NATIONAL WATER QUALITY MANAGEMENT STRATEGY

Guidelines for Sewerage Systems Biosolids Management

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Natural Resource Management Ministerial Council

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Preamble

This document is one of a suite of documents forming the National Water Quality Management Strategy (NWQMS). This Strategy aims to achieve the sustainable use of the nation's water resources by protecting and enhancing their quality, while maintaining economic and social development.

The series *Guidelines for Sewerage Systems* covers sewerage systems as a whole. Five separate documents deal with particular aspects of sewerage systems as set out in Figure 1. This document provides national guidelines for the management of biosolids. The focus of the document is to facilitate the beneficial use of biosolids.

It sets out principles that can form the basis for a common and national approach to the management of biosolids throughout Australia.

Figure 1 Diagrammatic Structure of the *Guidelines for Sewerage Systems*.

Guidelines for Sewerage Systems				
Acceptance of Trade Waste	Sewerage System Overflows	Use of Reclaimed Water	Effluent Management	**Biosolids Management**

Further information on the National Water Quality Management Strategy is given in Appendices 1 and 2.

Introduction

Terminology

Biosolids are the stabilised organic solids produced by wastewater treatment processes, which in most cases can be beneficially recycled. There is a preference in the United States and in Australia to use the term biosolids rather than sewage sludge. The term biosolids does not include untreated wastewater sludges, industrial sludges or the product produced from the high temperature incineration of sewage sludge. It should also be noted that many other solid waste materials are not classified as biosolids e.g., animal manures; food processing or abattoir wastes; solid inorganic wastes; and untreated sewage or untreated wastes from septic systems/sullage wastes.

Blended materials containing biosolids (such as soil improvers, fertilisers and composts) are included in this guideline. Throughout the document the generic term biosolids is used for both biosolids and products containing such materials. The term sewage sludge is used for human sewage and septic wastes that are unsuitable for beneficial recycling, either because of inadequate treatment or elevated contaminant levels.

Background

Biosolids are produced during the treatment of wastewater (for information on managing treated wastewater refer to NWQMS *Guidelines for Sewerage Systems - Reclaimed Water* and Guidelines series 16a to 20 of the *NWQMS Effluent Management Guidelines*). Typically, prior to thickening and dewatering, the volume produced is less than 1% of the total flow. Biosolids contain organic matter and plant nutrients and hence provide a useful soil conditioner and medium grade fertiliser. However, untreated sewage sludges may also contain pathogens (capable of causing disease in humans and animals), microorganisms such as bacteria, viruses, helminths (parasitic worm-like invertebrates), protozoa (small single celled animals including amoebae, ciliates and flagellants) and fungi. These organisms must either be destroyed by treatment or managed through controls on recycling. In addition, biosolids may contain various levels of chemical contaminants including metals from domestic and industrial sources.

In recent years new treatment methods and technologies have improved biosolids quality. At the same time there is awareness in the community of the value of this product and increasing community demand for its use. Factors such as source control through trade waste management and increasingly stringent regulation will produce further improvements in biosolids quality, thereby increasing the quantity of biosolids suitable for beneficial use. The trend towards improvement in effluent quality by removal of nutrients by chemical means has the potential to adversely affect biosolids quality by increasing iron or aluminium and associated trace contaminant content.

Biosolids contain a wide range of essential nutrients that are beneficial for plant growth. These include nutrients, nitrogen and phosphorus, and the trace elements calcium, magnesium, potassium, sodium, manganese, copper, zinc, molybdenum, boron and others.

These elements come into the sewage system via stormwater infiltration and domestic and industrial inputs. Research has shown that biosolids are valuable fertilisers and soil ameliorants which enhances plant production. Biosolids can provide a complete fertiliser effect by adding nutrients as well as organic matter to the soil (which improves soil structure and so also improves microbial health, and ability of the soil to infiltrate and to store water for plant growth). The inclusion of these nutrient elements into soils from biosolids use will have a beneficial effect not only on agricultural production but also on soils for forestry and for rehabilitating land. (Most Australian soils have naturally low levels of the elements mentioned above).

The processes required for Australia to move towards increased use of biosolids include:

- a shift from disposal by land filling or storage at sites such as wastewater treatment plants to use for beneficial processing or land application;
- implementation of cost effective biosolids management strategies by sewerage authorities;
- continued improvements in trade waste management;
- provision of controls to protect the environment;
- provision of controls to protect public and occupational health and safety;
- provision of controls to protect food crops from exceeding residue limits;
- localised public education to provide useful information on the beneficial uses of biosolids in all sectors;
- encouragement of the use of biosolids by promoting biosolids products;
- definition and classification of various grades of biosolids;
- establishment of guideline procedures for monitoring, reporting, record keeping and auditing; and
- continued research to provide confidence in biosolids use.

Purpose of Document

The purpose of this document is to provide national guidelines and a uniform approach to the management of biosolids with the focus on the beneficial use of biosolids as a resource, however, where available, relevant State/Territory guidelines should be consulted for more detailed requirements. Where specific issues have necessitated that a parameter in a State/Territory guideline differs from this document, the State/Territory guideline should be followed. State/Territory guidelines and this National Guideline may also change as new information on biosolids become available.

The major risk of human contact with products derived from biosolids is infection from microorganisms. These guidelines describe procedures for minimising public health risks and environmental harm arising from the application of biosolids. The guidance provided on the application of biosolids to land should also ensure that microbiological and chemical contamination of the soil does not occur.

These Guidelines have been developed for water resource managers, sewerage authorities and regulators developing biosolids management systems. It can also be used as a reference for industry and environmental groups and the broader community.

The Guidelines are designed to provide a framework for biosolids management which:

- promotes responsible management of biosolids;
- protects public health and the environment;
- promotes consistent practices;
- is sustainable;
- informs and is acceptable to the community; and
- allows for local conditions and requirements to be considered.

The specific values used for classifying biosolids and management provisions may change in the future as further local knowledge and overseas research becomes available. These Guidelines are based on practices used overseas and in Australia that have been demonstrated to be protective of the environment, public health and agricultural produce. In areas of uncertainty, the guidelines are designed to take a conservative approach; however, this may be reconsidered as new evidence becomes available.

Scope

The management practices mentioned in these Guidelines include:

- use of biosolids by beneficial land application e.g., on agricultural lands, in landscaping, site rehabilitation and forestry;
- land disposal of sewage sludge e.g., by landfill; and
- use of biosolids as a raw material for other products, e.g., oil from sludge.

These Guidelines deal with biosolids from municipal (i.e., community) wastewater plants treating domestic and industrial wastes, but not with sludge/wastes from individual household systems e.g., sullage, grey water or effluent from residential aerobic treatment units or septic tanks. Concentrated solids from treatment plants for specific industries such as piggeries, tanneries, wineries and wool scouring are the subjects of separate guidelines under the NWQMS (these guidelines are listed in Appendix 2).

Use of biosolids within the boundaries of municipal wastewater treatment plants is typically covered by either State/Territory specific licensing requirements or 'in house' operational safeguards and practices and is outside the scope of these guidelines.

Objectives

The objectives of these guidelines are to:

- encourage development of sustainable and cost effective biosolids management strategies by sewerage authorities;
- ensure that adequate controls are developed when using biosolids to protect the environment, agricultural systems and public health and with regard for occupational health and safety;

- set guidelines for defining and classifying various grades of biosolids;
- establish guideline procedures for monitoring, reporting, record keeping and auditing; and
- inform and provide information to the community on the risks and benefits of this product.

Principles

These Guidelines are based on the following principles.

Sustainable Development

The principle of sustainable development is to improve social well-being and economic opportunity whilst using natural resources wisely and caring for the environment. This includes maintaining environmental quality and ecological integrity while providing for present and future generations. Recognition of the beneficial value of biosolids and maximising its use in the appropriate circumstances is compatible with the principle of sustainable development.

Existing practices previously demonstrated to be safe and beneficial together with the current state of knowledge and Australian conditions have been taken into account in the development of these guidelines.

Public Health and Environmental Protection

Guideline values for contaminants, levels of treatment and good management practices have been provided to safeguard public health, commodity markets and the environment.

These guidelines are based on a combination of Australian and European scientific data and practice, and the health and environmental risk assessment methodology used by the United States Environment Protection Agency (USEPA). The National Environment Protection Measure [National Environmental Protection (*Assessment of Site Contamination*) Measure 1999] and regional requirements and practices have also been considered.

These guidelines provide a broad generic framework to manage biosolids; it is not intended to recommend a detailed 'code of practice' which would be applicable in each State/Territory. This is because it is necessary to take into account local conditions and the need to consult with local regulators such as State/Territory health authorities or environmental regulatory agencies, which may approve or require practices different from, or more stringent than in these guidelines.

Community Involvement and Public Consultation

A high degree of public acceptance is essential for biosolids projects. There is a significant level of goodwill by the community towards the concept of beneficial use of biosolids provided procedures for managing the risks is in place. However, to retain this acceptance, communities should be kept well informed of the use of biosolids in their local areas. It may also be prudent to undertake community engagement/information/education programs to assist in promoting biosolids use.

The *Implementation Guidelines* of the National Water Quality Management Strategy (NWQMS) describe the steps in developing plans and taking action to manage water resources. The wider issues of community consultation in relation to treated effluent management are discussed more fully in the *1997 Guidelines for Sewerage Systems, Effluent Management.*

Simple Administrative Classification/Framework
A simple biosolids product classification framework indicates end-use options, while taking into account factors relating to risk analysis, assessment and assurance. The framework is also flexible, so that it can be updated as new information becomes available.

Integration with State/Territory Practice
These Guidelines may be complemented by State/Territory guidelines, 'codes of practice', regulations or legislation which take into account regional and local issues and specific site conditions.

Where there are particular concerns due to specific local conditions or there are industries sectors that require particular attention, additional measures may need to be taken at State/Territory level.

Waste Minimisation
Beneficial use involves principles of risk management, but the aggregate risks and benefits of well-managed use should outweigh non-utilisation disposal options such as the premature filling of sanitary landfill. Of equal importance is the reduction of the level of contaminants in biosolids. Source control of industrial and domestic waste is essential if the objectives of volume reduction and a reduction in contaminant levels in biosolids are to be achieved (refer to 1994 *Guidelines for Sewerage Systems - Acceptance of Trade Waste (Industrial Waste).* Source control should go beyond achievement of trade waste standards and focus on cleaner production and waste minimisation.

Legal Liability

This document identifies procedures and practices for the management of biosolids which are considered both reasonable and responsible in relation to other parties and the environment.

Statutes have identified penalties for actions that may, or do degrade the environment. In some cases 'due diligence' is claimed to be a defence against penalties. In this context, 'due diligence' may be seen as a proactive caring for the environment. The procedures identified in this document provide a means of avoiding degradation of the environment but will not absolve those people responsible from their 'duty of care'. Compliance with these guidelines does not guarantee a defence against penalties. It remains for each individual to be aware of the requirements of the various statutes and be satisfied that they have complied with all necessary safeguards and procedures.

There are many precedents in common and statutory law that identify the responsibility and the liability of individuals for the products they manage, distribute and/or dispose of. Such responsibilities also apply to managers of biosolids.

To minimise exposure to legal and financial risks biosolids managers should have appropriate environmental management systems in place (such as ISO 140001). These systems should ensure:

- compliance with relevant State/Territory standards and regulations and compatibility with Federal guidelines;
- sampling and testing programs are in place;
- the development of a system for reprocessing or disposal of biosolids which are unsuitable for use;
- appropriate training for staff and contractors to understand legal requirements and risks;
- biosolids records, including where the biosolids were disposed of or applied, so that these records can be retrieved at a later date;
- provision of clear, accurate and comprehensive information to consumers on limitations or restrictions on biosolids uses and other relevant issues;
- the development and implementation of a quality assurance program that provides public confidence in treatment, monitoring, reporting, record keeping and auditing; and
- the development of protocols ensuring that appropriate contractual arrangements are in place and those responsibilities of the respective parties are clearly set out.

Issues

Public Health Issues

Inappropriate management of biosolids has the potential to pollute surface waters, groundwater the soil, the air and the food chain. All of these pathways can lead to health risks in humans. Proper management of biosolids is therefore essential to avoid these problems.

The primary public health concern from the use of biosolids arises from exposure to microbial contaminants. Adverse health effects can occur from a single exposure to relatively low numbers of organisms. Conversely, adverse health outcomes from chemical contamination of biosolids could result from repeat exposure over long periods of time.

Microbial
These national guidelines recognise the need to ensure that public health is not compromised through using biosolids with inappropriate pathogen levels. Table 1 provides a biosolids pathogen grading according to the amount of pathogens present and treatment techniques to reduce pathogens in biosolids.

The major risk of human contact with product derived from sewage wastewater is infection from microorganisms. Sewage sludge should be managed on the assumption that a proportion of the population, at any given time is excreting pathogenic organisms. Of the variety of human pathogens present in wastewater, those of particular concern are:

- viruses;
- bacteria;
- protozoa; and
- helminths (worms).

Viruses derived from human faeces may be present in untreated sewage sludge in large numbers. They can survive for prolonged periods in moist conditions.

E.coli and/or faecal coliforms are widely used as bacterial indicators of faecal contamination and biosolids treatment efficiency. However, these organisms are not typically pathogenic. The key bacterial pathogens that need to be considered with biosolids management include Salmonella and Campylobactor sp.enterohaemorrhagic E.coli of erotype 0157:H7 and Listeria montocytogenes.

Protozoa can cause disease in humans and infective forms are known to be present in wastewater as oocysts (Rose, 1997). Transmission of several protozoan infections by vegetables was reported to be due to use of contaminated water on the crops (Froese and Kindzierski, 1998). Three species of enteric protozoa are of particular importance and can cause moderate to severe enteritis. These are:

- *Giardia intestinalis = Lamblia;*
- *Entamoeba histolytica;* and

- *Cryptosporidium* spp.

Two water borne free-living amoebae, *Naegleria* and *Acanthamoeba,* which occur naturally in aquatic environments and soil have been responsible for opportunistic human infections in Australia (ARMCANZ/NHMRC 1996 *Australian Drinking Water Guidelines*).

Parasitic helminths are of two types:

- roundworms (nematodes); and
- flatworms.

Their life cycle may be very complex, and many require an intermediate host. Helminths, which can be transmitted to humans through wastewater, are endemic in some areas of Australia. In hookworm endemic areas (northern areas of Australia) it may be necessary to test biosolids for the presence of hookworm and thus determine whether special precautions will be necessary.

Chemical
If biosolids are tainted by contaminants from domestic or industrial sources its use for agricultural purposes may result in the accumulation of chemicals in agricultural commodities. Maximum levels of chemicals in food are established in national food standards (ANZFA Food Standards Code 2000 Standard A12), which are generally based on measures such as standards for Acceptable Daily Intake (ADI) specified contaminants. The main compounds of concern in biosolids are metals, chlorinated organic compounds and pesticides.

In urbanised areas, pest control, household and garden products may be significant sources of contaminants through incorrect disposal of waste to sewers. However, for some compounds, such as copper and zinc, relatively high proportions of the contaminant can arise from less obvious sources such as household plumbing. The level of source control of contaminant discharges to the sewer, including domestic household products, is therefore an important factor in determining biosolids management practices in urban and industrial areas.

Metals and persistent organic chemical contaminants in biosolids are difficult and costly to remove. The increasing concentrations of these contaminants may result in the situation where recycling of biosolids is not environmentally sustainable or economically viable.

The possible presence of trace amounts of organic contaminants such as hormones and antibiotics in sewage is an emerging issue. Presently there are limited requirements related to these groups of chemicals where biosolids are applied to land for beneficial use in other countries. Further research in this area is being carried out both overseas and in Australia (see section on Research and Development).

Vector Attraction Control
Insect vectors such as mosquitos, cockroaches, common flies and rodents are attracted to unstabilised sewage sludge and provide a mechanism for transmission of human infectious disease. Vector controls are therefore a necessary part of biosolids

management. Vector attraction controls and pathogen reduction systems are important aspects in managing the stabilisation of wastewater solids and the production of biosolids for recycling. Vector attraction must also be managed during storage of (stabilised) biosolids.

Environmental Issues

There are several environmental constraints that have a bearing on biosolids application to land, some of which are specific to Australia. These include:

- the potential to pollute surface and groundwater which will require restrictions on applications;
- the fragile nature of Australian soils and poor soil structure;
- the relatively low pH value of some Australian soils which dictates a need for a cautious approach to biosolids application and land usage due to the potentially higher mobility of metals. Management practices e.g., lime addition (which is often used to stabilise biosolids when stored *in situ*) can be used to overcome this constraint. In general, biosolids should not be applied to soils having a low pH-.
- (i.e., pH $CaC1_2$ method) less than 5.5 or pH (water method) less than 6. However, if application at lower pH can be demonstrated to be safe (by agreement with the appropriate regulator) it can proceed with appropriate safeguards (Note: soil pH can vary according to the method of determination and agreed standard methods should be consistently used);
- the effects of the nutrients (nitrogen and phosphorus) and trace elements, (calcium, magnesium, potassium, sodium, manganese, copper, zinc, molybdenum, boron and others) provided by the biosolids on geologically old and nutrient deficient soils;
- the nitrogen and/or phosphorus content in recently produced biosolids may be the limiting factor determining rates of application in the short term. The increased level of nutrients resulting from applications of biosolids may affect native plant communities which have evolved in soils of low fertility;
- the effects of chloride ions in soils or in irrigation waters increasing plant uptake of cadmium;
- whether application will cause or contribute to the harm of an endangered or threatened species of plant, fish or wildlife; or will result in the destruction or adverse modification of the critical habitat of endangered or threatened species;
- whether such an application will affect Australia's biological diversity (the *National Strategy for Conservation of Australia's Biological Diversity,* http://www.ea.gov.au) provides general principles that are relevant to biosolids projects; and
- noise and nuisance issues such as truck movements and odour from inadequately stabilised biosolids.

Economic Issues

A number of factors affect the costs of biosolids management practices. A range of these factors is discussed below.

Increasing Costs of Landfill

The scarcity of urban landfill, reluctance to accept biosolids and the increasing costs of disposal via this route provides an impetus for both volume reductions by uses such

as energy recovery and application of biosolids to land. Furthermore, the Australian and New Zealand Environment and Conservation Council (ANZECC) strategy to minimise disposal of organic material to landfill reaffirms the need for alternative options in biosolids management.

Biosolids Treatment Costs and Alternative Management Technologies
Sludge treatment and handling costs (for a relatively high-grade product) account for approximately 50% of total wastewater treatment costs. There is a trend amongst sewage treatment operators to improve the quality of the biosolids product to increase its value, decrease the need for large storage areas, lower transport costs and make biosolids available for a wide range of beneficial options.

Practical Distribution Considerations
Biosolids transportation can be costly. Costs depend on the moisture content of the biosolids, the distance travelled and the standard of the transport route. There is clearly a trade-off between the level of biosolids dewatering and transportation costs.

Sludge Quantity/Quality
Effective management of inputs of industrial wastes to the wastewater stream results in improved sludge quality. Improvements to the quality of treated wastewater through increased treatment efficiency, coupled with population growth will increase the amount of biosolids available. Waste minimisation is a strategy being widely adopted with avoidance of waste and separation of contaminants at the source being encouraged.

Protection of Australia's Commodity Markets
The potential costs of livestock contamination, including the loss of markets and veterinary costs from diseases and treatment, which could occur from inappropriate biosolids use, is a concern for rural industries. Management practices, treatment standards and contaminant limits within these guidelines have been devised to ensure the protection of livestock and the lands in which they graze.

Markets for some agricultural products (e.g., salad or vegetable production) may perceive the use of biosolids negatively and may not wish to source produce that has been grown on land to which biosolids have been applied. Persons wishing to use biosolids in agricultural applications should consider consumer and market acceptance of the practice.

It is important to identify the potential risks of using biosolids to the health of the environment, humans and animals and to Australia's reputation as a commodity supplier. Proper implementation of these national guidelines combined with the implementation of State/Territory guidelines will help to ensure health concerns are addressed and Australia's reputation as a food commodity supplier in the international market place is maintained.

Protection of Future Land Use Options
In order to maintain land value for any given property, the current and future land uses should be taken into account in the evaluation of biosolids application schemes. When applied correctly, biosolids should improve soil characteristics due to its

capacity to improve soil structure and increase productivity, however, when incorrectly applied biosolids may affect property values.

Need for Cost/Benefit Analysis
Biosolids have commercial value as substitutes for commercial fertilisers or soil amendments. Currently, few suppliers charge fees for biosolids but this situation is expected to change, as biosolids become more readily accepted and more widely used. Any income generated will offset some treatment costs. There are some limited examples of biosolids products (i.e., pelletised products) being charged at prices sufficient to recover treatment costs.

Quality Assurance (e.g., ISO)
Quality assurance of treatment processes and the resulting products may assist in expanding consumer confidence. Quality management systems usually provide a net benefit to the operator through adding value to generated product and services provided.

Market Forces and Developments
There is a need to continuously review management options in the light of market forces and developments including improved technology. Application of biosolids to land should become increasingly attractive because of its economic benefits and the appeal of using a valuable resource. Sound management practices are needed in order to maintain public perceptions and hence the viability of the option of using biosolids.

Ongoing Research and Development
There are opportunities to reduce costs of biosolids disposal and use through the application of appropriate research and development. Accurate information transference and community education on the impact of biosolids on the environment and human health is crucial to prevent uninformed opinion having a significant negative effect on biosolids use.

Alternative Technologies/Approaches
It is expected that technologies and approaches will include:

- the conversion of sludge to oil and other products;
- thermal drying with pelletisation/granulation;
- optimisation of existing treatment processes or the development of new processes producing pathogen free biosolids;
- co-treatment with other waste streams;
- complexing, extraction or immobilisation of contaminants; and
- improved methods of composting.

It is expected that these and other technologies will affect the cost structure of options for sludge treatment and biosolids disposal/use in the future.

Social Issues

Cultural Sensitivities
Schemes that encompass plans to use biosolids should incorporate appropriate protection for disempowered communities. NWQMS guidelines recognise that land

and water resources have important cultural and spiritual values, particular for indigenous peoples. No specific guidance for protection of those values is provided, but consideration must be given to cultural issues in the planning and management of land and water resources, and as required by existing legislation, regulations and guidelines. Mechanisms should be in place to protect the economic, cultural and spiritual values of indigenous communities and other minorities.

Community Involvement and Public Consultation
A high degree of public acceptance is essential for biosolids projects. There is a high level of goodwill towards the concept of beneficial use provided procedures for managing the risks are in place, the procedures are transparent and the community is well informed. Community issues that may need to be addressed in some circumstances include nuisance issues, such as odour, dust, vehicle movements and public access.

Risk Assessment

The proper management of biosolids is essential for the protection of public health and the environment. In regards to the environment, the major risk from biosolids is pollution of surface or groundwater and contamination of soil and the food chain. Alternatively, the major risk in an economic sense to the use of biosolids is contamination of soil and food crops and the exceeding of food residue limits for export crops, particularly as many agricultural exports from Australia are utilising a 'clean and green' marketing approach. Appropriate biosolids management and agricultural practices are necessary to ensure acceptable levels of chemical residues and the sustainability of agricultural land.

The benefits to be gained from the use of biosolids must be balanced against the costs and risks associated with its use. The level of risk should also be viewed in the context of major options such as:

- the application to suitable land in a diffuse manner under controlled conditions;
- the concentration of biosolids by disposal at a very small number of landfill and on-site stockpiles at treatment plants; and
- technologies such as conversion of sludge to oil and energy generation.

Food Safety Risks
Biosolids applied to land to grow crops for human and stock consumption should not result in the unacceptable microbial or chemical contamination of produce or have an adverse impact on human health or produce quality. The major risk of human contact with products derived from biosolids is infection from microorganisms. The survival of some pathogens, notably parasites and viruses, is not completely understood. Because there is no final barrier with crops that are eaten raw (i.e., a kill step such as cooking or pasteurisation in which micro-organisms are destroyed by elevated temperatures) biosolids users should use appropriate quality and post-application management practices.

A number of industries (e.g., dairy, meat, horticultural etc.) have adopted quality management systems, such as Hazard Analysis and Critical Control Point (HACCP) systems to manage produce safety risks.

Persons wishing to use biosolids in agricultural applications should ensure the market acceptance of this practice. Advice in relation to produce safety regulations, issues, risks and quality systems associated with the use of biosolids can be obtained from various sources including food safety regulators, industry associations and product buyers (e.g., supermarket chains).

National Framework

The beneficial use of biosolids is dependent on a number of control mechanisms. The first step is the classification of biosolids according to:

- stabilisation status (including pathogen reduction and Vector Attraction Controls; and
- chemical contaminant levels.

Where a sludge or biosolids product does not meet a reuse classification and is to be disposed by landfill, it is classified according to:

- leachate status (for landfill disposal only) e.g., Toxicity Characteristics Leaching Procedure TCLP test, see glossary.

Further safeguards are provided by:

- the regulatory pathway determining where the biosolids are to be used dependent on the biosolids classification;
- limitations on the application rate (see Table 3);
- monitoring of soil contaminant levels before application;
- ceiling concentrations for soil contaminant levels;
- dilution by incorporation into soil; and
- monitoring of groundwater before application.

Classification and Use of Biosolids

The level of treatment to reduce pathogens and the maximum level of contaminants in biosolids depends on the proposed use of the resource. The classification system, shown in Table 3, contains seven categories of biosolids related to recycling or disposal.

1. ***All land application uses, including residential*** - biosolids suitable for distribution, marketing and use in the community throughout Australia. This includes public sale and distribution and for use in home gardens.
2. ***Agriculture*** - biosolids suitable for land used for the grazing of cattle, crops consumed raw, crops consumed cooked or processed.
3. ***Institutional Landscaping - Recreational*** - biosolids suitable for urban land application (e.g., parks, racecourses etc.) subject to specific site management practices and excluding household application.
4. ***Institutional Landscaping - Non Recreational*** - biosolids suitable for urban land applications such as freeway road and landscaping where public access is limited.
5. ***Forestry, land rehabilitation*** - e.g., mine sites or similar land application such as landfill final surface rehabilitation, subject to specific site management and environmental protection practices.
6. ***Municipal landfill*** – biosolids (sewage sludge) not suitable for beneficial use, which may be disposed of to municipal landfill, on-site disposal at a wastewater treatment plant or on land specifically dedicated for biosolids disposal.

7. ***Controlled landfill or thermal processing*** – biosolids (sewage sludge) untested or containing high levels of contaminants which fail TCLP testing and require disposal to a controlled landfill, or by thermal processing.

Biosolids disposed to landfill are classified according to results of the Toxicity Characteristics Leaching Procedure (TCLP) tests (USEPA 1986) and other appropriate tests for assessing leachate production and contamination (e.g., AS 4439 Preparation of Leachate Series).

Pathogen grades achievable following stabilisation of sewage sludges are listed in Table 1. Vector attractant reduction is required for all biosolids classes and processes to reduce vector attraction are discussed in the next section of these guidelines.

Guideline values for chemical contaminants are given in Table 2.

To achieve a particular classification the biosolids must comply with:

- stabilisation grade (includes pathogen reduction and vector attraction controls);
- chemical contaminant levels; or
- in the case of disposal of sewage sludge to landfill the TCLP test (for categories 6 & 7 only).

Higher-grade materials can be used in a less restrictive category.

Each category for recycling of biosolids has a list of appropriate safeguards comprising:

- maximum soil contaminant levels;
- biosolids application rate;
- soil controls; and
- land use controls.

These safeguards are guidelines only. Management of biosolids is site-specific in nature, therefore other practices may be acceptable where demonstrated to be safe.

Stabilisation Grades

Stabilisation of biosolids needs to be designed for two key components, namely the reduction in pathogen loads and controls to avoid attraction of vectors. Stabilisation of the biosolids in conjunction with application management controls is also needed to avoid generation of offensive odours.

Requirements to achieve the pathogen reduction grade requirements are given in Table 1. The pathogen reduction grades have taken account of USEPA CFR 503 with additional information from research published in 1995 by Gibbs and Ho. Biosolids should be graded according to the achievement of pathogen reduction grade requirements as stated in Table 1.

Stabilisation to control vector attraction is discussed in detail later in this section.

Chemical Contaminants

Key objectives
The derivation of limits for chemical contaminant grades needs to reflect the following key objectives.

- Ensure that contaminants do not reach levels in the soil that threaten the safety of agricultural produce, i.e., ensure that Maximum Permitted Concentrations (MPC) or Maximum Residue Limits (MRL) are not exceeded.
- Ensure that contaminants do not reach levels in the soil that exceed relevant limits for protection of ecosystems and human health.
- Ensure compliance with local regulatory requirements e.g., limits on contaminant concentrations in products used as fertilisers.

These objectives are not hierarchical, i.e., the most stringent limit for any objective is used as the basis for grading. This is to ensure biosolids use does not result in future limitations on land use.

It is recognised that within Australia there are variations in soil types, environmental conditions and agricultural activities, which mean that individual jurisdictions may derive quantitatively different grade limits, yet still achieve the above key objectives.

As a generic principle, it also needs to be recognised that soil and contaminant grade limits do not represent 'pollute to' limits. Sewerage authorities need to couple biosolids use with source control programs to minimise the concentrations of contaminants entering the sewerage system, and land managers should ensure soils do not become contaminated to such an extent that the key objectives are not met.

Contaminants to be considered
The following contaminants should typically be considered in biosolids classification.

- Metals such as Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium and Zinc.
- Persistent organic compounds such as organo-chlorine pesticides and polychlorinated biphenyls.

The need to provide limits for additional contaminants should be considered on a 'case-by-case' basis, reflecting the inputs (i.e., trade waste) into individual sewage treatment plants and the catchments they exist in.

Guideline Values
A set of guideline contaminant grade values for biosolids derived in accordance with the principles developed in the section above is provided in Table 2. State or Territory guidelines should be used where available. Otherwise, the limits provided in Table 2 can be used.

Contaminants that are not listed in Table 2, but which may be of concern at a particular sewage treatment plant, can have contaminant grade limits derived based on the above principles, with relatively detailed guidance provided in the National Environment Protection (NEPM) (*Assessment of Site Contamination*) Measure 1999.

Application of objectives to determine Grade C1 criteria
Contaminant Grade C1 biosolids (see Table 2) which also meet Grade P1 stabilisation criteria (Table 1) can be applied in a unrestricted manner to all lands excluding 'sensitive sites' (i.e., sites to which a relevant authority has determined as sensitive because of the potential of biosolids to cause unacceptable environmental, social or economic impact eg sites might include national parks, recreational areas or surface and groundwater systems). Reflecting this unrestricted use, the contaminant Grade criteria are derived to provide protection for a worse case scenario. On this basis, the contaminant Grade C1 limits in Table 2 are also the soil contaminant ceiling concentration limits.

As an initial default, the more stringent of the NEPM (*Assessment of Site Contamination*) Measure 1999 Health Investigation Level (HIL) or Ecological Investigation Level (EIL) should generally be adopted as the chemical contaminant Grade C1 limit.

NEPM levels have been derived to provide protection of ecosystems and human health (in regards to human health NEPM levels have been set at investigation threshold levels, and levels harmful to human health are typically much higher), however, they have not been set for protection of agricultural produce. Therefore, where a limit lower than the NEPM criteria is considered necessary for protection of agricultural produce, this lower limit should be adopted (e.g., as for cadmium in Table 2). Similarly, if an individual jurisdiction has regulatory requirements which necessitate a lower Grade C1 limit, these should also be adopted.

Application of objectives to determine Grade C2 criteria
The contaminant Grade C2 criteria reflect a quality of biosolids that although exceeding the contaminant Grade C1 limit for one or more contaminants, can still be safely used for beneficial use. In contrast to Grade C1 biosolids, sustainable use requires the application to be managed to ensure the relevant limits in the receiving soil are not exceeded (refer to Grade C1 criteria for soil limits in Table 2).

The contaminant Grade C2 limits are derived as an upper limit:

- to protect soil limits under a nominal repeat application scenario (e.g., involving ten annual applications of 10 dry tonnes of biosolids per hectare); and
- representing what is achievable through good practice for wastewater solids management and trade waste management.

While an important aspect in managing contaminant Grade C2 biosolids is ensuring contaminants do not accumulate in soils to the soil contaminant ceiling concentrations, it is recognised that factors such as alterations to bioavailability (i.e., availability of a substance for uptake by biological systems) and high background concentrations can be considered in establishing site specific soil limits. The NEPM (*Assessment of Site Contamination*) Measure 1999 provides a suitable framework for deriving these site specific limits, however, the need for protection of agricultural produce should also be taken into account when deriving site-specific limits.

Table 1 Pathogen Grades

(This table is adapted from a number of sources including: Gibbs, R. and Ho, G.E. (1995), *Risk associated with pathogens in composted biosolids;* USEPA (1992), US Sewage Sludge Regulations USEPA 40 CFR Rule 503; US EPA (1995), *A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule* and the USEPA (1999), Control of Pathogens and Vector Attraction in Sewage Sludge).

Note: Processes identified in Table 1 Pathogen Grades have already been verified to achieve pathogen removal including (viruses and Helminth ova). Microbiological criteria are used as an indicator of performance. In some jurisdictions new facilities using approved processes will need to verify removal of viruses and helminth ova, refer to local regulatory agencies for requirements.

New treatment processes will need to verify removal of viruses and helminths ova's prior to be accepted as approved stabilisation process. Proponents of new technology should approach relevant regulatory agencies for detail of approval processes.

Pathogen Levels	Approved Process	Microbiological Criteria based on dry weight of the product	Other Conditions
Grade P1. Very low pathogen levels with minimum regrowth potential.	1. Composting in-vessel method: The temperature of all the compost material is to be maintained ≥55°C for 3 continuous days.	1. <1 Salmonella (undetected) per 50 gram of final product. 2. <100 "E. coli (or thermotolerant coliforms[1])" per gram of final product. 3. Analysis of 50 gram samples can be determined using methods and media based on those described in AS 1766.2.3, AS 4276.6 and 4276.14 and total "E. coli (or thermotolerant coliforms)".	1. 30 days maturation of product required before use. 2. Certified Quality Assurance to AS NZ ISO 9002 2000 or equivalent processes. 3. AS 4454 (1999) Composts, Soil Conditioners and Mulches.
	2. Composting Windrow method: Compost in windrow for minimum of 15 continuous days to be maintained ≥55°C with minimum of 5 turnings.	As above	1. A minimum of 5 turnings of the windrow. 2. 30 days maturation of product required before use. 3. Certified Quality Assurance to AS NZ ISO 9002 2000 or equivalent processes. 4. AS 4454 (1999) Composts, Soil Conditioners and Mulches.

Table 1 Pathogen Grades Continued

Pathogen Grade	Approved Process	Microbiological Criteria	Other Conditions
	3. pH and Heating: pH of the biosolids product to be raised above 12 and pH to remain > 12 for a minimum of 72 continuous hours. During this 72 hour period the temperature must be >52°C.	As above	1. At the end of the 72 hour period, product shall be air-dried to a final solids content >50% by weight. 2. Certified Quality Assurance to AS NZ ISO 9002 2000 or equivalent processes. 3. Undigested sludge: either (i) aerated in a windrow for 15 days with a minimum of 5 turnings; or (ii) Demonstrate minimum regrowth potential by assay.
	4. Heating and Drying: Biosolids dried by heating particles to >80°C to achieve a final solids content of at least 90% by weight.	As above	1. Final product to be kept dry until applied. 2. Certified Quality Assurance to AS NZ ISO 9002 2000 or equivalent processes. 3. Product from undigested sludge shall demonstrate minimum regrowth potential by an approved assay method.
	5. Long Term Storage: Sludge is digested; Dewatered to a solids content >10% by weight; Stored for > 3 years.	As above	1. Product must be stored in a manner that ensures no contamination. 2. Note that storage can sometimes result in the regrowth of salmonella.
	6. Other Processes: That meet the microbiological criteria described in column 3 and relevant 'other condition' described in column 4 (i.e., demonstrates that biosolids will not attract vectors or generate offensive odours).	As above	Other process will also be required to demonstrate: 100% egg inactivation using a Taenia or Ascarid Parasite egg-seeding assay ;< 1 enteric virus present in 100g sample of final product.

Table 1 Pathogen Grades Continued

Pathogen Grade	Approved Process	Microbiological Criteria	Other Conditions
Grade P2. Low pathogen levels but with some pathogen regrowth potential.	1. Composting: The temperature of all the compost material to be maintained ≥53°C for 5 continuous days or ≥55°C for 3 continuous days.	1. <10 Salmonella per 50 gram of final product. 2. <1000 "E. coli (or thermotolerant coliforms)" per gram of final product. 3. Analysis of 50 gram samples can be determined using methods and media based on those described in AS 1766.2.3, AS 4276.6 and 4276.14 and total "E. coli (or thermotolerant coliforms)".	1. Compost may need to be matured to ensure toxic organic compounds do not subsequently affect plant growth. 2. Weed seed control of compost may be required in some agricultural applications.
	2. Heating and Drying: Biosolids is to be heated to >70°C and dried to a solids content of at least 75% by weight.	1. <10 Salmonella per 50 gram of final product. 2 < 1000 "E. coli (or thermotolerant coliforms)" per gram of final product. 3. Analysis of 50 gram samples can be determined using methods and media based on those described in AS 1766.2.3, AS 4276.6 and 4276.14 and total "E. coli (or thermotolerant coliforms)".	1. Undigested sludge shall be dried to at least 90% by weight. 2. Final product to be kept dry until applied.
	3. Aerobic Thermophilic Digestion[2].	As above	1. Maintain aerobic conditions at a temperature of 55°C to 60°C for 10 continuous days. 2. Volatile solids reduction >38%. 3. Product dried to a final solids content >50% by weight.
	4. Other Processes: Processes e.g., storage where safety can be demonstrated.	As above	

Table 1 Pathogen Grades Continued

Pathogen Grade	Approved Process	Microbiological Criteria	Other Conditions
Grade P3. Established processes that achieve significant pathogen reduction.	1. Anaerobic Digestion.	< 2,000,000 "E. coli (or thermotolerant coliforms)" per gram (dry weight).	1. 15 days at 35°C or 60 days at 15°C. 2. >38% volatile solids reduction.
	2. Aerobic Digestion (This may include extended aeration).	As above.	1. 40 days at 20°C or 60 days at 15°C. 2. >38% volatile solids reduction.
	3. Composting.	As above.	1. Aerobic conditions to be maintained. 2. 5 days at >40 °C including 4 hours at >55°C.
	4. Other processes assessed by regulatory authorities as achieving appropriate pathogen reductions for Grade P3 uses.	Criteria as determined by State/Territory regulatory authority.	Criteria as determined by State/Territory regulatory authority.
Grade P4 Minimum pathogen reduction.	1. Any stabilisation process not meeting the above microbiological criteria and other conditions.	N/A.	

Table 1 Notes:

[1] Thermotolerant coliforms refer to a subset of coliforms found in the intestinal tract of humans and other warm-blooded animals which can ferment lactose at 44°C to 44.5°C to produce acid and gas. They are used as indicators of faecal pollution.

[2] Aerobic thermophilic digestion: Sludge digestion process carried out in an aerobic (oxygen containing) environment utilising microorganisms tolerant to elevated temperatures (optimally 49 – 57 C) to increase the rate of biological activity.

Table 2 Guideline Biosolids Contaminant Grade Values

Table 2 provides guideline contaminant values that may be considered if State/Territory guidelines are unavailable. Due to variations in parameters such as soil types, individual jurisdictions may derive different limits, yet still achieve key objectives of protecting agricultural produce, ecosystems, human health, and comply with local requirements.

CONSTITUENT	GRADE C1 – unrestricted use **Soil Contaminant Ceiling Concentration Guidelines** **mg/kg dry solids**	GRADE C2– **if exceeded should not be used** **mg/kg dry solids**
Arsenic	20	60
Cadmium	1[1]	20
Chromium (Cr III)	100 – 400[2]	500 – 3000[2]
Copper	100 – 200[3]	2500
Lead	150 – 300[4]	420
Mercury	1	15
Nickel	60	270
Selenium	3	50
Zinc	200 - 250[5]	2500
DDT/DDD/DDE	0.5	1
Other organochlorine pesticides	0.02 – 0.05[6]	0.5
PCB	0.05 - 0.3	0.5

Table 2 Notes:

[1] Cadmium	the grade C1 limit of 1 mg/kg reflects food safety concerns regarding plant uptake of cadmium. Some plants have a higher uptake of cadmium under certain conditions. The local Agriculture Department or equivalent should be consulted for information. This limit will be reviewed in light of investigations by the National Cadmium Minimisation Committee in conjunction with the National Biosolids Research Program. Biosolids applied to agricultural land should be limited to an application rate of 30g/ha/yr Total Cadmium for a maximum period of five years.
[2] Chromium	although the NEPM (*Assessment of site contamination*) includes limits for both Cr (III) and Cr (VI), Cr (III) is expected to be the dominant form in biosolids.
[3] Copper	values of between 100 to 200 mg/kg have been adopted in State/Territory guidelines. The most stringent NEPM value is 100 mg/kg based on ecological protection. Where biosolids are applied to land the Soil Contaminant Concentration should not exceed the lower criteria.
[4]Lead	values of between 150 to 300 mg/kg have been adopted in different State/Territory guidelines. The most stringent NEPM value is 300 mg/kg based on ecological protection.
[5]Zinc	values of between 200 to 250 mg/kg have been adopted in various State/Territory guidelines. The most stringent NEPM value is 200 mg/kg based on ecological protection. Where biosolids are applied to land the Soil Contaminant Concentration should not exceed the lower criteria.
[6] Organochlorines	a range of values for organo-chlorine pesticides and PCBs has been adopted in, or are proposed for, State/Territory guidelines. The most significant risk associated with these compounds is food safety due to accumulation in grazing animals. The values reflect scientific assessment of uptake studies such as Michalk et al 1996. In deriving State/Territory specific limits, the limits of detection of readily available analytical techniques should also be taken into account.

Table 3 Biosolids grading, uses and management controls.

[This table is adapted from numerous sources including: for Grade C1 NEPC (1999) National Environmental Protection (Assessment of Site Contamination) Measure 1999. Schedule B (1) Guideline on the Investigation Levels for Soil and Groundwater.
For Grade C2 collectively from values derived from the NEPC (1999) NEPM on Site Contamination EPA NSW (1997) 'Use and Disposal of Biosolids Products'; ARMCANZ Water Technology Committee (1995) Occasional Paper WTC No. 1/95; *Guidelines for Sewerage Systems - Biosolids Management.*
Consideration was also given to relevant research and literature and State/Territory practices and State/Territory guidelines].

Allowable Biosolids Use	***Pathogen Grade*** **Table 1**	***Chemical Contaminant Grade/Level*** **Table 2** [3]	***Leachate Test e.g. TCLP[1] or AS 4439***	***Maximum Soil Contaminant Level*** **Table 2**	***Application Rate***	***Soil Controls***	***Land Use Controls*** [2]
Unrestricted all appropriate uses including residential.	P1	C1	N/A	C1	N/A	N/A	N/A
Agriculture (Salad plants and root crops) (Crops consumed cooked/processed, grazing animals, dairy cattle pasture and fodder).	P2 P3	C2 C2	N/A N/A	C1 C1	Calculated to meet crop nutrient requirements and ensure Maximum Soil Contaminant levels are not reached.	Soil pH controls, to minimise metal uptake by plants.	Land use maintained in stated category (i.e. biosolids should not lead to a limitation on the land use). Biosolids to be incorporated into the soil within 36 hours of spreading. A suitable withholding period should be observed post biosolids application before crops are harvested or animals are allowed to graze.
Institutional Landscaping Recreational.	P1	C2	N/A	C1	"		Land use maintained in stated category (i.e. biosolids should not lead to a limitation on the land use). Biosolids to be incorporated into the soil within 36 hours of spreading.
Institutional Landscaping Non Recreational.	P3	C2	N/A	Subject to approval by the regulator on case by case basis.	"	Soil pH Controls.	Land use maintained in stated category (i.e. biosolids should not lead to a limitation on the land use).

Table 3 Biosolids grading, uses and management controls continued.

Forestry and Land Rehabilitation. (e.g., landfill, mine, quarry and degraded land rehabilitation) or sub surface application.	P3	C2	N/A	Refer to state guidelines and regulations.	"	Soil pH controls.	[4]Land use maintained in stated category (i.e. biosolids should not lead to a limitation on the land use [5]Biosolids to be incorporated into soil within 36 hours of spreading. Incorporation is not required for biosolids applied to areas of forests used for timber production, private plantations, or where the forest is not used for grazing with a suitable withholding period.
Categorisation as below is only required for material that does not meet any of the reuse categories above and is therefore to be disposed							
Landfill not including landfill final surface rehabilitation.	P4	N/A	PASS	N/A	N/A		
Secure Landfill or other disposal options e.g., incineration etc.	P4	N/A	FAIL	N/A	N/A		

Table 3 Notes:

1) Toxicity Characteristics Leaching Procedure test. An analytical test used to determine the leaching characteristics of a material under standardised conditions as described in USEPA or similar approved method.
2) Refer to State/Territory guidelines for additional controls on withholding periods and site restrictions.
3) It is unlikely that repeated applications or soil monitoring would be conducted for residential applications. For residential purposes contaminant levels for applied biosolids should be at, or close to, background.
4) Appropriate minimum standards-individual regulatory schemes may choose more stringent controls to reflect specific concerns eg human and livestock diseases endemic in an area and the associated risks with agricultural applications e.g., Bovine Johnes and beef measles and taeniasis, or the effects of climatic conditions on pathogen survival.
5) Surface application may be considered on a case-by-case basis by the regulator.

Controls of Insect/Vector Attraction

A vector is an animal or insect that could potentially play a role in transmitting pathogens from biosolids to humans. Vectors could include flies, mosquitoes, fleas, rodents, birds or domestic animals.

Sewage sludges or inadequately stabilised biosolids can attract insects such as flies or mosquitoes. Vector Attractant Control is necessary for all biosolids applications and may be achieved by biological processes which breakdown volatile solids, reducing the available food nutrients for microbial activities and odour producing potential; chemical or physical conditions which stop microbial activity; and physical barriers between vectors and volatile solids in biosolids.

Vector attraction reduction can be achieved through:

- reducing the moisture content of the biosolids;
- reducing the organic content of biosolids be either aerobic or anaerobic digestion;
- adding alkalis (e.g., lime) and/or heating;
- composting; or
- incorporation or injection of biosolids into the soil.

Further guidance on Vector Attraction Control (VAC) options is given in Table 4 below (USEPA 1999, 'Control of Pathogens and Vector Attraction in Sewage Sludge').

Table 4. Suggested Vector Attraction Control (VAC) Requirements
(adapted from USEPA 1999)

Option no.	Suggested VAC Requirements	Biosolids most suited:
1	Biosolids treatment process reduces volatile solids by ≥38%.	All biological anaerobic or aerobic processes.
2	Biosolids containing stabilised solids only, dried to ≥75% solids content.	Fully stabilised by anaerobic or aerobic process.
3	Sludge containing unstabilised solids, dried to ≥90% solids content to create biosolids.	Heat dried biosolids.
4	Aerobic treatment for ≥14days at temperatures: minimum 40^0C and average >45^oC.	Composted.
5	Biosolids pH raised to ≥12, and without addition of further alkali pH maintained at ≥12 for 2hrs and then at pH ≥11.5 for an additional 22hrs.	pH (alkali/lime addition) and temperature.
6	Other methods demonstrating minimum re-growth potential verified by an approved testing regime.	Biosolids that do not satisfy any of the VAR Options 1-5.

VAC (particularly for higher quality biosolids) should be met after or concurrent with pathogen reduction to prevent regrowth of pathogens. It should be understood that many VAC methods are only conducive to biosolids produced from certain treatment/stabilisation processes.

Monitoring

Monitoring programs are designed to record:

- the quantity and quality of biosolids;
- any subsequent processing of biosolids to produce biosolids products; and
- the use and disposal of biosolids.

The following is a guide to typical records for biosolids product movements.

Biosolids Generation/Receipt/Transfer
Generators should record batches of biosolids generated, received or transferred and record the quantity (on a dry weight basis), the moisture content, and the class of biosolids (pathogen grade and chemical contaminant grade). Individual jurisdictions should ensure that documentation identifying the biosolids and reflecting on the biosolids grade is supplied when transferring to another party.

Biosolids Treatment /Processing
Processors should have available records of the treatment process and blending records or other data to demonstrate any change in categorisation.

Biosolids Usage
Where restricted biosolids are applied in bulk to land the applier should monitor the site and record:

- quantity and classification of biosolids used;
- location, ownership and current land use;
- land area and application rate of biosolids and contaminants;
- soil pH prior to application;
- level of contaminants present in the soil before application;
- estimated concentration of contaminants in the soil after application;
- classification, batch quantity, cumulative quantity, method and location of biosolids and application; and
- steps taken to prevent movement of contaminants off site by leaching, surface drainage etc.

The end user should take monitoring samples periodically, the frequency to be consistent with the level of risk posed by the specific recycling scheme.

In the case of landfill uses it will generally only be necessary to keep records of the volume generated. States/Territories will generally have licence requirements for landfill and records should be kept as required on a site-specific basis. The States/Territories may also have specific prohibitions or restrictions on the land filling of biosolids.

Biosolids Storage
The generators of biosolids should record inputs and outputs to and from storage. During storage monitoring for nuisance insects may be required and operators should plan to keep storage times to the minimum required. Operators should keep a register of all complaints received and actions taken to address these complaints.

On farm stockpile areas should be located within the biosolids application area and conform to relevant site management practices, including groundwater and surface water protection controls, vector controls, buffer distances and controls on animal and human access.

Availability of Data
Data should be made available to the regulator on request.

Plastic and other Materials

Plastic, rubber and similar materials in biosolids are an obvious undesirable foreign material in the product and they can have a negative effect on the value of biosolids for use.

Most plastics are non-biodegradable and will build up in soils to which biosolids are continually applied. Plastics can also cause damage to stock or wildlife by ingestion, while plastics and sharp objects can give rise to health and safety concerns among biosolids workers. It is therefore desirable to minimise the amount of plastics in biosolids.

Treatment processes may be reviewed for efficiency of removal of plastics. Coarse and fine screens should be utilised and removed materials should be kept separate from biosolids and effluent streams.

Grit tanks will remove heavy plastics, sharp objects, etc and may precede primary sedimentation (i.e., the initial treatment of wastewater involving primary treatment screening and sedimentation to remove solids) or extended aeration tanks. Screens may also be necessary to remove floating plastics.

A public engagement/education program is recommended to encourage the disposal of solid materials to solid waste disposal routes or recycling rather than to the sewerage system.

Testing Requirements

Several approaches could be taken to sampling and testing batches of biosolids, including:

- a statistical approach where the regulatory authorities set levels of confidence for each constituent, listed in Table 2 (a statistical approach should also be used when analysing biosolids for stability parameters). The generators and processors would then develop a sampling procedure which achieves these confidence levels for the biosolids product;

- a regulatory approach where minimum sampling and testing frequencies are set considering the quantities of biosolids produced the type and size of the treatment plant, any subsequent processing and/or the intended end use; and
- any combination of the above.

Statistical Treatment of Data

Careful design of sampling and analytical protocols is necessary to minimise sampling and analysis costs and the risk of erroneously categorising a batch of biosolids. The objective of the sampling and analysis program is to determine the mean and variance of a particular constituent throughout the batch. A batch may be a truckload; the contents of a continuously monitored single digester; the contents of a lagoon or drying bed; or an individual biosolids stockpile. The total sample variance is the result of the sampling and analytical variances. In all cases it will be advantageous to reduce sources of variance where possible by process modification, attention to sampling procedures and quality control procedures at laboratories.

These guidelines recommend laboratories accredited for testing biosolids by the National Association of Testing Authorities or equivalent accreditation organisations.

Control Procedures

Regulatory Controls

Each authority should clarify State/Territory regulatory controls and agreements on the use and disposal of biosolids. This will involve discussion and agreement with appropriate health, environment and agricultural bodies on guidelines for biosolids products. The management of biosolids quality and application should be via licensing of accreditation of suppliers of biosolids products or through the management of individual application sites.

Regulators

Regulators are the authorities identified by State/Territory Governments as having responsibility and authority to set standards for biosolids management and to audit performance. Regulators should use these national guidelines for developing guidelines specific for the needs of individual States and Territories. Regulators should identify monitoring programs required to satisfy their auditing responsibilities.

Options may involve any of the following mechanisms:

- full inspection;
- partial inspection with assessment on a statistical basis;
- quality assurance procedures;
- self assessments by operators; and
- compliance monitoring.

Generators

The generator is responsible for planning and organising the recycling or disposal of biosolids in a responsible manner. In particular, the generator has a duty of care to ensure the public and the environment is protected.

Generators should implement monitoring programs and keep records accounting for all biosolids produced. Authorities should take care when transferring biosolids to others to ensure the receivers are aware of their responsibilities, the nature and classification of the product received and the appropriate health and safety precautions. In this context a certificate should be given with each batch of biosolids transferred identifying the generator, the quantity, and the biosolids classification. Only operators/truck drivers who have been trained in transporting biosolids and have an emergency contact in case of spills should undertake the transference of biosolids.

Records should be kept of any biosolids leaving the generators' site so that it can be tracked to its approved destination with full knowledge of quantities, classification and final use. For unrestricted products, the processor need only keep records of the quantities produced and sold. A legal contract may be established with a processor or major user, transferring ownership and liability.

Processors

Processors accept biosolids from generators or other processors to make further products. Processors include organisations, which use biosolids in producing fertilisers, compost, soil conditioners and other products that use biosolids as one of the constituents. Processed biosolids are classified based on the characteristics of the final product, rather than on the grade of the biosolids received by the processor, i.e., processors could potentially treat an unstabilised and chemical grade C2 biosolids to a pathogen grade P1, chemical grade C1 product.

For all biosolids products processors should keep records of sources, quality and quantity, classification of biosolids received and products produced. For restricted grade products, the processor also needs to record the quantities produced and sold and the destination, including specific field location, of the processed products.

Nutrient Application Rate

In most cases the limiting factor setting maximum loading rates of biosolids per unit area of treated land will be nutrients, although metal contaminants can also be a limiting factor. For fresh biosolids nitrogen will often be the limiting nutrient but aged biosolids are more likely to be limited by phosphorus. The agronomic rate is dependent on cropping or pasture management practices and advice should be sought from an agronomist to determine site-specific rates for agricultural purposes. Because these factors are variable between States and Territories biosolids appliers and producers should refer to State/Territory guidelines for application rates for nutrients.

Site Management Practices

Site management practices vary depending on the biosolids quality and the intended end use on a site-specific basis.

Site management practices should be implemented to manage any environmental or health impacts. Suitable practices, depending on land use, include:

- the dilution of the product by incorporation into the topsoil, for example, by ploughing, by subsoil injection or by some other means;
- the setting of maximum loading rates per unit area of biosolids treated land should be based on contaminants covered in this guideline plus nitrogen and phosphorus balances;
- restrictions on public access to land treated with C2 grade biosolids; for example, fencing may be used to limit access to treated agricultural land, and signage used to indicate restrictions to public use in forests for a certain period after treatment with biosolids;
- restrictions on application methods to avoid off-site movement of dust or aerosols into sensitive areas, e.g., restrictions of application on windy days, not applying products with fine dusts;
- restrictions on zoning of land to prevent changes in land use providing new risk pathways;
- restrictions on applications where there is the potential to pollute groundwater;
- implementation of storage and runoff controls on storage and application sites;

- restrictions on applications to frozen, snow covered land, highly permeable, very slowly permeable, acidic and waterlogged soils;
- restrictions on land where run off into water bodies is possible i.e., steep hillsides located near water bodies;
- restrictions on application to or near sensitive areas (e.g., national parks, heritage sites, landscapes where endangered species exist, schools, sportsgrounds floodplains, estuaries etc.);
- monitoring of soil and groundwater;
- the establishment of buffers around the processing or application site e.g., adjoining properties, surface waters; and
- the established practice of withholding periods for livestock access and harvesting of crops from biosolids treated sites to minimise direct ingestion of pathogens.

Where the primary goal of biosolids is to provide nutrients, application should be based on the nitrogen requirement of the crop as well as metal and organo-chlorine content of the soil and biosolids. It is advisable to apply a number of smaller loads of biosolids rather than a single large application, and maximum soil contaminant levels should not be exceeded after either a single or multiple applications.

It is advisable that where biosolids are to be applied to agriculture, and the quality requires that it be mixed with soil to ensure Soil Contaminant Ceiling Concentrations are not exceeded, that the biosolids be applied as uniformly as possible.

Health and Safety Precautions

Biosolids contain contaminants and microorganisms, although at low levels for Pathogen Grades P1 and P2, and it is therefore good practice to exercise sensible care when working with biosolids products. For more information on this issue refer to Public Health Issues on Page 7.

Individuals handling biosolids should ensure that:

- hands are washed and nails scrubbed well with soap before eating, drinking or smoking, and at the end of the working day;
- cuts and skin abrasions are covered with waterproof dressings;
- no food or drink is consumed or smoking permitted by employees while working with biosolids or biosolids products;
- a suitable change of clothing is worn during work and safety footwear and gloves are worn to protect against injury from sharp objects;
- showering facilities are available to workers;
- eye protection is worn to protect against dust; and
- if dust or aerosols are considered a problem, masks conforming to the Australian Standard AS1715 should be worn to prevent inhalation. Wherever possible workers should be upwind of the application process.

Products such as mud bricks, fired bricks etc. developed from dried biosolids are unlikely to contain disease-causing microorganisms because of treatment processes. Handling of such products is not expected to cause problems if normal hygiene measures are practised.

Procedures Checklist - Biosolids Transfer

General Provisions

The following checklist serves as guidance for any party wishing to apply or process bulk biosolids on a site for the first time.

- Discuss proposal with relevant regulators, e.g., EPA, Health, Agriculture and planning authority.
- Keep communities informed about biosolids application sites in their local area.
- Contact generator and ascertain biosolids classification and contractual arrangements.
- Determine need for approvals and/or licences and make application if necessary.
- Determine application rate.
- Determine site characteristics and constraints.
- Calculate application rate.
- Apply or process biosolids; and report to regulators as required.

Typical Contractual Arrangements and Provisions

A contract should exist between any parties involved in the transfer of ownership of bulk quantities of biosolids. Agreements should provide the following.

- Name, address and contact numbers of person(s) receiving and applying biosolids.
- Location(s), map grid reference and legal description of the site(s) to which the biosolids will be applied.
- Size(s) of the sites (or portion thereof) to which the biosolids will be applied, in hectares.
- Statements indicating each party's awareness of the National Biosolids Management Guidelines, and State/Territory guidelines where applicable.
- Transportation requirements including the need to cover vehicles, the means to avoid spillages and contingency plans in case spillages occur.
- A requirement for the supplier to classify the biosolids.
- Consideration of the mechanism for clean-up etc, in case of recall or dereliction of duty.

Provisions for Agricultural Lands

In addition to the general provisions, State/Territory regulators should require that agreements include the following requirements whenever biosolids (not of an unrestricted grade (P1, C1) are applied to agricultural lands.

- Prohibition on applying biosolids in amounts greater than specified in State/Territory guidelines.
- The amount of biosolids in tonnes per hectare that may be applied in a consecutive twelve month period without exceeding the annual pollutant loading rates as specified in State/Territory Guidelines.

- The application method to be used (i.e., injection below the surface of the soil, spraying, surface application, etc) and whether or not the biosolids are to be incorporated into the soil.
- The storage method to be used in case of inclement weather and public health and environmental protection practices to be used until the biosolids are applied.

Note that if the quality of the biosolids changes, the amount of biosolids that may be applied to the land also changes. If biosolids quality improves more could be applied to that land provided that the increment does not exceed the nutrient requirements of the crops. However, if the biosolids quality deteriorates, less biosolids may need to be applied to the land to avoid exceeding the numerical limits.

Provisions for Beneficial Use on Non-Agricultural Lands

In addition to the general provisions, agreements may establish the following requirements whenever biosolids (not of an unrestricted grade (P1, C1) are applied to non-agricultural lands e.g., urban landscaping, forestry, mine site rehabilitation and landscaping at wastewater treatment plants.

- A prohibition on growing or harvesting food or feed crops on the land during the period when biosolids are applied to that land and for the specified period after the final application of biosolids.
- A prohibition on grazing animals on the land during the period when biosolids are applied to that land and for the specified period after the final application of biosolids or until testing shows concentrations are acceptable to the authorities.
- A requirement that a vegetative cover be established on the land.
- A prohibition on public access to the land to which Pathogen Grade biosolids P2 or P3; have been applied for a certain period or until establishment of vegetative cover.

Provisions for Distributed and Marketed Biosolids

For customer information a suitable label or data sheet should be provided with the product.

For biosolids marketed under 'unrestricted conditions' jurisdictions should consider labelling the product as follows.

- Name and address of the distributor of the product.
- A statement that the product is derived from wastewater biosolids.
- A statement that the product is classified for unrestricted use in terms of these guidelines.
- A list of contaminant levels.
- A list of the typical nitrogen, phosphorus and potassium concentrations.
- A statement prohibiting use of the product if it could end up in a waterway i.e., on steeply sloped land that is subject to frequent flooding.
- A warning to keep the product out of reach of children.
- A warning to avoid inhaling the dust.

For composts, soil conditioners and mulches please also refer to Australian Standard AS 4454-1999.

Further Development

Research

National and/or State/Territory Guidelines are expected to evolve as the results of research applicable to Australian conditions become available. It is not possible to base these guidelines on strict quantitative risk assessment principles, as appropriate research is yet to be completed. However, it should be noted that a significant amount of research into the suitability of guidelines has been undertaken in NSW and other states have extensive experience of biosolids management (NSW has an extensive data base built over ten years into biosolids use and management supported by the NSW Agriculture/Sydney Water Research Program 1993-2000 see bibliography).

It is expected that up to ten years research including more extensive monitoring and evaluation may be required to provide more extensive data to better quantify risks, therefore these guidelines may be viewed as conservative at this time. The 'Precautionary Principle' has been used in the guidelines when considering the human and environmental health risks associated with the use of biosolids (e.g., 100% bioavailability has been assumed for each metal in biosolids).

Research is currently being carried out in:

- risk assessment with respect to pathogens in biosolids;
- pathogen regrowth in dewatered product;
- recommended method for detection of salmonella in composted biosolids;
- procedures for composting;
- land application of biosolids in NSW;
- uptake and bioavailability of metals in biosolids amended soils; and
- fate of phosphorus in biosolids land applications.

This research will provide a more rigorous risk assessment methodology and understanding of the effectiveness of composting in removal of pathogens.

The metal cadmium deserves special attention. Some plants have a higher uptake rate of cadmium so it is necessary to exercise caution. It is also advised that:

- controls on cadmium are best achieved at source (i.e. trade waste policies);
- a maximum annual loading rate of cadmium of 30g/ha/yr averaged over 5 years (150g/ha/5yr) be adopted;
- a maximum soil concentration 1.0 mg/kg be adopted, unless local data indicates a lower limit is needed;
- research to suggest soil/biosolids availability index and sustainable system be encouraged; and
- monitoring of cadmium in biosolids in treatment works with high cadmium concentrations is encouraged to determine where additional controls are needed on influent concentrations through trade waste policies.

Due to improvements in analytical techniques over the last decade, trace amounts of a range of chemicals have been detected in sewage and biosolids. Some of these

chemicals are known to have the capacity to disrupt hormones in animal and humans. Included in this group are natural hormones which are normally excreted, synthetic hormones (eg, from the contraceptive pill and hormones replacement therapy) as well as some industrial chemical (eg, alkylphenol ethoxylate detergents) and pesticides.

Knowledge is limited in relation to the quantities of these compounds in Australian biosolids, however, monitoring undertaken to date indicates that the levels are generally lower than in other countries. The small quantities of these chemicals found in biosolids and the management practices presented in this Guideline means that the risks they pose are expected to be low, however, further work and research is presently being undertaken in this area in Australia and overseas to confirm this.

Appendix 1: The National Water Quality Management Strategy

In October 2001 the Natural Resource Management Ministerial Council superseded the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). The Council will continue the development of the National Water Quality Management Strategy (NWQMS).

The guiding principles for the NWQMS are set out in the *1994 Policies and Principles - A Reference Document*, which emphasises the importance of:

- ecologically sustainable development;
- integrated (or total) catchment management;
- best management practices, including the use of acceptable modern technology, and waste minimisation and utilisation; and
- the role of economic measures, including user pays and polluter pays.

The process of implementing the Strategy involves the community working in concert with government in setting and achieving local 'environmental values', which are designed to maintain good water quality and to progressively improve poor water quality. It involves development of a plan for each catchment and aquifer, which takes account of all existing and proposed activities and developments, and which contains the agreed environmental values and feasible management options.

Appendix 2: NWQMS: Guideline Documents

No.	Paper Title
Policies and Process for Water Quality Management	
1	Water Quality Management - An Outline of the Policies 1994
2	Policies and Principles - A Reference Document 1994
3	Implementation Guidelines 1998
Water Quality Benchmarks	
4	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) revised
5	Australian Drinking Water Guidelines – Summary 1996
6	Australian Drinking Water Guidelines 1996 revised
7	Australian Guidelines for Water Quality Monitoring & Reporting 2000
Groundwater Management	
8	Guidelines for Groundwater Protection in Australia 1995
Guidelines for Diffuse and Point Sources	
9	Rural Land Uses and Water Quality - A Community Resource Document 2000
10	Australian Guidelines for Urban Stormwater Management 2000
11	Australian Guidelines for Sewerage Systems - Effluent Management 1997
12	Guidelines for Sewerage Systems - Acceptance of Trade Waste (Industrial Waste) 1994
13	Guidelines for Sewerage Systems - Biosolids Management 2004
14	Guidelines for Sewerage Systems – Use of Reclaimed Water 1999
15	Guidelines for Sewerage Systems - Sewerage System Overflows 2004
16a	Effluent Management Guidelines for Dairy Sheds 1999
16b	Effluent Management Guidelines for Dairy Processing Plants 1999
17	Effluent Management Guidelines for Intensive Piggeries 1995
18	Effluent Management Guidelines for Aqueous Wool Scouring and Carbonising 1995
19	Effluent Management Guidelines for Tanning and Related Industries 1995
20	Effluent Management Guidelines for Australian Wineries and Distilleries 1998

The guidelines for diffuse and point sources are national guidelines which aim to ensure a high level of environmental protection broadly consistent across Australia. For more information on these guidelines please visit either of these websites: http://www.daff.gov.au/ or http://www.deh.gov.au/

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Glossary of Terms

aerobic thermophilic digestion	A sludge digestion process carried out in an aerobic (oxygen containing) environment utilising microorganisms tolerant to elevated temperatures (optimally 49 - 57°C) to increase the rate of biological activity.
agri-ash	The term used in the ACT for the product produced through high temperature incineration of sewage sludge.
bioavailability	Availability of a substance for uptake by biological systems.
biosolids	Stabilised organic solids derived from wastewater treatment processes solids which can be managed safely to utilise beneficially their nutrient, soil conditioning, energy, or other value (biosolids does not include untreated raw wastewater sludges, industrial sludges that cannot be used beneficially without further processing or the product produced from the high temperature incineration of sewage sludge).
dry weight	An assumed property of biosolids typically used in calculations. Dry weight is determined by assuming only the 'total solids' content of the biosolids contributes to its mass (total solids is the term applied to the material residue left after evaporation of a sample and its subsequent drying in an oven at a defined temperature, according to a standard method).
groundwater	Subsurface water from which wells or springs are fed; strictly, the term applies only to water below the water table.
guideline	Numerical concentration or narrative statement recommended to support or maintain a designated activity.
helminth	Parasitic worm-like invertebrate.
landfill, controlled	Licensed landfill area which is suitable for the disposal of household solid waste.
landfill, secure	Licensed landfill that has been constructed with impermeable liner or other means of preventing the migration of contaminants.
most probable number	Sample analysed by dispersal in an extracting solution be excessive dilution then using statistical analysis based on the positive or negative sample growth for each sample.
pathogen	Micro-organisms which can cause disease in humans and animals.

pH	A measure of the hydrogen-ion concentration in a solution. On the pH scale of 0-14, a value of 7 represents a neutral condition; decreasing values, below 7, indicate increasing hydrogen-ion concentration (acidity); and increasing values, above 7, indicate decreasing hydrogen-ion concentration (alkalinity). Soil pH should be determined by an approved method.
primary sedimentation	Initial treatment of wastewater involving (primary treatment) screening and sedimentation to remove solids.
protozoa	Small single celled animals including amoebae, ciliates and flagellants.
sensitive sites	Refers to those sites to which a relevant authority has determined as sensitive because of the potential of biosolids to cause unacceptable environmental, social or economic impact eg sites might include national parks, recreational areas or surface and groundwater systems.
sewage	See wastewater.
sludge	The unstabilised concentrated organic solids produced during a wastewater treatment process. Sludge cannot be beneficially used without further treatment and stabilisation to produce biosolids.
standard	An objective that is recognised in enforceable environmental control laws of a level of government.
TCLP test	Toxicity Characteristics Leaching Procedure test. An analytical test used to determine the leaching characteristics of a material under standardised conditions as described in USEPA or similar approved method.
thermophilic digestion	A aerobic digestion process that operates in the thermophilic temperature range (40 - 80 C) without supplemental heat.
thermophilic microorganisms	A group of micro-organisms requiring, tolerating, or adapted to high temperatures, i.e., 49 - 70°C.
thermotolerant coliforms	A subset of coliforms found in the intestinal tract of humans and other warm-blooded animals which can ferment lactose at 44° to 44.5°C to produce acid and gas. They are used as indicators of faecal pollution.
vector	Insects and animals such as flies, mosquitos and rodents which are attracted to putrescible organic matter and which may spread pathogens.

vector attraction control (VAC)	Controls implemented to avoid biosolids attracting vectors.
waste activated sludge	Sludge removed from the activated sludge process – a process involving the continuous recirculation of solids from a secondary sedimentation tank to an aeration tank.
wastewater	The used water of a community or industry, containing dissolved and suspended matter.
water quality guideline	Numerical concentration limit or narrative statement recommended to support and maintain a designated water use.
water quality objective	A numerical concentration limit or narrative statement that has been established to support and protect the designated uses of water at a specified site. It is based on scientific criteria or water quality guidelines but may be modified by other inputs such as social or political constraints.