylphenol + mono and diethoxylates.

[d] di(2-ethylhexyl)phthalate.

[e] 0.015 by 1/1/2001.

[f] sum of 7 congeners 1.2g/ha/y.g Linear alkylbenzene sulphonates.

[h] Σ acenaphthene, phenanthrene, fluorene ; fluoranthene ; pyrene ; benzfluoranthene (b+j+k) ; benz (a) pyrene, benz(ghi)perylene ; indeno(1,2,3-cd)pyrene.

[i] nonylphenol + mono and diethoxylates.

[j] di(2-ethylhexyl)phthalate.

Table C.4 — Sludge hygiene regulations

Austria Burgenland	<1000 enterobacteria / 1g	0 Salmonella / 1g	0 parasite ova / 1g
Austria Lower Austria	<1000 enterobacteria / 1g	0 *Salmonella* / 1g	0 parasite ova / 1g
Austria Salzburg (guideline)	<1000 enterobacteria / 1g	0 *Salmonella* / 1g	0 parasite ova / 1g
France	<3 cfu mpn enterovirus / 10gDS	<8 mpn *Salmonella* / 10gDS	<3 helminth ova / 10gDS
Switzerland for land growing fodder crops or vegetables	100 enterobacteria / 1g		0 parasite ova / 1g
Italy		<1000 *Salmonella* / 1g	
Luxembourg	<100 enterobacteria / 1g		no viable parasite ova / 1g

Annex D
(informative)

Comparison of approaches to sludge quality standards in the United States and Europe

The US approach

Probably the largest risk assessment ever conducted in the field of environmental protection was by the United States Environmental Protection Agency (USEPA) to formulate the federal regulations for the use and disposal of sewage sludge. This involved an 11 year programme and cost US$15 million. It was completed in 1992, 6 years after publication of the EC Directive and is known as "Part 503" of the Clean Water Act or 40 CFR. The steps in the RA were:

— postulate the possible hazards ;

— select a sample of wastewater treatment works representative of the whole country on the basis of the EPA `Needs Survey' of 1986 which identified 11,407 works with secondary treatment ;

— a 50 page questionnaire was sent to 479 works to gather more detailed information about treatment, use and disposal of biosolids ;

— sample the biosolids from a sub-set of 208 works and analyse the samples for the 412 analytes (342 organic, 70 inorganic) plus pathogens ;

— model 14 exposure pathways using all the available literature on crop uptake, food chain concentration etc., tolerable intakes and competing exposure ;

— test the exposure levels for the hazards presenting the highest risk ;

— subject the proposed exposure limits and methodology to 183 day public comment period international peer review ;

— analyse the response from the peer review (5500 pages of comment from 656 commentators) and modify the assessment ;

— publish the revised risk assessed tolerable exposure limits.

The risk assessment was published in 1992 (USEPA 1992) with 40 CFR Part 503 in the following year (USEPA 1993). Table D1 shows the exposure pathways considered and their relationship to sludge use and disposal options (Table D2). This integration between sludge management options is lacking in EC legislation.

The objective of the risk assessment was to protect a highly exposed individual (HEI) or the environment from a $1x10^{-4}$ risk. The HEI was modelled as being exposed for 70years. The modelling of HEIs was based on some fairly extreme theoretical exposures. For example in the case of assessing cadmium, the hobby gardener was assumed to smoke 40 cigarettes (tobacco is a CD accumulator plant) and get 50% of daily food intake from a garden that had been fertilised with biosolids for the whole of the individual's life. For lead the highest risk pathway was, a pica child living in an old neighbourhood with housed painted with white-lead-paint, this was modelled as the HEI and the exposure considered was the child eating dried sludge (0.2gDS/day for the first 5 years of life).

The term ‘Distribution & Marketing' in table D2 refers to the sale or giving away of biosolids in bags or containers for example to hobby gardeners through retail outlets, a practice not controlled by the EC Directive 86/278/EEC.

Table D.1 — Environmental pathways of concern identified for application of sewage sludge (biosolids) to agricultural land

No.	Pathway	Description of impact
1.	Biosolids→Soil→Plant→ Human	Human ingesting plants grown in sewage sludge-amended soil
2.	Biosolids→Soil→Plant→Human	Residential home gardener
3.	Biosolids→Human	Children ingesting sewage sludge
4.	Biosolids→Soil→Plant→Animal→Human	Farm households producing a major portion of the animal products they consume. It is assumed that the animals eat plants grown in soil amended with sewage sludge
5.	Biosolids→Soil→Animal→ Human	Farm households consuming livestock that ingest sewage sludge while grazing
6.	Biosolids→Soil→Plant→Animal	Livestock ingesting crops grown on sewage sludge-amended soil
7.	Biosolids→Soil→Animal	Grazing livestock ingesting sewage sludge
8.	Biosolids→Soil→Plant	Plants grown in sewage sludge-amended soil
9.	Biosolids→Soil→Soil organism	Soil organisms living in sewage sludge- amended soil
10.	Biosolids→Soil→Soil organism→ Soil organism predator	Animals eating soil organisms living in sewage sludge-amended soil
11.	Biosolids→Soil→Airborne dust→Human	Tractor operator exposed to dust while ploughing large areas of sewage sludge-amended soil
12.	Biosolids→Soil→Surface water→ Human	Water Quality Criteria for the receiving water for a person who consumes 0.04 kg day^{-1} of fish and 2 l day^{-1} of water
13.	Biosolids→Soil→Air→Human	Human breathing volatile pollutants from sewage sludge
14.	Biosolids→Soil→Ground water→ Human	Human drinking water from wells contaminated with pollutants leaching from sewage sludge-amended soil to ground water

Table D.2 — Relationship between exposure pathway and disposal or use practices

Outlet	1	1F	2F	3	4	5	6	7	8	9	10	11	12A	12W
Use in agriculture	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Distribution & marketing		X	X					X	X	X		X		
Use on non-farm land												X		X
Monofill													X	X
Landfill													X	X
Incineration													X	

F denotes ‘future use change’.

A denotes ‘air’.

W denotes ‘water’.

Comparison of sludge quality measures

The quality limit values derived by the USEPA risk assessment are generally, but not always, higher than the equivalent EC limits, as shown by Tables D3 and D4. The values for potentially toxic elements adopted by individual European countries are summarised in ANNEX C. Some of these values are considerably lower than the EC Directive maxima, and this reflects their environmental, economic and political priorities.

Table D.3 — Comparison of sludge quality limits in USEPA 40 CFR Part 503 and EC Directive 86/278/EEC (mg/kgDS)

PTE	USEPA Part 503		EC Directive 86/278/EEC	
	Ceiling concentration	"Exceptional quality"	Recommended	Mandatory
Zinc	7500	2800	2500	4000
Copper	4300	1500	1000	1750
Nickel	420	420	300	400
Cadmium	85	39	20	40
Lead	840	300[**]	750	1200
Mercury	57	17	16	25
Chromium	3000	1200	-	-
Molybdenum	75[++]	18[++]	-	-
Selenium	100	36	-	-
Arsenic	75	41	-	-

** To protect children who eat 0.2 g/day biosolids used in gardens for the first 5 years of life.

++ This has been withdrawn for re-evaluation.

Table D.4 — Comparison of loading and soil quality limits in USEPA 40 CFR Part 503 and EC Directive 86/278/EEC

PTE	Loading limit kg/ha/y		Soil concentration mg/kgDS	
	EC[a]	USEPA	EC	USEPA[b]
Zinc	30	140	150 to 450[c]	1460
Copper	12	75	50 to 210[c]	770
Nickel	3	21	30 to 112[c]	230
Cadmium	0.15	1.9	1-3	20[d]
Lead	15	15[d]	50-300	180[d]
Mercury	0.1	0.85	1-1.5	8.5[d]
Chromium	-	150	-	1530
Molybdenum	-	0.9[e]	-	9.5[e]
Selenium	-	5	-	50[d]
Arsenic	-	2	-	21[d]

[a] The loading rate is averaged over 10 years in the EU.

[b] Calculated values as Part 503 does not set soil limits for PTEs.

[c] The value depends on soil pH.

[d] To protect children who eat 0.2 g/day biosolids used in gardens for the first 5 years of life.

[e] This has been withdrawn for re-evaluation.

The USEPA regulations refers to “ceiling limits” and “exceptional quality”. If a biosolids exceeds the ceiling limit for any element, it is considered too polluted for beneficial use and must be disposed by incineration or landfill. If a biosolids is below the exceptional quality limits, and if it satisfies the Class A pathogen standards described below, it can be sold or given away without any requirement for monitoring or control except the advice on the application rate so as not to exceed the annual pollutant loading rate (Table D4). For biosolids falling between the two limits, they can only be used on “Permitted” sites. Users of biosolids must also take account of crop nitrogen requirements.

The rule prescribes a monitoring programme which is dependent on the annual production of biosolids which ranges from once per year if production does not exceed 290 t DS y^{-1} to monthly if production exceeds 15,000 t DS y^{-1}. After two years, if the analyses of the prescribed elements and pathogens is reasonably constant, the frequency can be decreased but never to less than once per year.

The pathogen requirements of 40 CFR Part 503 are that for Exceptional Quality, i.e. where biosolids can be sold or given away, the density of faecal coliform is less than 1000 MPN per gram of dry solids (MPN = Most Probable Number) or the density of Salmonella is less than 3 MPN per 4g DS. There is also a requirement that the density of enteric viruses shall be less than 1 plaque-forming unit per 4g DS and that there shall be less than 1 viable helminth ova per 4g DS. Biosolids meeting these criteria are described as meeting Class A pathogen requirements. There is an alternative Class B criterion of 2×10^6 MPN faecal coliform per g DS. If biosolids are Class B, then site restrictions similar to the cropping and no-grazing restrictions which apply in Europe. The USEPA rule also imposes `Vector Reduction' requirements, i.e. management practices that reduce the attraction of insects, animals etc. The treatment processes include anaerobic digestion, aerobic stabilisation (including composting) and lime stabilisation or injection or ploughing in within 8 hours.

This dual standard approach is in contrast to the that adopted in the EC Directive, which requires that sludge should be treated before use in agriculture, and if untreated sludge is used it should be incorporated or injected into the soil. Land use restrictions following sludge application are also prescribed to further reduce the risk of disease transmission. Treated sludge is defined in the Directive as "sludge which has undergone biological, chemical or heat treatment, long term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use", the intention being that Member States set national requirements to meet with this overall objective. This has not worked well and the Commission is currently considering introducing more exacting requirements to ensure minimum sludge hygiene criteria are met. Table D5 compares the sludge treatment requirements of USEPA with those in the UK.

There are major differences in the approach to regulating biosolids recycling on the two sides of the Atlantic. The process of deriving the regulations in the USA was more transparent than in the EU and it was a participatory process with all interested parties having opportunity to comment and contribute. The USA regulations were finalised 6 years after the EC Directive and hence the EPA had access to a far larger body of relevant experimental data on which to base its legislation whereas the EC applied the precautionary principle to more limited data.

The USA concept of biosolids as a product that can be sold without detailed regulation of use is far more enabling for developing income generating markets than that in the EU. However, the approach to regulating the `lower quality' biosolids is more bureaucratic and more prone to focus these biosolids onto smaller areas of land which is contrary to the intention of the regulators.

Table D.5 — Comparison of US regulations and UK Code of Practice

Process*	UK Code of Practice	US Regulations	
	Examples of effective sewage sludge treatment processes	Processes to significantly reduce pathogens	Processes to further reduce pathogens
Aerobic digestion		40d-20 °C to 60d-15°C	
Drying beds, dewatering and storage	3 months ; if anaerobically digested 14d	3 months, during this period 2 months ambient temperature > 0°C	
Anaerobic digestion	12d MRT/35 ± 3 °C, or 20d/25 °C ± 3 °C; both followed by secondary digestion, 14d MRT	Between 15d MRT/35-55 °C and 60d/20 °C	
Liquid storage	3 months		
Composting	40°C or higher for 5d during which >4h @ >55°C followed by maturation	40°C or higher for 5d during which >4 h @ >55°C	Within vessel or static pile, 55°C/3d ; turned windrow - 55°C/15d & turned 5x
Drying			Sludge particles dried to >90%DS and >80°C in sludge or exhaust gas >80°C
Heat			Liquid sludge heated to 180°C for 30 min
Thermophilic aerobic digestion	7d MRT, with at least 55°C for 4 h.		Liquid sludge 55-60°C/10d MRT and aerobic
Pasteurisation	30 min/70°C or 4 h/55°C followed by mesophilic anaerobic digestion		70°C for 30 min
Lime stabilisation	pH 12 for 2 h	pH 12 for 2 h	pH exceeding 12 for 72 h and >52°C for >12hC

* Times are for batch treatment or plug-flow conditions unless mean residence time (MRT) is specified for continuous processes with mixing of the contents of the vessel.

Annex E
(informative)

SWOT (strengths, weaknesses, opportunities and threats) Analysis of sludge management

Table E.1 — Analysis of the strengths, weaknesses, opportunities and threats associated with the management of sludge from public water supply works

Strengths	Weaknesses	Opportunities	Threats
— "Constant" quality (per variety) — Limited varieties — Predictable in content and amount — Easily identified sources — Relatively good "image" — Association with a "clean" process — Possible beneficial uses based on future R&D	— Seasonal changes of quality — No (or low) perceived value - low interest — Unpredictable contaminant potential — Lacks methods of physical characterisation — Production and use are not in balance — Not interruptible (long term) — Lots of small sites (not France) — Poor knowledge of content — Limited markets (volatility) — High water content - expensive to dewater — High disposal costs - most is disposed of to landfill	— **Now** — most disposed of in landfill — softening sludges + pellets in agriculture, toothpaste, paper — limited agricultural use — [coagulant] — brick/cement production — **Future** — cement production (but the "wet" process is being replace by "dry" kilns) — coagulant use for H_2S binding in wastewater treatment — use in digestion — land restoration (poor soils -> natural regeneration) — mix with other wastes — replacement for end-of-day or final landfill cover — component of specialised soil/growing media — recycle coagulants — new technology e.g. membranes -> separation of components of sludge — new (cheaper) dewatering techniques	— Sludge quality will increasingly reflect contaminated raw water — Increasing concern over the use of polymers and aluminium for flocculation — Lack of obvious agronomic benefit may restrict the agricultural outlet — Decreasing acceptance in landfill due to physical condition — Change in legislation could require higher quality standards and may make it a "hazardous" waste — All use and disposal options will cost more in the future — Higher sludge management costs will be passed on to the customer

Table E.2 — Analysis of the strengths, weaknesses, opportunities and threats associated with the management of sludge from wastewater treatment works

Strengths	Weaknesses	Opportunities	Threats

— Valuable constituents
— Predictable quantity (may fluctuate seasonally e.g. holiday resorts)
— Strong established framework:-
  — for requiring pre-treatment/source control (particularly for large industrial inputs)
  — for use in agriculture
— Extensive and intensive body of research into environmental impact
— Long-term practical experience
— Energy (non-fossil)
— Organic matter
— Local use minimises economic / ecological / environmental cost
— Indicator of the environmental quality (contamination) of the drainage catchment
— Conforms to aspects of "sustainable development" espoused by Rio Summit
	— Open pipe to pollutants
	— Sewage treatment design and management are focused on effluent quality
	— Faecal association (legacy of toilet training) leads to irrational aversion
	— Supply not interruptible
	— Public antipathy to incineration
	— Difficult to identify and control small sources
	— Bulky (i.e. High volume relative to beneficial constituents) incurring high haulage and disposal costs; this expense can be reduced by spending on treatment (dewatering etc.)
	— Possibly malodorous
	— Possible undesirable constituents (chemical and/or physical)
	— Food purchasers/processors are hostile in some countries
	— Existing alternative products are more attractive / predictable / flexible (e.g. Mineral fertilisers)
	— Some markets are already saturated in some areas (e.g. pig manure in The Netherlands)
		— Possibility of earning income by co-recycling or co-treating biowastes in existing wastewater facilities
		— World prices for mineral fertilisers are rising giving greater opportunity for acceptance of biosolids or to introduce charge/raise price
		— Manufacture new products e.g. Recycling coagulants
		— Pressures on the use of fossil energy and likely increased world price promotes energy recovery from biosolids
		— Income opportunity
		— Producer can enhance its "green" credentials
		— New processes / products to eliminate pollutants from the biosphere (e.g. brick making)
		— Growing antipathy to peat extraction opens market for alternatives products (composts, dried pellets, etc.)
		— Emerging technologies may offer more secure use and disposal options, but at a higher cost (mostly thermal e.g. pyrolysis, wet oxidation, pasteurisation, etc.)
			— All use and disposal outlets are vulnerable
			— Environmental scares could frighten customers and politicians
			— Local competition from other organic wastes, particularly livestock manure
			— Introduction of inappropriate or disabling legislation
			— A event with a wide area of effect (e.g. another Chernobyl or Seveso) could introduce atmospheric deposition on the catchment that would cause the biosolids producer to shut down a route
			— All use and disposal options will cost more in the future
			— Higher biosolids management costs will be passed on to the customer

Table E.3 — Analysis of the strengths, weaknesses, opportunities and threats associated with the management of industrial sludges

Strengths	Weaknesses	Opportunities	Threats
— Constant quality according to industry — Valuable constituents — Predictable — Easily defined sources — Interruptible production	— Some are only produced seasonally — Possible unwanted components — Little R&D into environmental impact — Poor knowledge of quantities and quality — Production and use are not in balance - most is disposed of to landfill — Sometimes small quantities (lack of economy of scale) — Technology changes could result in quality changes — Inadequate and inconsistent legislation, particularly compared with wastewater biosolids	— Material recovery — Product formulation/identity — Possibility of using by-products — Mixing with other wastes or materials to make useful products - secondary raw materials — Financial benefits — Economic benefits — Market creation — Energy generation — Producer can enhance its "green" credentials — Emerging technologies in product and waste production and treatment will increase use and disposal options and security, but at increased cost	— Introduction of inappropriate or disabling legislation — Increased restrictions disposal of organic wastes in landfill (opportunity for use) — Contamination — Risks to the environment — Local displacement/competition with other waste streams — All use and disposal options will cost more in the future — Higher waste management costs will be passed on to the consumer

Annex F
(informative)

Strategic decision tools for sludge management

F.1 An outline methodology of risk assessment for wastes used on land

Sludges contain variable concentrations of chemical and / or microbiological constituents that may have environmental impact. Their presence and concentration depend on the source of water or wastewater being treated and the efficiency of the treatment process. Higher effluent quality standards result in a greater proportion of the constituents being transferred to sludge. Some of the constituents are potentially harmful to the environment and human health if in high concentrations and sludge is used or disposed of inappropriately. This requires an understanding of their nature and behaviour, their concentrations and their fates and effects on the environment at large. Some constituents that are beneficial for crop production may also have adverse effects, particularly to water quality, if not managed appropriately.

To identify the potential impact of a particular contaminant in a sludge, a risk assessment is usually required to evaluate the potential exposure pathways, assess which is at risk of potential adverse impacts according to environmental and health quality objectives. From this, appropriate precautionary quality standards or limit values can be set.

The identification of the potential risk of contaminant sludge to be applied to land could include the following main steps[2)] :

a) the critical exposure routes (pathways) under realistic ‘worst case’ conditions (Figure F1.1) :

1) *exposure of man via crops, meat and dairy products (routes 6, 8 and 9 in Figure F1.1).* Cattle grazing on sludge-amended farmland may ingest considerable amounts of soil, and thus take in sludge particles. Also the potential uptake into fodder may be significant. Restrictions on the use of sludge on areas used for edible crops may be laid down. These restrictions could apply for one year after application ;

2) *exposure of man via drinking water (routes 7 and 9 in Figure F1.1).* Some of the substances that occur in sludge have poor water solubility and may be expected to sorb to soil particles. The risk of contamination of ground water may therefore seem of little significance. Water soluble substances appearing in high concentrations in wastewater may, however, also be present in sludge in significant concentrations and degradation products of poorly water soluble substances may prove more water soluble than the parent compounds. The risk of contamination of groundwater should therefore not be neglected ;

3) *exposure of organisms and biological processes in the soil environment (route 5 in Figure F1.1).* Soil micro-organisms are exposed to the highest concentrations of sludge contaminants compared to other potential targets ;

4) *exposure of surface water and man via consumption of contaminated fish.* The contamination of fish may not be considered critical if there are limits on the use of sludge to areas where run-off to surface water is of low risk.

The identification of exposure routes could be performed for both single hazard contaminants and for complex contaminants.

[2)] Use of Waste Products in Agriculture. Environmental Project No. 336, Danish EPA, 1997

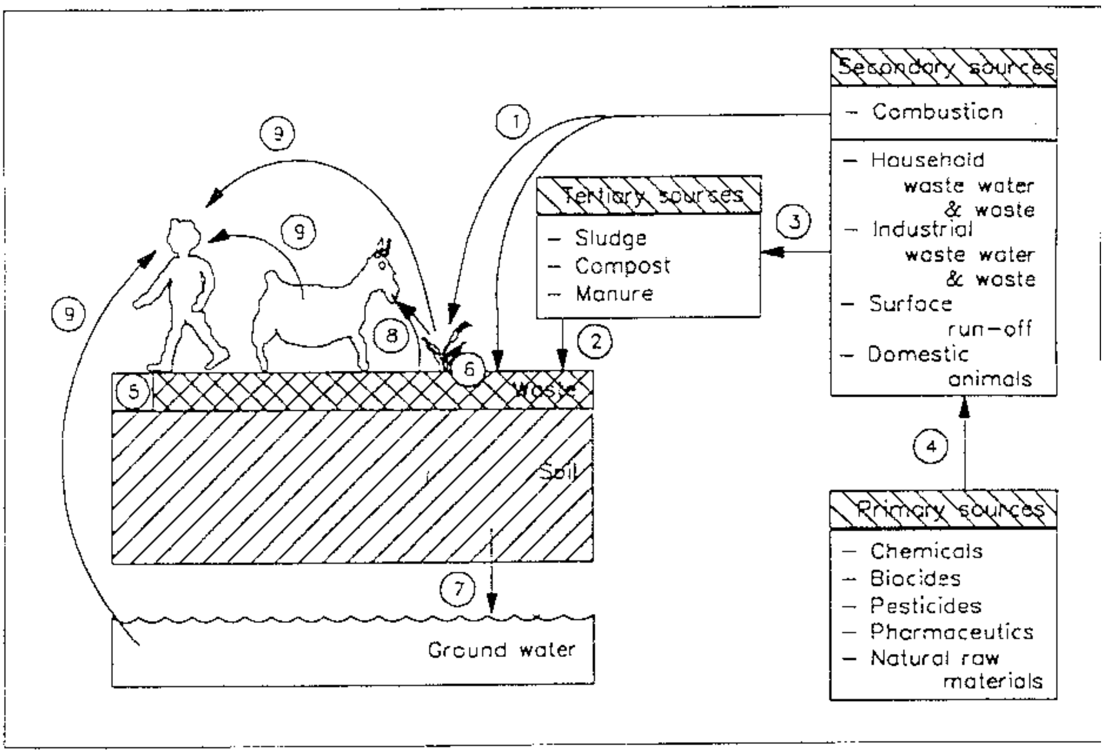

Figure F.1 — Overview of primary exposure routes from the use waste products in agriculture

b) The contamination level of substances known to be highly hazardous to man or to the environment.

An analysis programme should be performed on samples of contaminated sludge for identification of the contamination level of chemical residues (organic contaminants, heavy metals, etc.) in sludge and identified critical substances or groups of substances in relation to the above defined quality criteria.

The selection of parameters may be based on previous sludge analysis programmes or a preliminary screening.

c) Definition of the quality objectives for the protection of the critical targets and thus the quality criteria for the exposed environment.

In a risk assessment framework the acceptable exposure of critical targets should be identified - the quality criteria. These criteria should reflect the quality objective for protection of the targets of the exposure. The principal targets are: consumers of products grown on sludge-amended fields; consumers of groundwater from areas where sludge is applied as fertiliser; and the biological diversity and function of the soil ecosystem exposed to contaminants from sludge. The quality criteria may be based on limit concentrations in the critical targets or be defined toxicologically.

d) Quantification of the potential impact of the contaminants at the ‘terminal end’ of the critical exposure routes (critical targets), taking into consideration both single high hazard contaminants and complex mixtures.

The potential impact of identified critical compounds may be evaluated using the criteria for evaluating single chemicals for the protection of the environment within the EC Directive 93/67/EEC and the supporting Technical Guidance Document. Application factors may be used for taking into account that test data may not be sufficiently safe for the protection of the ecosystem at the quality objective selected. The evaluation of the complex mixtures may be performed with the same approach as for single chemicals using data from ecotoxicological tests of the mixtures. The predicted no effect concentration (PNEC) is used as the quality criteria for the protection of agricultural soil quality, soil organisms and human health. The predicted environmental concentration (PEC) in the critical target (i.e. soil, plants, groundwater, etc.) and the PNEC are used for the quantification of the potential impacts. Ratios of PEC/PNEC are determined for the different critical targets. When PEC/PNEC <1, there is at present no need for further testing or risk reduction measures.

The determination of PEC for individual chemicals is based on modelling of the fate and transport in soil systems using a conservative assessment scenario. Modelling of the fate and transport of complex mixtures with unidentified hazardous components can be very problematical, and the most appropriate approach may be to a combination of physico-chemical fractionation techniques with modelling and ecotoxicity testing.

e) Validation of the risk assessment with emphasis on critical steps.

The validation may often be made on a generic level by assessment of previously conducted field experiments and, if needed, by conducting specific controlled experiments or monitoring activities for evaluating the critical parameters in the risk assessment.

f) Assessment of the risk to the critical targets (man and the environment), including the margin of safety required - i.e. the level of precaution.

If the level of risk identified be unacceptable, a refinement of the critical steps of the assessment should be performed and/or measures taken in order to reduce the risk by :

1) removal or reduction of critical contaminants up-stream of the treatment plant ;

2) further treatment of the sludge in order to reduce the contamination level (e.g. use of clean technologies, etc.) ;

3) regulation of sludge in order to reduce the effects on the critical exposure routes.

g) Setting criteria for the protection of soil and other directly or indirectly exposed compartments of the environment.

The quality criteria for the exposed environment should be used for setting limit values for the minimum quality of sludge for high priority contaminants. The limits should take into account long-term effects and incorporate the concept of sustainability.

F.2 A methodology for developing precautionary soil protection values[3]

The objective this methodology (as with others) is to ensure the sustainable use of soils. Therefore it is considered inappropriate to relate soil protection values to the intended use of the soil because the objective is to maintain complete flexibility of use. However it would be appropriate to set different limits appropriate to the natural composition of soils and their sensitivity to pollutants.

The basic premise of this methodology is that a soil precautionary value will be effective if ecotoxicological effect thresholds, balanced by data on background values, are not exceeded, and if, at this concentration, there is no evidence of unwanted effects on plants or groundwater, and if the value is below the trigger value proposed for the pathway soil ⇒ humans.

A further premise is that there is no sense is setting precautionary values at concentrations that are below background values. For this reason, the specifically determined effect thresholds are balanced with representative background values. For soils having naturally high background concentrations of substances the concern, it is anticipated that hazardous soil changes will only occur (and subsequently the precautionary duties triggered), if these substances have been or will be released by anthropogenic influences (e.g. cultivations, uses, etc.).

For deriving precautionary values the following technical requirements are applied :

a) data on the accumulation and effect of pollutants in soils provide the basis for establishing precautionary values. Reference is made first of all to the variety of data given in literature on ecotoxicological effect thresholds. If possible, the effect of soil pollutants on other targets to be protected (e.g. food plants including phytotoxic effects, groundwater and human health) is also evaluated ;

[3] After the official reasoning of Soil Protection Ordinance, Germany (Bodenschutzverordnung (Soil Protection Ordinance); Bundesratsdrucksache 780/98 vom 10.09.1998)

b) the sensitivity of soils is accounted for by considering the soil texture (clay, loam, sand) and the soil pH ;

c) in order to account for the worst-case possible long-term ecological relevance of a substance including its potentially mobilizable fraction, values are derived as the “total” concentrations of that substance, i.e. ignoring soils’ potential for sorbing the substance and attenuating its effects. This provides a high factor of precaution.

Methodological considerations for implementation of requirements. In the past different possibilities for determining the ecotoxicological effects of pollutants on organisms living in soil have been investigated and developed. The aim of these studies was the development of a generally applicable method to derive generic soil values. For deriving precautionary values for the substances mentioned it seems necessary and justifiable to do without a uniform and stringent mathematical formula for all substances[4].

Ecological effect thresholds for PTEs, PCB, and PAH will thus be derived on the basis of direct assessment of data on No Effect Level. To this end, the variation range given in literature as to the low/lowest No Observable Effect Concentrations (NOECs) and Lowest Observable Effect Concentrations (LOECs) for individual species is used. If available, reference will be made to data on differentiation of soil texture, metal binding/solution form in soil and sensitivity of species in order to assess the significance of the species used and of the effect thresholds (place in the food chain, significance for soil related key processes in ecosystems).

Comparison with data on background contents. Ecotoxicologically founded effect thresholds are compared with data on actual soil background contents, which are supposed to reflect the range and frequency distribution of the pollutant contents (background) found in soils today. In doing so, the following definition is applied: background values are representative values for common contents of a substance or a substance group in topsoils. The background content of a topsoil is composed of the naturally caused (geogenic/pedogenic) content and also the ubiquitous substance distribution as a consequence of diffuse man-made substance inputs in soils.

The available databases show the need to differentiate the data on background values according to distinct criteria. Pedogenesis, variety of soils and the type caused by the different uses require the differentiation of background values. From the today’s point of view it does not seem useful or appropriate to indicate highly aggregated values in the sense of "one figure for all soils".

Soils properties are a function of their parent material, climate, vegetation, time, use and topography. In some countries where soils are predominately young, the effect of time is not apparent. This means that soils have a range of compositions and sensitivities to added substances. This methodology considers that a differentiated system of soil values is required in regulations covering the use of organic materials. The background values show that the lowest pollutant concentrations can generally be found in sandy soils (in particular of Pleistocene origin), loamy soils come next after, which however stand out from clay soils.

Differentiation of soils. For deriving precautionary values soils can be combined in certain classes. The classification is based on the main soil type groups. Soil textures are characterised by the grain size of the mineral soil material. The grain size distribution can reliably be determined by relevant laboratory methods as well as by field tests.

The following differentiation of soils seems useful :

— soil type clay : clay content > 25 % ;

— soil type loam : clay content 12 % to 25 % and silt content > 50 % ;

— soil type sand : clay content < 12 % and silt content < 50 %.

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4 For other pollutants and pollutant groups the usefulness of a procedure according to the factor method or distribution-method shall be proved in detail

The category "Soils with specifically increased background values", can be defined on the basis of regionally representative background values supported by a supplementary list of European precautionary values or by the individual countries within the frame of the enforcement of soil regulations. Soils generally belonging to this category are e.g. magmatites, metamorphites (e.g. granite, gneiss) as well as of sandstone and limestone, soils with predominately anthropogenic increased contents (due to the settlement structure) and soils in marshes and flood areas. Organic soils shall be subject to special considerations.

A differentiation of the pH values of soils is additionally necessary in order to pay due regard to the substance dynamics of PTEs, which in this case is essentially caused by the pH value, which is dependant on the substance. A limit pH value which is given for the mobilisation of the relevant PTEs is taken as basis. Within the frame of the derivation of precautionary values the substance-specific pH limit value is used, below which a significantly increased mobilisation of cadmium, zinc, nickel and lead is to be expected. For cadmium, zinc and nickel the pH limit value amounts to 6,0 and to 5,0 for lead. For Cd, Zn and Ni , the precautionary values of the category "loam" apply to soils of the category "clay" with pH < 6,0 and for Pb with pH < 5,0; the precautionary values of the category "sand" apply to soils of the category "loam" with pH 6,0, and for Pb < 5,0.

For organic substances not the pH value but rather the humus content of soils is decisive for the mobilisation or immobilisation of substances. A differentiation of soils according to the humus content has to take into account that - at least in case of agriculturally used soils - the humus content is above all determined by cultivation. The humus content of arable land (topsoils) amounts to 2-3 %, and is sometimes even higher depending on the cultivation history. For grassland, the humus content is in comparison significantly higher and is additionally differentiated according to depth (0 to 10 cm: 6 - 12 %, 10 to 30 cm: 3-6 % and below 30 cm normal content not dependant on use). The humus content of forest soils, which are however not considered in this context, differs in dependence on the horizon.

The differentiation of humus contents required for precautionary values shall be chosen in such a way that it corresponds to the different forms of cultivation. This requirement is fulfilled by the distinction in "greater than or less than 8 %".

Example precautionary values expressed as solid material contents as recommended by UBA[5].

Substances and in particular PTEs exhibit different binding forms in soil, which depend on how strongly a substance is bound to the soil matrix and how readily or not readily it can thus be taken up by the plants, whether it is available for soil organisms or can be relocated with soil leachate. In this context soil-related characteristics and processes (above all pH value, soil texture, humus content, redact conditions) play an essential part in addition to substance-related properties.

When evaluating substances in soils it is in particular necessary for PTEs to chose the digestion method appropriate to the proposed aim of the evaluation (extraction method) and to indicate it for the values derived. In general it will be possible to cover separately by using specific extraction methods the different binding forms (fractions) in which a metal is present in soil (can be present). For precautionary purposes of soil protection it is however neither technically feasible nor appropriate in terms of the efforts needed to carry out a sequential extraction with numerous extraction agents. It is rather necessary to determine the total contents or a similar fraction as parameter of the total presumed hazardous potential.

For PTEs the precautionary value is given on the basis of the fraction extracted by aqua regia (often called “total” content). By describing the potentially mobilizable substance contents it indicates the ecological-relevant fractions of metal contents in soils.

Soil contents extracted by aqua regia offer for soil precaution a standard for evaluation of the substance contents in soil with regard to all ecologically relevant pathways. This is as well true of the pathway soil⇒leachate, if evident risk factors can be excluded (e.g. presence of solution additives, disturbed soils, unusually high or low pH value, stagnant water).

---

5 Federal Environmental Agency (Germany)

Table F.1 — Precautionary values for metals in soils, in mg/kgDS total content (aqua regia[6])

Soil texture	Cd	Pb	Cu	Cr	Hg	Ni	As	Zn
clay	1,5	100	60	100	1	70	20	200
loam	1	70	40	60	0,5	50	15	150
Sand	0,4	40	20	30	0,1	15	10	60
soils with specifically increased background contents: established, if required, on the basis of regionally representative background values.								

It has to be taken into account that the data used for determining soil background values for PTEs have been collected by using different extraction methods (total extraction and aqua regia). As stated above, precautionary values shall be shown for PTEs as contents to be determined by aqua regia, only. As a result of the reasoning given in this report the following soil precautionary values are recommended:

Guidance for application of table 1a "Precautionary values for PTEs". With regard to Cd, Ni and Zn it is evident that the precautionary values of the category "loam" apply to soils of the category "clay" with pH < 6,0 (pH limit value); the precautionary values of the category "sand" apply to soils of the category "loam" with pH < 6,0. This is also true for Pb using, however, a pH limit value of 5,0.

Table F.2 — Precautionary values for PCB_6, benzo(a)pyrene and $PAH_{(16)}$ in soils mg/kgDS total content[7]

Soils	PCB_6[8]	Benzo(a)pyrene	$PAH_{(16)}$[8]
Soils with a humus content > 8 %	0,1	1	10
Soils with a humus content < 8 %	0,05	0,3	3
Soils with specifically increased background contents established, if required, on the basis of regionally representative background values			

F.3 Best practicable environmental strategy

The Best Practicable Environmental Option (BPEO) is a well-founded strategic management methodology for assessing a wide range of developments which impact the environment in its widest sense. A specific BPEO procedure has been developed by WRc for identifying the optimum sewage sludge treatment and disposal strategy (Powlesland and Frost, 1990)[8]. It can be applied to the sludge management problems of individual wastewater treatment plants as well as regionally. It provides a thorough and flexible approach which can be applied to any strategic sludge or waste management problem, either on an individual sludge basis or as an integrated regional approach to single or mixed wastes.

The essential criteria in the selection of the BPEO for sludge treatment and disposal require that the route selected :

— represents that which is best for the environment as a whole, is secure and sustainable, and does not incur excessive cost ;

— observes all regulatory standards for emissions to air and water, use on land and disposal to landfill, and improves upon them if practicable ;

— incorporates safety factors to overcome uncertainty about any environmental impacts or their scale, and to reduce the possibility of inadvertent pollution transfer between different environmental media.

---

[6] Extraction according to DIN 38 414-7, analysis using ICP OES according to DIN 38 406 22

7 Analysis for PCB_6 : DIN 38 414-20 for benzo(a)pyrene (sun of 6 PCB) and PAH(16) : method according to LUA of north-Rhine Westphalia Guidance sheet No. 1 (sum of the 16 PAH in USEPA list).

[8] Powlesland, C. ad Frost, R. (1990) A methodology for undertaking BPEO studies fo sewage sludge treatment and disposal. WRc Report PRD 2305-M/1 for HMIP. WRc, Medmenham, SL7 1FD, England

The development of the BPEO should result in a stand-alone document with the following characteristics :

- openness and clarity. It should be suitable for use by technical and non-technical interest groups ;
- all data and decisions are audited and cross referenced. This should detail sources and dates of all data, decisions made and information used ;
- all potential options are considered. Options include minimising sludge and pollutant generation, co-treatment and disposal with other wastes and fuels, novel and conventional methods ;
- all decisions are taken primarily on environmental grounds ;
- a reasonable and justifiable balance is made between benefits and costs ;
- all long and short term effects are considered ;
- the selected management plan is fully substantiated and justified ;
- a document is produced that forms the basis of an environmental impact assessment.

An audit trail is maintained throughout the study to ensure that independent scrutiny is possible. An audit trail includes :

- references for all primary data sources ;
- documentation of all assumptions ;
- records of the individuals responsible for assumptions and judgements ;
- a justification of the methods used ;
- reasons for the use of criteria ;
- illustrations of the information flows.

Table F.3 — Main stages in a BPEO study

STAGE	ACTION
1	Establishment of objectives and constraints
2	Data collection on existing operations and the study area
3	Identification of all possible treatment and disposal options
4	Screening of possible treatment and disposal options
5	Evaluation of selected options, for : — Practicability ; — Environmental impacts ; — Economic implications ; — Operational security.
6	Selection of preferred option (the BPEO)
7	Further examination of the preferred option
8	Summary and presentation of the evaluation
9	Implementation and monitoring

F.4 The multi-scaling diagram concept: a tool for sludge strategy development[1)]

General concept

Multi-scaling diagrams are appropriate concepts for technology analysis and Environmental Management Audit Scheme (EMAS). Technology analysis employs a hexagonal diagram, while Environmental Management Audit Scheme uses a five branch design

AIMS of the multi-scaling diagram concept

The main goal of the multi-scaling diagram concept should be to give to decision makers a new tool in order to compare and differentiate between several alternatives the most appropriate sludge use or disposal route by comparing different scenarios.

This approach is different from the usual tabular approach which cannot consider multiple factors simultaneously, such as the possible development of sludge input characteristics, trends and levels of selected technologies (BATNEEC Analyses), environmental impacts, sludge disposal hierarchy, etc.

The multi-scaling diagram allows an integrated approach and provides a dynamic vision of potential operational scenarios.

This tool can be considered alongside other methods of process analysis and decision tools to assist in the development of sewage sludge management in the European Union.

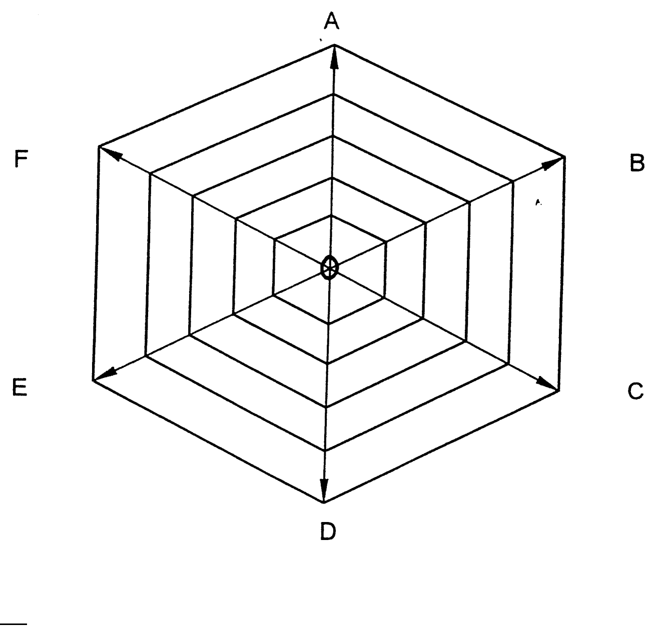
The method

The implementation of the multi-scaling diagram concept is an analytical tool for preliminary studies of sludge management and disposal options.

The diagrammatic approach is as follow :

- Frame : hexagonal support design ;
- number and coding of axis: 6 - OA, OB, OC, OD, OE, OF ;

scale of axis or levels: 6, where 1 = minimum level, and 6 = maximum level.



1) REFERENCE - OKO Effizienz Durch OKO - Controlling Zur Praktischen Umsetzung Von EMAS Und ISO 14001

Each axis is assigned as follows.

Axis 1 (OA) - European priority for sludge disposal routes :

- Level 1 : no sludge volume minimisation + landfill ;
- Level 2 : sludge volume minimisation + landfill ;
- Level 3 : no sludge volume minimisation + beneficial use (agriculture) ;
- Level 4 : sludge volume minimisation + single option (agriculture use or combustion) ;
- Level 5 : sludge volume minimisation + double options (beneficial use and combustion) ;
- Level 6 : maximum sludge volume reduction + use of beneficial materials and energy recovery (sustainable development).

Axis 2 (OB) - Sludge quality criteria for all use and disposal routes

The scale of the levels has to be determined after a comparison of parameters, including :

- stabilisation criteria (biological-chemical) ;
- presence of heavy metals ;
- presence of organic contaminants ;
- other negatives parameters ;
  - Level 1 : minimal or very low quality level ;
  - Level 2 : low level quality ;
  - Level 3 : low average quality level ;
  - Level 4 : high average quality level ;
  - Level 5 : high quality level ;
  - Level 6 : maximal or very high quality level.

Axis 3 (OC) - Operational and personnel management items

The scale of the levels is determined after analysis and comparison of different criteria :

- daily operations management ;
- maintenance aspects ;
- skilled operators ;
- general management ;
- operators and staff training ;
- personnel involvement.

Standards such as ISO 9002 and 14000 could be useful for improved notation. Notation is made in the same way as Axis 2.

- Level 1 : minimum level ;
- Level 2 : low level ;
- Level 3 : low average ;
- Level 4 : high average ;
- Level 5 : high level ;
- Level 6 : maximum level.

Axis 4 (OD) - Economic variables

The scale of the levels is determined after balancing of investment and operating cost options. This analysis has to be made on the real life cycle of equipment and should be comparable to similar equipment and processes (depreciation costs). Level 1 corresponds to the maximum cost (not optimal), while Level 6 is the most cost effective solution at the time of calculation. Between the maximum and minimum costs, the branch has to be divided in 6 equal levels.

Axis 5 (OE) - Risks

This axis takes account of data and information on :

- precautionary and proximity principles ;
- process and sludge disposal route safety ;
- reliability of the process ;
- references ;
- personnel acceptance ;
- sociological acceptance.

Level 1 corresponds to maximum risk, while Level 6 is minimum risk.

Axis 6 (OF) - Environmental impacts

Each final disposal option has to be planned and assessed in the context of sustainable development. The environmental impact analysis takes in account :

- waste avoidance ;
- energy consumption and balance of input/output ;
- CO_2 balance ;
- smells and noises ;
- local impacts (landscaping integration).

EXAMPLES

Case study : Scenario N° 1

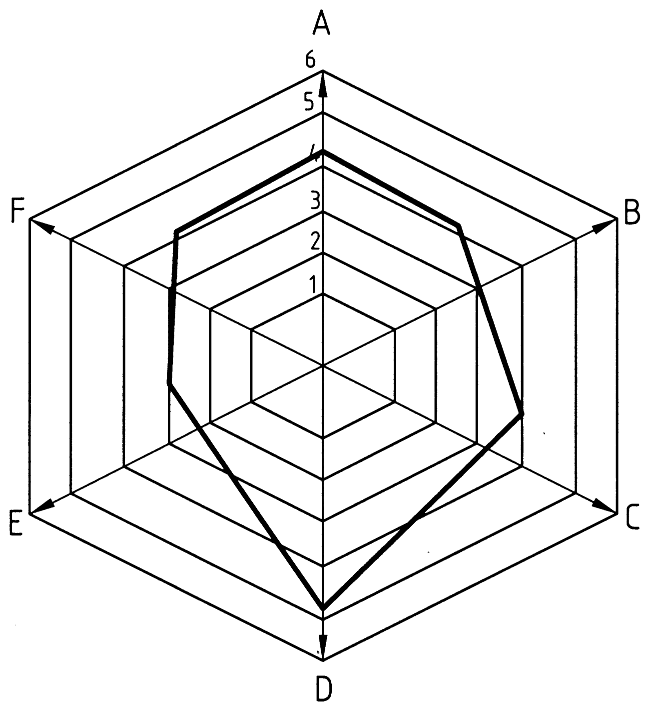
A primary raw sludge is produced in an urban WWTP, the sludge is dewatered on band filters after conditioning with polymer. Dewatered sludge is used in agriculture as a soil improver in a radius of 30 - 40 km from the WWTP.

Local storage of dewatered sludge is located besides the dewatering building for the winter time and non-spreading periods. The sludge quality in terms of heavy metals and organic contaminants is good, but it is not biologically stabilised. The dry solids content is about 30%, making the sludge mechanically easy to handle.

Daily operations required are basis, the maintenance of the bands filters is easy to manage and the operators do not require a high level of training. All operations are classified as easy. Investment and operating costs including transport and spreading are minimised to the low level cost. Risks are not from the process side, except for the proximity principle and sociological acceptance.

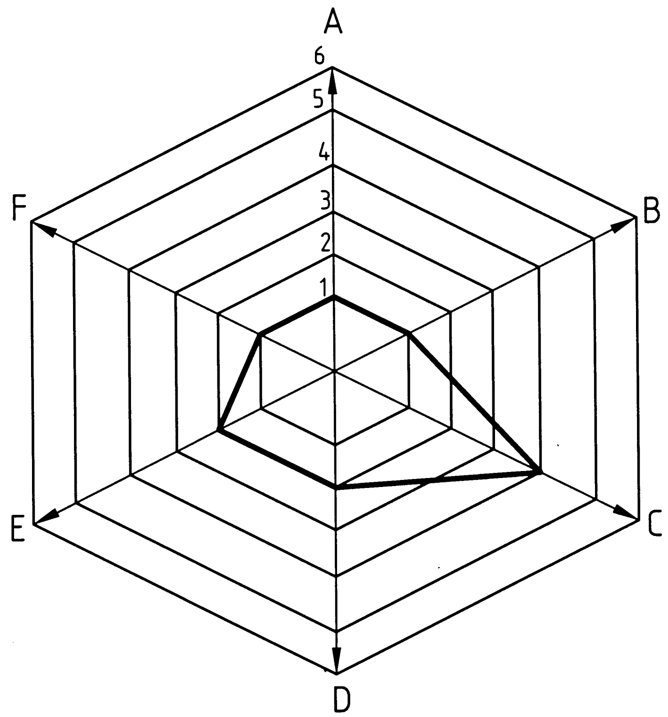
Finally, environmental impacts are reduced to a minimum level, no volume of waste is disposed in landfill. Energy is only used for transport and spreading. The CO_2 balance is not affected, but smells and local impacts (storage) are unpleasant.

The table gives the different degrees for Axes 1 to 6. They are :



Case study : Scenario N° 2

The scenario described above changes. The primary sludge becomes contaminated by organic pollutants above the maximum limit for agriculture use. At this time, operators have no other route than to transport the sludge to landfill. The situation stays the same for operators and maintenance. There are no changes in terms of operations and management as seen from their perspective. All others points become worst and the new matrix becomes the following :

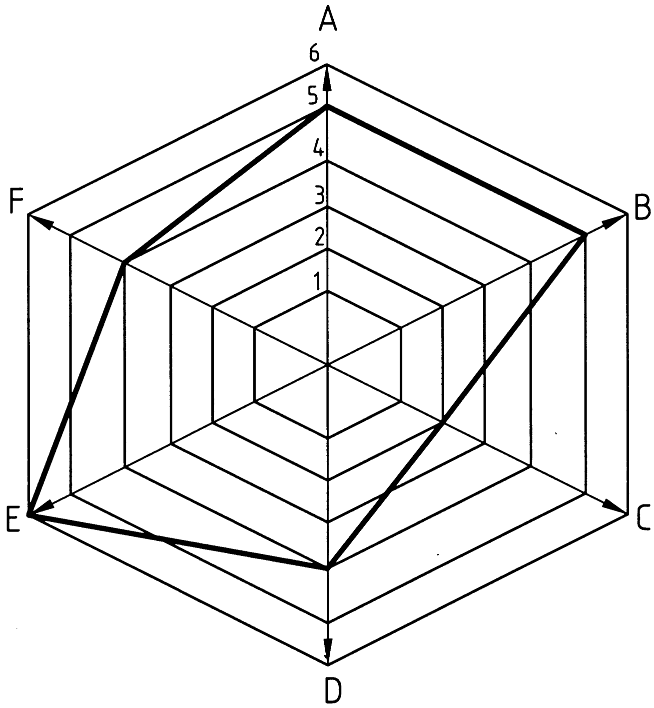


Axis A:1
Axis B:1
Axis C: remains 4
Axis D:2
Axis E:2
Axis F:1

Case study : Scenario N° 3

For this case study, a preliminary feasibility study gives the following conclusions: increased landfill cost indicates that the primary sludge has to be reduced in terms of volume and that the material could be burnt as a source of energy (e.g. cement industry, power generation). One option is to reduce dramatically the volume by drying and pelletising to 90% DS.

Operations and maintenance have to be reinforced and operators must be trained. The cost analysis shows that the average cost of treatment decreases. Long term waste is avoided. Energy is consumed for drying but economy is realised in sludge handling. The CO_2 balance is increased but energy level is maintained low and because natural gas produces low level in CO_2 as well. Odours are located to the drying building and local impacts are improved (no storage of dewatered sludge on site). Then, the matrix becomes :



Axis A: increase 1 to 5
Axis B: increase 1 to 5
Axis C: increase 4 to 2
Axis D: increase 2 to 4
Axis E: increase 2 to 6
Axis F: increase 2 to 4

Conclusion

The multi-scaling diagram shows a dynamic method of a real strategic and a global approach of sludge disposal. This is a tool for undertaking the preliminary studies of sludge processes and final disposal route.

Annex G
(informative)

Sludge questionnaires

The following questionnaires were developed by CEN/TC 308 Working Group 3 to collect data on the production, quality and disposal of sewage sludge, water treatment sludge and industrial sludges in each of the Member States. However, no finance has been available to support the data collection exercise and the questionnaires have not so far been used.

G.1 Draft Questionnaire : Sludge from Public Water Supply Treatment Plants

Please complete the following questions/tables. Please use SI Units.

A General Information

1 Please indicate on which of the following your data are based :

The period 199_ to199_ ☐

Statistical data for the year 199_ ☐

Predictions for the year 199_ ☐

2 Name and address of the person to whom correspondence should be addressed :

Name ___________________

Institution ____

Mailing Address ____

____

____

City and Province ____

Postal Code ____

Country ____

Telephone Number _______________ Fax Number _________________

e-mail ___________________________

3 Quantity of water supplied (sum of treated and untreated):______ x 10^6 m^3/year

B Treated water

4 Please give the amount of water treated for the period specified in A.1 referring to the capacity of the treatment plants in operation:

Capacity of treatment plant $10^6 m^3$/year[a]	**Number of plants in operation with this capacity**[b]		**Amount of treated water** 10^6 m^3/year	
	not producing sludge	**Producing sludge**	**not producing sludge**	**Producing sludge**
>20				
10-20				
5-10				
1.5-5				
0.5-1.5				
<0.5				
Total				

5 Please characterise the raw water that was treated:

Raw water specification

Raw water specification	**Amount of treated water** 10^6 m^3 /year	**Sludge produced** t DS/year
spring water		
groundwater		
recharged groundwater		
groundwater from bank filtration		
lake-water		
river-water		
reservoir-water		
other raw water		
Total		

[a] Every treatment plant should be mentioned

[b] If a value for capacity is not available, refer to the amount of water treated

C Sludges produced

6 Please characterise the different types of sludge produced :

Table G.1 — Sludge specification according to the EWC (European Waste Catalogue)

EWC code number		Amount of treated water 10^6 m/year	Sludge produced t DS/year
19 09 02	sludges from drinking water clarification		
19 09 03	sludges from decarbonation		
19 09 04	used activated carbon		
19 09 99	other wastes		

Table G.2 — Sludge specification according to this questionnaire

Sludge specification	Amount of treated water $10^6 m^3$/year	Mass of sludge produced t DS/year
Al-flocculation sludge		
Fe-flocculation sludge		
Sludge from slow sand filtration		
Sludge from the reduction of iron or manganese		
Sludge from softening processes		
Powdered activated carbon sludge		
Water sediments		

7 Please fill in the amounts of sludges that were obtained as a result of producing water for different purposes (if known).

Table G.3 — Sludge produced

Usage of water	**Amount of treated water** 10^6 m^3/year	**Produced mass of sludge** tDS/year
Drinking water		
Water for industrial use (used at your plant		
Water for industrial use (used at another plant)		
Water for infiltration		
Water for other use		

8 Please specify the treatment of the sludge:

Table G.4 — Sludge treatment

Treatment process	**Total amount of sludge** t/year	**Additives** t/year	**Dry solids** tDS/year	**L.O.I.** [a] **%**
physical conditioning (heating, freezing)				
Chemical conditioning				
Draining (e.g. drying bed)				
Mechanical draining (e.g filtration centrifuge)				
Other process:				
no treatment (e.g. pumping to sewage treatment plant)				

[a] Loss on ignition

9 Parameters characterising the sludges (if available) :

Parameter	**Minimum**	**Maximum**	**Arithmetic mean**
L.O.I %			
pH-Value			
% DS			
Calorific value			
Others:			

10 Chemical characterisation of the sludge (if available):

Substance	**Minimum** mg/kg DS	**Maximum** mg/kg DS	**Arithmetic mean** mg/kgDS	**Total amount of substance** kg/year
Al				
As				
Ca				
Cd				
Cr				
Cu				
Fe				
Hg				
Mo				
N				
Ni				
P				
Pb				
Zn				
Others: (e.g. S, Mn, B, K, Ag, etc.)				
Others:				

D Utilisation and disposal

11 Utilisation of water supply treatment plant sludges. The utilisation methods are subdivided in groups marked by the underlined bold title.

Utilisation	**Total amount of sludge** t/year	**Dry solids** t/year	**Sludge characterisation**[a]	**Average cost** Euro/tDS
Water utilities:				
Coagulant recovery				
Municipal waste water treatment				
H_2S Binding				
Phosphate removal				
Waste water sludge dewatering				
Coagulant recovery				
Compost production with waste water sludge				
Agriculture and Forestry				
Soil conditioning				
Lime products				
Fertiliser				
Industrial business				
Cement production				
Brick production				
Filler for e.g. paper				
Others (specify)				
Environmental Technology				
Cultivation of wasteland, heaps of refuse, landfills				
Landscaping works				
Others:				

[a] Please give the treatment process that produced the main part of the sludge used for this utilisation. Code numbers for treatment processes: 1: Al-flocculation-sludge, 2: Fe-flocculation-sludge, 3:Sludge from slow sand filtration, 4: Sludge from the reduction of Iron or Manganese, 5: Sludge from softening processes, 6: Powdered activated carbon sludge, 7: Water sediments

12 Please give the amount of disposed sludge:

Way of disposal	**Total amount of Sludge** t/year	**Dry matter** t/year	**Average cost** Euro/tDS
disposal as waste water			
municipal landfill			
landfill owned by the water treatment company			
Others:			

13 Do you expect a major change within the near future (next 5 years) for the data given above ?

____

If so, please specify the expected change, e.g. amount of treated water, amount of sludge, specification of the sludge, number of treatment plants, total capacity…

G.2 Draft questionnaire : Sludge from waste water Treatment Plants

Please fill in the following questions/tables. Please use SI Units.

A General Information

1 Please indicate on which of the following your data are based :

The period 199_ to199_ ☐

Statistical data for the year 199_ ☐

Predictions for the year 199_ ☐

2 Name and address of the person to whom correspondence should be addressed :

Name ____________________________

Institution____

Mailing address____

____

____

City and province ____

Postal Code ____

Country ____

Telephone Number_____________________ Fax Number _____________________

e-mail ________________________________

3 Quantity of water treated __________ x 10^6 m^3 /year

Table G.5 — General Information

	Waste water Treatment Plant (WWTP) actual population equivalent			
	<2,000	2,000-15,000	15,000-150,000	>150,000
Total population (millions)				
Population connected to sewer (%)				
Population connected to WWTP (%)				
Population connected to sewer in 2005 (%)				
Population connected to WWTP in 2005 (%)				
Number of WWTP				
WWTP with combined sewerage (%)				
WWTP currently with primary treatment (%)				
WWTP currently with secondary treatment (%)				
WWTP currently with advanced treatment (%)				
WWTP with primary treatment in 2005 (%)				
WWTP with secondary treatment in 2005 (%)				
WWTP with advanced treatment in 2005 (%)				

Table G.6 — Amounts of sludge stabilised and dewatered (tonnes dry solids per year)

Stabilisation	**Dewatering**							**Total**
	None <10%DS	**Mechanical 10-50%DS**	**Drying bed**	**Thermal drying>50%**	**Other -------**	**Liquid storage**	**Dewatering storage**	
None								
Aerobic								
Anaerobic								
Other*............								
………								
....								

— e.g. composting, lime treatment

Table G.7 — Sludge quality - general parameter`s and nutrient contents

Determinand	Units	Arithmetic mean	Weighted mean	Median	Minimum	Maximum	Number of samples
Dry solids (DS)							
Volatile solids							
Loss on Ignition							
pH							
Calorific value							
Conductivity							
Nitrogen (total)							
Ammonia							
Phosphorus (total as P)							
Potassium							
Magnesium							
Calcium							
Others........................							
....							
....							

Table G.8 — Sludge quality - cocentrations of potentially toxic elements

Determinand	Units	Arithmatic mean	Weighted mean	Median	Minimum	Maximum	Number of samples
Zinc							
Copper							
Nickel							
Cadmium							
Lead							
Mercury							
Chromium							
Selenium							
Arsenic							
Molybdenum							
Fluride							
Others (e.g. Ag)							
....							
....							
....							

Table G.9 — Sludge quality - concentrations of organic contaminants

Determinand	Units	Arithmatic mean	Weighted mean	Median	Minimum	Maximum	Number of samples
PCB Σ							
Congener..........							
....							
....							
PAH Σ							
Dioxins ∑TEQ...							
AOX							
Pesticides							
....							
....							
Others							

Table G.10 — Quantities of sludge recycled or disposed (tonnes dry solids per year)

Outlets		Quality tDS/year
Recycling	Agriculture - arable	
	- grassland	
	- other	
	....	
	Land reclamation	
	Forestry - timber production	
	- wood energy crops	
	Composted	
	Fertiliser products	
	....	
	Subtotal	
Incineration*	Sludge only	
	Other	
	....	
	....	
	Subtotal	
Landfill**	Mono-disposal	
	Co-disposal	
	Subtotal	
Sea	Vessel	
	Pipeline	
	Subtotal	
	TOTAL	

* e.g. co-combustion, gasification, pyrolysis, etc.

** exclude incinerator ash disposal

Table G.11 — Quantities of energy and ash produced from sludge incineration

Sludge incineration	
Energy generated	MW/year
Ash use	t/year
....	t/year
....	t/year
....	t/year

Table G.12 — Estimated sludge production by the year 2005

Size range of WWTP (pc)	tDS per year by 2005
<2,000	
2,000-15,000	
15,000-150,000	
>150,000	

Table G.13 — Trends in sludge treatment and disposal by the year 2005

		Trend*
Treatment	None	
	Aerobic	
	Anaerobic	
	Composting	
	Thermal Drying	
	Lime Stabilisation	
	Other*	
	....	
	....	
Outlet Utilisation	Agriculture – arable	
	- grassland	
	- other	
	....	
	Land reclamation	
	Forestry - timber production	
	- wood energy crops	
	Other	
	....	
	....	
Incineration	Sludge only	
	Other	
	....	
	....	
Landfill	Mono-disposal	
	Co-disposal	

* indicate trend by: = no change +, ++, +++ small to large increase in use of outlet
--, --- small to large decrease in use of outlet

G.3 Draft for Questionnaire

Industrial Sludges

Please complete the following questions, tables. Please use S1 units.

Introduction

This questionnaire concerns industrial organic sludges, which are similar to sludges produced in urban waste water treatment plants.

The following industrial sectors are addressed according to urban waste water directive 91/271/EEC) :

1 Dairy Farming ;

2 Production of fruit and vegetable products ;

3 Production and bottling of soft drinks ;

4 Potatoes processing industry ;

5 Slaughterhouse industry ;

6 Breweries ;

7 Production of alcohol and alcoholic liquors ;

8 Production of animal food of vegetable products ;

9 Production of gelatine and gule of hide, skin and bone ;

10 Malt factories ;

11 Fish processing ;

12 Tanneries ;

13 Other agro-industries ;

14 Dyeing industries ;

15 Pulp and paper industries ;

16 Pharmaceutical Industries ;

17 Others (please specify).

The following are examples of industrial sectors excluded from this questionnaire :

— Mining industries ;

— Oil and refineries ;

— Metal processing ;

— Chemical industries.

and all industries producing nuclear or hazardous waste.

A General Information

1 Please indicate on which of the following your data are based:

The period 199_ to199_ ☐

Statistical data for the year 199_ ☐

Predictions for the year 199_ ☐

2 Name and address of the person to whom correspondence should be addressed:

Name ______________________________

Institution ______________________________

Mailing address ______________________________

____

City and province ______________________________

Postal Code ______________________________

Country ______________________________

Telephone Number ______________________ Fax Number ______________________

e-mail ______________________________

Please complete this questionnaire separately for as many of the above sectors as possible.

B General Data

1 Industry sector: Please insert your sector number according to the list in the introduction ____

2 Total effluent load produced by all industries of this sector: __________ t BOD^5/year

3 Total effluent load treated on site of the sector: _____________________ t BOD^5/year

4 Effluent load treated on external plant like municipal sewage plant:: ________ t BOD^5/year

5 Production of products in tons, m^3 or H1 (Hectolitres) from this sector: _______________

6 Previous given figures represent: _____________ % of the production of the industrial sector

7 Water consumption from sector including only the total water released as waste water

_____________ m^3/year

8 Does the sludge production include the production of process water: Y/N

Question 9 should only be answered if question 8 is yes.

9 Please estimate the volume of sludge arising from the process water production:

_____________ tonne/year wet sludge. Estimation of water content.

10 Total number of waste water treatment plants on site: ________________

11 Total design capacity of the waste water treatment plant: _____________ m^3

C Quantities of sludge produced

Amount of sludge in the sector		Liquid <10% DS	Dewatered 10-50% DS	Dried >50% DS
	Tons of sludge that are stabilised			
	Tons of sludge that are not stablised			
	Tons of sludge that are composted			

D Sludge outlet (tons/year)

	Liquid <10% DS	Dewatered 10-50% DS	Dried >50% DS
Recycling			
Agriculture			
Incineration			
Land reclamation			
Landfilling			
Other*			
Total			

* please specify other outlet ____

V Principal components in the sludge

Sludge Contents																				
		N-tot	P-tot	Ca	Mg	K	Zn	Cu	Ni	Cd	Pb	Hg	Cr	Se	As	Mo	F	PCB	Nonyl-plenol	Toluene	Others (e.g. Ag)
Outlet	Units																				
Utilised	Maximum Average																				
Agriculture	Maximum Average																				
Reclamation	Maximum Average																				
Landfilling	Maximum Average																				
Other use	Maximum Average																				

Annex H
(informative)

National inquiry in Germany to test the practicability of the draft questionnaires

Introduction

CEN/TC 308 WG3 developed three questionnaires to derive information on type, quality and outlet of water treatment sludge, sewage sludge and industrial sludges. The translated draft questionnaires were the basis of a national inquiry in Germany. The study was conducted by DIN, Burggrafenstr. 6, 10787 Berlin and sponsored by Umweltbundsat, Bismarkplatz 1, 14193 Berlin under research reference number 298 71 278.

This Annex presents the results of testing the applicability of the draft questionaires for Public Water Supply Treatment Plants and Waste Water Treatment Plants. It was not possible to assess the practicability for industrial sludges because there was only one partially completed questionnaire.

Sludges from Public Water Supply Treatment Plants

There are more than 6,300 waterworks utilities (WWU) in Germany. In the survey carried out by questionnaire into sludge from public-sector waterworks (waterworks sludge), a random sample of 29 WWU was addressed. The selection of the WWU was not intended to be representative of Germany as a whole, but instead it was oriented to the following criteria :

— WWU where waterworks sludge is accumulated ;

— the main types of residuals, namely sludge from the separation of iron and manganese, Fe-flocculation sludge, Al-flocculation sludge and sludge from softening processes ;

— a range of sizes of WWU ;

— a regional distribution of WWU throughout Germany ;

— selection of a few WWU where more precise knowledge is available. In the case of these WWU, it was possible to check whether any difficulties in completing the questionnaire had led to errors.

The questionnaires were returned by 22 WWU (= 76% of the sample) their total water treatment was $969 x 10^6$ m^3/y ($19 x 10^6$ m^3/y without sludge production and $950 x 10^6$ m^3/y with sludge production). This is approximately 20% of the total water treatment in Germany.

It must be stressed that the detailed results of the survey are not representative of Germany as a whole. For example, the utilization rate within the sample was 87% which is is certainly considerably more than for Germany as a whole.

The survey indicates that the landfill disposal method is tending to be used less. Of the 22 WWU who responded, 3 WWU stated that they wanted to abandon the landfill disposal method and intend to perform disposal either as wastewater to public sewer or through utilization.

A most significant conclusion from the survey is that the questionnaires generally proved to be usable. Nevertheless, the following basic criticisms can be made :

— it proved difficult to compare the costs of different methods of disposal because the questionnaire did not enquire into the component costs.

The inquiry into costs in the unit ECU/tDS proved difficult for WWU. Generally WWUs recognise costs per ton disposed or per cubic metre disposed in DM and often stated DM/t, DM/t DS or EURO/t without detailing the unit used. Several phone calls had to be made to clarify the situation. It would have been easier to ask the questions in DM and convert to the EURO during the evaluation of the questionnaires.

The main current utilization possibilities according to the DVGW work sheet W 221/III and statements from specialist literature on the utilization potential of waterworks residuals are presented. A rough estimate of the utilization potential is put at some 95-100%, depending on the type of sludge. The DVGW/ESWE study of 1992 put the total amount of waterworks residuals for 1992 at around 125,000 tDS - the works responding to this survey produced a total of 35,000 tDS (28% of 1992 total). The breakdown of the disposal methods for waterworks residuals was also taken from the specialist literature. According to this, landfill is used for approx. 50% of residuals. However, apart from sludge, the amounts stated also include other waterworks residuals.

Sludges from Wastewater Treatment Plants

152 communes and federations who operate Wastewater Treatment Plants were asked to complete the questionnaire. 63 of them answered (sometimes with more than one questionnaire), but the data reported were very different. Some respondants only completed some of the tables in their questionnaires and often the data about sludge quality could not be related to data about sludge outlet. Therefore different amounts of data are available for the interpretation of different parameters. In most cases the data were from investigations in 1996 to 1998.

The information from the 62 institutions gave a total amount of treated wastewater of $1.7x10^9m^3$ per year, which is 17 % of the wastewater treated in Germany in 1995. The actual population in the 59 institutions who returned data is about 16 million inhabitants (nearly 20% of the population of Germany). The 63 institutions work with 184 WasteWater Treatment Plants (WWTP), nearly the same amount in each group of the actual capacity which are named in the questionnaire. The majority of WWTP works have combined sewage. Often there is a secondary (biological) or advanced treatment, a few, usually small plants only have primary treatment. Respondents forecast an increase of advanced treatment from the current 40 % to 54 % by 2005.

62 institutions gave information about the outlet of sewage sludge. The total annual amount was about 406,200tDS, which is nearly 20 % of the total amount of sewage sludge in Germany. Anaerobic stabilisation and mechanical dewatering were the principal treatment methods.

60 institutions gave data about general parameters and nutrient content from 84 plants. Often only information about dry solids, pH, nitrogen (total), ammonia, phosphorus, potassium, magnesium and calcium were given. Data for all these parameters fluctuate within a wide range. Differences between treatment methods and differences between the collection areas of WWTPs may explain some for this variation. To get an average nutrient content, valid data were weighted with the amount of sludge (tDS) used or disposed. The following weighted means of nutrient contents represent 40 % to 50 % of the total sludge output of the WWTPs in the inquiry :

Nitrogen (total)	2,4%DS
Ammonia	0,3%DS
Phosphorus (P_2O_5)	3,9%DS
Potassium (K_2O)	0,2%DS
Magnesium (MgO)	0,7%DS
Calcium (CaO)	8,1%DS

Considering the plant availability and content of nutrients in 5 tDS sewage sludge in relation to the nutrient requirement of a typical 3 year crop rotation, one could classify the supply of nitrogen, potassium and magnesium as ranging from poor to moderate whereas phosphorus would be between adequate and rich, depending on the content of available phosphate in the soil. In a phosphorus-rich soil the supply from 5 tDS sludge may exceed the requirement of the crop rotation and the sludge may have to be reduced accordingly.

Also the contents of PTEs (arithmetic mean) fluctuated in a wide range. Contents above the limit values of the Sewage Sludge Ordinance were given by three institutions in the case of zinc (respectively 6 institutions in the case of the special limit value for sandy soils or pH between 5 and 6) and by one institution in the case of cadmium and copper. Contents of lead, mercury and chromium never exceeded the limit value. But this result could change if the limit values of the Sewage Sludge Ordinance were lowered in the future. A valid part of the data (representing nearly 73 % of total sludge outlet of this inquiry) give the following weighted means of heavy metal content :

Zinc	1107 mg/kg DS
Copper	393 mg/kg DS
Nickel	32 mg/kg DS
Cadmium	2,0 mg/kg DS
Lead	93 mg/kg DS
Mercury	1.6 mg/kg DS
Chromium	81 mg/kg DS

Contents of organic contaminants (arithmetic mean) above the limit value of the Sewage Sludge Ordinance of Germany were given only by one institution in the case of AOX. The contents of PCB and dioxins never exceed the limit values. PCB contents cannot be weighted because data were often reported as being below the detection limit. The weighted mean of dioxins was 14,5 ngTEQ/kgDS, and of AOX was 155 mg/kgDS (representing nearly 60 % of the total sludge production of the inquiry). Information about some PAHs were given by a few institutions (there are no limit values for these contaminants), but there was no information about other organic contaminants.

Nearly 56% of the current sludge output was recycled (the majority being utilized on arable land), 44% was disposed (the majority by incineration). Overall sludge from small WWTPs is more likely to be recycled whereas sludge from large plants is more likely to be disposed. The ash from sludge incineration will be recycled too.

Large WWTP forecast that sludge production will increase by the year 2005, the small ones (< 2,000 pe) forecast that sludge production will decrease. Considering all the WWTPs in inquiry, sludge production by the year 2005 is expected to increase by 8%.

Many institutions expected no change in sludge treatment by the year 2005. Those that did expect a change, thought there would be a ‘small to large increase’ in anaerobic treatment, and in sludge incineration and a ‘small to large decrease’ in agricultural utilization.

The institutions were also asked about the practicability and usefulness of the questionnaire and on perceived problems in interpreting the questionnaire. Only 14 (out of 63) institutions gave an opinion, and this was often limited to particular tables. However the following criticisms were submitted:-

The questionnaire about quality and outlet of sludge from WWTP is very extensive and the data which were asked for are sometimes not present at WWTP, this may be a reason for the small return of completed questionnaires (less than 50 %).

Some institutions commented that data are already available at some federal and state agencies and therefore a new inquiry was not efficient.

Other criticisms were that some tables were either not efficient or not intelligible, especially table 1. It was felt that the data in table 1 about combined sewage and treatment methods should be relate to the amount of combined sewage or treated wastewater and not to the number of WWTP.

In general, it was felt that the content of the tables should be adapted to national realities (for example dewatering techniques, units, allowed recycling or disposal routes). This would reduce the extent and minimise the confusion during answering the questionnaire, and also minimise some problems in the interpreting the data. In addition, it was felt necessary to define some parameters such as PAH-Σ and to give information about the background and intention of some tables.

Summarising the remarks above, the draft questionnaire is not suitable for a representative national inquiry about quality and outlet of sludge from WWTP. Depending on structure and extension of the questionnaire, it is sometimes not possible to set information about sludge quality into relation with other data. Therefore a detailed description of sludge quality and the outlet of sewage sludge of a specific quality is only possible with a small, valid part of the whole data (40 to 70 % of total sludge amount of the inquiry). Because the questionnaire was not adapted to national realities, some information were not comparable with some others to the same subject and information could be misunderstood. For this reason a transfer of results of this inquiry on a German level is not possible.

Conclusions

It was always recognised by CEN/TC 308 WG3 that the questionnaires would have to be tested and would probably need to be refined in order to make them practicable for data collection. Respondents returned very interesting and useful data, and the study was a very valuable test of the draft questionnaires. Respondents found the questionnaire for water treatment works sludges easier to complete than the one for wastewater treatment sludges. Both proved that before the questionnaires are used, they need to be tailored for each country (e.g. into local currency and terms and expressions) in order that they are intelligible to those being surveyed, and that surveyors will have to transform the data so that they can be consolidated for European purposes. Respondents also felt that completion of the questionnaires would have been facilitated by explanatory information about the data fields and the aims and intentions of the questionnaires. Regrettably there was only one respondent for industrial sludges and therefore it was impossible to draw any conclusions about the practicability of that questionnaire.

ANNEX I Case study – demonstration of the effect of source control on chemical contamination of sewage sludge

The report has stressed the importance of source control to minimise the risk of chemical contamination of sludges. Figure 1 demonstrates the effect that source control has had in two urban wastewater catchments in London. Both catchments collect a combination of domestic and industrial wastwater and the drainage is a combined system, i.e. it collects surface water as well as wastewater.

Mogden wastewater treatment works serves a population equivalent of about 1.8 million in the west and north of London, and Deephams serves a population equivalent of about 0.8 million in north-east London. Source control has been practiced since the 1930s. Initially controls were set in order to protect the fabric of the sewers, workers in the sewers and on the treatment works, the treatment process itself and the rivers into which the treated water was discharged. Subsequently account was also taken of the potential impact from using the sewage sludges on farmland.

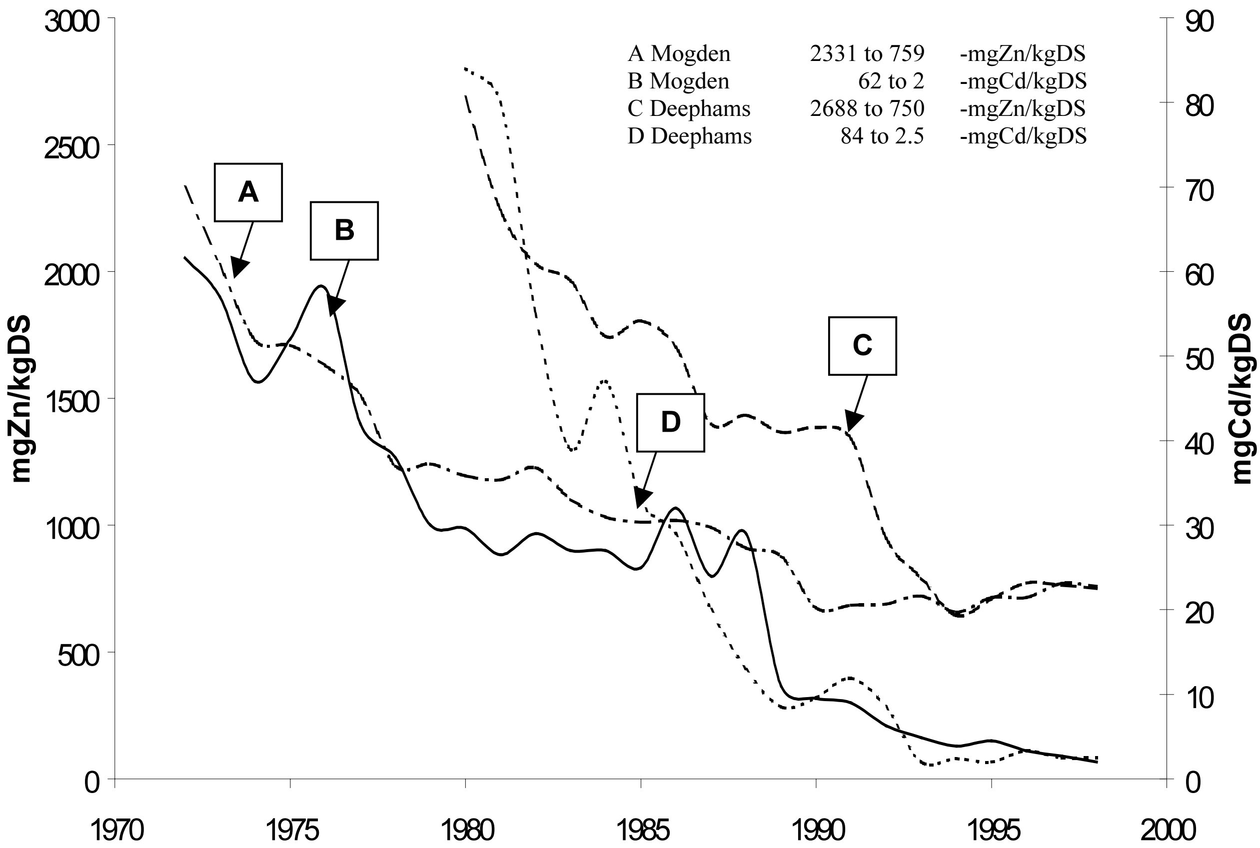


Figure I.1 Impact of source control on the content of zinc and cadmium in the digested sludges of two large urban wastewater treatment works that both have domestic and

Table I.1 shows the change in dioxin content of sewage sludge from Mogden between 1942 and 1988. The effect of legislation to regulate how such substances are used and discharged is obvious and very impressive. The analyses dated 1942 to 1960 are from samples that had been dried, stored and archived by Rothamsted Experimental Station as part of a long term field trial into the effects of sewage sludge. They were analysed in 1998 by Dr Rappe at University of Umea in Sweden. Surveys of modern sewage sludges in UK have consistently found <5ng∑TEQ/kgDS. These results confirm observations from elsewhere that legislation on the use and discharge of organic pollutants has controlled the risk of sewage sludge being contaminated.

Date	∑TEQ (ng/kgDS)
1942	18
1944	36
1949	61
1953	127
1956	402
1958	229
1960	166
1998	4.2

Table I.1 Change in dioxin content of Mogden's digested sewage sludge

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